IETC
International
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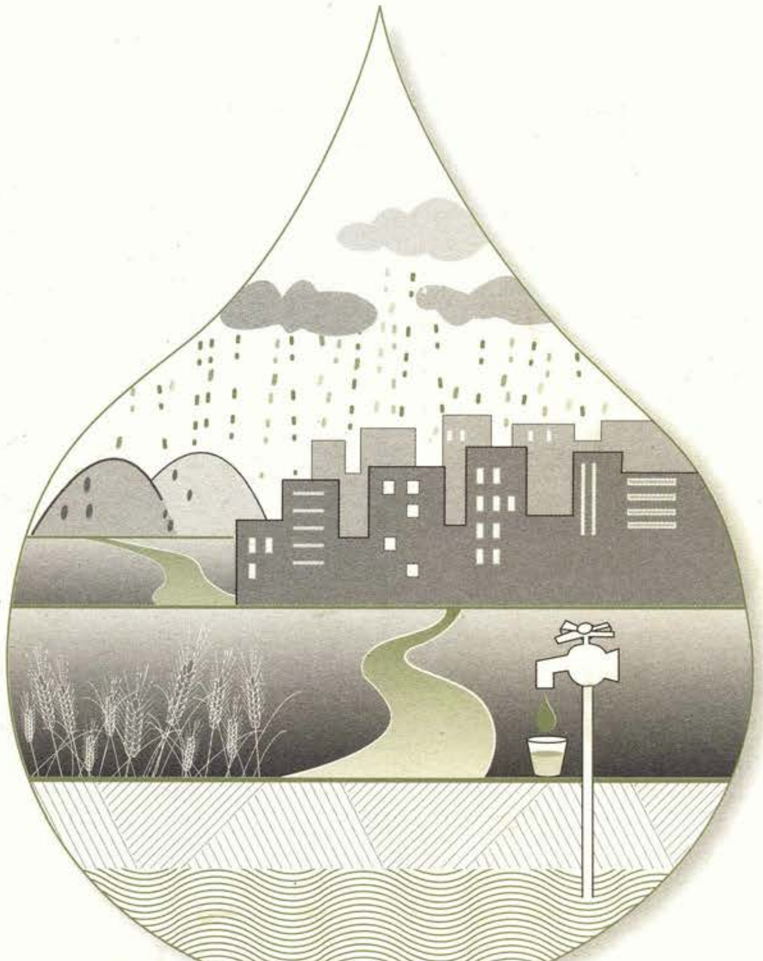
PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON EFFICIENT WATER USE IN URBAN AREAS

– Innovative Ways of Finding Water for Cities –



Implemented 8-10 June 1999 in Kobe, Japan

Organised by
UNEP International Environmental Technology Centre (UNEP-IETC)

Co-organised by
Environment Agency, Government of Japan
Global Environment Centre Foundation (GEC)
International Lake Environment Committee Foundation (ILEC)

Supported by
WHO, UNCHS(Habitat), UNU, UNCRD, Environment Australia,
American Water Works Association, Fukuoka City Waterworks Bureau

IETC REPORT 9

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Preface

In the face of continuing burgeoning urban populations, the need to supply adequate water to meet societal needs and to ensure equity of access to water persist as most urgent and critical, especially in developing countries. Vanishing freshwater resources due to global warming and other natural factors could lead to worse conditions in these countries. However, as reported by UNEP in its 1999 GEO Report, pollution from land-based activities of cities contributes tremendously to the depletion of freshwater resources.

Freshwater is one of the concentration areas of UNEP. Global environmental assessments, which include assessment of freshwater resources and freshwater use, and conservation and management of freshwater resources, are part of UNEP's priorities for the current biennium, 2000-2001. On the other hand, the principles of a 'sound hydrological cycle' have been adopted as guiding principles by Japan in its water policy. Japan's Environment Agency has undertaken studies on the basic strategy and policy direction that Japan will follow to ensure that the principles of a sound hydrological cycle is integrated in watershed management. Along this line, Japan recognizes that the application of technologies and approaches in efficient water use will be imperatives not only in developing countries but in developed countries as well.

Under these circumstances, the UNEP International Environmental Technology Centre (UNEP-IETC) organised an International Symposium on Efficient Water Use in Urban Areas – Innovative Ways of Finding Water for Cities on 8-10 June 1999 at WHO Kobe Centre, and in collaboration with the Environmental Agency of Japan, the Global Environment Centre Foundation (GEC) in Osaka and the International Lake Environment Committee Foundation (ILEC) in Shiga.

The symposium was aimed at enhancing the capacity of urban managers and decision-makers in water resources management. About 150 delegates from 45 developing countries, mostly managers and decision/policy-makers, from national and local government agencies, water supply authorities, urban planning departments, as well as from international agencies and NGOs with interest in efficient water use, participated in the symposium to reflect on these issues and share their views.

This publication contains session summaries, technical papers presented and information materials produced for the symposium. At IETC we think that it is a valuable source of information and reference for all who are involved or are interested in water policy development and promoting sustainable water use.

Lilia GC. Casanova
Officer-in-Charge/Deputy Director
UNEP-IETC

December 1999

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I. INTRODUCTION

I. INTRODUCTION

Aiming to enhance the capacity of urban managers and decision-makers in water resources management, IETC organised an **International Symposium on "Efficient Water Use in Urban Areas** – Innovative Ways of Finding Water for Cities" from 8 to 10 June 1999 at the WHO Kobe Centre Conference Room.

The Environmental Agency of Japan, the Global Environment Centre Foundation (GEC) in Osaka and the International Lake Environment Committee Foundation (ILEC) in Shiga co-organised the event. The World Health Organization (WHO), the United Nations Centre for Human Settlements (Habitat) (UNCHS (Habitat)), the United Nations University (UNU), the United Nations Centre for Regional Development (UNCRD), the American Water Works Association (AWWA), Fukuoka City Waterworks Bureau, and Environment Australia also supported the symposium.

A. Background

The United Nations General Assembly identified freshwater as a global priority at its nineteenth special session in June 1997. Furthermore, the Commission on Sustainable Development, at its sixth session in April 1998, focused on building a consensus on the necessary actions to implement a strategic approach for the sustainable use of freshwater.

Adequate freshwater supply is the most important precondition for sustaining human life and for achieving sustainable development. Nevertheless, over a billion people around the world lack access to satisfactory supplies of freshwater. In many large cities in developing countries, population is increasing rapidly and the issue of supplying adequate water to meet societal needs and to ensure equitable access to water for all urban residents is one of the most urgent and critical problems faced by decision-makers.

With respect to the physical alternatives to fulfil sustainable management of freshwater, there are two solutions: finding alternate or additional water resources using conventional centralised approaches; or better utilising the limited amount of water resources available in a more efficient way. To date, much attention has been given to the first option and only limited attention has been given to optimising water management systems.

Specifically there is a need to:

- Improve management of water resources and increase the availability of water for urban use;
- Avoid water shortages and energy inefficiencies in supplying water;
- Avoid human health hazards due to contaminated water; and
- Improve the knowledge base and skills of administrators and decision-makers in developing countries and countries in economic transition.

B. Objectives of the Symposium

The objectives of the Symposium on Efficient Water Use in Urban Areas were to:

- Increase awareness of needs for efficient water use in urban;
- Increase awareness of benefits, including improved health, from efficient water use in urban areas;
- Compile available technology options and sound practices for efficient water use, and encourage the adoption of appropriate solutions;
- Enhance the capacity of administrators and managers to understand and identify sustainable options in the water sector; and
- Profile case studies where more efficient water use and water resource management practices have been applied.

C. Scope and Structure

The Symposium featured various approaches for water augmentation in cities. The topics of the Symposium included the following areas:

- Direct approaches for water augmentation with alternative sources to supplement or substitute for available water, including;
  - Harvesting and utilisation of rainwater
  - Water reuse for non-potable applications
- Indirect approaches for water augmentation by increasing the potential for water, including augmentation of groundwater resources through aquifer recharge.
- Indirect approaches for water augmentation through the efficient management of existing water supply, including leakage control and the reduction of unaccounted-for water.
- Demand side approaches for water augmentation.
- Integrated approaches for efficient water use.

The contents of each session focused on:

- The advantages of each approach;
- The special features and characteristics that must be taken into account in applying each approach;
- Specific technologies for each approach;
- Why each approach has not been applied although there are many advantages and technologies have been developed;
- Solutions to overcome obstacles and barriers;
- Ways of promoting the adoption of appropriate solutions;
- Actual examples of each approach including successes and failures.

D. Participants

The Symposium involved 145 delegates from 45 countries, mostly managers and decision/policy-makers in either national or local governments; senior managers of aid agencies, water supply authorities, urban planning departments, international agencies and NGOs with an interest in efficient water use.

II. SESSION REPORTS

– Summary/Recommendations –

II. SESSION REPORTS – Summary / Recommendations

A. Session 1: Opening and Keynote Addresses

Ms. Lilia Casanova, Deputy Director of UNEP-IETC, welcomed the symposium participants, giving special recognition to 145 representatives from 45 countries, including 30 international experts. She stressed that water is a priority of UNEP and a continuing priority of the new Executive Director, Dr. Klaus Töpfer.

1. Welcome Address

Mr. Takashi Nakamoto then gave a welcoming address, as Japan's Ministry of Foreign Affairs' Ambassador Extraordinary Plenipotentiary to Osaka. He praised the symposium as an unprecedented event, in that it involves an extremely broad spectrum of decision-makers and other relevant authorities: representatives from both national and local governments, aid agencies, water supply authorities, research institutes and NGOs. Working together, he said, would surely bring us closer to ensuring adequate supplies of clean, safe water – one of humankind's most essential needs.

2. Overview of UNEP-IETC

Ms. Casanova presented a brief overview of UNEP-IETC (United Nations Environment Programme - International Environmental Technology Centre. IETC is part of UNEP's Division of Technology, Industry and Economics (DTIE), headquartered in Paris. IETC first started operations in 1994. It is supported by the Japanese government through a trust fund. IETC has two Offices in Japan. The office in Osaka City focuses on urban environments and the office in Shiga near Lake Biwa (Japan's largest lake) concentrates on freshwater issues.

IETC's mandate is to promote the adoption and use of Environmentally Sound Technologies (ESTs) for managing urban environments and freshwater basins. ESTs include both "hard" and "soft" technologies: "hard" technologies refer to equipment, machines and their accessories, while "soft" ESTs are management systems and procedures, including policy, regulations, and economic instruments. IETC considers soft technologies to be of greater value, since hard technologies would not be able to function effectively without their soft counterparts.

IETC has three functional areas:

(i) *Information Delivery:* help users and providers of ESTs access information about ESTs, particularly through maESTro, IETC's information system.

(ii) *Capacity Building:* helping decision-makers, urban managers, advisors and trainers become aware of ESTs and acquire skills and knowledge to make an informed technology choice.

(iii) *Technology Co-Operation:* building partnerships with various institutions all over the world to facilitate information delivery and capacity building.

3. Objectives of the Symposium

The symposium was organised to increase awareness of the need for and benefits of efficient water use in urban areas. Presentations of the technology options available and relevant case studies were used to enhance the decision-making capacity of administrators and urban managers. Discussions in each session covered the advantages and disadvantages of each approach, including the many issues and questions that remain to be studied.

4. Keynote Addresses

(a) "The Health Implications of Efficient Water Use in Urban Areas" by Dr. Gregory Bevan Goldstein, Co-ordinator, Healthy Cities Programme, World Health Organisation

Dr. Goldstein emphasised that health and sanitation need to be considered in the planning of water supply systems, especially since the lack of sanitation remains one of the greatest threats to urban populations. This approach to water use is the most efficient one in terms of municipal and national budgets, since much capital can be saved through the prevention of water-borne diseases. All water use programmes must address the winners and losers involved, and Dr. Goldstein pointed out that the losers are most often the urban poor. Water shortages – especially in urban areas and regions with low rainfall—are signalling an end to water management on a project-by-project basis. In addition to technology and other hardware, **soft approaches** involving education are vital. Health and sanitation measures have been found to be most effective when based in the local community: homes, schools, marketplaces and the like.

(b) "Joint UNCHS/UNEP Regional Initiative on Managing Water for African Cities" by Dr. Graham Philip Alabaster, Human Settlement Officer, United Nations Centre for Human Settlements (Habitat)

Dr. Alabaster stressed that governments must give top priority to the current water crisis in Africa, focusing on establishing long-term capacity and changing peoples' attitudes towards water resources. By the year 2000, twelve African countries will be in a "water stress" situation. And by 2025, about two-thirds of the African population may be in this predicament. Quality of life will suffer and development will be further strained. The scarcity of available fresh water is often due to the effects of increased urbanisation and industry, limited water resources, poor distribution systems, inequality in distribution, contamination, and exploitation of resources. According to Dr. Alabaster, many governments do not appreciate the urgency of the situation, and there is generally greater political support for new capital schemes than for conservation, though the latter is often more important.

This regional initiative seeks to achieve efficient use of freshwater at the city level, including improved, more equitable service and quality of life, through **water demand management**. It attempts to minimise the impact of urbanisation on freshwater resources, and encourages the exchange of information and good practices on urban water resources management. It will also take steps leading to much-desired capital investment for sound conservation and development projects, while using conservation and "soft" approaches to defer investments in non-essential, hardware-oriented water resources development projects.

(c) "Towards an Ensured and Sound Hydrological Cycle" by Mr. Seiji Ikkatai, Director, Water Quality Management Division, Environment Agency of Japan

Mr. Ikkatai presented outlining how the Japanese government is approaching a comprehensive national water use programme by studying the country's natural hydrological cycle and human impacts, plus the diverse interests of various government agencies and consumers. The natural hydrological system in Japan has deteriorated due to factors common in many other countries: the development of urban and industrial areas, increases in water demand, the use of toxic chemicals, and an fragmented government approach towards the water cycle, with each government ministry pursuing its own water needs. Mr. Ikkatai suggested a balance of development (to minimise the threat of floods, droughts, etc.) and conservation, so that humankind may continue to enjoy the practical and spiritual benefits of clean water and healthy ecosystems. **A sound hydrological cycle** can maintain this balance.

In Japan, some of the main steps that need to be taken are education about the problems and goals involved, and more research and information-sharing about indicators of hydrological health. The government needs to establish and implement an effective, inter-agency, comprehensive water policy, including urban planning that encourages aquifer recharge, and implementation of polluter-pays and user-pays principles. Such a programme requires the co-operation of national and local governments, experts, local residents, and NGOs.

B. Session 2: Harvesting and Utilisation of Rainwater

Moderator: Mr. John H. Neate, Strategies for Change, Canada
Rapporteur: Mr. Makoto Fujita, Associate Programme Officer, UNEP-IETC

Presenters:
(1) Prof. Adhityan Appan, Nanyang Technological University, Singapore
(2) Mr. Klaus W. König, Professional Association for Water Recycling and Rainwater Utilisation, Germany
(3) Dr. Makoto Murase, Chief of Environmental Protection Section, Sumida City Government, Japan

The "Harvesting and Utilisation of Rainwater" session addressed a wide range of case studies, including applications in villages and large cities at the household, community and institutional / commercial facility levels. Various issues were presented, including: *planning and design* of rainwater collection and utilisation systems; *water quality and regulatory aspects*; *costs and innovative financing alternatives*; *public acceptance*; and *institutional barriers*. The session also emphasised the need for integrated approaches to improve water resource management leading to the establishment of a more resilient, autonomous hydrological cycle at the local level.

<u>Key Points Presented:</u>

Planning & Design

- Urban catchment integration is an important aspect of rainwater collection and utilisation.
- Rainwater collection and utilisation are effective flood control strategies.
- Rainwater collection and utilisation schemes are optimal when implemented in conjunction with water demand management, as well as measures to enhance aquifer recharge.

- A decentralised water supply system is more flexible and resilient than conventional, centralised systems.
- Measures should be taken to establish **autonomous water systems** that are not dependent on water resources outside a given watershed.
- The incorporation of dual mode systems and adequate storage are key considerations.
- Smaller rainwater catchment systems are excellent additions when **integrated with existing conventional water supply systems**.
- The standardisation of systems and equipment design can significantly enhance the implementation of rainwater collection and utilisation.
- Durability and reliability of infrastructure and equipment are also key considerations.

Water Quality & Regulatory Aspects

- Water quality is a significant but manageable issue; particular care must be taken to ensure that potable water is not negatively affected by proposed rainwater utilisation schemes.
- World Health Organisation **(WHO) Guidelines** should be considered in any proposed rainwater utilisation scheme.
- Research and development related to rainwater quality should continue.

Costs & Financing Alternatives

- With rising water prices, the economics of rainwater utilisation are often very attractive, particularly if the system is designed and built properly.
- The economic benefits of rainwater utilisation and savings in water consumption are often greater for institutional investments (like airports, schools, etc.).
- To lower the overall costs of rainwater collection and utilisation, simple roof water collection systems may be preferable.
- Innovative approaches are needed to finance rainwater collection and utilisation systems.
- Appropriate subsidisation of users may in some cases accelerate the implementation of rainwater collection and utilisation.

Public Acceptance & Institutional Barriers

- Public awareness and education are essential in order to improve acceptance of rainwater collection and utilisation.
- Efforts should be made to change public perception of water from being viewed as a nuisance to being viewed as an asset.
- Metering both potable water and rainwater utilisation can create awareness of these valuable resources.
- **Demonstration projects** are key for improving public acceptance and assisting in the removal of institutional barriers.
- It should be recognised that in some cases existing water providers may be threatened by rainwater collection and utilisation options, particularly where excess capacity already exists.
- To promote rainwater utilisation, basic policies, implementation strategies, technology development and networking are required.

Session Recommendations:

1. Rainwater collection and utilisation should be viewed as an effective flood control strategy.

2. Rainwater collection and utilisation schemes should be implemented in conjunction with water demand management, as well as measures to enhance aquifer recharge.
3. Measures should be taken to establish autonomous water systems that are not dependent on water resources outside a given watershed.
4. Smaller rainwater catchment systems should be integrated with existing conventional water supply systems where possible.
5. Particular care must be taken to ensure that potable water is not negatively affected by proposed rainwater utilisation schemes.
6. World Health Organisation (WHO) Guidelines should be considered in any proposed rainwater utilisation scheme.
7. Research and development related to rainwater quality should be supported and encouraged.
8. Innovative approaches should be sought to finance rainwater collection and utilisation systems.
9. Public awareness and education are essential to improve acceptance and implementation of rainwater collection and utilisation.
10. Demonstration projects should be undertaken to improve public acceptance and assist in removing institutional barriers.
11. To promote rainwater utilisation, basic policies, implementation strategies, technology development and networking are required.

C. Session 3: Water Reuse for Non-Potable Applications

Moderator: Mr. Saul Arlosoroff, Water Resources Management-Consultant, Israel
Rapporteur: Mr. Brig Akhtar Zamin, Environmental Protection Agency, Pakistan

Presenters
(1) Prof. Takashi Asano, University of California at Davis, USA
(2) Dr. Bruce E. Jank, Canadian Global Environmental Technologies, Canada
(3) Dr. Gregory Bevan Goldstein, Co-ordinator, Healthy Cities Programme, WHO

Three presentations were made dealing with advantages and problems associated with the reuse of wastewater for non-potable use.

Key Points Presented:

- Population and urban growth cause enormous increases in the discharge of human wastes, which are often untreated and discharged, polluting streams, lakes, groundwater resources and other receiving bodies.
- Flows of untreated human wastes lead to contamination of water resources and edible agricultural crops, causing health hazards and serious economic implications.
- Governments should give priority to the treatment of human wastes, with the objective of enhancing potential **reuse for irrigation of non-edible crops**, as well as industrial water uses (for example, for cooling and process water needs).
- Reuse of treated human wastes represents a significant water resource, containing important nutrients for intensive agricultural practices.
- Treated sewage effluents can be traded for freshwater resources with local farmers, thereby making precious water resources available to accommodate requirements for expanded urban water supply and distribution, to help meet the needs of the unserved population.

- Reliable measures are required to **stop the reuse of raw sewage for edible crops** while at the same time promoting and creating incentives to connect the flows of treated effluents to agricultural areas.
- Special attention should be given to the potential for chemical contamination of human wastes from industrial facilities such as metals or plastics plants, as the treatment and removal of these contaminants is costly, and the health hazards can be very serious.
- For cities (or sections of cities) without sewers, planning and design should consider **potential future reuse of treated sewage effluents**, and should take steps to direct wastewater flows towards potential reuse areas.
- Government funds to bridge the gap between discharge points and potential users (such as farmers and/or industries) should be made available.
- On-site decentralised treatment and reuse should be analysed in terms of cost-effectiveness, health risks, ecological aspects and overall benefits (mainly derived from the avoidance or deferral of sewage costs).

Session Recommendations:

1. Governments should give priority to the treatment of human wastes, with the objective of enhancing potential reuse for irrigation of non-edible crops, as well as industrial water uses (for example, for cooling and process water needs).
2. Reliable measures are required to stop the reuse of raw sewage for edible crops while at the same time promoting and creating incentives to connect the flows of treated effluents to agricultural areas.
3. For cities (or sections of cities) without sewers, planning and design should consider potential future reuse of treated sewage effluents, and should take steps to direct wastewater flows towards potential reuse areas.
4. Government funds should be allocated to bridge the gap between discharge points and potential users (such as farmers and/or industries).
5. On-site decentralised treatment and reuse should be analysed in terms of cost-effectiveness, health risks, ecological implications and overall benefits (mainly derived from infrastructure avoidance or deferral).
6. Reuse of treated human wastes is a major source of water otherwise wasted and a potential polluting source. Governments (federal, national or local) should create the enabling environment to promote reuse by providing adequate budgets, incentives and disincentives, especially in water-scarce cities and regions.

D. Session 4: Augmentation of Groundwater Resources through Aquifer Recharge

Moderator: Dr. Bruce E. Jank, Canadian Global Environmental Technologies, Canada
Rapporteur: Dr. John Bwalya Mwanza, Project Manager, Barbados Water Authority

Presenters:
(1) Prof. Peter Fox, Arizona State University, USA
(2) Prof. Takashi Asano, University of California at Davis, USA
(3) Dr. Peter James Dillon, Centre for Groundwater Studies and CSIRO Land and Water, Australia

Three presentations were made dealing with advantages, regulatory perspectives, technologies, risks and implementation issues associated with aquifer recharge.

Paper 1: "Advantages of Aquifer Recharge for a Sustainable Water Supply" by Prof. Peter Fox

Key Points Presented:

- Wastewater reuse is a water resource issue which should be incorporated in water resources management planning.
- **Water banking** is an important water resources management strategy. Criteria should be established to determine who has the rights to the "banked" water.
- There is a need to establish regulations or controls for water quality used in recharge schemes.
- **Decentralised treatment with subsequent aquifer recharge** in strategically located recharge sites represents a cost-effective option for mega-city systems. The decentralised treatment/recharge sites should be selected to effectively control the water table.
- Natural watercourses or flood plains can be used to reduce water transport costs.

Issues to be Evaluated:

- What is the time required to recharge an aquifer?
- What is the cost of maintaining/cleaning direct injection wells?
- What parameters should be used, and what are the specific limits for each parameter, in establishing regulations and water quality standards for aquifer recharge?
- How should the impact of aquifer recharge on existing potable water wells be measured?
- Can groundwater recharge systems be used to replace surface water storage impoundment?

Paper 2: "Groundwater Recharge with Reclaimed Municipal Wastewater – Regulatory Perspectives," by Prof. Takashi Asano

Key Points Presented:

- The level of nitrogen in the aquifer recharge water must be controlled and monitored. The recommended limit for total nitrogen is 10 mg/l.
- The costs for pollution control should be separated from water reclamation costs. It is recommended that secondary treatment costs be allocated to pollution control, with the tertiary treatment costs allocated to water reclamation.
- Monitoring programmes are required for aquifer recharge programmes. Parameters used in California for regulatory purposes are TOC, Total Coliform Count, TDS and TN.

Additional Questions Raised:

- Have there been any incidents of health issues associated with aquifer recharge? Based on health studies conducted to date, there have been no epidemiological incidents reported.
- What is the cost per m^3 of water recovered from aquifer recharge schemes? While this is generally expensive, it needs to be compared with other options on a case-by-case basis.
- Are there any problems associated with the accumulation of recharge water in the aquifer? Any potential problems can be addressed by creating steady state conditions, where withdrawal is balanced against recharge.
- What are the issues associated with public acceptance of aquifer recharge? It is important that detention time in the aquifer be estimated to ensure public acceptance of the product.

Issues to be Evaluated:

- Hydrogeologic conditions must be established for each site.
- Parameters to be monitored need to be established.

Paper 3: "Aquifer Storage and Recovery in Urban Areas – Technology, Risks and Implementation Issues," by Dr. Peter James Dillon

Key Points Presented:

- An aquifer recharge option was described, involving a single well for recharge and subsequent withdrawal.
- It was noted that groundwater recharge occurs below all irrigation operations.
- Both reversible and irreversible clogging of injection wells have been noted to occur, but this can be addressed by redevelopment of the well at various intervals.
- The use of a separate injection well and a separate withdrawal well (appropriately spaced to take advantage of the aquifer cleaning capacity) can be used to substantially improve the quality of injected water.
- Aquifer storage capacity needs to be available for aquifer recharge to be successful.
- It was suggested that it is more appropriate to use nutrients for irrigation of agricultural crops than to release them into the atmosphere during treatment.
- Acceptance of aquifer recharge schemes involves proper presentations to the community.
- It is proposed that developmental maps be provided to local authorities regarding potential areas of recovery/recharge.

Issues to be Evaluated:

- Do pathogens injected into the aquifer survive or grow?
- Does the injected water induce growth of opportunistic or indigenous pathogens?
- For groundwater recharge through irrigation schemes, are pesticides and herbicides a potential problem?
- Sulphate reducers in aquifers should be monitored because of the potential for aquifer clogging.

Session Recommendations:

1. Where aquifer recharge is being considered, an appropriate regulatory framework should be established.
2. Policies should be established for the banking of water, to encourage the safe and beneficial application of aquifer recharge.
3. Water and wastewater treatment plants should be located in areas where the subsurface geology is appropriate for effective aquifer recharge.
4. Decentralised wastewater treatment plants should be located adjacent to aquifer recharge sites, thereby ensuring minimal impact on the groundwater table.
5. Further research is needed to determine appropriate and safe methods of water injection and withdrawal, to ensure inactivation of pathogens.
6. Where possible, excess treatment plant capacity should be used to provide treatment for aquifer recharge.

E. Session 5: Leakage Control and the Reduction of Unaccounted-for Water (UFW)

Moderator: Ms. Cristianne Chauvet-Urquidi, Mexico City Water Commission, Mexico
Rapporteur: Dr. Antonio L. Fernandez, United Nations Centre for Regional Development

Presenters:
(1) Mr. Jose Augusto Hueb, Sanitary Engineer, World Health Organisation
(2) Mr. Richard G. Sykes, Manager, Water Treatment and Distribution, East Bay Municipal Utility District, USA
(3) Mr. Alexander Rizzo, Operations Engineer, Malta Water Services Corporation, Malta

Three presentations were made regarding leakage control and the recovery of UFW.

The World Health Organisation (WHO) representative made a comprehensive proposal focusing on managerial approaches for **reengineering traditional ways** of providing water services, both public and private. It was noted that these services should not only be cost effective through water recovery, but also capable of directing the newly available water to people in underserviced urban areas, who are more vulnerable to water-related health risks.

A more specific example of managing UFW was provided by the representative of a public municipal utility. This perspective addressed the need for new approaches for water loss reduction in terms of the types of leaks related to pipe material performance, age, and other technical considerations, as well as labour costs, with a view to more cost-effective management.

Another example of UFW and leakage control was presented, illustrating a planned and structured approach to protect limited availability of water resources.

<u>Key Points Presented:</u>

- Worldwide, the population unserved with a safe water supply and sanitation was almost the same in 1990 as in 1980.
- Basic elements that affect the operation of water systems include:
  - inadequate data on operation and maintenance (O&M)
  - the need for broad and comprehensive decision-making
  - inefficient use of funds
  - poor management
  - inappropriate system design
  - political interference
  - inadequate policies and legal framework
  - accountability – responsibilities
  - economic leakage level setting (where marginal cost of leakage control = marginal cost of water being lost)
  - environmental constraints
  - R&D
- Unaccounted-for water (UFW) in cities in the developing world has been reported to be more than 50 per cent, to as high as 70 per cent of the total water supplied. Any reduction of UFW can help in expanding water supply coverage; thereby reducing deaths resulting from unsafe water and related poor sanitation practices.
- Definitions of UFW differ depending on the needs of the particular city, country, professional group, etc. A usual definition applicable to localities where metering is

practised, is production minus metered use. The term "UFW" refers basically to water losses and leaks not accounted for, including distribution losses, illegal connections and water theft.

- Goals and targets (long-term and short-term) must be set with respect to reducing water losses. Moving targets must be avoided. It is best to set targets that can be measured and compared against international benchmarks such as cubic m/hr or cubic m/km/day, and not a percentage. The targets should also be controllable by the facility owner or regulatory authority. This is particularly important when outsourcing services for dealing with UFW.
- A zoning scheme that uses the hydrological unit concept as practised in Malta is an example of a decentralised approach in which analysis of UFW can be done effectively.
- Corporate commitment, choice of adequate equipment and instrumentation are all important.
- Ideally, programmes dealing with water losses should be undertaken by water authorities or companies. Leakage control is only one component of efficient water use; other components include applied network surveys, leakage detection, meter testing, and other initiatives.
- Leakage control for both visible and invisible leakage is essential. Controlling leakage requires a mix of **passive control** and **consumption monitoring**. A balance between preventive and corrective maintenance is essential to minimise costs.
- Baseline data are necessary for future comparisons. The information can be stored in the form of spreadsheets and augmented through the use of geographic information systems (GIS).
- It is important to involve users, and inform them about the water company/utility and about technologies and approaches that save water.
- Issues pertaining to UFW arise from the following:
  - The water supply system
  - Water sources and water shortages
  - Location and geographical characteristics (inland, island, etc.)
  - Water rich or water poor
  - Age of pipelines
  - Universal metering vs. no metering
  - Institutional and organisational frameworks and commitments
  - Water price
  - Cost of labour (particularly for pipeline rehabilitation and replacement)
  - Profile, composition and characteristics of consumers and their consumption patterns.

Session Recommendations:

1. Water authorities and companies need to be supported by effective laws and regulations. Legal barriers must be overcome to ensure that measures and programmes for preventing and controlling UFW are implementable.
2. To facilitate the transfer of know-how, guidance documents and training packages must be made available to water authorities and companies.
3. Training the staff of water authorities and companies should be undertaken to improve the quality of service to users and to help develop positive corporate attitudes.
4. The implementation of sound operational practices by water companies and authorities may require reengineering and new institutional frameworks. Information on actual cases should be disseminated widely to learn from these experiences.
5. Information and education of decision makers and citizens must be given due emphasis.

6. Decentralising water systems through zoning levels or hierarchies based on hydrological and water balance principles should be examined further to ensure that appropriate measures are implemented in a manner which is responsive to local conditions.
7. Government must play a leading role to ensure that safe water is made available to the population. In so doing, closer links between water supply, environmental sanitation and health must be established, taking the perspective of users into account.
8. The involvement of the private sector in the provision of water services is welcome; however governments must provide good controls and regulations. Controls are particularly needed regarding concessions and the purchase of assets.

F. Session 6: Water Demand Management

Moderator: Mr. Ignacio Armillas, Director, UNCHS (Habitat), Fukuoka Office
Rapporteur: Dr. Ryo Fujikura, Ritsumeikan University, Japan

Presenters:
(1) Mr. Saul Arlosoroff, Water Resources Management-Consultant, Israel
(2) Mr. Peter Thomas, HATI company for craft technology and innovation, Germany
(3) Mr. John Olaf Nelson, John Olaf Nelson Water Resources Management, USA
(4) Ms. Madeleen Wegelin-Schuringa, Programme Officer, IRC International Water and Sanitation Centre, The Netherlands

Four presentations were made regarding water demand management.

The first presentation addressed the social and economic characteristics of managing water resources. Water conservation is the cheapest and largest available source of water within cities. Appropriate water management should be seen as an integral element in all countries' strategies for sustainable development. Although water management alone can not completely solve water resource problems in the long term, it can delay marginal expenditures by postponing expensive capital projects. **Complete metering** is a basic tool for demand side management, as is the introduction of progressive tariffs. Raising public awareness through ongoing education is also important.

The second presentation introduced an actual case study of water demand management in Germany. In the mid-1970s, older residential homes in Berlin had neither private bathrooms nor toilets, and water consumption was 50 to 70 litres per person a day. In the same period, the consumption in modernised houses amounted to 170 to 210 litres. The current target for water demand management is 70 litres per house. In order to attain this target, various sophisticated technologies have been introduced, including four-litre toilets and graywater purification plants. It was emphasised that co-ordination of central and decentralised approaches is needed, and that no single approach alone is enough to significantly reduce water consumption.

The third presentation presented the results of recent research on the residential use of water in the United States. Following a survey, data on flow rates passing through meters equipped at 100 homes were corrected and analysed. Average daily water use was measured at 1,548 litres a day, with the indoor component amounting to 655 litres. Water consumption by toilets and clothes washers amounted 70.0 and 56.8 litres a day, respectively, greater than that of other uses. For these two purposes, rainwater could be utilised. Reducing the amount of water used by toilets and eliminating leaks was found to be the most efficient approach to water conservation.

The last presentation addressed water demand management in low-income urban areas in developing countries. The urban poor often have access only to expensive water, and these people possess a high level of awareness about water conservation. The key issue is not reduction of consumption, but how to provide water to the vast majority of the urban population; this implies **conservation by the more affluent sectors**. A significant amount of water is also lost due to leakage. Motivation to reduce these losses is key. Education in schools is important, because educated children can teach their parents about appropriate water use.

Session Recommendations:

1. Appropriate water management should be seen as an integral element of all countries' strategies for sustainable development.
2. The importance of raising public awareness through ongoing education should be emphasised.
3. Co-ordination of centralised and decentralised approaches is needed.
4. There should be more equitable access to water in cities.

G. Special Speech and Introduction to IETC's "maESTro"

"Changing the Concept of Sewage Works for Sustainable Society—Separation of urine and feces for recovery of useful materials and stopping contamination of water bodies" by Prof. Saburo Matsui, Kyoto University, Japan

Prof. Matsui pointed out the potential value of urine as a natural and non-toxic fertiliser for edible crops, and that of treated feces for non-edible crops. The treatment of feces is much easier if separated at source from urine. Prof. Matsui described different types of toilets that could help with this separation and collection process for ultimate use. This approach could solve many problems currently faced in terms of human waste storage and water resource contamination from untreated human waste.

Key Points Presented:

- Urine has the ideal composition and balance of elements for fertiliser, and is generally pathogen-free.
- If urine can be removed from wastewater, the wastewater is much easier to treat.
- Separating urine and feces makes handling sewage much easier in terms of sanitation – a very important issue for developing countries. Water consumption is also drastically reduced.
- Since ancient times, China and later Japan collected human waste to use as fertiliser, an excellent form of recycling. Japan's conversion to a western sewage system was, in a sense, moving backwards.
- Eutrophication (the discharge of mass quantities of nitrogen and phosphorus into water bodies, resulting in algae or white plankton blooms) is a major problem in freshwater

bodies world-wide; separating urine and feces and using them instead of chemical fertilisers could improve this situation greatly.

- In Sweden "ecological sanitation" is being promoted; this is especially relevant to countries where sanitation is not readily available.
- More research is necessary to implement feces and urine separation systems and consequent fertiliser use.
- The greatest obstacle to utilising such a system is people's mindset, which can be changed.

"Introduction to IETC's *maESTro*" by Mr. Robert Rodriguez, Information Network Officer, UNEP-IETC

The second presentation introduced *"maESTro"*, IETC's specialised directory of Environmentally Sound Technologies (ESTs). *"maESTro"* is an integration of three databases: one on institutions, one on information systems, and one on available technologies. The format has been kept simple, to make the programme more manageable.

As an example of how *maESTro* works: Technologies may be accessed according to the type of technology or geographical area. The technology database presents general information and contact information, as well as relevant technical, financial and cultural information. The information is presented so that users can find out whether this technology may be a good solution for their situation; if so, they may then contact the technology developer or other relevant party for more information.

Key Points Presented:

- *"maESTro"* offers information on both "soft" technologies (management systems, etc.) and "hard" technologies (equipment and other hardware).
- IETC is currently working with more than 120 institutions worldwide to collect and present this information.
- The database features more than 1200 technologies available worldwide.
- The cheapest and quickest way to access the *maESTro* database is via the internet. Since many countries do not have ready access to the internet, IETC has also developed a PC tool that offers all the same information offline, on CD-ROMs and floppy diskettes. These are distributed free of charge.
- Hard-copy format of *maESTro* is provided free of charge to users upon request. The information is available by subject and location and is not computer dependent.
- Currently about 30 new technologies every week are received at IETC, and all *maESTro* users are updated every 6 months. This will become more frequent as funding becomes available.
- *"maESTro"* is not just a database, it is also an effective data management tool. Information can be inserted and modified at will. It also features working group facilities so that information can be sent from one computer to another, via internet or floppy disks.
- *"maESTro"* is requesting constant input—the more global technology users, producers, and consultants contribute, the more information will be available for everyone.

H. Session 7-I: Integrated Approaches for Efficient Water Use - Learning from Case Studies (1)

Moderator: Prof. Adhityan Appan, Nanyang Technological University, Singapore
Rapporteur: Dr. Vicente Santiago-Fandino, Programme Officer, UNEP-IETC

Presenters:
(1) Mr. George Madhavan, Senior Engineer, Water Department, Public Utilities Board, Singapore
(2) Dr. Indira Khurana, Co-ordinator, Natural Resource Management Unit, Centre for Science and Environment, India
(3) Mr. Saul Arlosoroff, Water Resources Management-Consultant, Israel
(4) Mr. Dhesigen Pydiah Naidoo, Director, Water Conservation, Department of Water Affairs and Forestry, Republic of South Africa

Two case studies were presented, outlining a variety of water management methods using technological and policy approaches. Integrated approaches – including demand management in Singapore and water harvesting in India – based on the particular conditions, scale, level of development in the society, available economic resources and public participation, were shown to be very successful.

In the case of arid and semi-arid areas like the Middle East, stringent water policies, sharing scarce water resources with neighbouring countries, and economically viable technologies were shown to be crucial to ensure the availability of water to all stakeholders.

In South Africa, where significant political change has recently taken place, a revision of existing water policies will be required to make them more in tune with the current and future needs of the country. A strategic integrated approach to water use will be needed.

Session Recommendations:

1. An integrated system based on a holistic approach is the most effective way to optimise water resource use.
2. The use of appropriate technologies and maintenance in storage and distribution systems will have an enormous impact on water savings.
3. For effective water resource management, public awareness and public participation are crucial factors.
4. To ensure effectiveness of water-related projects supported by international agencies, involvement of the communities as well as active participation of the public must be considered.
5. Small-scale rainwater harvesting systems could prove to be more efficient than centralised ones in many locations like villages and in other small-scale developments in urban and rural areas.
6. Based on the specific characteristics of a location, low-cost technologies for water harvesting and distribution should be considered and adapted.
7. Reuse of “safe” sewage effluents is strongly recommended for agricultural use ("fertigation"), particularly in arid and semi-arid areas.
8. Desalination should be considered as an alternative water source in many coastal countries, as the production price continues to fall.

9. Demand management is a more economic approach for water supply than transporting water from remote sources.
10. There is a need to look at water allocation strategies considering regulatory aspects, as well as providing sufficient economic and technical incentives to the users.
11. In many cases, a strategic framework for water conservation will result in considerable savings through deferred capital expenditures.
12 For effective water resource management, there should be appropriate regulations supported by the political will to enable implementation at all levels.

I. Session 7-II: Integrated Approaches for Efficient Water Use – Learning from Case Studies (2)

Moderator: Prof. Saburo Matsui, Kyoto University, Japan
Rapporteur: Eng. Alexander Rizzo, Operations Engineer, Malta Water Services Corporation

Presenters:
(1) Mr. John Bwalya Mwansa, Project Manager, Barbados Water Authority, Barbados
(2) Mr. Farooq Mohamed Hassan, Director, Maldives Water and Sanitation Authority, Maldives
(3) Mr. Teruyoshi Shinoda, Assistant Chief, Water Administration Section, Fukuoka City Waterworks Bureau, Japan
(4) Ms. Cristianne Chauvet-Urquidi, Director of Informatics, Mexico City Water Commission, Mexico

Four case studies were presented on the different water resource management issues that cities and countries face.

The first presentation introduced how the water-scarce island country of Barbados is currently adopting approaches for integrated, efficient water use. The country is totally dependent on groundwater and susceptible to saltwater intrusion. Recent efforts to encourage efficient water use have included a universal metering programme, a public education and awareness campaign, and a pilot project for water conservation in schools.

The reduction of high levels of unaccounted-for water has been targeted, through intensified leak detection and repair, water pressure reduction, and pipe rehabilitation and replacement. With its economy largely reliant on tourism, efforts are aimed at assessing the impact of water usage by this sector on the total water resources. It is proposed to change the tariff structure to an increasing block structure, which is conducive to efficient water use. Rainwater roof catchment systems have been compulsory for new buildings since 1995, with tax rebate incentives.

The second presentation outlined the policies and strategies contained within the integrated water resource management programme of Maldives. The major consumer of water is the domestic consumer, not agriculture or industry. Since the size and geological conditions of small island communities limit options for the development of surface water resources, conventional options for freshwater supplies are limited to groundwater utilisation, rainwater harvesting and desalination. The urban water supply was recently **privatised** and it is showing good results. The key strategy of the programme is to apply a **"demand driven"**

approach in the provision of water supply and environmental sanitation services. To implement this strategy, the government is gradually changing its role from that of a "**provider" to** that of a **"facilitator"**.

The following conclusions and recommendations were presented:

- Although desalination is now a major source of freshwater especially in the tourist industry, it is not an economically viable option for small island communities.
- Although technically feasible, wastewater treatment for reuse may not be economically viable for small island communities. However, in the tourist resorts, wastewater treatment is being made mandatory and recycled water is used for sanitary flushing and gardening.
- Technology options must match the resources available to sustain them.
- Lack of reliable data, scarcity of capital resources, shortage of skilled labour, and poorly developed organisational structures are major factors that hinder implementation of integrated water resources management.
- Development and management of water resources on these small islands requires techniques, methods and approaches unique to the socio-economic situation of islands.

The third presentation presented approaches for efficient water use implemented in Fukuoka City with highly sophisticated technologies in Japan. Leak detection on water mains is implemented in 4-year cycle, and about 6000 leaks are fixed per year. Aged water mains are actively replaced to prevent leakage from deterioration, to meet increased demand, and to meet earthquake-resistant standards.

Serious water shortages in 1978 led to the development of a computerised, 24-hour monitoring and control system for efficient water distribution. A wastewater reuse system for flushing toilets is promoted and adapted in redeveloped districts, newly constructed apartment complexes and large buildings. **Water-saving fittings** on faucets and low-flush toilets are promoted and widely used.

The fourth presentation detailed Mexico City's whole-scale water use reduction programme to ensure the technical and financial sustainability of its water supply system. An autonomous agency to manage the programme was established to avoid influence by various government agencies. The main strategies of the programme were a) promotion of efficient water use by **billing for metered consumption**, and b) water loss reduction by leakage control and facility improvement. To implement the project, contracts with private firms were made to utilise their expertise and latest technologies in water supply services.

The project consisted of three consecutive stages. In the first stage, preparation of updated registration data of customer's connections and utility maps as well as installation of meters were carried out. Then, bill collection based on meter reading on a 2-month cycle was started and a new customer service system was introduced in the second stage. In the third stage, a leakage control programme and upgrading of water mains and connections were initiated.

With these efforts, Mexico City can obtain another 500 litre per second water without developing new water resources in remote areas. The cost of conserved water is estimated at almost half that of new water resource development. Public Awareness of water conservation was also enhanced and **a new "water culture"** was created through implementation of the project.

Session Recommendations:

1. Technological optimisation and innovation can improve the efficient operation and management of water supply. This applies wherever there are water shortages.
2. Case studies demonstrate the effectiveness of conservation measures – such as alternative tariff structures, education campaigns, and water saving devices – in reducing excess consumption.
3 Privatisation at a certain level can be beneficial where external help is required. It is good to get qualified external expertise, but it is also advisable to avoid losing control of management entirely.

J. SESSION 8: Summary and Conclusion

Ms. Lilia GC. Casanova, Deputy Director of UNEP-IETC, noted that the symposium served to give participants an overview of how different countries are each dealing with their respective water challenges, according to their different situations. Presentations described water use approaches at the municipal, state and national levels. It is expected that some of the many approaches presented can provide answers to developing country problems and improvements in water use practices whether in developed or developing countries.

Dr. Gregory Bevan Goldstein, Co-ordinator of WHO's Healthy Cities Programme, presented a summary of the recommendations consolidated by each of the session rapporteurs.

Summary of Recommendations

1. Awareness, Education and Training

- Public awareness and education are essential to improve the acceptance of innovative ways to augment water supply.
- To facilitate the transfer of know-how, guidance documents and training packages must be made available to water authorities and companies.
- Training the staff of water authorities and companies should be undertaken to improve the quality of service to users.
- Demonstration projects should be undertaken to improve public acceptance and assist in removing institutional barriers.

2. Planning and Policy

- Appropriate water management should be seen as an integral component of all countries' strategies leading toward sustainable development.
- Government must play a leading role to ensure that safe water is made available to the population. In so doing, closer links between water supply, environmental sanitation and health must be established, taking into account the perspective of users.
- The involvement of the private sector in the provision of water services is welcome, however, governments must provide good controls and regulations.
- Coordination of centralised and decentralised approaches is needed.
- Governments should give priority to the treatment of human wastes, with the objective of enhancing its potential reuse for irrigation of non-edible crops as well as industrial water uses.

- For cities (or sections of cities) without sewers, planning and design should consider future reuse potential, and should take steps to direct wastewater flows towards potential reuse areas.
- Rainwater collection and utilisation should be viewed as an effective flood control strategy, and should be implemented in conjunction with water demand management, as well as aquifer recharge enhancement measures.
- Steps should be taken to establish autonomous water systems that are not dependent on water resources outside a given watershed.
- Care must be taken to ensure that potable water is not negatively affected by proposed water supply augmentation schemes.
- To augment water supply for urban areas, policies, implementation strategies, technology development, and networking are required.

3. Regulatory and Legal Frameworks

- Water authorities and companies should be supported by effective laws and regulations. Legal barriers must be overcome to ensure that measures and programs for augmenting water supply are implementable.
- Where innovative approaches are being considered, an appropriate regulatory framework should be established.

4. Financing

- Policies should be established for the banking of water, to encourage the safe and beneficial application of aquifer recharge, water efficiency and other water supply augmentation initiatives.
- Innovative approaches are needed to finance water supply augmentation.

5. Research and Development

- Research and development on innovative technologies and approaches is important for augmenting the sustainability of water supply.
- Further research is needed to ensure appropriate and safe methods of water supply.

Following the presentations, the comments of participants were solicited. Prof. Saburo Matsui from Japan pointed out that water use is relevant not only for humankind, but also for all other species, and for the local and global environment in general. He stressed the importance of humans remembering how human activity affects the delicate balance of our complex ecosystem. Another participant raised the concern that the word "health" was not mentioned in the recommendations, and pointed out that in fact human health is one of the main considerations. Ms. Madeleen Wegelin-Schuringa from IRC International Water and Sanitation Centre, indicated that the equitable use of water resources among persons of different economic and social status also needs to be emphasised.

Finally, concluding remarks were made by Mr. Masaharu Yagishita, Director, Planning Division, Global Environment Department, Environment Agency of Japan. Ms. Casanova moved on to thank all those present, on behalf of UNEP and IETC, for their contributions in making this symposium—IETC's first—a very successful one. She went on to thank IETC's supporting partners, particularly Japan's Environment Agency and Environment Australia for their financial support, as well as WHO and its Kobe office, and UNCHS (Habitat) and its Fukuoka Office.

IETC's Deputy Director also thanked the expert participants who had come from 45 countries all over the world, and without whom the meeting could not have been so fruitful. Attendance by so many experts from the developing world made this a particularly special event. IETC is particularly proud that all regions of the world were represented.

The event also would have not been possible without the staff and other major contributions from the Global Environment Centre Foundation (GEC) and the International Lake Environment Committee Foundation (ILEC). Special thanks were given to the symposium staff; their hard work, friendliness and efficiency made the event go smoothly. Special thanks were given to Mr. Makoto Fujita, the principal co-ordinator of the event. Mr. Fujita and the other staff expressed their appreciation for the participants' patience and understanding, given the many cultural and linguistic differences that crop up in the course of such an event.

Finally Mr. Saul Arlosoroff of Israel spoke a few words on behalf of all the participants. He noted that, of the one hundred or so symposiums he'd attended in his life, this one was the best organised. He praised the preparation efforts and efficiency of the staff and other organisers, and the important function that the maESTro database serves. He opined that he and perhaps all the symposium participants would return to their respective countries as ambassadors for UNEP-IETC.

III. SYMPOSIUM PROGRAMME

III. Symposium Programme

Day 1 Tuesday 8 June	9:30 - 12:10	**Session 1** (Plenary) Opening and Keynote Addresses	
	12:10 - 13:10	Lunch	
	13:10 - 16:00	**Session 2** (Room A) Harvesting and Utilisation of Rainwater	**Session 3** (Room B) Water Reuse for Non-potable Applications
	16:10 - 16:30	Daily Report (Plenary)	
	19:00 -	<Welcome Reception> at Portpia Hotel	
Day 2 Wednesday 9 June	9:30 - 12:20	**Session 4** (Room A) Augmentation of Groundwater Resources through Aquifer Recharge	**Session 5** (Room B) Leakage Control and the Reduction of Unaccounted-for Water
	12:20 - 13:20	Lunch	
	13:20 - 17:10	**Session 6** (Plenary) Water Demand Management	
	17:10 - 17:30	Daily Report (Plenary)	
Day 3 Thursday 10 June	9:30 - 10:30	Special Speech and Introduction to IETC's "maESTro" (Plenary)	
	10:50 - 12:30	**Session 7-I** (Room A) Integrated Approaches for Efficient Water Use I	**Session 7-II** (Room B) Integrated Approaches for Efficient Water Use II
	12:30 - 13:30	Lunch	
	13:30 - 15:10	**Session 7-I** (continued)	**Session 7-II** (continued)
	15:30 - 16:00	**Session 8** (Plenary) Summary and Conclusion	
	16:30 - 18:00	<Farewell Cocktail> at Restaurant Hygeia	

Tuesday, 8 June 1999

Session 1 Opening

9:30 – 9:50 Mr. Takashi Nakamoto, Ambassador Extraordinary Plenipotentiary to Osaka, Ministry of Foreign Affairs, Japan
- Welcome Address

Ms. Lilia G. C. Casanova, Deputy Director, UNEP-IETC
- UNEP-IETC Overview and Orientation of the Symposium

Master of Ceremony: Ms. Lilia G. C. Casanova, Deputy Director, UNEP-IETC

9:50 – 10:30 Keynote Address by Dr. Gregory Bevan Goldstein, Coordinator, Healthy Cities Programme, WHO
"The Health Implications of Efficient Water Use in Urban Areas"

10:30 – 10:50 Coffee/Tea

10:50 – 11:30 Keynote Address by Dr. Graham Philip Alabaster, Human Settlement Officer, UNCHS
"Joint UNCHS/UNEP Regional Initiative on Managing Water for African Cities"

11:30 – 12:10 Keynote Address by Mr. Seiji Ikkatai, Water Quality Management Division, Environment Agency of Japan
"Towards an Ensured and Sound Hydrological Cycle"

12:10 – 13:10 Lunch

Session 2 Harvesting and Utilisation of Rainwater

Moderator: Mr. John H. Neate, Strategies for Change, Canada
Rapporteur: Mr. Makoto Fujita, Associate Programme Officer, UNEP-IETC

13:10 – 14:00	Prof. Adhityan Appan, Nanyang Technological University, Singapore "Economic and Water Quality Aspects of Rainwater Catchment Systems"
14:00 – 14:50	Mr. Klaus W. König, Fachvereinigung Betriebs- und Regenwassernutzung e.V.: Professional Association for Water Recycling and Rainwater Utilization (NGO/NPO), Germany "Rainwater Utilization: Facilities and Equipment"
14:50 – 15:10	Coffee/Tea
15:10 – 16:00	Dr. Makoto Murase, Chief of Environmental Promotion Section, Department of Environmental Protection, Sumida City Government, Japan "Creating a Rainwater Utilization Based Society for Sustainable Development"

Session 3 Water Reuse for Non-potable Applications

Moderator: Mr. Saul Arlosoroff, Water Resources Management-Consultant, Israel
Rapporteur: Mr. Brig Akhtar Zamin, Environmental Protection Agency, Pakistan

13:10 – 14:00	Prof. Takashi Asano, University of California at Davis, USA "Wastewater Reuse for Non-Potable Applications: An Introduction"
14:00 – 14:50	Dr. Bruce E. Jank, Canadian Global Environmental Technologies, Canada "Case Studies of Domestic and Industrial Water Reuse for Non-Potable Applications"
14:50 – 15:10	Coffee/Tea
15:10 – 16:00	Dr. Gregory Bevan Goldstein, Coordinator, Healthy Cities Programme, WHO "Health Protection Measures and Health Safeguards in Water Re-use for Non-potable Applications"
19:00 –	Welcome Reception at Portpia Hotel

Wednesday, 9 June 1999

Session 4 Augmentation of Groundwater Resources through Aquifer Recharge

Moderator: Dr. Bruce E. Jank, Canadian Global Environmental Technologies, Canada
Rapporteur: Dr. John Bwalya Mwansa, Project Manager, Barbados Water Authority

--9:30 – 10:20	Prof. Peter Fox, Arizona State University, USA "Advantages of Aquifer Recharge for a Sustainable Water Supply"
-10:20 – 11:10	Prof. Takashi Asano, University of California at Davis, USA "Groundwater Recharge with Reclaimed Municipal Wastewater – Regulatory Perspectives"
-11:10 – 11:30	Coffee/Tea
-11:30 – 12:20	Dr. Peter James Dillon, Centre for Groundwater Studies and CSIRO Land and Water, Australia "Aquifer Storage and Recovery in Urban Areas – Technology, Risks, and Implementation Issues"

Session 5 Leakage Control and the Reduction of Unaccounted-for Water

Moderator: Ms. Cristianne Chauvet-Urquidi, Mexico City Water Commision
Rapporteur: Dr. Antonio L. Fernandez, United Nations Centre for Regional Development

9:30 – 10:20	Mr. José Augustus Hueb, Sanitary Engineer, WHO "Advantages of Leakage Control and the Reduction of Unaccounted-for Water"
10:20 – 11:10	Mr. Richard G. Sykes, Manager of Water Treatment & Distribution, East Bay Municipal Utility District, USA "Monitoring and Managing Unaccounted for Water"
11:10 – 11:30	Coffee/Tea
11:30 – 12:20	Eng. Alexander Rizzo, Operations Engineer, Malta Water Services Corporation, Malta "Leakage Control and Unaccounted-for Water Analysis"
12:20 – 13:20	Lunch

Session 6 Water Demand Management

Moderator: Mr. Ignacio Armillas, Director, UNCHS (Habitat) Fukuoka Office
Rapporteur: Dr. Ryo Fujikura, Ritsumeikan University, Japan

13:20 – 14:10	Mr. Saul Arlosoroff, Water Resources Management-Consultant, Israel "Water Demand Management"
14:10 – 15:00	Mr. Peter Thomas, HATI company for craft technology and innovation, Germany "Approaches for Water Demand Management: Water Saving Devices and Appliances"
15:00 – 15:20	Coffee/Tea
15:20 – 16:10	Mr. John Olaf Nelson, John Olaf Nelson Water Resources Management, USA "Residential End Uses of Water and Demand Management Opportunities"
16:10 – 17:00	Ms. Madeleen Wegelin-Schuringa, Programme Officer, IRC International Water and Sanitation Centre, The Netherlands "Water Demand Management and the Urban Poor"

10 June, Thursday

Special Speech and Introduction to IETC's "maESTro"

Master of Ceremony: Ms. Lilia G. C. Casanova, Deputy Director, UNEP-IETC

9:30 – 10:10	Special Speech by Prof. Saburo Matsui, Kyoto University, Japan "Changing the Concept of Sewage Works for Sustainable Society – Separation of urine and feces for recovery of useful materials and stopping contamination of water bodies"
10:10 – 10:30	Introduction to IETC's "maESTro" by Mr. Robert Rodriguez, Information Network Officer, UNEP-IETC
10:30 – 10:50	Coffee/Tea

Session 7-I Integrated Approaches for Efficient Water Use – Learning from Case Studies (1)

Moderator: Prof. Adhityan Appan, Nanyang Technological University, Singapore
Rapporteur: Dr. Vicente Santiago-Fandino, Programme Officer, UNEP-IETC

10:50 – 11:40	Mr. George Madhavan, Senior Engineer, Water Department, Public Utilities Board, Singapore "An Integrated Approach for Efficient Water Use in Singapore"
11:40 – 12:30	Dr. Indira Khurana, Coordinator, Natural Resource Management Unit, Centre for Science and Environment, India "Potential of Water Harvesting in India: Some Case Studies"
12:30 – 13:30	Lunch
13:30 – 14:20	Mr. Saul Arlosoroff, Water Resources Management-Consultant, Israel "Integrated Approach for Efficient Water Use – Case Studies"
14:20 – 15:10	Mr. Dhesigen Pydiah Naidoo, Director, Water Conservation, Department of Water Affairs and Forestry, Republic of South Africa "Integrated Approaches for Efficient Water Use in South Africa"

Session 7-II Integrated Approaches for Efficient Water Use – Learning from Case Studies (2)

Moderator: Prof. Saburo Matsui, Kyoto University, Japan
Rapporteur: Eng. Alexander Rizzo, Operations Engineer, Malta Water Services Corporation

10:50 – 11:40	Dr. John Bwalya Mwansa, Project Manager, Barbados Water Authority, Barbados "Integrated Approaches for Efficient Water Use in Barbados"
11:40 – 12:30	Mr. Farooq Mohamed Hassan, Director, Maldives Water and Sanitation Authority, Republic of Maldives "Integrated Approaches for Efficient Water Use in Maldives"
12:30 – 13:30	Lunch
13:30 – 14:20	Mr. Teruyoshi Shinoda, Assistant Chief, Water Administration Section, Fukuoka City Waterworks Bureau, Japan "Integrated Approaches for Efficient Water Use in Fukuoka"
14:20 – 15:10	Ms. Cristianne Chauvet-Urquidi, Director of Informatics (Systems Management), Mexico City Water Commission "Whole-Scale Reduction of Water Use: The Mexico City Project"
15:10 – 15:30	Coffee/Tea

Session 8 Summary and Conclusion

Master of Ceremony: Ms. Lilia G. C. Casanova, Deputy Director, UNEP-IETC

15:30 – 15:45	Dr. Gregory Bevan Goldstein, Coordinator, Healthy Cities Programme, WHO - Presentation of Summary Recommendations
15:45 – 16:00	Mr. Masaharu Yagishita, Director, Planning Division, Global Environment Department, Environment Agency of Japan Ms. Lilia G. C. Casanova, Deputy Director, UNEP-IETC - Concluding Remarks
16:30 – 18:00	Farewell Cocktail at Restaurant Hygeia

International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
Kobe, Japan, 8-10 June 1999

IV. PAPERS AND PRESENTATION MATERIALS

Session 1: Opening and Keynote Addresses

WELCOME ADDRESS

by Mr. Takashi Nakamoto
Ambassador Extraordinary Plenipotentiary to Osaka, Ministry of Foreign Affairs, Japan

Distinguished Participants, Ladies and Gentlemen,

On behalf of the Government of Japan, it is my privilege to welcome all of you to the "International Symposium on Efficient Water Use in Urban Areas – Innovative Ways of Finding Water for Cities" organised by UNEP-IETC. It is a real pleasure for me to participate in the opening ceremony of this symposium and address such a distinguished audience on this important occasion here in the city of Kobe, to which I particularly express my gratitude for its co-operation. I would like to thank all the participants for your interest and efforts in helping us make this symposium possible, especially those of you who have travelled great distances and taken valuable time from your very busy schedules to attend.

I understand that this is an unprecedented event in that it involves the participation of experts, managers and decision-makers from both national and local governments, aid agencies, water supply authorities, urban planning departments, research institutes and NGOs, all working together on the crucial issues of bringing water to urban dwellers and the sustainable use of freshwater.

Adequate supplies of clean, safe water remain one of humanity's most fundamental needs. The United Nations General Assembly identified freshwater as a global priority at its nineteenth special session in June 1997. Furthermore, the United Nations Commission on Sustainable Development, at its sixth session in April 1998, focused on building a consensus on the actions necessary to implement a strategic approach for the sustainable use of freshwater.

It is my sincere hope that your deliberations will lead to a clear perspective on the objectives of the symposium, and that the participants will gain greater insight regarding the importance of efficient water use. Recognising the global dimension of environmental issues, today I would like to request from all of you in attendance your opinions, advice and encouragement in helping us build a network based on the broad exchange of people and information, with the aim of creating and protecting a healthy and sustainable environment.

Let me conclude by wishing you every success in your deliberations and an enjoyable stay in Kobe.

Thank you.

The Health Implications of Efficient Water Use in Urban Areas

Dr G Goldstein
Coordinator, Healthy Cities Programme, Department of Health Promotion, WHO

Introduction

We see every day increasing competition for water among alternative uses: in industry, agriculture, wildlife and protection of natural resources, urban development, environmental quality, and last but not least human health. Everywhere there are indications of this competition, for example in northern Nigeria water diverted for irrigation leads to loss of livelihood for people downstream, or in India a falling water table threatens the loss of water resources for a peri-urban community. As a result of the competition, we can no longer address water planning and management on a project-by-project basis; increasingly we must integrate water resource use across different users and across different economic sectors. Whilst agriculture is frequently highlighted as using an overall 70 per cent of abstracted water and as being typically very inefficient, it is likely that irrigated agriculture will be extended to meet future food demands - substantial water savings within the sector are therefore unlikely. Other potential approaches to relieve volumetric demands exist – most representing some form of demand displacement through use of locally-captured water, or waste water re-use in urban green space or peri-urban agriculture. Many approaches raise new questions concerning their health impact.

In my talk today I would like to examine one key aspect of the water-health relationship – faeco-oral transmission of disease. I will try to explain why we have failed to break this transmission, and propose a solution to this issue. I will argue that efficient water use requires attention to breaking faeco-oral transmission of disease as an integral part of water management, and discuss how WHO is addressing this issue.

First I would like to look briefly at this idea of efficient water use. The economic efficiency of water use is measured in terms of the economic benefits of each use, less its costs. However in a given water management scheme, who gains and who loses may not be part of the efficiency criterion per se. Because of the externalities inherent in water development projects there are almost always winners and losers. Upstream users may pollute rivers with wastes or choke them with sediment, causing severe damages to downstream users. Local people lose their lands in a dam project, so that urban populations can have electric power and lowland farmers can have irrigation. Irrespective of efficiency, the health impacts of displacement – relocation or resettlement – are frequently severe. Many examples of dams that were justified on the grounds of efficient water use have not considered the costs to the displaced persons from inundated land, or the loss of livelihood that results for people downstream (Acreman, 1996). Another common conflict occurs between surface and groundwater users in irrigated agriculture. Improvement in the efficiency of application of the surface water results in a decline in the availability of groundwater.

I propose that models of efficient water use integrate inputs, outputs and impacts across different users and across different economic sectors, and in particular include health impacts. How one might approach the task to develop such an integrated model? I would propose several premises: that a given category of water use, use that leads to a health benefit is more efficient than water use that fails to achieve a potential health benefit; and that the efficiency of health interventions in relation to water and sanitation projects should be judged "cost-effective" or economical in terms of measurable outcomes produced by money spent. Cost-effectiveness of an intervention can be evaluated with a cut-off or test value. For example, an intervention to reduce diarrhea with a cost-effectiveness of less than $100/DALY would be considered cost-effective (Varley 1995).

Relationship between water and health

Rogers (1992) has pointed out that a relationship between water and health has been accepted since at least the time of Frontinus, the Water Commissioner of Rome in AD 97, however the details still present challenges. More recently in 1990 the Global Burden of Disease Study provided the public health community with a set of consistent estimates of disease and injury rates (Murray and Lopez, 1996). A glance at the global burden of disease shows us that even after 2 millennia, diarrheal disease is still prevalent, and the faeco-oral route of disease transmission continues to confound health authorities (Table 1).

The "global burden of disease" that is attributable to deficient water and sanitation, and personal and domestic hygiene - and another 9 major identifiable risk factors included in the table on the basis of major impact on the disease burden - is set out in Table 1.

YLL Years of Life Lost;
YLD Years lived with Disability (adjusted for severity of disability),
DALY Disability Adjusted Life Year

Table 1:Global Burden of Disease and Injury Attributable to Selected Risk factors, 1990

Risk Factor	Deaths (thousands)	As % of total Deaths	YLLs (thousands)	As % of total YLLs	YLDs (thousands)	As % of YLDs	DALYs (thousands)	As % of total DALYs
Malnutrition	5881	11.7	199486	22.0	20089	4.2	219575	15.9
Poor water supply, Sanitation and personal and domestic hygiene	2668	5.3	85520	9.4	7872	1.7	93392	6.8
Unsafe sex	1095	2.2	27602	3.0	21100	4.5	48702	3.5
Tobacco	3038	6.0	26217	2.9	9965	2.1	36182	2.6
Alcohol	774	1.5	19287	2.1	28400	6.0	47687	3.5
Occupation	1129	2.2	22493	2.5	15394	3.3	37887	2.7
Hypertension	2918	5.8	17665	1.9	1411	0.3	19076	1.4
Physical Inactivity	1991	3.9	11353	1.3	2300	0.5	13653	1.0
Illicit drugs	100	0.2	2634	0.3	5834	1.2	8467	0.6
Air Pollution	568	1.1	5625	0.6	1630	0.3	7254	0.6

Table taken from page 311, "The Global Burden of Disease", Eds Murray C and Lopez A, 1996

As a major risk factor or hazard to health, water and sanitation ranks second only to malnutrition in its impact on the disease burden (Table 1). In the case of water and sanitation, (and malnutrition), virtually the entire burden is borne by the poor, with only 0.1% of the YLL's in developed regions and 10.4% in developing regions. This compares for other risk factors in the table, such as tobacco use, which has 16.2% of the total YLLs in developed regions and only 1.5% in developing regions.

I will now focus on the faecal-oral route of disease transmission as the key "water-health issue". Of course there are other categories of water-related disease, (including chemical contamination of water supplies, e.g. the arsenic problem in Bangladesh and other countries, or problems of mosquitoes that are disease vectors breeding in stagnant pools of water where neighborhoods lack adequate surface water drainage). However in terms of the global burden, other water-related diseases are much less important.

Faecal-oral diseases occur when faeces from a person infected with the disease enters the mouth of another person. The pathogens contained in the faeces may be transmitted to hands, water or food, and water or food is then ingested by another person. Different faecal-oral diseases include diarrhoea, dysentery, cholera, giardia, typhoid, infectious hepatitis and intestinal worms. In understanding approaches to interrupt the faeco-oral route, we may consider this model:

Water supply infrastructure + sanitation infrastructure + good hygiene practice ⇒ health benefit

We see there are three factors or determinants on the left hand side of the model, needed to secure health. A deficiency of any one factor may lead to disease. While all three are complex, and inter-related, it will be argued that combining infrastructure with good hygiene practice is a highly cost-effective option in water management, and is integral to efficient water use.

Water supply infrastructure

The poor, by definition, lack financial resources. Highly populated urban centres act as intense "point sources" of pollution and create large (volumetric) demands on local water resources. In the context of urban environmental health, the poor, paradoxically, typically pay proportionately (and often absolutely) more for less access to a lower quality environment, be it water supply or housing. In many peri-urban areas of developing countries, water is supplied by trucks, and inhabitants have to buy it at higher costs than the more wealthy inhabitants of the city with access to piped water. Approaches to service provision designed for regular wage earners may be inappropriate for those with irregular income although their overall expenditure may in fact be greater.

Established policy and legislation may worsen inequities in access to basic services. Subsidies and investment (both public and private sector) are more readily available for provision of traditional water supply service by agencies providing piped supply predominantly to individual households than to poorer and under-served population segments. Regulatory frameworks may orient investment to improving generally adequate supplies with no substantial health problems rather than towards upgrading supply to the most disadvantaged.

For good health, a common calculation of requirements of the basic water need is an average figure of 25 litres per person per day. Key issues are:

access to the water supply is universal in the community,
that continuity of supply is assured and
that costs do not prevent households or individuals from using the water.

Where water resources are limited, it is often difficult to decide whether a greater emphasis should be placed on quality or quantity. In general, it is better to provide larger quantities of water of a slightly lower quality than supply small volumes of very high quality water.

Deciding what level of contamination that can be accepted is difficult and will depend on the willingness of communities to pay increased costs for better water and their willingness to treat water within the home.

There are many ways in which water used for drinking and other domestic uses can be provided or augmented. In rural areas traditional sources such as wells, ponds and unprotected springs may be used. In many situations, unprotected sources can be improved and this may be preferable to construction of completely new supplies, as people will be able to use, maintain and repair these supplies. Where protected supplies have been provided, but unprotected sources still exist, education and awareness raising may be required to encourage the community to always use the protected sources for their drinking water needs, reserving nearby poor quality sources for bathing and laundry.

Groundwater sources for a village or peri-urban community are safe when all the following criteria are met:

the water is fully enclosed or protected (capped),
people and animals do not step into the water while collecting it,
water from the surface is not able to drain into it,
latrines are as far away as possible and preferably not on higher ground
the nearest solid waste pit, animal excreta or other pollution sources are as far away as possible,
no stagnant water is within 2 to 5 meters of the water source,
the collection buckets are clean and kept off the ground or a handpump is used.

Sanitation infrastructure

The lack of adequate sanitation services remains one of the greatest threats to human health in urban areas of the developing world. In 1994, only about 60 per cent of the urban populations in Africa and Latin America had access to safe sanitation facilities. The "conventional" sanitation model involves collecting the human waste of an entire area in a waterborne sewer system and treating it in a centralised mechanical-biological wastewater treatment plant. This model has served populations well in places where 2 conditions apply: there is an abundance of rain, and there is relative prosperity, allowing large investment in public health schemes. These conditions are often not fulfilled, due to a scarcity of water resources and/or of financial resources. The status of water-borne sewerage as the *de facto* gold standard for urban areas world-wide is in part responsible for poor performance in sanitation coverage even in urban areas. More recently research and pilot studies are being carried out on technologies and methods of implementation that are more successful and adapted to the special needs of urban communities in developing countries.

Good hygiene practice

Varley has identified the following 5 categories of hygiene practice:

Excreta hygiene: disposal of feces and user-friendly designs to encourage use of excreta disposal systems by all family members.
Water hygiene: protection of water sources, safe water storage and handling, and household-level disinfection systems.
Personal hygiene: washing of hands with an abrasive after defecation and handling children's feces, as well as before meal preparation and consuming foods.

Food hygiene: protection of food supply from contamination and food preparation practices to reduce existing contamination.
Domestic hygiene: reduction of pathogen-transmitting vectors through the containment of domestic livestock, as well as wastewater, organic waste, and solid waste management.

Hygiene practice is of course closely related to the availability of water and sanitation facilities. Increasing the number and convenience of hand-washing, bath and laundry facilities may be as effective as hygiene education in encouraging good hygiene, however we shall see below (Table 3) that hygiene education is highly effective. Many traditional bathing practices do not use water efficiently, and ensuring cleanliness may be difficult with limited supplies. Modification of existing practices, for example the use of water containers with a tap suspended above the bathing area may help improve efficiency of water use. Some practices that can only be undertaken by the community as a whole are best understood as "community hygiene". These include water source protection, solid waste disposal, wastewater drainage, some communal excreta disposal systems and preventing animal rearing inside homes and near to kitchens.

Community level shower units with separate facilities for men and women are increasingly used in peri-urban areas and may have added benefit as income-generating enterprises. Such facilities require careful maintenance and are best managed by community and non-government organisations, often in partnership with municipal authorities.

In general, all 5 types of hygiene may be needed to achieve a substantial impact on diarrhoeal diseases, and hygiene education requires a participatory methodology that can influence hygiene practice in local settings: households and neighborhoods, schools, food-markets, and workplaces.

Health Impacts of Water/Sanitation Programmes

Esrey et al (1991) have reviewed a large number of studies that have sought to understand and estimate the impact of improved water and sanitation facilities on water-related diseases: ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis and trachoma (Table 2). Some issues and difficulties in arriving at estimates of effectiveness of water and sanitation interventions have been discussed by Varley (see Box 1 below)

Table 2: Expected Reduction in morbidity/mortality from improved water and sanitation

Disease	All studies		Rigorous studies	
	Number of studies	Median reduction (%)	Number of studies	Median reduction (%)
Ascariasis	11	28	4	29
Diarrhoeal diseases				
Morbidity	49	22	19	26
Mortality	3	65	-	-
Dracunculiasis	7	76	2	78
Hookworm infection	9	4	1	4
Schistosomiasis	4	73	3	77
Trachoma	13	50	7	27
Child mortality	9	60	6	55

No single study has tried to find out whether combined packages offer substantially greater efficacy than single interventions.

Varley has pointed out that environmental health interventions (such as water and sanitation interventions) may not be perceived to be cost-effective or considered the responsibility of the health sector.

Box 1: Interpretation of Health Studies (Varley)

Many studies view changes in behavior at the household level as the outcome of the intervention and the results are not expressed by reductions in morbidity and mortality.

Many factors other than the intervention can explain changes in diarrhea incidence and severity. These confounding variables cannot easily be added and subtracted except under controlled conditions.

The studies often use non-parametric statistical techniques, which show causation or a significant relationship but not the size of the effect.

Because the epidemiology of diarrheal disease varies widely geographically, a large number of results are required to draw general conclusions.

Few studies look at effectiveness under implementation conditions. For example, pilot studies of hygiene education using skilled personnel may not be replicable using ordinary personnel. The results represent an upper bound of effectiveness for the intervention.

If the order in which an intervention is introduced determines its effectiveness, no single measure of effectiveness can be determined. For example, the conclusion that sanitation is more effective than water supply is usually an artifice of the order of implementation. If the interventions were carried out in the opposite order, water supply might appear more effective than sanitation.

Why are these measures not considered cost-effective? The origins of this view can be traced to an influential short article by Walsh and Warren, published in 1979, that advocated a strategy of *selective* primary health care. These authors argued the case against *comprehensive* primary health care (or a broad public health strategy) in favor of selection of only the most cost-effective interventions to achieve maximum health impact. Their analysis showed water supply and sanitation cost $10,000 per death averted in 1996 prices, and selective primary health care only cost $600-750 per death averted in 1996 prices.

Favored interventions of selective primary health care include immunization for childhood diseases, promotion of breastfeeding, vitamin supplementation, and oral rehydration therapy (ORT) for the treatment of severe diarrhea. The selective primary health care idea may have influenced thinking in public health against preventive environmental health interventions, in favor of narrowly defined and focussed interventions. I propose that recent work done by Varley et al. undermines the selective intervention strategy, and provides a useful basis for hygiene interventions in water and sanitation. I will briefly review some key methods and conclusions. Hygiene interventions to prevent diarrheal disease were studied in a cost-effectiveness model with 3 principles (Box 2).

Box 2: Principles of the Cost- Effectiveness Model

1. the preventive effectiveness, or percentage reduction in incidence, of a health-sector intervention depends upon the environment in which it takes place.

2. that program performance should be measured by a unit which combines both morbidity and mortality.

3. that the financial or budgetary impact of an intervention or program on the health sector agency alone should be used as the measure of cost.

Many aspects of water and sanitation are beyond the direct control of public health authorities, including urban water supply and sanitation hardware. Water and sanitation hardware, or infrastructure, is rarely financed directly from the ministry's health budget, and in the model infrastructure was considered an additional and essentially free resource for the health sector. To fully exploit the health potential of the hardware, the health sector must supply the education, social marketing, and advocacy. While the hardware (HW) i.e., the water infrastructure, and sanitation infrastructure, are not health-sector interventions, the health sector should influence the design of infrastructure and even how it is operated for health results. Only the software (SW - the interventions to improve hygiene practice) is the responsibility of the health sector. A review of 65 water supply and sanitation studies (Solari 1996) was used to estimate the health effectiveness of these interventions as measured in reductions in diarrhoea mortality and morbidity. Effectiveness of water and sanitation in terms of reduction in diarrhoea episodes is shown in Table 3, and these results are modelled to produce estimates of intervention impact in Table 4.

Table 3: Percentage Reduction in Diarrhoea Episodes/Year/Child for Four Scenarios (Varley)

Combinations	**SW +** (Software for health impact present)	**SW -** (Improper use of hardware for health impact)
HW + (Hardware present and Used)	**40%** (Base assumption) 30% (Pessimistic) 50% (Optimistic)	**15%** (Base assumption) 10% (Pessimistic) 20% (Optimistic)
HW - (Inadequate or no Hardware)	**15%** (Base assumption) 10% (Pessimistic) 20% (Optimistic)	**0%**

Table 4: Percentage Reduction in Episodes/Year/Child for Four Scenarios (modified from Varley)

Pre- and Post intervention	Description	Impact
(HW-, SW-) ⇒ (HW+, SW+)	Adding software to existing hardware. This is likely to be the most cost-effective intervention.	**25%**
(HW-, SW-) ⇒ (HW+, SW+)	Adding both hardware and software where none currently exists. This corresponds to the traditional treatment of WS&S where the health sector is assumed to be responsible for both hardware and software.	**40%**
(HW-, SW-) ⇒ (HW+, SW-)	Adding hardware only. This is not a scenario that is relevant for the health sector. It would be inconsistent to spend large sums on hardware without achieving the full preventive impact.	**15%**
(HW-, SW-) ⇒ (HW-, SW+)	Adding software only. Although this scenario assumes there is no coverage of adequate software or hardware. Of course every community, however poor, does address its need to establish a rudimentary water supply and method of disposal of wastewater and sewage at low costs.	**15%**

The Walsh and Warren analysis assumed that the health sector bore the costs of water and sanitation infrastructure. Varley argues that when cost-effectiveness analysis is applied to environmental health interventions, the costs should be *limited to those which* *have to be financed from the health sector budget and which lead to health impact*. In the case of controlling childhood diarrhea the relevant cost for the health sector is that which is required to ensure adequate hygiene, whereas the cost of water supply and sanitation infrastructure is financed by some combination of user fees and public investment subsidies. The costs for hygiene in the short-to-medium term assumed ongoing campaigns of hygiene promotion and maintaining contact with target clients. A costing matrix derived costs for hygiene per annum, using cost variables such as health extension worker-client ratios, number of contacts per year, and the time required for program implementation. The cost derived for hygiene was $3 per household per year, and in a city of one million inhabitants, this indicated an annual budget for environmental prevention of childhood diarrhea of approximately $600,000.

Table 5: Cost-effectiveness of Four Scenarios and ORT

	Add SW to HW	SW and HW Combined	HW only	SW only	ORT
$ per case averted	2.2	45	112	4	NA
$ per death averted	523	10654	26433	966	800
$ per DALY saved	**16**	**320**	**794**	**29**	**24**

Table 5 shows that the dollar cost per disability adjusted life year saved or preventive hygiene interventions is $16, compared to an estimate of $ 24 for oral rehydration treatment. Varley concludes that when cost-effectiveness analysis is limited to health-sector costs, **environmental health interventions are as cost-effective as many of the well-known child survival interventions**.

Interventions for Better Hygiene Practice

The complexity of hygiene practice poses a challenge in communicating the many messages needed to promote social change and ensure better practice. Many international health programs (including WHO programs) communicate their messages in a patchy, opportunistic and non-systematic way to the various target groups, with frequent errors of communication, e.g. failing to distinguish the actors and the different roles of target groups, stakeholders and intermediaries.

WHO has learned from the networks of "healthy cities" in all regions of the world that an integrated approach based on "settings" may be effective for mobilizing communities and implementing hygiene education. It can involve people and organizations in the programs and activities needed for better health, and help to put the programs into operation (Harpham et al).

We have learned that living conditions including domestic and community hygiene are greatly affected by local action, by the work of local government and by community groups and organizations. A healthy city or village project enables a village to mobilize the human (and at times financial) resources required to address many health and quality of life issues. The process works as a communication strategy that develops political and popular health awareness and support for health.

Settings are major social structures that provide channels and mechanisms of influence for reaching defined populations for examples the workplace setting (small-scale industry, agriculture), the food-market, the housing setting, the school setting etc. A neighbourhood or village has a complex structure: within it each setting has a unique set of members, authorities, rules and participating organizations who all have a major stake in its operation. Settings involve frequent and sustained interaction, and are characterised by formal and informal membership and communication. These qualities create efficiencies in time and resources for hygiene education programming and offer more access and greater potential for social influence.

Mullen (1995) has identified these characteristics (see box 3) of settings that facilitate health promotion:

Box 3: Characteristics of Settings

Provide channels for delivering health promotion
Diffusion of information occurs in, is facilitated by settings
Builds on relationships between participants, authorities, and organisations
Provides access to gatekeepers
Provide entry points and access to specific populations
Unique practices and training traditions
Professional identities linked to settings

The implementation infrastructure for healthy cities and villages world-wide includes WHO staff at the HQ and regional office levels, and WHO country offices, and the project teams of the projects. The *local* project teams of a healthy city or village project usually have an institutional organization based on a steering committee, a project office and working groups.

The *steering committee* is formed by members of various organizations, which are involved in different aspects of the development of the village or town. It is generally presided by the leading authority of the local government (i.e. the Mayor or village chief or chairperson, or the District Administrator), and its roles include the approval of the Plan of Action and monitoring its implementation. The *healthy city/village project office* supports the steering committee, and is the operational arm of a project. It has a co-ordinator at its centre, generally with supporting staff and finances. The roles of the project office include: (i) awareness raising and community consultation, (ii) ensuring the overall development of the project, with constant encouragement of all the partners involved, (iii) co-ordinating publicity for the project, (iv) networking with other healthy city or village projects, (v) monitoring and assessing activities, and (vi) developing sources of information on health issues. The *working* groups are responsible for the specific plans and actions related to the different sectors of activity in the city or village and making their connection to the health of the population (e.g. housing, water, food-markets, school health, agriculture, transport, etc.). The working groups are not counterparts of municipal or district public departments, which operate only within the structure of the district or local government. A given working group includes representatives of all sectors of society involved with a given field of activity.

Implications and Conclusions

1. Efficient water use requires that health considerations be incorporated into the planning and analysis models for water resource development and management.

2. One may challenge the view that heath-sector managed water supply and sanitation interventions for preventing diarrhea are not cost-effective. The model discussed above finds interventions to improve hygiene practice to be cost-effective in comparison with other leading public health interventions.

3. Water-related diseases continue to cause a high burden of disease in the world, with the children in developing countries being at highest risk. New approaches need to be found to prioritize implementation of water and sanitation infrastructure and effective hygiene education to effectively address this challenge.

4. Delivery of water and sanitation hardware should be accompanied by creation of demand for improved infrastructure and hygiene education to ensure its best use. (This was of course a conclusion of the experience of the 1980s Water Decade). The complexity of the health-water use relationship requires that better hygiene practice becomes imbedded in the daily life of people in their homes, neighborhoods, workplaces, schools and food-markets. Better hygiene awareness and practice increases the possibilities of stronger private and public investment in water and sanitation infrastructure.

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outline

water competition signals an end to water planning and management on a project-by-project basis

EWU integrates inputs, outputs and impacts across different users/sectors and in particular includes health impacts

water-health relationship and faeco-oral transmission of disease are issues in efficient water use (EWU)

WU that leads to a health benefit is more efficient than WU that fails to achieve a potential health benefit

outline (cont.)

interventions to improve hygiene practice are cost-effective

delivery of water and sanitation hardware should be accompanied by creation of demand for improved infrastructure and hygiene education to ensure its best use

EWU requires better hygiene practice is embedded in the daily life of people in their homes, neighborhoods, workplaces, schools and food-markets

a "settings" strategy is an effective approach to improved hygiene practice

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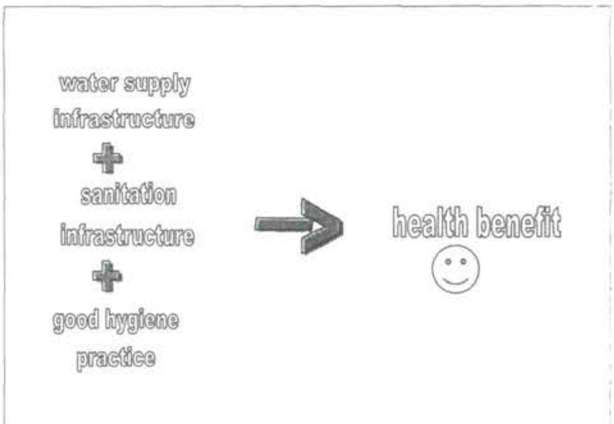

hygiene practice (Varley)

Excreta hygiene: disposal of feces and user-friendly designs

Water hygiene: protection of water sources, safe water storage and handling, and household-level disinfection systems.

Personal hygiene: washing of hands

Food hygiene: protection of food supply, food preparation practices

Domestic hygiene: reduction of pathogen-transmitting vectors -containment of domestic livestock, wastewater, organic waste, and solid waste management.

Table 2: Expected Reduction in morbidity/mortality from improved water and sanitation

Disease	All studies		Rigorous studies	
	Number of studies	Median reduction (%)	Number of studies	Median reduction (%)
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Mortality	3	65	-	-
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Schistosomiasis	4	73	3	77
Trachoma	13	50	7	27
Child mortality	9	60	6	55

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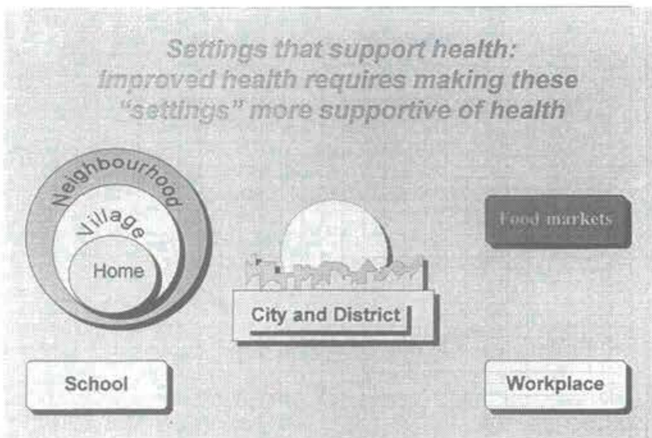
$ per DALY saved	16	320	794	29	24

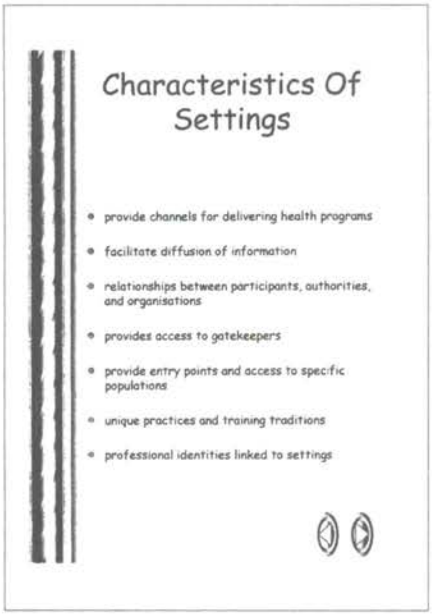
Interventions

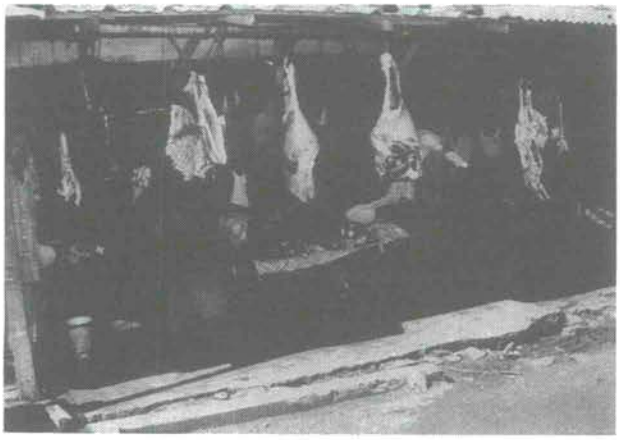
A large proportion of diseases and accidents are preventable by improving the physical environment and social and economic conditions of everyday life.

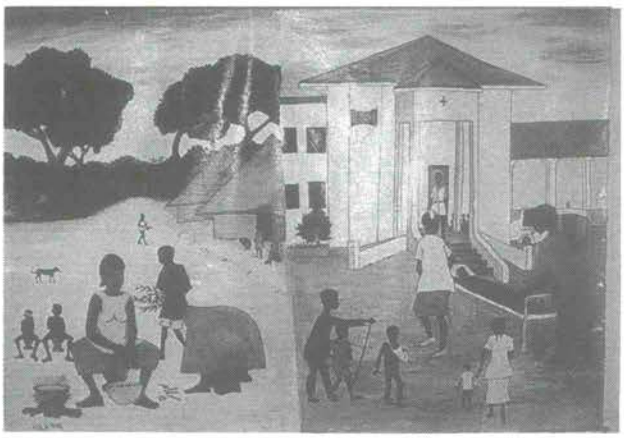
- identification and assessment of health hazards associated with environment and development;
- development of a health policy for the competent development sector (eg the housing sector, industry, local government, environment, transportation, agriculture etc), and
- Communication and advocacy of this policy to the various sectors.

supporting the contributions of households, communities, NGOs and voluntary organizations to health and through allowing these a greater say in establishing health priorities




Characteristics Of Settings
• provide channels for delivering health programs
• facilitate diffusion of information
• relationships between participants, authorities, and organisations
• provides access to gatekeepers
• provide entry points and access to specific populations
• unique practices and training traditions
• professional identities linked to settings






PUBLIC BATHHOUSE

MANAGING WATER FOR AFRICAN CITIES
UNCHS (Habitat) & UNEP JOINT INITIATIVE

Dr. Graham Alabaster
Human Settlement Officer, Infrastructure Unit, UNCHS (Habitat)

Problem Statement

Africa is experiencing the most rapid rate of urbanization in the world. The growing number of medium and large cities in the continent face a major challenge of providing their populations with adequate water supply, with large parts of the continent facing severe water stress. African cities urgently need to put in place effective water demand management strategies that could use the limited water resources efficiently without wastage, and widen the service coverage, particularly in the burgeoning urban low-income settlements.

A major environmental crisis is also looming large in the continent as the African cities continue to discharge ever increasing volumes of waste into freshwater bodies, threatening water quality and aquatic ecosystems. Several African cities share one or more international river basins which present a special challenge of managing water resources in these basins, avoiding future conflicts. A business-as-usual approach to urban water resources management threatens not only the sustainability of its cities but also its precious water resources and supporting ecosystems which are closely linked to Africa's future.

Solution Proposed

The project is a collaborative initiative of UNCHS (Habitat) and UNEP within the framework of the United Nations System-wide Special Initiative on Africa, and is a direct follow-up of the Cape Town Declaration (1997) adopted by African Ministers addressing the urgent need for managing water for African cities.

The project intervention will be the first comprehensive initiative to support African countries to effectively manage the growing urban water crisis and protect the continent's threatened water resources and aquatic ecosystems from the increasing volume of land-based pollution from the cities. The project will, specifically, focus on the following two interlinked priorities:

- ☐ *Water Demand Management in African Cities: The project will put in place an effective water demand management (WDM) strategy in ten African cities for efficient water use by al users; the project will institutionalize WDM measures in ten selected African cities by providing technical assistance to establish dedicated WDM units within existing city-level institutions and facilitate city-wide action plans for WDM.*

- ☐ *Mitigating the impact of urbanization on freshwater resources and aquatic ecosystems: The project will assist African countries to put in place in four river and lake basins early warning mechanisms for timely detection of potential 'hot spots', where sustainability is likely to be threatened; the project will also facilitate the assessment of long-term environmental impact of the growing ecological footprints of large cities on the continent's water resources.*

The project will be implemented in collaboration with the Ministries of Water Resources, Environment and Urban Development in the participating countries. Other collaborative agencies will be the Southern African Development Community (SADC), Lake Basin Authorities, Global Collaborative Council for Water and Sanitation and the Water Utility Partnership for Capacity Building in Africa.

BACKGROUND OF THE INITIATIVE

Africa is witnessing an unprecedented urban transition as it approaches the twenty-first century. The region, which, until recently, was predominantly rural, is experiencing the world's most rapid rate of urbanization at nearly 5 per cent per annum. Its urban population will nearly quadruple from 138 million in 1990 to 500 million in 2020, with increasing concentration in medium and large cities. By 2020, Africa's major cities (with more than one million population) will accommodate almost 200 million people – 20 per cent of the region's population and 40 per cent of its urban population.

African cities are already playing a key role in the development efforts of countries in the region, contributing to growth, exports and employment. These include not only the megacities with act as centres of political power and commerce (e.g. Cairo, Lagos, Abidjan and Johannesburg), but also some 25 million-plus cities (1990) which account for half or more of the gross domestic product of the respective countries. With increasing emphasis on industrialization and the growth of the tertiary sector, cities will continue to act as nerve centres and engines of growth in the continent.

As the African continent follows patterns of unprecedented urbanization, the demands for water supply for industrial, commercial and domestic sectors continue to rise and outpace the capacities of governments resulting in gaps which have steadily widened over the years, threatening sustainable development and the environment of cities. Drinking water supply coverage in African cities is the poorest among all regions, with more than a quarter of urban populations remaining without adequate access to safe water.

The increasing concentration of populations in urban areas and the growth of large cities in the continent also pose enormous pressure on the fresh water resources of African countries. The per capita water availability continues to decline in Africa. A survey of 29 Sub-Saharan African countries in 1990 showed that 8 were suffering from water stress or water scarcity. By 2025 this number will increase to 20 out of the 29. Many cities require freshwater to be conveyed great distances or abstracted from deep aquifers. Cities are also discharging ever increasing volumes of waste into freshwater bodies, threatening water quality and aquatic ecosystems. Please see indicators collected by Habitat on cities.

Some of the key factors which aggravate the situation and could pose serious threat not only to the sustainability of cities but also to the supporting ecosystems can be identified.

Increasing needs of cities

As the African cities continue to grow, the hinterland from which they draw upon water resources also expand. Many African cities have already outgrown the capacity of local sources to provide adequate, sustainable, water supplies.

Dakar (Senegal), for instance, with a population of 250,000 in 1961, relied on its basalt aquifer for drinking water supplies. By 1988, its population had reached 1.5 million and the local ground water supplies were already over-pumped, resulting in saline intrusion. A large part of the city's water has now to be brought in from the Lac de Guiers, 200 kilometers away.

The agricultural hinterlands supporting the cities are also expanding with growing urban populations, often resulting in deforestation and accelerated soil erosion. The sedimentation loads caused by deforestation in Malawi, Tanzania and Mozambique (urban populations in these countries have grown three to ten fold between 1950 and 1990) are inhibiting fish reproduction in Lake Malawi.

Urban growth in water stress regions

Several African countries experiencing rapid urban growth, or already with large urban agglomerations, currently suffer from chronic water stress or water scarcity and, what is more important, the per capita water availability is sharply declining the large majority of these countries.

For example, urban centres relying fully or in part on the Nile (Cairo, Alexandria), Tana (Nairobi), Limpopo (Johannesburg, Pietersburg, Bulawayo and Gaborone) and Orange river (Upington) basins already experience water scarcity, and those in Lake Chad (N'Djamena, Maiduguri), and Niger (Bamako, Niamey and Abuja) basins currently experience water stress. By 2020, water scarcity will extend to al these basins, with per capita water availability reduced to less than 1000 cubic metres per year.

Urban centres sharing international river basins

Several large African cities share at least one international river basin (Nile, Niger and Congo; Limpopo, Volta and Zambezi). The growing water demand and the discharge of wastewater from these cities pose a special challenge of managing water resources of these river basins in a coordinated manner. The interdependence of riparian states (as also the water-sharing cities) is further heightened by the high seasonal variation in river flows, and the concentration of rainfall in upstream countries.

Threat to water quality and aquatic systems

Sharing of the same water body by several African Cities pose a special threat to freshwater quality and many of the delicate aquatic ecosystems. Some of these ecosystems such as Lake Victoria are already facing severe degradation by the land-based pollution generated by urban settlements like Kisumu (Kenya), Jinja (Uganda) and Mwanza (Tanzania). The scale and intensity of this degradation is likely to increase significantly in the coming years, with expanded economic activities, industrialization and urbanization.

The Cape Town Declaration

The Cape Town Declaration, adopted by African Ministers at the International Consultations addressing Africa's urban water challenge, held in Cape Town, South Africa, in December 1997, has expressed serious concern at the inability of cities to provide safe drinking water to their populations which result in an increased burden of health care, reduced productivity and quality of life. The Declaration also draws attention to the serious threat of depletion, pollution and degradation of Africa's freshwater resources posed by the expanding urban areas in the continent.

The Declaration underscores the strong political resolve to deal with this threat and recommends that governments at appropriate levels work with their partners to develop and implement programmes of action to meet the growing urban water challenge.

A PROJECT TO MANAGE WATER FOR AFRICAN CITIES

Project Objectives

The *development objective* is to support African countries to effectively address the growing urban water crises and protect the continent's threatened water resources and aquatic ecosystems from the increasing volume of land-based pollution from the cities.

The *immediate objective* is to improve urban water resource management practices in African cities by enhancing awareness, promoting effective policies, programmes and investments, and by building capacity at city level and in key national and regional institutions, addressing the following interlinked and complementary priorities:

- ☐ Improving efficiency of water-use in urban areas, both in productive and domestic sectors, through the introduction of water demand management (WDM) measures at the city level;
- ☐ Mitigating the environmental impact of urbanization on freshwater and aquatic ecosystems, through the adoption of an integrated approach to managing urban water resources, taking cognizance of the links between water, urban development and the environment;
- ☐ Enhancing flow of information and best practices on urban water resource management among African cities.

EXPECTED BENEFICIARIES

Water demand management in participating cities

Primary beneficiaries

Building capacity for water demand management in African cities will directly benefit the following:

- ☐ City Managers responsible for water supply to the city and other related departments of civic administrations;
- ☐ Managers in both pubic and private utilities in the project cities;
- ☐ Professionals in national water ministries in participating countries.

Secondary beneficiaries

Indirect beneficiaries who will benefit from improved water supply in the project cities include:

- ☐ Urban households including those living in low-income peri-urban settlements benefiting from expanded/enhanced service coverage;

- Private and public sector industries and commercial and service sector consumers relying on municipal water supply.

Note: Enhanced water supply resulting from water demand management will provide the opportunity to improve service coverage particularly in peri-urban low-income settlements which are homes of the urban poor.

Mitigating the environmental impact of urbanization on freshwater resources and aquatic ecosystems

Primary beneficiaries

- Professionals in national ministries of water, environment and urban development associated in project implementation;

- City-level professionals directly associated in project implementation;

- Professionals in associated regional organizations

- Professionals in research institutes to be associated in the implementation of the project

Secondary beneficiaries

The secondary (indirect) beneficiaries, of improved water quality expected to result from the project intervention will include the affected human settlement in affected river/lake basins and the aquatic eco-systems which are currently threatened by the land-based pollution generated by the urban settlements located within these river/lake basins.

PROJECT ACTIVITIES

(i) Activities Related to Water Demand Management

Expected Outputs	Related Activities
(a) Current water use patterns and assessment of WDM potential	☐ Assess existing legislation, institutional and operational factors hindering introduction of effective WDM measures. ☐ Assess needs for human resource development and for strengthening relevant institutions. ☐ Assess information needs and those for developing policies on WDM measures. ☐ Assess other relevant programmes and proposals for interfacing possibilities with project. ☐ Consolidate findings for city-level consultations.
(b) Strategy development in consultation with stakeholders	☐ Identify key city-level actors and stakeholders. ☐ Consultations for developing city-level WDM strategy. ☐ Develop strategy paper for introducing city-level WDM measures.
(c) Establishment of WDM Units in participating cities	☐ Identify required institutional arrangements and training needs for implementing WDM strategy. ☐ Give technical guidance on WDM unit creation within city administration or water utility. ☐ Give training support for WDM staff, including study and exchange visits between cities. ☐ Give technical help in Plan development.
(d) Development of city-level Action Plans	☐ Identify legislative and other interventions needed for implementing WDM Action plan. ☐ Identify human and other resource needs for implementing the Plan. ☐ Prepare comprehensive proposal for implementing the Plan, identifying areas requiring external and other financial support.

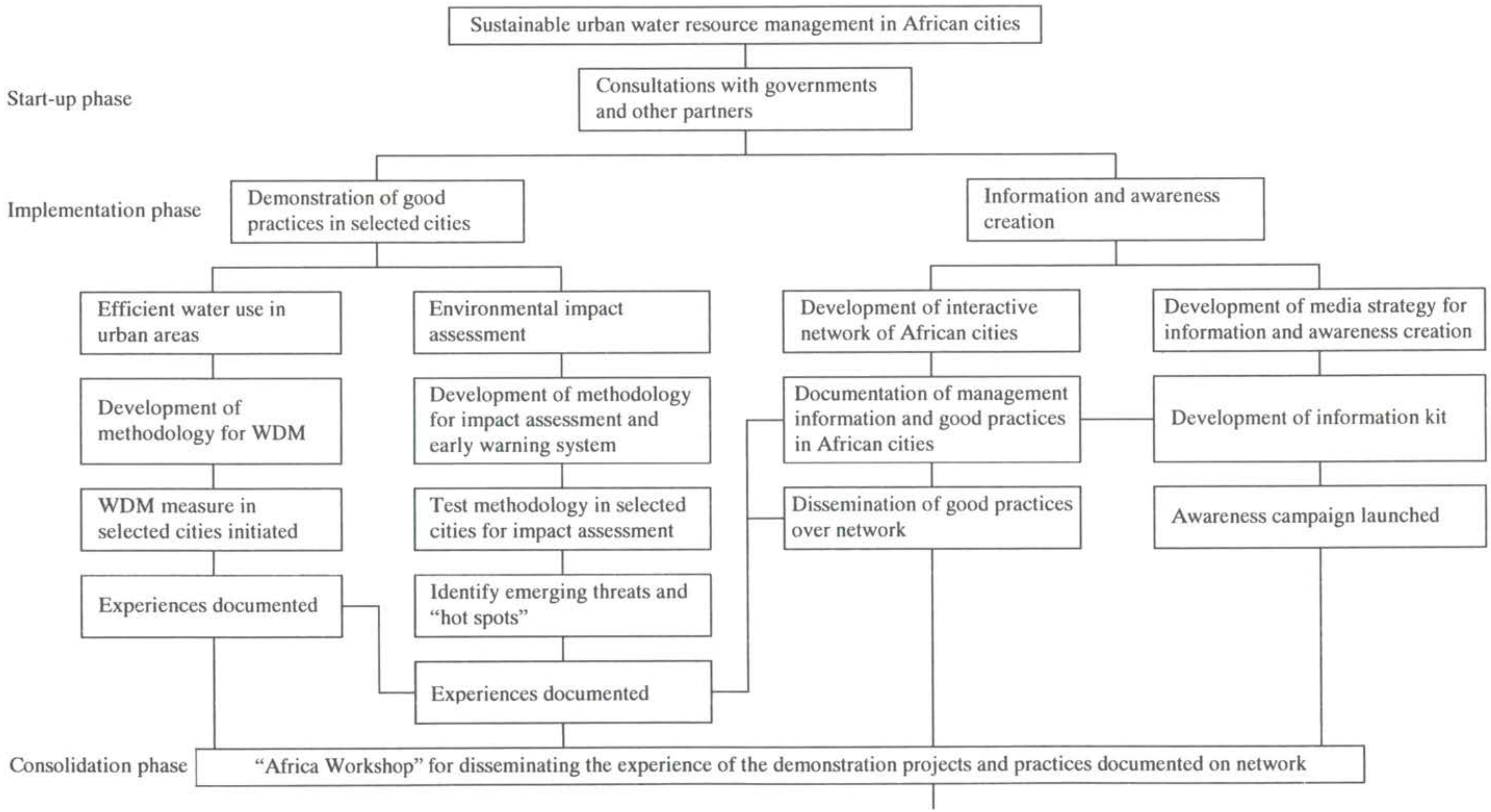
(ii) Activities Related to Environment Impact Mitigation

Outputs Expected	Related Activities
(a) **Develop city-wide baseline information**	☐ Identify, compile, analyze information and data on types and quantity of pollutants that are generated by participating cities. ☐ Identify, analyze data on point and non-point pollutant sources at city level. Determine information gaps. ☐ Consult UNEP GEMS/Water Collaborating Centres, their partners and other relevant agencies or organisations on pollutant generation and sources in urban areas, as well as about the previously determined data gaps. ☐ Create appropriate, or ensure existing information storage and retrieval system for the amassed data is functional and up-to-date. ☐ Assess environmental impacts of urban water discharges and urban storm drain run-off.
(b) **Develop Strategies for assessing impacts of urban pollutants on water quality**	☐ Identify and apply appropriate indicators and standards in impact assessments. ☐ Identify, test and evaluate appropriate modelling tools including GIS, for assessing pollution impacts on downstream and river basins.
(c) **Identify long-range pollution patterns and develop early warning systems**	☐ Apply selected model to target river basin(s) with one or more of the project cities. ☐ Evaluate and refine the modelling approach, as necessary. ☐ Develop handbook for local authority managers on sources and types of urban pollutants and the strategies for mitigating them. ☐ Develop and disseminate findings as public awareness materials bringing out the role of urban water consumers as polluters and their role in mitigation.
(d) **Enhance regional capacity for managing urban water resources**	☐ Conduct national training workshops on water pollution assessment and monitoring.

(iii) Activities Related to Sharing and Exchange of Information and Best Practices

Outputs Expected	Related Activities
(a) **Establish on-line network for sharing information and best practices**	☐ Develop an information network on urban water resources management. ☐ Test, refine and disseminate network widely to users within and outside the African region. ☐ Launch network with participation of senior policy makers of the region.
(b) **Develop public awareness campaign**	☐ Formulate media strategy. ☐ Launch public information campaign in participating cities. ☐ Support introduction of water-education in selected educational institutions.
(c) **Region-wide conference for dissemination of the project experiences and sustaining regional capacity (Consolidation phase)**	☐ Prepare background documentation for the conference. ☐ Identify host country, key participants (about 40) from the region and collaborating partners. ☐ Organize and have the conference. ☐ Conference recommendations on the project's follow-up actions and sustaining the capacity developed, including the establishment of a regional clearinghouse of information on urban water resources management. ☐ Produce and disseminate conference report, including the follow-up action plan.
(d) **Develop proposal for project follow-up**	☐ Write specific proposals for follow-up actions, addressing the need for sustaining the developed regional capacity. ☐ Identify, with participating countries and regional partners, a suitable host organization for a regional information clearing house. ☐ Assist the identified host organization to develop terms of reference and assess its resource needs. ☐ Seek and establish the initial funding support form donors for the establishment of the information clearing house.

PROJECT OVERVIEW



PROJECT STRATEGY AND IMPLEMENTATION ARRANGEMENTS

Implementing Agency and Collaboration Arrangements

UNCHS (Habitat), the implementing agency, has been active in the Africa region, advising and supporting governments and their partners in urban development and management for two decades. UNCHS (Habitat) also acts as the focal point agency within the United Nations System for water and sustainable urban development, and has been assisting several African governments in the urban water sector.

In implementing the project, UNCHS (Habitat) will work in close partnership with UNEP, drawing upon is expertise in the areas of monitoring and assessments (particularly through GRID and GEMS water programmes) and in the area of environmentally-sound management of internationally-shared water resources (particularly through EMINWA). UNEP's experience of implementing the Global Programme of Action for the Protection of the Marine Environment form Land-based Activities will also be of special advantage in project implementation. A joint UNCHS/UNEP working team will be established for the implementation of the project.

Collaboration with UNDP, the World Bank, UNICEF and the Commonwealth Secretariat, is anticipated in project implementation. UNCHS (Habitat) has already established (in April 1997) MOUs with the World Bank, UNICEF and the Commonwealth Secretariat for collaboration in the context of the Cape Town Declaration.

Implementation Arrangements

The project will be implemented n three consecutive stages:

- ☐ an initial *start-up phase* for in-country consultations and consultations with other partners to firm up implementation arrangements;
- ☐ an *implementation phase* for the execution of demonstration activities in selected cities and for the region-wide implementation of information and awareness-building activities; and (c) a *consolidation phase* for a region-wide dissemination of project results and experience and for anchoring the strengthened. Details of implementation in each stage are described below:

Start-up Phase

The project envisages an initial three month start-up phase for in-country consultations which will be devoted to the following activities:

- ☐ Selection of cities for project implementation through in-country consultations[1];

[1] The selection of cities will be base on the following criteria:
- ☐ Location within a water-stress region;
- ☐ Availability of adequate local institutional and human resources capacity;
- ☐ Demonstrated commitment by relevant city and national authorities to be associated in project implementation;
- ☐ Geographical distribution and coverage.

- ☐ Identification of relevant government agencies at national and city level and appropriate regional bodies to be associated in project implementation, and securing firm government commitments (demonstrated through exchange of communication) in participating countries for required contributions;
- ☐ Consultations with UNDP country offices and exploring linkages with UNDAF, as appropriate;
- ☐ Establishing coordination with other relevant programmes and development efforts;
- ☐ Establishing steering committees as city level to oversee project implementation;
- ☐ Designation of national focal points by participating coutries.

Implementation Phase

The start-up phase will be immediately followed by project implementation in the designated cities. The project will be implemented in two distinct, but complementary, thrust areas:

- ☐ Demonstration of good practices of urban water resources management in selected cites; and
- ☐ Enhancing flow of information and awareness among policy makers, professionals and user communities in African countries of the needs, opportunities and good practices of water resource management in urban areas (see Project Overview attached).

The demonstration of good practices of urban water resource management will specifically, focus on:

- ☐ Promoting efficient water-use in urban areas through the introduction of water demand management measures, and
- ☐ Mitigating the environmental impact of urban activities on fresh water resources. Demonstration activities will be undertaken in selected African cities (upto a maximum of ten cities, depending on demonstrated commitment, to be selected during start-up phase).

The information and awareness-building components of the project will focus on:

- ☐ Facilitating exchange of information and experience, including good practices of urban water resources management, among city managers and policy makers, and
- ☐ Developing a public information campaign for water conservation in African cities. Region-wide participation of African cities is expected in the sharing of information and experience through an on-line information network to be established by the project.

Consolidation Phase

The result of all studies and documentation carried out by the project in the selected basins will be discussed and disseminated at a regional conference to be organized in the final stage of the project

(September 2001). The conference will provide an opportunity to policy makers, planners and mangers from all African countries to exchange their experiences and identify action priorities for their respective countries in the area of urban water resources management.

The proposal for a regional clearing house of information on urban water resources management will be developed by the project and will be presented at the regional conference for endorsement.

PLANNED INPUTS (Over 24 months)*

UNFIP Inputs	**US $ 2,270,000**
UNCHS Inputs	**US $ 800,000**
UNEP Inputs	**US $ 400,000**
UN Volunteers inputs	**US $ 130,000**
TOTAL	**US $ 3,600,000**

*Expected Inputs from other participants as indicated

GOVERNMENT INPUTS

Prior obligations of participating governments will include:

- ☐ Designation of national focal points and commitment to coordinate in-country activities and to ensure participation of various stakeholders (various ministries, NGO's, private sectors, etc.)
- ☐ Government participation in appropriate project steering committees (to be established before project implementation starts)
- ☐ Agreement on counterpart contribution
- ☐ Agreement to make available necessary information/available reports etc., as required for project implementation.

Annex

Current Status of Progress in Candidate Cities

Candidate City	Current Status	Potential Partners
1. West Africa		
Dakar (Senegal)	• Fact finding mission undertaken jointly with the World Bank (Dec/98); second project formulation mission fielded in March 99; third mission with the World Bank scheduled in April 99 • Strong commitment from the Government • Government counterpart funds and WB support committed • Final Government proposal with costs received	• The World Bank • Private Sector (SDE) • Sustainable Cities Programme
Accra (Ghana)	• Country missions undertaken (Nov/98 and March/99) • Joint mission with the Word Bank scheduled (May/99) • Government Counterpart funds committed;	• The World Bank • Sustainable Cities Programme
Abidjan (Cote d'Ivore)	• Country missions undertaken (Dec/98 and March/99) • Strong commitment from the Ministry of Water and Ministry of Environment • Government proposal with costs finalized	• African Development Bank • Private Sector (SODECI)
2. South Africa		
Lusaka (Zambia)	• Country missions undertaken (Jan/99 and March/99) • Strong commitment from the Ministry of Local Government, Lusaka City Council • Govt. proposal with costs received Govt. funds committed • Collaboration arrangements being discussed with the European union and NORAD; initial discussions held with	• The World Bank • UNDP • NORAD • European Union • Sustainable Cities Programme
Johannesburg/ Umtata (South Africa)	• Country missions undertaken (Feb-March/99) • Strong commitment from the Ministry of Water and City Mayor of Johannesburg; Govt. proposal with costs received	• UNDP • Private Sector (Rand Water)
3. East Africa		
Addis Ababa (Ethiopia)	• Country missions undertaken (Jan/99 and March/99) • Strong commitment from the Government • Government proposal with financial commitment received • Collaborative arrangements being discussed with European Union and the World Bank	• European Union • The World Bank • African Development Bank
Nairobi (Kenya)	• Consultations under way with the Govt. country proposal expected by mid-April 99	• UNDP/WB Regional Water and Sanitation Programme • GTZ (Kenya Water Institute)
4. North Africa		
Cairo/Ismaiia (Egypt)	• Govt. has expressed strong interest to participate • Country mission planned (April/99)	• Sustainable Cities Programme • Partnership with bilaterals being explored

UNCHS (Habitat) & UNEP
Managing Water for African Cities

(supported by UNFIP)

by Dr. Graham Alabaster, Infrastructure Unit, UNCHS (Habitat)

Managing Water for African Cities

How bad is the water crisis in Africa?

- By year 2000, 12 African countries will be in "water stress"
- By 2025, 22 African countries will be in "water stress" (about 1.1 billion or 2/3 of the African population)
- RESULT: The quality of life will suffer and development will be further constrained

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Managing Water for African Cities

What are the main reasons for "stress"?

- **Limited Resources**, insufficient surface or groundwater available
- **Poor Distribution,** the reticulation systems within the city is inadequate or in a poor state of repair/leakage
- **Inequality in distribution, sector/income**
- **Contamination of resources**

Managing Water for African Cities

What are the main reasons for "stress"?

Limited Resources

- Insufficient surface or groundwater available close to consumer/finite transfer capacity (Dakar, Senegal)
- Source unsustainable/recharge resulting for urbanization
- Source contaminated (Accra, Ghana)
- Excessive demands (tourism)

Managing Water for African Cities

What are the main reasons for "stress"?

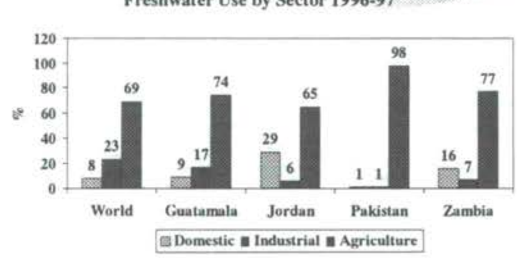
Poor Distribution

- High unaccounted for water losses due to leakage/un-metered illegal connections (in Nairobi 30% in 1990 to 51% in 1997)
- Low service coverage for the urban poor

Managing Water for African Cities

Equality of Distribution amongst sectors?

Freshwater Use by Sector 1996-97



Managing Water for African Cities
What are the main reasons for "stress"?

Contamination & exploitation of resources

Related to the CITIES "Eco-footprint"

- wastewater from point and diffuse sources domestic/industrial/agricultural
- poor attitudes to water use & conservation

MORE URBANIZATION MORE STRESS!

Managing Water for African Cities
What are the main obstacles to overcome?

- **There is a failure to consider both the quality AND quantity issues when considering how to address water stress**
- **Governments don't appreciate the urgency**
- **Political support is stronger for NEW CAPITAL SCHEMES than for conservation**

Managing Water for African Cities
What does the project seek to achieve?

- **Efficient** use of freshwater at city level through WDM
- **Minimizing** the impact of urbanization on freshwater resources
- **Exchange** of information and good practices on urban water resources management
- **Leveraging** investment

Managing Water for African Cities
What are the benefits?

- Improved service coverage (the urban poor)
- More equitable allocation
- Delaying of investment in new water resources development projects
- Changed attitudes to water use
- Improved quality of life & environment
- More efficient industry and agriculture

Managing Water for African Cities
How will the project be implemented?

In two distinct but complimentary phases

- Demonstration of good practices ***in urban water resources management***
- Enhancing the flow of information and awareness creation ***amongst policy makers, professional and communities***

Managing Water for African Cities
How will the project be implemented?

Demonstration of good practices

- Promoting efficient water use through WDM
- Mitigating the environmental impact of urban areas

Information and awareness building

- Facilitating exchange of information
- Developing a public information campaign through networking

Managing Water for African Cities

How will the project achieve these goals ?

- **Start-up phase:** In country consultations; firm-up collaborative arrangements with partners, revise programme of action(completed May 99)
- **Implementation phase:** rapid assessment, stakeholder consultations, develop local capacity; institutional strengthening and coordination; strategize follow-up investment (starting June 99)
- **Consolidation:** Region-wide dissemination of results; formalize network arrangements; catalyze investment

Managing Water for African Cities

What is the current status ?

- **Joint project team operational**
- **Collaborative agreements signed** with: the World Bank, Commonwealth Secretariat and UNICEF, In progress: UNDP, AfDB, GWP, WWC, WSSCC
- **Country-level consultations:** completed by end march 1999
- **Water demand management manual -** in preparation (first draft available)
- **Scientific & technical implementation strategy-** prepared by EGM April 1999
- **Media strategy** -first draft available

Managing Water for African Cities

What was the criteria for city selection?

- Location within a water stress region
- Availabilty of local institutional and human resources capacity
- Demonstrated commitment by relevant city and national authorities to be strongly involved in project implementation
- Active presence of partner agencies in the city
- Geographical distribution around the continent
- Identification of a "Champion" to maintain momentum

Managing Water for African Cities

What type of activities will be implemented at country level ?

- **Pilot demonstrations of Water Demand Management (retro-fitting, leakage detection, metering, public education) for domestic, institutional and industrial establishments.**
- **Development of simple models for groundwater management/pollution control**
- **Wastewater reuse schemes**
- **Awareness and information campaigns**
- **Development of MISs for local authorities**

Managing Water for African Cities

What the current commitments of participating countries?

Participating cities

- Abidjan (Cote d'Ivoire), Accra (Ghana), Addis Ababa (Ethiopia), Dakar (Senegal), Johannesburg (South Africa), Lusaka (Zambia), and Nairobi (Kenya)

Financial commitments

- UNFIP inputs US $ 1.317 million. Participating governments & agencies US $ 5.521 million UNCHS/UNEP contributions in HR

Water for African Cities: Conclusions

- Governments must give top priority to the current water crisis in Africa
- Establishing long-term capacity essential and focus on changing peoples attitudes
- Creation of awareness to both quality(EI of cities) & quantity (WDM) essential
- Development of good practices through demonstration and replication

Towards an Ensured and Sound Hydrological Cycle

By Seiji IKKATAI, Director
Water Quality Management Division
Water Quality Bureau
Environment Agency, Government
of Japan

Introduction

The policy concept of an ensured and sound hydrological cycle was established in 1994 by Japan's Basic Environment Plan. The national policy to ensure sound water cycles is very important, but realization of the policy is complicated by the fact that it is not easy to coordinate the relevant policies of each Ministry and Agency in charge of various water management issues.

In March 1999, after one and a half years of intensive discussions that included public comments, the Central Environment Council, an advisory board of the national government, published a report titled "The Basic Concept and Policy Measures for Ensuring a Sound Hydrological Cycle" and submitted it to the Director General of the Environment Agency. The Environment Agency is currently formulating policy measures in response to this report. In addition, the Environment Agency and five other Ministries and Agencies have established an inter-Ministerial working group in order to form a common approach for better management that leads towards ensured and sound hydrological cycles.

This paper presents an outline of the March 1999 report and also describes the progress of the ongoing discussion among the Ministries and Agencies concerned.

I. Outline of the March 1999 Report

1. Basic Background

A sound natural hydrological system maintains a vast variety of ecosystems; it purifies water and tempers extreme meteorological conditions because of the specific heat capacity of water and evaporation from vegetation and water surfaces. The natural water cycle transports heat and substances and is available to support many of humankind's uses. We know that such healthy hydrological cycles are necessary to ensure human survival, both physically and spiritually.

Japan's actual hydrological cycle of today has been created by adding human-made, artificial hydrological processes to the natural hydrological system. These artificial systems were created to secure effective societal water use and to protect against floods. For example, rice paddies, the most traditional form of agriculture in Japan, use the water from rivers. The water feeds not only the rice but also beautiful local ecosystems; then the water reenters the river once again. This is a case where the artificial hydrological cycle is in harmony with the natural hydrological cycle. But of course, not all cases of artificial water cycles reflect such harmony.

2. Background of Deterioration

The concentration of the Japanese population in urban areas and the resulting rapid development of these areas since the mid-century have resulted in many changes to the hydrological cycle. The size of the area where rain cannot permeate the ground has increased, and the area for forests and rice paddy fields has decreased. This has caused destruction to part of the natural water cycle, which has in turn resulted in unstable water flow rates, depletion of the water in wells and springs, deterioration of ecosystems, and various other problems.

In other words, rapid urbanization and improvements in living conditions produced huge water demands for use in peoples' daily lives, industry, hydro-electric power plants, etc. It also produced the need for public works designed to prevent floods. During this time, the government concentrated its efforts on the solution of sectorial issues by separate agencies, not on the development of comprehensive measures that would help ensure sound hydrological cycles. The result of this rapid urbanization and segmented government approach is that there are now many artificial hydrological systems that do not function in harmony with the natural water cycle.

3. Examples of Various Kinds of Deterioration

Forest Areas

The decrease in the size of virgin forests and poor forest management have lessened the previous natural capacity of forests to contribute to healthy water cycles in such ways as replenishing and maintaining ground water levels.

Agricultural Areas

Decreasing the area for farmland, especially rice paddies, has resulted in a decline in filtering functions that previously enhanced water purification, as well as the replenishment and storage of groundwater. In addition, the excessive use of fertilizer and pesticides has caused ground water pollution.

Urban Areas

Permeation of water into the ground is currently hampered by the asphalt pavement and storm water drainage systems associated with urbanization. Consequently, there are such problems as intensified fluctuation in the flow of rivers (i.e. floods during heavy rains and unnaturally reduced flows during periods of normal precipitation), dried up springs, and a lowered capacity to purify water. The quality of river waters in urban areas remains degraded, and the health of aquatic ecosystems has deteriorated. In addition, heat island phenomenon has been recorded in major urban areas.

Coastal Areas

Seaweed beds and shallow water areas have decreased because of development. The natural supply of sand and soil from rivers has been changed by the construction of dams and other water projects.

4. Basic Concept for an Ensured and Sound Hydrological Cycle

A "sound hydrological cycle" exists when the benefits derived from the natural hydrological cycle have basically not been diminished.
To ensure such a state, efforts should be made to minimize the impacts of human activities and to maximize the sustainable functions of the natural hydrological cycle.
Important issues which should be considered simultaneously are:

1. The scope of a "sound hydrological cycle" includes not only surface water but also ground water. We should understand the watershed as a 3-dimensional structure.
2. Increases in water demand and water contamination created conditions that led to the deterioration of the natural hydrological cycle. Thus, technology development that makes the goals of water use and water conservation compatible must be stressed. At the same time, activities the result in the reuse and saving of water should also be emphasized.
3. Public works to address flood control are inevitable, but environmental considerations that make flood control and sound hydrological cycles compatible must be integrated more and more into these public works.
4. Policies regarding sound hydrological cycles should not increase the consumption of fossil fuel or natural resources, rather, they should result in the use of more renewable energy sources.

Visualizing the Goal

* Affluent water flow rates of rivers and springs are maintained. Ground water is managed properly and ground subsidence and water shortages are avoided.
* Clean water is conserved by proper water pollution control; natural water purification occurs through soil filtration, which also helps maintain water flow rates.
* The situations of dried up rivers are avoided and a healthy system of flora and fauna populate rivers and lakes.
* Rainwater infiltrates the ground properly and damaged urban river ecosystems recover properly. In addition, urban greenery is increased, decreasing the "heat island" phenomena.
* Beautiful waterfronts and springs become common in neighborhoods and are enjoyed by residents. People understand the inherent value of sound hydrological cycles and they make efforts to conserve water and enhance the functions of the natural hydrological cycle.

5. Working Toward Widespread Implementation of Policy Measures:

The Central Environment Council has identified three main steps for implementation.

(i) Development of widespread recognition of the problems and action targets:

It is fair to say that we do not have sufficient information to fully understand the mechanisms within the natural hydrological cycle or the problems and effective countermeasures within this cycle. In order to formulate widespread recognition within a watershed, indicators which enable one to evaluate the health of the hydrological cycle of the region should be developed. Then, based on the evaluation of these indicators, a data-base that is shared with the people who live in the watershed should be prepared. After this, targets and necessary counter-measures should be prepared.

(ii) Establishment of a comprehensive policy:

As mentioned before, the ministries and agencies concerned with water management have had the tendency to independently seek their own separate policy targets, as opposed to seeking coordinated comprehensive policies that support sound hydrological cycles. It is now necessary to form a common understanding among the concerned Ministries and Agencies of what a sound hydrological system is, what problems exist, etc. Following this, a basic outline of a comprehensive national policy should be coordinated and established as soon as possible. Public control for underground water management especially needs to be strengthened. Permeation of rain water should be enhanced by using land use plans. In addition, the difficult issue of allocating costs based on "Polluters Pay Principle" and "Users Pay Principle" should also be discussed.

(iii) Policy implementation in watersheds:

Each watershed has its own natural and social conditions, and the master plan that is developed to restore the area's sound hydrological cycle must reflect these conditions if it is to be effective. The plan should therefore be developed by some kind of association that is comprised of residents, scholars, water users, public officials, NGOs, and others.

6. Basic Policy Direction for Each Area within a Watershed:

Forest Areas

* Conservation and management of the forest based on an evaluation of its environmental functions.
* Cooperation between up-stream municipalities and down-stream municipalities.

Agricultural Areas

* Conservation and management of farmlands, including rice paddies, based on an evaluation of its environmental functions.
* Improved agricultural systems that decrease the use of fertilizers and pesticides that cause water pollution.
* Reserved rice paddies, although not in use for farming, continue to be filled with water in order to recharge groundwater and to purify surface water.

Urban Areas

* Enhancement of rain infiltration and green areas through improved urban planning activities.
* Increased use of rainwater and reuse of domestic and industrial waters.
* Enhancement of water saving activities.
* Counter-measures for non-point source pollution from roads, etc.
* Counter-measures for the heat island issue based on an evaluation of the effect of greenery and water bodies.

Coastal Areas

* Conservation of seaweed beds and shallow water areas based on an evaluation of their environmental functions.
* Establishment of comprehensive management plans for soil and sand flow management within river systems.

Rivers, Lakes, and Ground Water

* Integration of environmental considerations into flood control activities by using " environmentally friendly technologies".
* Balanced allocation of river water between human use and ecosystem maintenance by establishing rules for allocation.

II. State of the Discussion within the Inter-Ministerial Working Group

1. The Water Management System of Japan:

The following six national organizations are responsible for water management.

-Environment Agency:	In charge of environmental protection, especially water quality management.
-National Land Agency:	In charge of water resource development.
-Ministry of Health and Welfare:	In charge of drinking water issues.
-Ministry of Agriculture:	In charge of agricultural water use and forest management.

-Ministry of International Trade and Industry:	In charge of industrial water use and hydro-electric power plants.
-Ministry of Construction:	In charge of river management issues that include flood control, coordination of river water use, etc. Also in charge of the construction and management of sewage treatment facilities.

2. Establishment of the Inter-Ministerial Working Group

Since water management has been implemented by many national organizations with their own policy objectives, there has been no common understanding of what constitutes a sound hydrological cycle. However, all of the organizations recognize that, as we approach the 21^{st} century, efforts to support the realization of "sound hydrological cycles" are very important. They also recognize that there are many problems that have been caused by the lack of a well-coordinated and comprehensive policy.

For these reasons, in August 1998, the Division Directors of six Ministries and Agencies agreed to establish for the first time an inter-Ministerial working group on sound hydrological cycles. The following points were also agreed to by the involved organizations: 1) It is necessary that all of the concerned Ministries and Agencies have a common understanding of what constitutes a sound hydrological cycle. 2) It is important to exchange information and to discuss each organization's activities and approach to the issue. 3) After a thorough discussion and sharing of ideas, the inter-ministerial workgroup will produce a "basic policy for sound hydrological cycles". The policy will, among other things, clarify the concept of "sound hydrological cycles", identify existing problems, and outline the direction of counter-measures. 4) Based on the basic policy, each Ministry and Agency will develop and implement their own activities, working in cooperation as needed.

3. Activities of the group

Since August 1998, the group has had meetings, with intensive discussions, once a month. The meetings have been very interesting and valuable. While not always easy to coordinate, the participants all recognize the importance of this work. It is expected that the agreed upon policy will be finalized in the near future.

International Symposium
on
Efficient Water Use in Urban Area
-Innovative Ways of Finding Water for Cities-

Kobe, Japan
8th-10th June 1999

TOWARDS AN ENSURED AND SOUND HYDROLOGICAL CYCLE

Presentation
by

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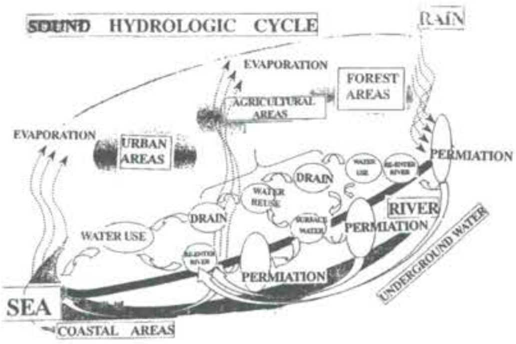
INTRODUCTION

1 OUTLINE OF THE MARCH 1999 REPORT

" The Basic Concept and Policy Measures for Ensuring a Sound Hydrological Cycle "
(by Central Environment Council)

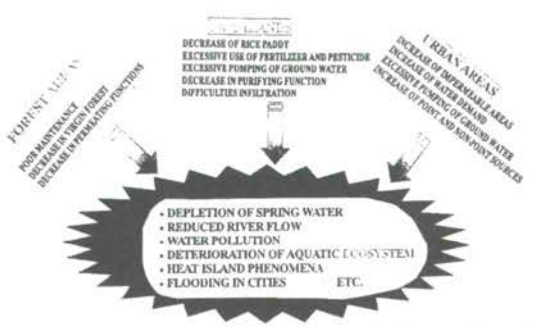
2 EFFORT FOR WELL COORDINATED AND COMPREHENSIVE POLICY

→ Establishment of the Inter-Ministerial Working Group

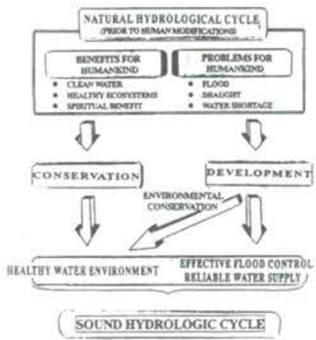


BACKGROUND OF DETERIORATION

- **Development of Urban Areas**
- **Increase of Area Where Rain Cannot Permeate**
- **Decrease of Area for Forest and Rice Paddies**
- **Increase of Water Demands**
- **Increase Use of Toxic Chemicals**
- **Excessive Use of Ground Water**
- **Segmented Government Approach etc.**



PROBLEMS CAUSED BY UNSOUND HYDROLOGICAL CYCLE



BASIC CONCEPT OF SOUND HYDROLOGICAL CYCLE

BASIC CONCEPT OF SOUND HYDROLOGICAL CYCLE

DEFINITION

A " Sound Hydrological Cycle " Exists When the Benefits Derived from the Natural Hydrological Cycle Have Not Been Diminished .

IMPORTANT ISSUES TO BE CONSIDERED

1 Watershed Has a 3-Dimensional Structure
2 Technology Development
3 Water and Energy Savings
4 Integrate Environmental Considerations into Flood Control

GOAL

- **Proper Water Flow**
- **Clean Water**
- **Healthy Aquatic Ecosystems**
- **Decrease of Heat Island Phenomena**
- **People Understand and Act for Sound Hydrological Cycles**

MAIN STEPS FOR IMPLEMENTATION

1. Development of Widespread Recognition of the Problems and the Action Targets
2. Establishment of Comprehensive Policy
3. Policy Implementation in Watersheds

MAIN POLICIES FOR EACH AREA

- **Forest Areas**
- **Agricultural Areas**
- **Urban Areas**
- **Coastal Areas**
- **Rivers , Lakes and Groundwater**

ORGANIZATION OF WATER MANAGEMENT IN JAPAN

- Environment Agency
- National Land Agency
- Ministry of Health and Welfare
- Ministry of Agriculture
- Ministry of International Trade and Industry
- Ministry of Construction

ESTABLISHMENT OF THE INTER-MINISTERIAL WORKING GROUP

1. Established in August 1998
   - 6 Ministries and Agencies
2. Goals
   - Frank Discussion
   - Creation of "Basic Policy for Sound Hydrological Cycles"

International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
Kobe, Japan, 8-10 June 1999

Session 2: Harvesting and Utilisation of Rainwater

ECONOMIC AND WATER QUALITY ASPECTS OF RAINWATER CATCHMENT SYSTEMS

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INTRODUCTION

Basic perceptions in engineering have been used for the collection, storage and use of water from time immemorial. With the advent of technological developments, harnessing techniques have advanced considerably. The twin factors that realise such development are economic viability and the sustenance of an acceptable quality of water. On the one hand, the funds expended for any water project should ensure that the final product viz., water, should be costed such that it's use is within the means of the potential user while on the other, this very same product should have a quality level that should be of an acceptable order. The main objectives of this paper are to define and explain the design, construction, maintenance aspects of water resources development, with emphasis on rainwater catchment systems, in terms of economic viability and water quality. Special emphasis will be made on experience accrued, in terms of design, construction and maintenance in developing countries like Thailand, Indonesia and the Philippines where there has been considerable development in rainwater catchment systems. Systems developed in Singapore, in an urban environment, will also be mentioned in terms of methodology and economic aspects.

ECONOMIC & ASSOCIATED FACTORS

The major driving force in providing water, be it for domestic, industrial, commercial, irrigation or other purposes is its inherent cost. Conventional freshwater sources are limited to 2% of the available water resources of the world and the development of the sources, be they from rivers, impoundments, lakes or groundwater, largely dictate the viability of a project. The rest of the brackish and salt water can be abundant sources, but there has not been a sufficient break-through in treatment methodologies so as to make such sources economically viable. The main components in typical systems are the design of storage volumes and all associated factors that go towards the collection, treatment and distribution of treated water. The whole system will have to be costed and due attention also be paid to the utilization of systems involving a number of sources.

(a) **Design of the system:** The conventional design of any water resource system concentrates on the storage capacity of a reservoir or, in the case of a smaller rainwater catchment system, a cistern. The design of such storage systems has been formalized as long ago as 1883(Rippl) when the cumulative inflows were graphically plotted against the time to obtain a reliable yield or reliable supply corresponding to a specific reservoir volume. Subsequently, many other designs have come into existence. Typical examples are simulation analyses where the changes in storage are of a finite reservoir are calculated using a mass storage equation (McMohan et al, 1972), minimum flow approaches wherein the lowest flows for various durations are plotted against the duration forming drought curve (Waitt, 1945), extension of the mass curve and minimum flow approaches to provide the probability of storage failure by developing a series of drought curves (Alexander, 1962) and a series of probability matrix methods(Moran, 1959, Gould, 1961).

In a more recently developed input/output system (Appan, 1982), discretised rainfall time intervals as low as 15 minutes have been used in combination with corresponding demands to arrive at storage volumes that will ensure minimum waste. These systems tend to depict the real situation more accurately as they cater more for cistern systems where the storage volumes are relatively small.

In most cases, the major costs in water supply systems are associated with the storage systems.

(b) Types of rainwater catchment systems: The costing of such systems will largely depend on the magnitude of the project. Collection systems can vary from simple types within a household to bigger systems where a large catchment area contributes to an impounding reservoir from which water is either gravitated or pumped to water treatment plants. The categorization depends on widely varying factors like the sizes and nature of the catchment areas, whether the systems are in developed or developing countries etc., Some of the systems are described below.

(i) ***Simple roofwater collection system in developing countries:*** In this system, the main components are the size of the cistern, the piping that leads to the cistern and the appurtenances within the cistern. The materials and the degree of sophistication of the whole system will largely depend on the availability of funds. On the one hand there are highly expensive tanks utilised in affluent locations in Hawaii whereas in others there is evidence of simple and much cheaper systems in which the cisterns have been made with ferro-cement (Vadhanavikkit, 1983), bamboo reinforcement (Thiensiripipat, 1983) etc, In all these systems, every single element that contributes towards the collection system has to be designed and costed. In some cases, the water is subjected to some filtration processes whereas in others they have been nominally disinfected with some bleaching powder (Krishna, 1991).

(ii) ***Marginally larger systems in educational institutions, airports etc:*** When the systems are larger, but do not take the scale of a major project, the overall system can become a bit more complicated. Typical cases are, the collection of rainwater from the roofs and grounds in institutions, their storage in underground reservoirs, some minor treatment and then use for non-potable uses (Appan, 1998). An even larger scale of such activity exists in the Changi Airport in Singapore (Appan et al, 1995) wherein the rainfall from the runways and the surrounding green areas is diverted to two impounding reservoirs. One of the reservoirs is designed to balance the flows during the coincident high runoffs and incoming tides, and the other reservoir is used to collect the runoff. The waters are used primarily for non-potable functions such fire-fighting drills and toilet flushing. Such collected and treated water accounted for 28 to 33% of the total water used and savings per annum amounted to S$ 390,000.

(iii) ***Roofwater collection systems in high-rise buildings in urbanized areas:*** Almost 86% of Singapore's population lives in high-rise buildings (HDB, 1994). A light roofing is placed on the roofs to act as catchment and the collected roofwater can be kept in separate cisterns on the roofs for non-potable uses. Using such systems, studies have been carried out much earlier (Appan 1982, Appan et al, 1987). In the most recent study (Appan et al, 1997) involving an urban residential area of about 742 ha a model was developed to determine the storage volume of the cistern, taking into consideration the non-potable water demand and the actual rainfall at 15 minute intervals. This approach resulted in an effective saving of 4% of the water used, the volume of which did not have to be pumped from the ground floor. As a result of savings in terms of energy costs, deferred capital and water saving, the cost of collected roof water amounted to S$0.96 against the then cost of S$1.17 per cubic meter.

(iv) ***Collection of stormwater in urbanized catchments:*** In the Sungei Seletar - Bedok Water Scheme (Appan 1977), 45% of the catchment of 5825 ha lies in urban areas. Urban storm water is collected in 8 stormwater ponds and directed to the Bedok reservoir which has a yield of 14x 10^6 m^3/d. The urban area has high-rise buildings and the surface runoff is subject to a wide variety of contaminants. Hence control of water pollution is of cardinal importance. Six government departments met very frequently and chalked out programs for strict pollution control. The quality of the raw water, which has runoff from a better catchment, is of a high order (see Table 4). The overall cost is considerable, as all aspects of keeping catchments clean have to be considered.

(v) ***Conventional large water abstraction systems:*** The very large water resource projects involving the construction of dams and impounding reservoirs, with or without hydro-power, fall outside the purview of the smaller schemes.

(c) Some self-supporting simple systems in Asia: It is known that even in the second millinium there existed cisterns (Ozis, 1982). With the advent of larger water supply systems in the earlier part of this century, large capital outlay came from governments who not only undertook to supply water but also subsidized such systems (Prempridi, 1982). But, over a period of time, as capital - intensive systems could not be financed, there has arisen, in many developing countries, the need to supply drinking water to the people at very low costs. This situation has lead to considerable effort and energy being put in countries like Thailand, Indonesia and Philippines to build and maintain simple systems. These systems adopted a "total" concept (Appan and Lee, 1987) wherein the economic, social and cultural aspects of the location were taken into consideration with emphasis placed on the utilization of local available unskilled labour and indigenous building materials. Most important of all, an appropriate financial model was developed thus ensuring that the potential user could pay for the system installed in his household. Some of the successful schemes are as follows:

(i) ***Thailand:*** With foreign capital not forthcoming for major water schemes and the continuous demand for water escalating, in 1982 the emphasis shifted to providing potable water for rural areas through shallow and deep wells and rain harvesting programs. Funds were allocated for planned communal systems to be executed by village councils, foreign agencies, government or private organizations. A program that was very successful was that by the Population and Community Development Association (PDA), a non-profit organization.

The operations carried have been well-defined (Hayssen, 1983) and primarily involved the study of rainfall statistics to identify the feasible areas for the implementation of roofwater collection systems. The areas needing water most, low repayments and a simple system of collection were the main features of the systems. The modus operandi proved to be quite successful and villagers who were trained b the PDA carried out construction work for the whole village, the necessary hard-core labour being provided by the villagers

This scheme, with some foreign aid, proved to be so encouraging that an elaborate program was carried out in 1983 wherein indigenous material like bamboo reinforced concrete (brc) was used to cut costs by half. Interest was generated in materials and studies were carried out plastic, steel, bricks and inter-locking mortar, Ferro-cement etc were tried out. The costs at that time varied from US$1.29 to US$0.14 per cubic metre of volume of tank.

(ii) ***Indonesia:*** Even as early as 1979, the criteria used to execute such rainwater catchment systems was to select building material that was locally available, the design and construction should be within the understanding and technical capability of the villagers. Most important of all was the fact that the introduction of such collection systems should not conflict with the way of existing life. All these factors had to be met with besides which the cost had to be within that set by the government budget (Doelhamid, 1982).

By a systematic process of experimentation and application, brc and ferro-cement were introduced and a methodology was evolved for the introduction , and propagation of such simple systems (Aristanti, 1983). The general approach was very much akin to the Thai model and ensured that all level of villagers got involved. A non-governmental organization, known as Dian Desa, harnessed the special characteristic of Indonesian villagers who placed great importance on the joy and value of working together. It was ensured that skills were developed by community participation, and there was appropriate transfer of such skills including appropriate maintenance. In all cases, local lifestyles, tradition and local opinions were taken into consideration and it was always ensured that project schedules did not conflict with local time constraints.

The major feature of this scheme was the management of necessary financial backing . There was very limited external funding besides which the economic status of the users was very low. The most deserving cases of the "poorest of the poor" were identified and two she goats were lent to the family. When these bear (normally) four young ones, two of these were returned to the owner and the other two belonged to the borrower. The borrower than looked after the two young ones and when they had grown up used them as payment for the cisterns that had been built earlier in their premises (Aristanti, 1983).

(iii) ***The Philippines:*** Propagation of roofwater collection systems had the advantage in that a suitable study was done with respect to the Thai and Indonesian models before embarking on the project. Pilot project areas were selected and a total approach (Appan & Lee, 1987) was adopted to ensure that all the lessons learned were fully utilised to improve the quality of water being harnessed. Cost-wise ferro-cement was considered the most appropriate building material. Monitoring of initially built 30 tanks was carried out to ensure bacterial purity of the water and health education was imparted to ensure that collection methods, systems etc, were well looked after.

Again, since the villagers were extremely poor and had obtained the basic material for construction, they were convened to get their suggestions on the most appropriate payment method. They were ultimately very much in favour in engaging in hog-raising where the project authority provided the piglets and basic training on how to care for them. The proposal was very similar to the "two she-goat system" in Indonesia.

In all these countries, the extra effort has been put to make potable water to be attainable by the poorest of the poor at a cost that can be borne by them. Most important of all, there are number of NGO's in these countries, who have embarked on rigorous systems of maintenance so as to ensure that the existing rainwater collection systems that can not only be financed by the villagers but can also be sustained and continue to give water of an acceptable quality level.

(d) **Economic benefits by integrated systems:** In most countries there exist some form of conventional large schemes for the supply of water. However, with the uncontrolled population explosions, particularly in developing countries, and the concentration of most of humanity in emerging megacities (ADB, 1993), water demands are far exceeding the rate of development of projects. However, with limited funding and the inability of the impoverished users to pay for the water, there is a great demand to try to conserve the use of available water, to use urban catchments due to the extension of cities to the hinterland (Appan, 1998a) and to establish simple systems that can meet the needs of the urban poor. One such system is the development of individual roofwater collection systems which can be integrated with existing systems besides which it will have a considerable impact on both the rising demands and savings in deferred capital costs (National Water Council, 1980). When such relatively cheap rainwater catchment systems are established, they can replace the proposed new conventional projects. Consequently, these projects can be postponed which means capital borrowing can be delayed leading to considerable saving for the water authority.

WATER QUALITY ASPECTS

It has always been believed that rainwater is quite pure and can be imbibed without any treatment. While this belief is acceptable in many areas that are unpolluted, the fact remains that rainwater collected in many locations has some impurities. Particularly during the last three decades, alarms of acid rain have been raised that have not only proved to be harmful to aquatic life but have also warranted treatment of the collected water.

(a) **Drinking Water Quality Standards:** The WHO has published (1984) a set of guideline values for drinking water (See Table 1). While these values may be used as a reference level, the respective standards many countries are dictated by the availability of water.

(b) **Sampling of collected water:** Water sampling, of both rain and roof water, has been very scanty, particularly in developing countries. Except for a few isolated cases of high pH, rainwater is generally of a high order. However, in all collection systems, be they small roof water systems or major water abstraction systems, the quality of water reaching the cistern or impounding reservoir is largely influenced by the impurities that are collected either in the roofs or on the ground when surface runoff is collected. For appraising the quality of the collected water, the WHO guideline values will be used . Bacteriological parameters such as Faecal Coliform (F Coli) and Total Coliform (T Coli) have also been appraised and the ratio (Faecal Coliform/ Faecal streptococci) has also been determined. This ratio has been shown to indicate whether the sources of pollution are of human (FC/FS>1 to 4) or animal (FC/FS < 1) origin (Duktar, 1977).

Table 1: WHO's Guidelines for Drinking Water

Parameter	Guideline value*	Parameter	Guideline value#
Colour	15	Cadmium	0.005
Turbidity (NTU)	5	Chromium	0.05
pH	6.5 - 8.5	Cyanide	0.1
Hardness as $CaCO_3$	500	Fluoride	1.5
Iron	0.3	Lead	0.05
Manganese	0.3	Mercury	0.001
Sulphate	400	Selenium	0.01
Total dissolved solids	1000	Zinc	5.0
Nitrate	10	F Coli/100mL	0
Arsenic	0.05	T Coli/100mL	0

* Note: All units, except pH, in mg/L unless stated otherwise

(i) ***Roof water:*** In a study covering the whole of Thailand, 1292 samples were collected over a period of four years mainly from water collected in clay jars which are used in abundance (Nantana, 1987). From the results, in terms of physico-chemical parameters, more than 83% of the samples were satisfactory except for 40% of the samples exceeding the allowable limits for Lead. In terms of Coli, more than 76% of the samples had values exceeding the guideline limits.

In another investigation in Thailand (Wanpen, 1992), a series of tests was done in three locations in the dry area of Khon Kaen, 709 water samples were collected from tiled roofs and gutters, containers located in homes, jars and at the point of consumption. From the results (see Table 2), the three types of coli tests showed that only 10 to 67% of the samples lay within the guideline values. Samples collected from sources other than the container showed that 79 to 82 % of the contamination could have emanated from animal droppings. Besides, in all samples 2 to 20% and 4 to 26% of manganese and zinc respectively did not meet the guidelines.

Table 2: Roof water Quality (Thailand)

	Acceptable Quality			FC/FS	
Sampling Locations	Total Coli	F Coli	E Coli	>4	<1
Roofs and gutters	10%	10%	22%	18%	79%
Tanks and jars	35%	30%	47%	17%	82%
In-house containers	22%	22%	67%	47%	39%

In the Philippines, a simple study was carried out over a period of one year in three selected villages in the province of Capiz, where pilot roofwater collection projects were launched. Water samples, from 25 water cisterns that stored roofwater, were examined. 24% of the samples had a T Coli exceeding the guideline values (Personal Communication, 1986)

In a study in West Malaysia where the quality of rainwater and roof runoff was monitored (Yaziz et al, 1989), 72 water samples were collected from buildings having two types of roofs viz., galvanized iron and concrete tiles, were analyzed (see Table 3). The range of turbidity, lead and F Coli values far exceed the guideline values. The pH of the rainwater also has a tendency to lie towards the lower range of the guideline values.

Table 3: Roof Water Quality (Average) in Malaysia

Parameter	Galvanized iron	Roof concrete tiles
pH	6.6 to 6.4	5.6 to 6.9
Turbidity (NTU)	10 to 22	24 to 56
Total solids	64 to 119	116 to 204
Suspended solids	52 to 91	95 to 153
Dissolved solids	13 to 28	23 to 47
Zinc	2.94 to 4.97	0.05 to 1.93
Lead	1.45 to 2.54	1.02 to 2.71
F Coli/100mL	0 to 8	0 to 13
T Coli/100mL	25 to 63	41 to 75

Note: All parameters, except pH, in mg/L unless otherwise stated

(ii) ***Rainwater:*** Field investigations in the western half of Singapore have also shown that during Jan 1974 to July 1983, the range of pH in 11 monitoring stations distributed throughout the land area, was 4.6 to 5.5 (Tan,1984). The results in a more recent exercise, extending for a period of 6 years from 1989 are shown in Table 4. The values appear to be acceptable in terms of all physico-chemical parameters except pH which is quite low. T Coli and F Coli values also exceed the guideline values.

Table 4: Rainwater Quality in Singapore

Parameter	Range of annual means
Colour (Hazens)	3.3 to 5.2
Turbidity (NTU)	1.6 to 2.9
pH	4.2 to 4.3
Sulphate (mg/L)	2.9 to 10.0
Chloride (mg/L)	1.0 to 1.5
Total Dissolved Solids(mg/L)	4.8 to 20.2
NO_3 as N (mg/L)	0.3 to 0.6
T Coli/100mL	18 to 46
F Coli /100mL	2 to 6

(iii) ***Stormwater quality:*** In urban stormwater collection systems, the primary goal is to avoid the collection of first flush whenever there is a storm. This is to avoid the very high pollution loads that are encountered during the initial phase of the storm. One of the few locations where such a system is being practised is in the Sungei Seletar - Bedok Water Scheme in Singapore. In this scheme (Appan, 1997), almost half the catchment area is primarily urban area with high-rise buildings. There are a number stormwater collection ponds in this urban area with suitable designs to divert dry weather flows and also first flushes of storms. Water impounded in the Bedok reservoir is of a high order though mixed with urban stormwater (Lee & Nazarudeen, 1996). Its quality is comparable to that from conventional catchment (see Table 5) which is protected by law (Nature Reserves Act, 1951).

Table 5: Average raw water quality in Bedok reservoir Vs. Protected catchment

Parameter	Bedok reservoir	Protected catchment
Colour (Hazen)	12	20
Turbidity (NTU)	2.	2.9
pH	7.4	6.3
Total Alkalinity ($CaCO_3$)	43	7
TOC	2.9	3.1
Total solids	205	25
Chlorides	56	4
Ammonia N	< 0.02	< 0.03
Phosphorus	< 0.03	< 0.03
Iron	0.04	0.52
Cadmium	< 0.0005	< 0.0005
Chromium	< 0.005	< 0.005
Lead	< 0.001	< 0.001
Coliform/100mL	18	14

DISCUSSION AND CONCLUSIONS

Economic aspects

The storage volume, which is related to the yield, has to be computed very accurately by one of the many methods. This is the most critical factor in the costing of any scheme and pricing of water. Hence, the choice of method of determination is very important.

When simple roofwater collection systems are involved, the expenditure for the whole system bears paramount importance, albeit the overall running costs are low. This is because these systems are specifically used in developing countries where they have to be largely self-supporting and have to be sustained over a period of time. In this respect, it is worthwhile to note the major components in the financial models adopted in Thailand, Indonesia and Philippines. In all these schemes, materials and methods have been largely adjusted to suit the know-how, attitude, mentality, culture and economic status of the potential owner/user. The overall running costs of these schemes, though manpower-intensive, are generally very low.

The marginally larger schemes, which have been successfully implemented in airports, schools etc., are actually miniature projects. The savings effected in terms of non-potable usage and the cost of water have justified their existence.

In urban areas, the use of roofwater collection systems are economically viable and can be fine-tuned to suit existing systems. The use of urban catchments may involve dealing with stringent control measures for urban catchment management. However, as the raw water quality can be compared with those in conventional catchments, they should be pursued particularly as their implementation also improves the cleanliness of urban areas.

Ultimately, with the emergence of megacities, it is strongly recommended that smaller rainwater catchment systems be implemented in all possible sites and these schemes should be integrated with existing conventional schemes and operated optimally.

Water quality aspects

In terms of physico-chemical parameters, the collected roofwater, rainwater and urban stormwater appear to exhibit quality levels that are reasonably comparable to WHO's Guideline values. However, the low pH range can reflect the level of industrial activity at the sampling locations. High Lead values can be attributed to roofing material. Hence it can be recommended that in such roofwater collection systems, roofing material should be seriously taken into consideration besides which, the quality of fossil fuels in industries has to defined or laws on air-pollution be promulgated and strictly adhered to.

There were quite a few samples which exceeded the WHO's values in terms of T Coli and F Coli. Besides, the FC/FS ratios indicated that the source of pollution was largely of animal origin and could be the droppings of birds, rodents etc. The few cases of human contamination can be attributed perhaps to poor handing practices. The presence of different species of salmonella has also been reported (Wanpen 1987, Fujioka et al 1991). Hence, with frequent presence of F Coli and particularly Salmonella, there is the need to research its impact on human systems.

Currently quality control in roofwater collection systems is limited to diverting of first flushes, rearing of fish within containers and occasional cleaning of cisterns. Boiling, despite its limitations, is the easiest and surest way to achieve disinfection but there is generally a reluctance to accept this practice as taste is affected. Alternately, simple methods of adding one of the halogens can be practiced. Chlorine in the form of household bleach has been successfully applied (Krishna, 1991). The cheapest UV system still appears to be prohibitive. However, as abundant sunlight has been shown to remove both the coli group and streptococci (Fujioka and Chinn 1987, Wanpen 1992), it is recommended that further research should be undertaken in this area.

The roof water qualities have varied widely for different reasons. Though there are standards for drinking water, it is imperative that some standards be set for such water when it is used for drinking in some developing countries or when it is used for non-potable uses.

ACKNOWLEDGMENT

Grateful acknowledgment is made to Dr John Whitelaw, Ms Lilia G C Casanova and Mr Makoto Fujita of UNEP's International Environmental Centre at Osaka for having kindly invited me to read this paper.

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ECONOMIC AND WATER QUALITY ASPECTS OF RAINWATER CATCHMENT SYSTEMS

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Division of Env Eng & Water Resources

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Singapore

1

INTRODUCTION

- twin factors for water res. develop.
- economic viability
- acceptable quality
- objectives

ECONOMIC & ASSOCIATED FACTORS

a. Design of the System:

- principle - design for "dry" day
- design parameters (sto. vol. & rel. yield)
- examples (Rippl ,1883; Waitt, 1945)
- Input/Output model (1982)
- time discretization

2

b. Types of Rainwater Catchment Systems:

(i) Simple RCS in developing countries:

- typical setup (Figure)
- types (Hawaii), cheaper types
- bamboo reinforcement,
- ferro-cement
- treatment(filters & bleach)

(ii) Marginally Larger Systems in schools, airports:

- approximately 5 to 100 ha
- educational Institution (Figure)
- airport (Figure e), use of water
- 28-33% saving S$ 390,00/ann.

3

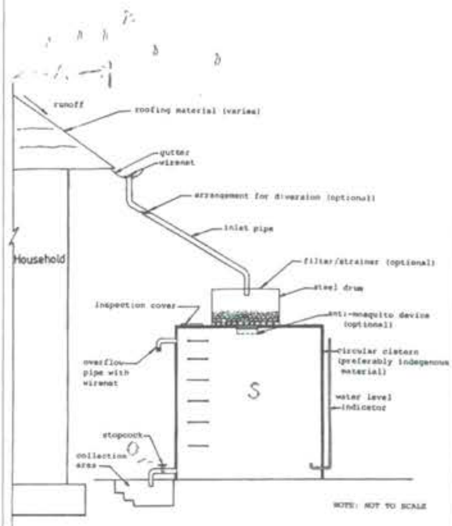

Figure 2 : Schematic Diagram of Typical RWCS

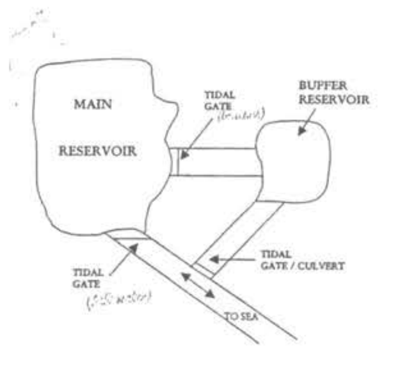

Figure 3: Schematic diagram of the water abstraction system – Singapore Changi Airport

(ii) Marginally Larger Systems in schools, airports:

- approximately 5 to 100 ha
- educational Institution (Figure)
- airport (Figure e), use of water
- 28-33% saving S$ 390,00/ann.

(iii) Roofwater collection in High-rise buildings:

- 86% in high-rise buildings in S'pore
- DMS, Rainwater priority
- case study in Ang Mo Kio (Figure)
- data 15 min intervals, non potable water
- 4% savings, energy, deferred cap.,others
- cost S$ 0.96 vs. S$1.17

4

(iv) Collection of stormwater in Urbanized catchments:

- The Sg Seletar-Bedok Scheme (Figure)
- urban catchment - quality problem
- anti-pollution measures
- water quality (Table 4)
- cost - very high for a/p measures

(v) Conventional water abstraction schemes:

- dams, impounding reservoirs
- with/without hydropower, treatment etc
- large capital outlay, economies of scale
- low cost of water but large system

5

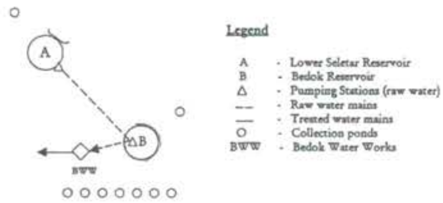

Figure 4: Schematic diagram of Sungei Seletar – Bedok Water Scheme

c. Some Self-supporting Systems in Asia:

- earlier part of century - large systems
- 1970s, developing countries - problem of capital
- simple systems, low cost
- need for proper Model
- consider social, cultural, economic factors

(i) Thailand:

- by 1982 rural water supply
- wells & RWCS
- PDA's model, only village labour
- low repayments, some foreign aid
- half cost due to bc, bricks, interlocking, fc
- US$ 1.29 to US$ 0.14 /m³ of tank

6

(ii) Indonesia:

- no conflict with style of village life
- low cost, Dian Desa
- selection of "poorest of poor"
- two she-goat system

(iii) The Philippines:

- improvements on Thai & Indon models
- the "Total Approach" (Figure)
- pilot projects, extension of scheme
- hog-raising for repayment
- maintenance, health education

7

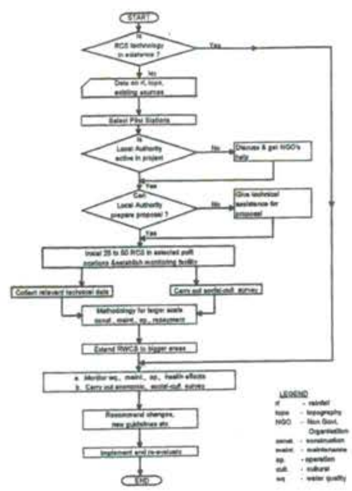

Figure 1 : Flowchart for a Total Approach in RCS

d. Economic benefits by integrated Systems:

- emergence of megacities (70% developing countries)
- integration of existing systems with RWCS
- principle of Deferred Capital (Figure)

8

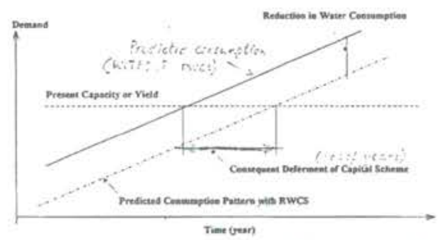

Figure 6.1 Diagrammatic Representation of Deferment of Capital Expenditure

WATER QUALITY ASPECTS

- purity of rainwater
- natural form, roofwater
- impact on health & aquatic systems

a. Drinking Water Quality Standards:

- 1984 WHO Guidelines (Table 1)

9

Table 1: WHO's Guidelines for Drinking Water

Parameter	Guideline value*	Parameter	Guideline value*
Colour	15	Cadmium	0.005
Turbidity (NTU)	5	Chromium	0.05
PH	6.5 - 8.5	Cyanide	0.1
Hardness as $CaCO_3$	500	Fluoride	1.5
Iron	0.3	Lead	0.05
Manganese	0.3	Mercury	0.001
Sulphate	400	Selenium	0.01
Total dissolved solids	1000	Zinc	5.0
Nitrate	10	F Coli/100mL	0
Arsenic	0.05	T Coli/100mL	0

* Note: All units, except pH, in mg/L unless stated otherwise

9a

b. Sampling of collected water:

- rainwater influenced by roof/nature of catchment
- compare with WHO Guidelines
- F Coli, T Coli, F Streptococci
- FC/FS>< 1, human or animal origin

(i) Roof water:

- Thailand (Table 2)
- Philippines 24% T Coli > allowable value
- West Malaysia (Table 3)

10

Table 2: Roof water Quality (Thailand)

Sampling Locations	Acceptable Quality Total Coli	F Coli	E Coli	FC/FS >4	<1
Roofs and gutters	10%	10%	22%	18%	79%
Tanks and jars	35%	30%	47%	17%	82%
In-house containers	22%	22%	67%	47%	39%

* Note: All units, except pH, in mg/L unless stated otherwise

10a

Table 3: Roof Water Quality (Average) in Malaysia

Parameter	Galvanized iron	Roof concrete tiles
pH	6.6 to 6.4	5.6 to 6.9
Turbidity (NTU)	10 to 22	24 to 56
Total solids	64 to 119	116 to 204
Suspended solids	52 to 91	95 to 153
Dissolved solids	13 to 28	23 to 47
Zinc	2.94 to 4.97	0.05 to 1.93
Lead	1.45 to 2.54	1.02 to 2.71
F Coli/100mL	0 to 8	0 to 13
T Coli/100mL	25 to 63	41 to 75

Note: All parameters, except pH, in mg/L unless otherwise stated

10

(ii) Rainwater:

- Singapore, 1974 to 1983, pH 4.6 - 5,
- 1989-95 (see Table 4)
- compare with WHO

(iii) Stormwater Quality:

- Sg Seletar-Bedok Scheme (Figure)
- avoid first flush
- catchment -urban (see Table 5)
- compare with protected catchment

11

Table 4: Rainwater Quality in Singapore (1989-'95)

Parameter	Range of annual means
Colour (Hazem)	3.3 to 5.2
Turbidity (NTU)	1.6 to 2.9
pH	4.2 to 4.3
Sulphate (mg/L)	2.9 to 10.0
Chloride (mg/L)	1.0 to 1.5
Total Dissolved Solids(mg/L)	4.8 to 20.2
NO_3 as N (mg/L)	0.3 to 0.6
T Coli/100mL	18 to 46
F Coli /100mL	2 to 6

* Note: All units, except pH, in mg/L unless stated otherwise

11a

Table 5: Average raw water quality in Bedok reservoir Vs. Protected catchment

Parameter	Bedok reservoir	Protected catchment
Colour (Hazen)	12	20
Turbidity (NTU)	2.	2.9
pH	7.4	6.3
Total Alkalinity ($CaCO_3$)	43	7
TOC	2.9	3.1
Total solids	205	25
Chlorides	56	4
Ammonia N	< 0.02	< 0.03
Phosphorus	< 0.03	< 0.03
Iron	0.04	0.52
Cadmium	< 0.0005	< 0.0005
Chromium	< 0.005	< 0.005
Lead	< 0.001	< 0.001
T. Coliform/100mL	18	14

* Note: All units, except pH, in mg/L unless stated otherwise

11b

DISCUSSION & CONCLUSIONS

Economic Aspects

- design of storage Vs rel yield very important
- simple roofwater collection systems- very low cost
- marginally larger sys. OK in schools, airports, cost-justified; urban areas - high rise buildings, DMS, econ viable
- urban catch, a/p measures, cost-intensive
- megacities(developing countries), integrate systems

12

Water Quality Aspects

- phy-chem aspects OK, low pH, Pb
- Legislate fuel, roof types
- T Coli & F Coli high (some samples)
- FC/FS animal origin (salmonella)
- Need for studies on salmonella
- disinfect: not only first flush diversion
- boiling, use halogens, household bleach
- research on sunlight (UV) disinfection

P.T.O.

13

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14

Rainwater Utilization *Facilities and Equipment*

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Several hundred thousand rainwater utilization installations were installed during the nineties in Germany. The installation components have been continually improved and now rainwater utilization is generally recognized as an advanced, ecological and permanently safe operating system. Rainwater utilization has thus developed into an important strategy for effective rainwater management.

Rainwater quality and areas of application

Illustration 1

Rainwater can be used

- in industry
- in the public sector
- in the household.

The savings of potable water through the use of rainwater amounts to about 50 % of household consumption. Household activities where potable water savings can be achieved through the utilization of rainwater include:

- Toilet flushing 33 %
- Washing clothes 13 %
- Floor Cleaning 2 %
- Garden watering 3 %

The quality of the rainwater collected depends directly upon the collection facilities and installation techniques used. Installations that are competently designed, based on technical standards, supply rainwater that can be used for the applications named above without hesitation. Rainwater collected from such installations is, for example, usually of better quality than authorities demand for lakes used for swimming. [Hollaender 1996]

Legal regulations and standards

It is in the public interest to ensure that the potable water system is protected and secure from possible contamination arising from improper house-owners' installations, including the dangers of a return flow from the rainwater pipework. There are legally binding regulations for this contained within the German potable water legislation for this, and the General Conditions of Water Supply that, apart from purely garden water storage without refilling equipment, are to be maintained in all cases. The technical measures for this are defined in DIN 1988. Of especial importance are potable water feeds and the labelling of pipework and extraction points.

The regulations in detail

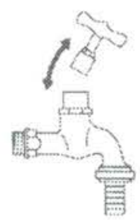
- No connection may be made between the rainwater system and the potable water system, not even temporarily! The connecting feed from the public potable water supply to the rainwater system may only be made in an open space of at least 20 mm, according to DIN 1988, part 4 !
- For clear identification of surface pipework, self-adhesive coloured tape with the words "no drinking water" or "rainwater" at short intervals, is to be attached. Where the pipework is under plaster, labels must be plastered in at every metre.
- According to DIN 1988, part 2, extraction points for non-potable water (i.e. also for rainwater installations) are to be labelled with the words "no drinking water", or in picture form.

Recommendations

Freely accessible extraction points should, despite the labelling, be secured with a socket key or a closable upper part to the valve, to prevent thirsty children from taking water. In addition taps for garden hoses can be installed at heights inaccessible to children.

It is recommended that the rainwater utilization installation be checked for the safety and protection of the public potable water supply! A maintenance contract with the plumber or company carrying out the work increases the operational safety of the installation and relieves the operator from his obligation of care. DIN 1988 determines, in Appendix A, to Part 8, that the open outlet for the feed is to be inspected at least once annually. Among other safety items, the spacing of the inlet valve and the overflow is to be checked with a fully opened inlet.

Illustration 2



'Socket key valve'

'No drinking water'

German Standards for installation

The European neighbours of Germany have generally oriented themselves towards experience gained in Germany. The professional association for water recycling and rainwater utilization "fbr", as a non-profit-making and non-governmental organization with headquarters in Darmstadt, provides a vehicle for information exchange. The essential elements, which pertain to the installation and operation of rainwater collection and utilization, are discussed below based on German experience.

Catchment areas and first flush

Only roof areas should be connected for household use. The separation of the initial quantities of water from a rainfall is unnecessary according to investigations made in the area of the City of Stuttgart [Rott, Schlichtig 1994]. The Environmental Ministry of the German Land of Hessen also writes, in an information brochure, that a first flush is unnecessary for non-potable applications in the household; it is also not recommended because of the reduced amount of water collected.

Filtering before the storage

Filtering before the storage cistern is necessary. The choice of the filtering system depends on the construction conditions. Low-maintenance filters with a good filter output and high water flow are preferred.

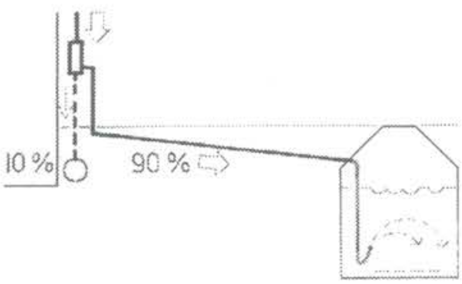
In Germany it is no longer current practice to install fine filters in the pressure pipe following the storage cistern. Regular cleaning was often forgotten, especially in private houses, leading to disruptions in the system, pump defects and a deterioration of the water quality.

The technical standard in Germany for fine filters in the storage inlet today is:

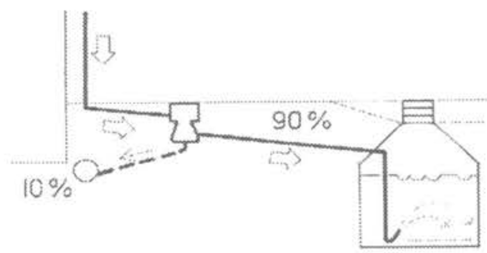
- Full cross-sectional area throughout in the size of the inlet, so that the drains cannot be blocked if the filter is not cleaned.
- Large filter capacity so that no back pressure occurs in heavy rainfalls, and cleaning does not have to take place more than 4 times per year.
- Filter unit 0,2 - 0m,8 mm (200 - 800 my)

Many filters of this type, when they have a separate outlet for dirt, reject the first flush as a side stream. Only when the fine mesh is completely saturated with water does it have the optimum permeability. But even with very heavy rainfalls, water is drained away when the permeability of the fine mesh is reached. The annual loss on average is about 10%. The mesh should be removed at least once a year and thoroughly cleaned.

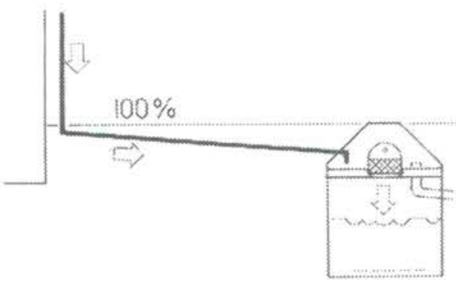
Illustration 3 - 6 Fine Filters in the storage inlet.



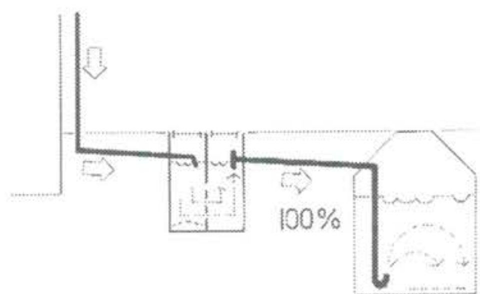
Downpipe filter collector



Underground fine filter



Storage fine filter



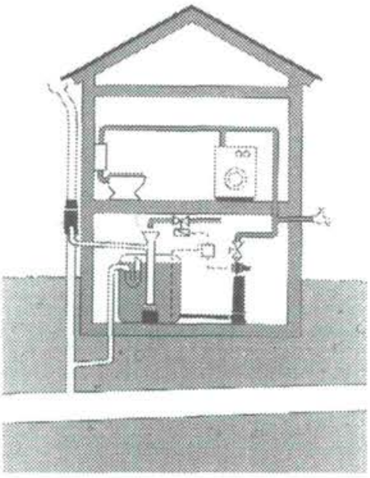
Filter pit

A second kind of filter that can be used works without loss, but also without self-cleaning. The dirt collects in front of the filter in a separate filter pit, or in the upper part of the cistern. This type of filter is usually used where high rainwater utilization requirements exist under low rainfall conditions.

Rainwater storage

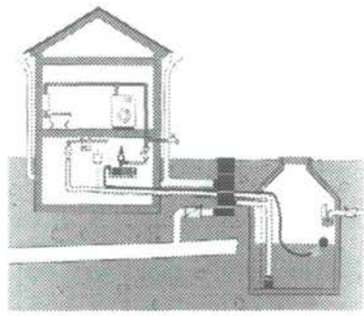
Storage containers protected from daylight and placed in cool surroundings are generally adequate. Basement storage is most suitable for existing buildings; the market share in Germany is about 5 %.

Illustration 7
Basement storage with filter collector in every downpipe



Rainwater storage can be achieved using a battery of individual 1000 litres plastic tanks. Their shape must be such that they can be transported through existing doorways. Stainless-steel tanks that are welded together are also used for large installations.

Illustration 8
Underground storage with separate underground fine filter

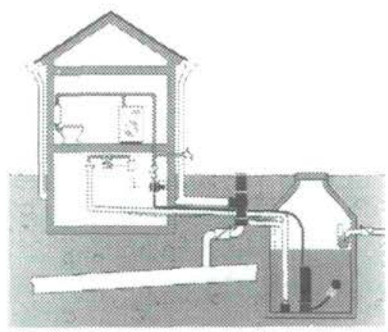


Underground storage is mostly used for new buildings; the market share in Germany is about 95 %.

The reasons for this:

- The larger the volume, the more favourable in price are the prefabricated cisterns. They are installed directly from the delivery vehicle of the manufacturing company by crane into the excavation.
- More and more buildings are built as low-energy houses. The installation of heating and cooling systems and energy conserving equipment, including insulation, often requires the use of available basement space.
- The ground is a good protection for the collected water against frost and heat.
- Apart from city centres, in most cases there is adequate space next to the house, e.g. below vehicle parking space.

Illustration 9
Same as Illustration 8 with submersible pump



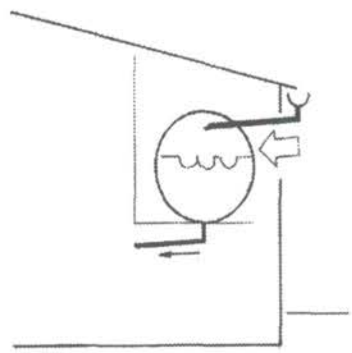
Underground cisterns, even for large installations, are almost exclusively composed of prefabricated parts. About 65 % consist of concrete, 30 % of plastic, 5 % of steel. Underground cisterns must be adequately stable against earth pressure and the loads from machines and vehicles. They must also be secured to prevent buoyancy under high groundwater conditions.

Although storage of rainwater in the roof of a building could supply water without a pump and electrical energy, it is generally not standard practice for the following reasons:

- High static loads arising from the water storage
- High potential for damages due to storage leaks
- Lower and different pressures at the extraction points
- Danger of frost and heat with non-insulated roofs
- Blocking valuable internal space with insulated roofs

Storage in the roof is generally only recommended for sheds and barns.

Illustration 10
Tempered water for cattle and horses by rainwater storage in the roof



Water flow in the storage container

Water flow is also an important factor, which influences the quality of the cistern water. Some current approaches include:

- Calm rainwater inlet to avoid stirring up the sediment.
- Suction of the rainwater from layers having the cleanest water, e.g. by means of a floating extraction filter.
- Sloping overflow trap to drain away any possible floating matter and to protect from sewer gases.
- Protection from vermin, e.g. rats.

Illustration 11
Floating extraction filter

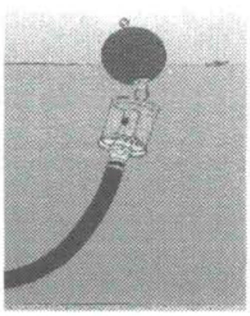


Illustration 12
Calm rainwater inlet

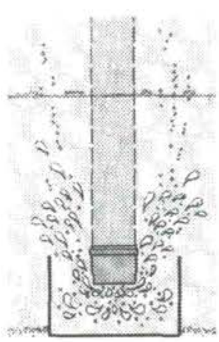
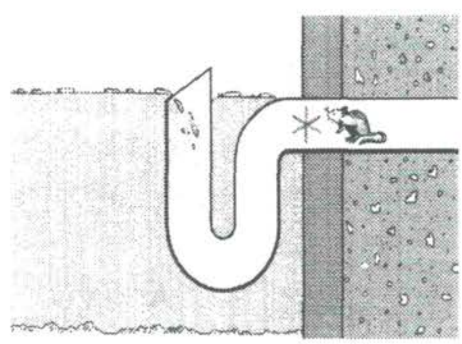


Illustration 13
Protection from vermin



Suction pipe

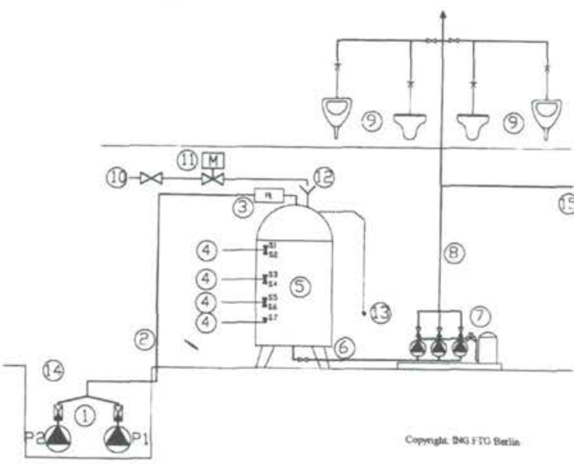
The suction pipe should be installed rising to the rainwater pump and below frost level.

Installation of equipment to increase pressure

Requirements for the installation of equipment to increase pressure are: low noise generation, low maintenance, long life, corrosion resistance and low electricity consumption. Multistage rotary pumps – especially designed for rainwater utilization applications – fulfill the requirements the best by far. If compensating pressure tanks are necessary they should have a flow of water through them to avoid stagnation. With distances between the storage and the pressure-increasing installation of more than 20 metres, or a difference in height between the pump and the minimum water level of more than 6 metres, submersible motor pumps must be used.

For more than 2 dwellings, in public buildings and in the industrial areas, hybrid systems are used. A submersible loading pump ① fills a daily storage cistern ⑤, from there rotary pumps ⑦ produce the required pipework pressure. For such applications the installation of a reserve pump is recommended. This back-up pump should incorporate an automatic control system with an acoustic alarm for faults.

Illustration 14
Hybid pumping technology



Potable water feed

The only permissible potable water emergency supply when rainwater is insufficient is the open feed type above the backflow level. This can be installed with the feed (11) arranged above a funnel (12). Alternatively a potable water feed module, that also takes over the installation controls, can be used. The amount of water feed should be less than the daily requirements to keep maximum storage volume empty for rain harvesting.

Pipework for rainwater

In Germany, it is required that all service water pipework and all tapping points should be clearly marked throughout. As noted previously, it is also recommended to use security against unauthorized use of the water. For durability non-corrosive materials should be used throughout the system. Suitable for the pipework are polyethylene (PE), polypropylene (PP) or stainless steel. For low-noise flexible connections to the pump should be used.

Storage overflow

The storage overflow from rainwater installations should, wherever possible, be returned to the natural water circulation and seeped away. If this is not possible the overflow must be connected to the soil sewer. For rainwater storage cisterns there is only the danger of soiling through the backflow of soil water when the overflow lies below the lid of the sewer in the road. Protection against backflow is possible for outside storage cisterns through a backflow flap or a lifting installation with a submersible pump in the storage cistern controlled by the level.

For internal storage cisterns this is not reasonable, because the backflow usually only occurs when a heavy rainfall fills the sewer system. With a closed backflow flap, an internal storage cistern could not empty and a backflow would build up in the inlet pipe with further rainfall, causing water damage through bursting pipes in the building. An internal storage cistern should therefore be avoided wherever it is impossible to drain above the critical height.

Low maintenance and safe operation

Most installation components only need to be checked or maintained once a year. Filters should be inspected about every three months. Regular cleaning of the storage cistern is unnecessary if fine filters are used in the inlet to the storage cistern. The sediment on the bottom of the storage cistern should only amount to a few millimetres per year.

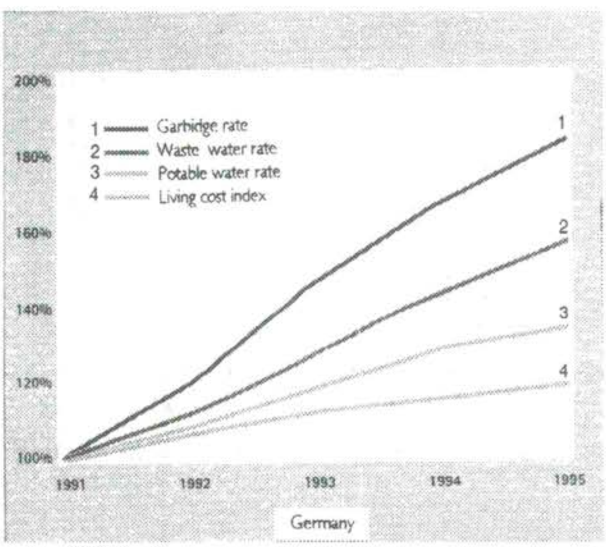
Approval

The construction and operation of rainwater utilization installations cannot be refused as long as the relevant regulations are adhered to. A building approval is usually not necessary, although the local water supplier should be advised of the construction of an installation.

Economic efficiency

For businesses that have a high demand for water, such as haulage contractors or market gardens, the conditions for the utilization of rainwater are favourable. Many of these firms have large roof areas and the extra costs for additional rainwater pipework, relative to the total building costs, are low because most of the necessary pipework can be installed inexpensively on the surface.

Illustration 15
Increasing water rates in Germany



A complete installation for rainwater utilization in the household, according to the standards described above, together with the installation costs, is estimated to be about 5,000 US$. It should be noted however that information on economic efficiency is very site specific, making general estimates very difficult. According to the regional peripheral conditions (water and sewage prices, possible grants, waste water rates) the amortisation can range between 10 and 20 years. If designed and built properly, the principal investment in the system, e.g. for storage cistern and pipework, should have a life of many decades. The above-average rising prices for water make rainwater utilization more attractive from year to year! Increasing privatization of European water supplies indicate that this is likely to remain so.

The usual storage size for individual houses in Germany with the best amortization is 3.5 cu.m. for basement storage and 6 cu.m. for underground storage. There is an additional saving for washing clothes: As rainwater is a very soft water there is also less washing powder needed.

Future technology

The technical development in this area is now sufficiently advanced that pressure-increasing installations and potable water feed, with all accessories for controlling the pump and valves, is offered as a plug-in module, as is the case for the storage tank with integrated filter, calm water inlet and sloping overflow trap with vermin protection. The design and installation costs have therefore become lower, with installation costs remaining generally stable.

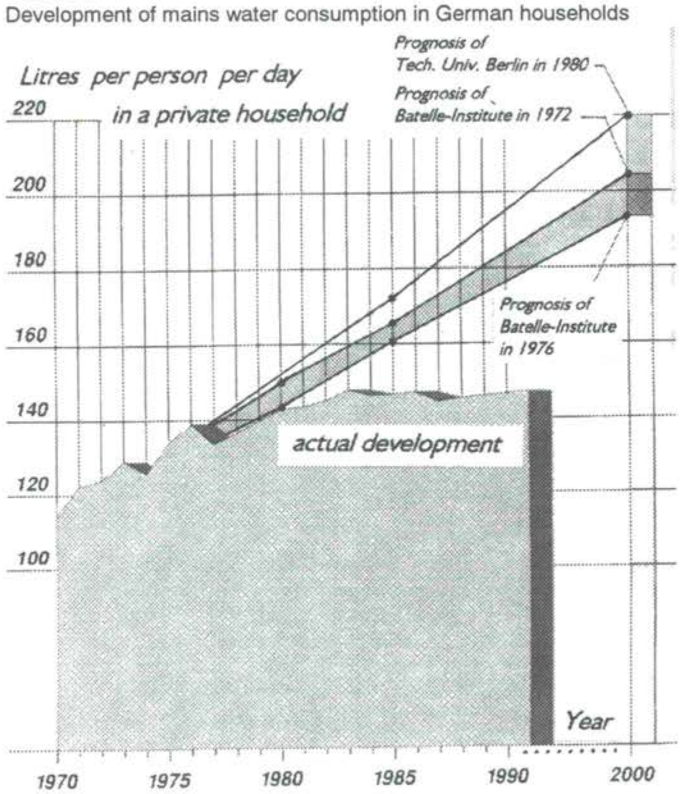
Economic efficiency for the community?

In Germany, the prices for potable water and waste water are set by individual communities, according to actual expenditures. Where the water supply was extended in 1975 according to the forecasts for the year 2000, there is now excess capacity, with the inherrent conflict of selling the largest possible quantities to amortize this public investment. Such communities generally do not support rainwater utilization!

Communities that have now reached the limit of their supply capacity pay grants and support rainwater utilization. This occurs in the German Federal Lands of Saarland, Schleswig-Holstein, Hessen and Bremen, throughout their entire regions.

Illustration 16

Development of mains water consumption in German households



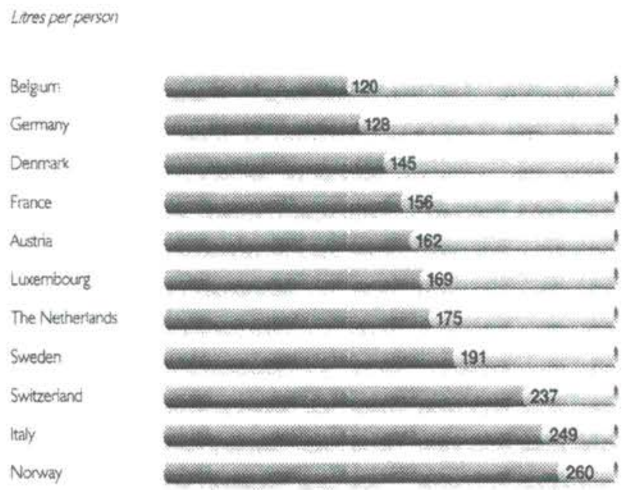
In new building areas the aim of effective rainwater utilization is that the requirement for central rainwater drainage can be avoided, and that inexpensive, small pipe dimensions are adequate. New storage development with buffer volume and delayed drainage can almost guarantee this. But how can this be implemented economically when it is unclear how many site owners will accept a subsidy program based on a free choice?

The government of the Land of Hessen has therefore empowered local communities to demand rainwater utilization in a new Building Regulation for the Land. This possibility of "fixing" has now also been integrated into the new editions of the Building Regulations of the Lands of Baden-Wuerttemberg, Saarland, Bremen, Thueringen and Hamburg. A new era has begun - lower flow quantities can be achieved in water supply and housing area drainage, without a communal budget for subsidy payments. [Koenig 1999]

Experience in rainwater catchment

An example of this is a household with 4 persons in Germany with annual rainfall of 837 mm.
How much roof surface must be available and how much storage volume is needed so that adequate rainwater is available for toilet flushing, washing clothes, floor cleaning and garden watering?

Illustration 17
Average potable water consumption in European countries



Calculation of requirements and storage size

With a daily requirement in the household of 128 litres of potable water per person per day and 50 % substitution through rainwater, there is a

- Daily requirement of rainwater per person of **128 ÷ 2** = **64 litres**
- Weekly rainwater requirements for 4 persons: **64 x 7 x 4** = **1792 litres**
- Usable volume of the rainwater storage as a 3 week supply:
  3 x 1792 = **5376 litres**

Calculation of the necessary roof surface

Annual rainfall 837 mm means 837 litres per sq.m. horizontal projection surface per year

- Annual requirements (52 weeks): **1792 x 52** = **93,184 litres**.
- With 25 % extra for loss by vaporization and drifting and

storage overflow: **93,184 + 23,296** = **116,480 litres**

- Roof surface required (horizontal projection):
  116,480 ÷ 837 = **139 sq.m.**

If filters with 10 % water loss are used, the surface must be 10 % larger.

The problem in cities

A rational utilization is hardly possible in cities with heavily built-up dwelling structures, and in high-rise flat developments. In these cases the relationship of a small collecting area to the high number of users is unfavorable. Normally in Germany, only the rainwater flowing off the roof is used for rainwater utilization. The annual quantity of rainwater is 837 mm on average. It is estimated that between 10 (with 6-litre-toilets) and 20 sq.m. of roof surface (horizontal projection) per person is needed for the toilet flushing. Another 5 (washing machines with low water-requirement) to 10 sq.m. is required for the other uses.

Possible measures to facilitate rainwater utilization in cities

- To install toilets with reduced requirement of 3 or 6 litres.
- To collect rainwater from the roofs of neighbouring buildings, if it is not used by them. This was implemented by a tennis club in Marburg/Hessen [Koenig 1996, page 75] and in an automobile washing installation in Ueberlingen [Koenig 1998 a].
- To collect rainwater from roads and pathways with appropriate cleaning.
- To supply only a part of the dwellings with the water collected, and thus to have a smaller, more efficiently used and favourably priced distribution network.

All of these measures were incorporated in the following project in Berlin.

Berlin project achieves a new dimension!

In this project, the rainwater from all roof areas is disposed of through the public rainwater sewers of the Berlin Water Companies, as before (separate sewers). It is then transferred, together with the outflow from the streets, parking spaces and pathways, into a cistern. The cistern capacity is 160 cu.m. The water is treated in several simple stages and used for toilet flushing as well as for garden watering [Koenig 1998 b].

The Berlin Communal Dwelling Rainwater Utilization Project is supported by a 50% contribution from the Senate Administration for Buildings, Dwellings and Traffic in Berlin, Department of Ecological Town Planning, as a model project. The other half of the cost is borne by the owners (the Berlin Communal Dwelling Company "GSW"). The sanitary design and specialist construction supervision for the project is Sanitärsystemtechnik Berlin.

Illustration 18
Section Collection/Cleaning/Utilization
Housing area Berlin-Lankwitz

The ecological effect

58% of the rainwater can be retained in the area. The estimated 90% of the pollutants in the initial flow are retained in the system and transferred through the cleaning process, out of the rainwater sewer and into the soil sewer, where they can be treated properly in a sewage plant. The savings in potable water through the utilization of rainwater amounts to about 2430 cu.m. per year, (based on a 10-year simulation). Accordingly the groundwater reservoirs of Berlin should be preserved by this amount.

The project data

Commissioning (trial operation)	May 1999	Drained surfaces	
Number of dwellings supplied with rainwater	80	Roofs, retention factor 1.3 mm	7,000 sq.m.
(213 persons calculated at 35 litres per day)		Parking spaces (paved), ret. factor 3.5 mm	2,000 sq.m.
Annual potable water saving	2,430 cu.m	Roads and paths (concrete), ret.factor 2.6 mm	2,200 sq.m.
Irrigated rented garden areas	1,100 sq.m	Buffer volume of cistern	160 cu.m.
Rainfall utilization	58 %	Diameter of public rainwater sewer	400 mm
(dependent on volume of cistern)		Utilizable volume of daily storage	6 cu.m.

The special thing about this

A scientific accompanying program of the Berlin Technical University is a part of the project and the complete treatment facilities, including the operating dials, are visible from a pathway through a "showcase window" on the end wall of the ground floor. The experience gained from this project can help solve problems of capacity in potable water supplies, as well as drainage of dwelling areas, particularly in highly populated areas where the utilization of run-off from roof areas alone is inadequate. German Ministry of the Environment Delphi-study experts project that in future, in densely populated regions, priority will be given to the efficient use of collected run-off water. The experts predict that in Europe, an average of 15 % of the run-off water in densely populated regions will be collected separately from the sewage in 2010. In the same year, it is estimated that the percentage will reach the 24 % level in Germany [Ministry 1999].

Ueberlingen/ Germany, May 1999

Person

Klaus W. Koenig, Dipl.-Ing., born in 1956, works as a freelance architect in Ueberlingen, Lake Constance. He is on the Board of the professional Association for Industrial and Rainwater Utilization in Darmstadt, that is active throughout Germany, and holds regular seminars for training tradesmen, architects, specialist engineers and employees in public services. He is the author of three books on the subject, "Rainwater Utilization from A - Z", "Guidelines for Rainwater Utilization for German Communities" and "Rainwater in Architecture - Ecological Concepts." He has been a member of the German DIN-NAW V8 Committee for Standardizing Rainwater Utilization Installations since 1997.

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Illustrations

No. 1, 7, 8, 9, 11	Wisy AG Haustechniksysteme, Filtertechnik D-63699 Kefenrod
No. 12, 13	ARIS Systeme zur Regenwassernutzung GmbH D-73269 Hochdorf
No. 14	ING.FTG mbH, Ingenieurges. für tech. Gebaeudeausruestung D-10318 Berlin
No. 15	ATV-Information 1996, GFA Verlag D-53773 Hennef
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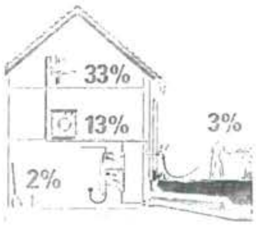
Private household



Substitution of potable water
Use for Rainwater

• *Toilet flushing*	*33 %*
• *Washing machine*	*13 %*
• *Floor cleaning*	*2 %*
• *Irrigation*	*3 %*
	51 %

Source ARIS Systeme zur Regenwassernutzung, Germany

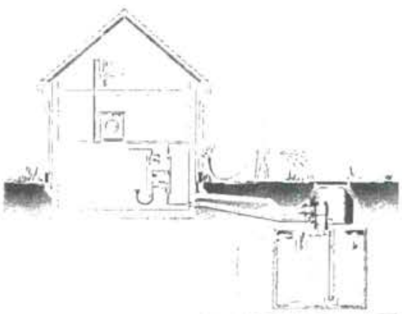
Private household

Rainwater network System -A-

- *Battery of plastic storage tanks inside*
- *Filter collector in every downpipe*

Source ARIS Systeme zur Regenwassernutzung, Germany

Private household

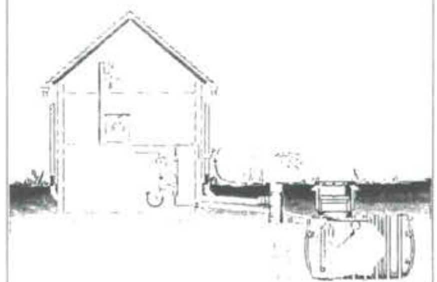


Rainwater network System -B-

- *Concrete storage tank outside with integrated filter*

Source ARIS Systeme zur Regenwassernutzung, Germany

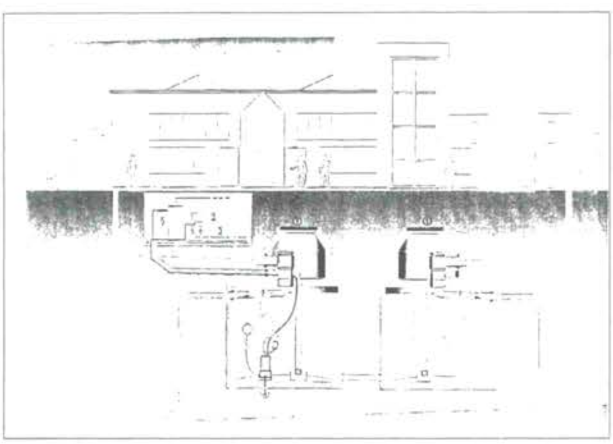
Private household

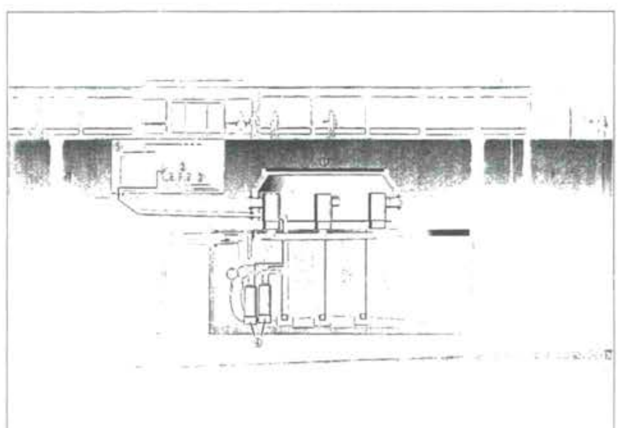


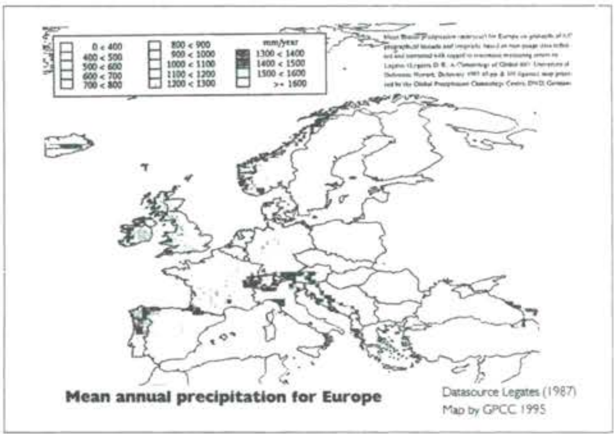
Rainwater network System -C-

- *Plastic storage tank outside*
- *Underground filter collector*

Source ARIS Systeme zur Regenwassernutzung, Germany






0 < 400
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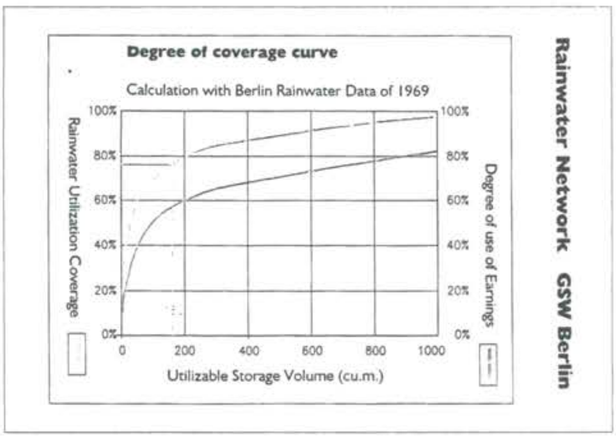
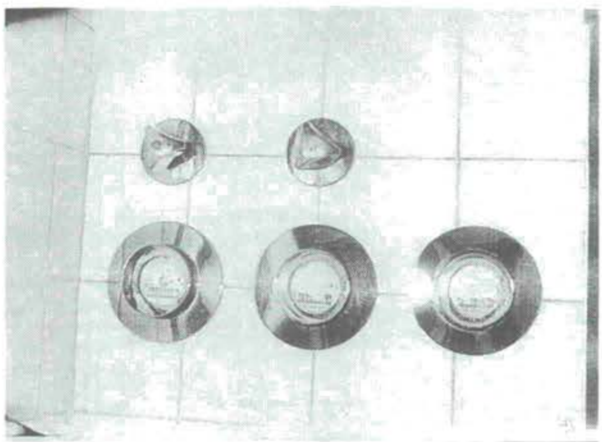
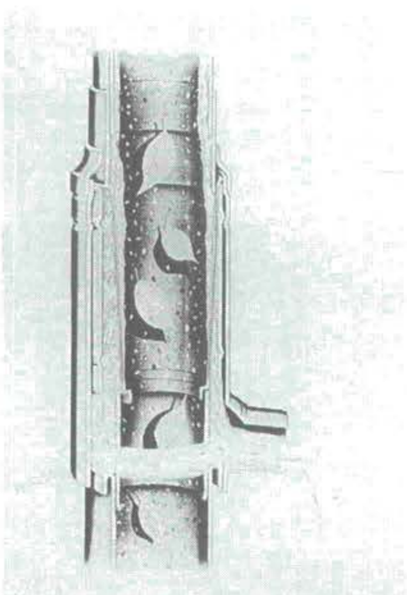
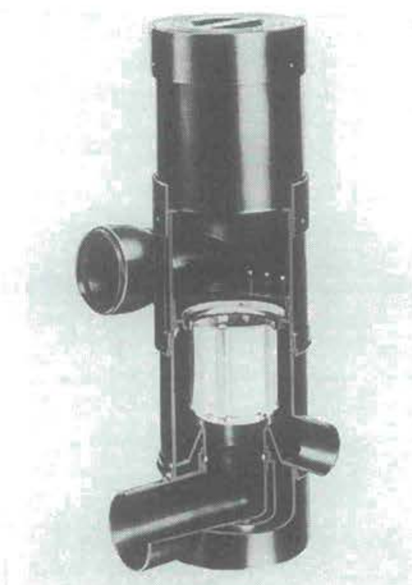
1200 < 1300
mm/year
1300 < 1400
1400 < 1500
1500 < 1600
>= 1600
Mean annual precipitation for Europe
Datasource Legates (1987)
Map by GPCC 1995


Degree of coverage curve
Calculation with Berlin Rainwater Data of 1969
Rainwater Utilization Coverage
Degree of use of Earnings
100%
80%
60%
40%
20%
0%
0
200
400
600
800
1000
Utilizable Storage Volume (cu.m.)
Rainwater Network GSW Berlin







Creating a Rainwater Utilization Based Society for Sustainable Development

Dr. Makoto Murase
Director of Urban Affairs, International Rainwater Catchment Systems Association
Chief of Environmental Promotion Section, Department of
Environmental Protection, Sumida City Government, Tokyo

1 Re-thinking of water policy in cities

(1) Autonomous water resources, not dependence on distant water resources

Until now, many cities of the world have had a policy based on the idea of drawing city water from a great distance; 100km or indeed several 100km away. Tokyo is no exception. On the basis that its water was insufficient, Tokyo has sought to build dams in its upper hinterland area. It is now true to say that for most of its piped water, Tokyo depends on dams in the Tone River water system. This is about 150 km distant from the center of the city. According to a water account drawn up by Tokyo Metropolitan Government this year, water resources is equivalent to 56 % of Tokyo's annual average rainfall of 1405mm, and the greater part of this comes from the Tone River water system.

But this policy of increasing dependence on the upper streams of the water resource hinterland area is beginning to show signs of deadlock. In 1987 rain did not fall in the upper streams of the water supply area for a long time and the Kanto area was faced with a serious water shortage. Development of the upper streams of the Tone River water resource area had reached a limit, so Shunichi Suzuki, the governor of Tokyo, worked out the so called "Shinano River Watershed Concept". This idea was to go outside the watershed area and draw water from the Shinano River into the Tone River. The governor of Niigata prefecture at the time, Takeo Kimi vehemently opposed this. He said, "Seeking water resources in another prefecture on the basis that ones own water is in short supply is too simplistic". Building dams in the upper watershed means submerging many houses and fields and mountain woods beneath the water, and it means destroying the culture of hill country villagers that has been nurtured over a long period of time. It is not easy to win over people whose homes will disappear under the water. Because of this it takes a very long time to complete the construction of dam. Compensation that has to be paid to people from submerged areas, and compensation for the submerged land has a tendency to increase over time, and there is usually a resulting increase in the cost of construction.

There is already no further opportunity for the development of large dams in the upper streams of the Tone River, Tokyo's principal water resource, and development of dams already proposed is progressing slowly. In addition, dams that have already been constructed have been filling with silt over a long period of time, and there has been a tendency for the quantity of water effectively collected to be reduced. Tokyo must now change its approach and must no longer depend on the water resources of the upper watershed area. Tokyo must aim for independent water resources depending as much as possible on rainwater, ground water, and wastewater reclamation. It must also progress with water conservation.

Up to now Tokyo has only thought of rainwater as a nuisance, and of how it can be disposed of quickly through drains. It has virtually ignored how rainwater can be used as a resource. But the piped water consumed in Tokyo during one year which is about 2 billion cubic meters, is exceeded by the 2.5 billion cubic meters of rain that falls. This rain should be harnessed as a resource, and should be actively used. Reclaiming the city's rainwater as a resource, and the importance of securing water by changing from "off-site" to "on-site" sources is a significant exercise which must be based on learning from Tokyo's water resource policy up till the present time.

(2) Independent "life-points", not dependent on a "life-line" for water supply

When the city increases the degree of its dependence on a distant water resource, and there is a long period without rainfall in the upstream dam sites, there is an immediate paralysis of the effective functioning of the city. The same thing can be said about reliance on a pipeline drawing water from a water resource area to the city. A city, which is totally reliant on a pipeline drawing water from a distant water resource, is very vulnerable in the face of a large-scale natural disaster.

The Hanshin Awaji great earthquake showed how this can happen in reality. Kobe City depends for most of its water resource on the distant Biwa Lake. Water is brought from there by a pipeline, but the earthquake destroyed the supply line. During the approximately one month until the pipeline was repaired, Kobe's municipal functions were completely paralyzed. During the long period that water was cut off from pipes, well water from within the city served as an alternative source of water. The Kobe City building, where the Disaster Restoration Center was set up is an example. From the time when the building was constructed, the water supply system was divided into city water and well water, with toilets using well water. The huge earthquake did not damage the well water system, and the toilets continued to function.

The move "from life-line to life-points" must be reinforced. The lesson learned from the Kobe disaster is about this change in thinking. Numerous small-scale scattered water resources must be secured as "life-points" within the city. These can draw on rainwater and ground water, making the city strong in the face of water shortages and earthquakes.

(3) From the flow of rainwater to the storage of rainwater to restore regional water circulation

Due to a speed up in urbanization, a lot of the world's large cities are facing problems with urban floods. For Tokyo, the central point of this problem is that the Tokyo regional water cycle is being destroyed. The cycle is made up of rain falling and over time seeping underground to become groundwater. A rich supply of underground water produces springs and the submerged flow of rivers. In 1991 the proportion of areas where rain did not permeate reached 81.8 %. An increase in the proportion of areas where water does not penetrate speeds up the flow of rainwater. Water then accumulates in drains and streams within a short time. Every time there is concentrated heavy rain, there is a flow back of sewage from drains, and medium and small sized rivers repeatedly flood. Without an overflow, the heavy rain often causes an outpouring of sewer water into rivers and streams, from countless sewer outlets and sewer pumping stations, and the quality of the city's river water becomes tainted. In Tokyo, New York and elsewhere prevention of water tainting has become an important aspect of conserving the river water quality.

The concrete and asphalt structure of cities has tended to eliminate the regional water cycle, and reduce the amount of rainwater permeating underground. Of the 1405mm of rainwater falling on Tokyo annually, only about 360mm penetrates underground. As a result, the amount of ground water that flows into rivers and ponds via springs is thought to be no more than 30-100mm in the Tokyo central area. Because many city springs have dried up, the flow of city rivers, dependant on these springs as their water source has been reduced.

City construction that destroys the regional water cycle has various effects on the city environment. One is drying of the city. This happens because the springs dry up, rivers and watercourses are covered, and greenery is cut down. The average humidity at the center of the Tokyo in January has fallen by close to 20 % in the last 100 years.

Then there is the city's heat pollution. Midsummer in Tokyo covered with concrete and asphalt is like a heated frying pan. In hot summer an asphalt road at midday reaches a temperature of over 60°C. The heat expelled from coolers further aggravates this. The number of tropical nights also rises with urbanization. The change in the city environment with the earth covered by concrete and asphalt has a profound impact on the ecology of the city. For example, the numbers of swallows in Tokyo has declined.

The destruction of the regional water circulation brought about by urban concrete and asphalt structures is the basic cause of significant problem, including urban flooding, tainting of the water quality in rivers caused by the overflow from drains when it rains, drying up of spring water, turning of the city into a heat island and its desiccation, and destruction of the city's ecological environment.

Integrated Utilization of Rainwater

Urban Flood Control

Storage of Rainwater

Rainwater Storage Tank

- Flushing water for toilet
- Sprinkling water for plant and trees
- Cooling water for coolers
- Initial water source for fire fighting
- Drinking water supply in emergencies

Permeation into Ground

- Restoring of local water circulation
- Rainwater cure for green
- Prevention of island formation
- Prevention of subsidence
- Use groundwater for disasters

In order to achieve a comprehensive solution to this problem, a complete change in city structure must be brought about. The problem must be examined from the perspective of the regional water cycle. There is a need to look for a basic solution through the restoration of regional water circulation. According to generally accepted city planning practices, sewer facilities have been developed with the assumption that the coefficient of rainwater drained away will have to be increased. From the stand point of preserving the regional water circulation, it is better to retain rain water and to promote its permeation, by preserving natural ground and greenery, thereby limiting the increase in the coefficient of rainwater drained away.

2 A New Paradigm for Rainwater Utilization

(1) Introducing Cycle Capacity

Until now water has been the limiting factor in development of cities. The scale of cities has been decided by water's environmental capacity. Tokyo's former source of water was from only one dam on an upper stream of the Tama River. With that alone, the present Tokyo could not have developed. In 1964, during Tokyo Olympics, Tokyo was affected by a serious drought, which provided the opportunity for Tokyo to shift its water supply from the Tama to the Tone River system. This broadening of the water resource hinterland removed a key limiting factor and accelerated Tokyo's high-density development. However even this policy has reached a limit.

Because there is not enough water, Tokyo has built a number of dams on the upper streams of the Tone River. However every three or four years in the summer there is a water-shortage, partly due to the lack of rain falling in the upper streams of the water supply area. It would appear that Tokyo's municipal policy of combining massive expansion, while neglecting the regional environmental capacity of water, is gradually reaching its limits.

There is a need to change the thinking behind Tokyo's policy. Tokyo must stop further dependence on the upper streams of the watershed. It must make its water supply as independent as possible, basing it on rainwater and ground water resources close at hand. To do this the concept of environmental capacity must be introduced within Tokyo's water resource policy. Also, plans must be made to limit the density of Tokyo and thus prevent further large growth in the water demand.

As previously noted, rain is part of the ground water cycle and supports the regional environment. Time is important for the restoration of the regional water cycle. Although the idea of environmental capacity has existed for some time, there has been a tendency to view it statically. However in thinking about sustainable development, one must consider time, and view environmental capacity from a dynamic perspective. "Cycle capacity" refers to the time that nature needs revive the water cycle. Although it is not referred to in this paper, the idea of cycle capacity is not limited to water problems; it can also be used in referring to natural resource problems and waste problems, as well as sustainable world environmental strategy.

Let us think of use of ground water from the point of view of cycle capacity. Rain seeps underground and over the time becomes shallow stratum ground water. Then over a very long period of time, it becomes deep stratum ground water. For sustainable use of ground water it is necessary to think in context of the storage capacity for ground water over time. If this is neglected and ground water is pumped too quickly, ground water will disappear within a short time. At present in Tokyo, in the region of the Tama, deep stratum ground water is being pumped up as a water resource for distribution through water pipes. If large quantities of water are pumped up from the deep stratum level, a squeeze down phenomenon takes place and shallow stratum ground water seeps into the low stratum ground water. For the most part, present use of deep stratum ground water utilizes some shallow stratum ground water. If the volume pumped up is increased further, the shallow stratum ground water will dry up, and the restoration of spring water will become difficult.

A lesson was learned about ignoring underground water cycle capacity and about rapid over pumping from what formerly occurred in the eastern part of Tokyo. In this area there was a serious sinking in the ground surface of 3 meters. In the future there should be a move from deep stratum ground water with a very long cycle time to shallow stratum ground water with a relatively short cycle time. There should also be a plan to use ground water in a manner that is consistent with the shallow stratum ground water cycle. At present, cities throughout the world are pumping up large quantities of deep stratum ground water because of its quality and its low cost. But the speedy consumption of this deep stratum ground water while overlooking its cycle capacity leads to ground water pollution and infiltration of seawater, as many cities have already experienced. This creates a situation that cannot be redeemed. There is a need now to rethink the use of ground water from the point of view of cycle capacity. This is a very important issue in relation to water strategies for sustainable development in cities.

(2) Controlling supply from the demand side

In addition to the concept of water cycle capacity there is another important strategy related to the supply and demand of water. Until now cities, in establishing their water supply plans, have taken as a preconception that the future demand for water will inevitably continue to increase. However the supply of water must be controlled from the demand side. Typically those employed in city water works departments have made excessive estimates of the demand for water and have built water works infrastructure based on continued excessive development of water resources and strategies to enlarge the area of water supply. Since these departments plan to recover the costs of development through water rates they have no option but to encourage citizens and enterprise consumers to use large quantities of piped water. When there is plenty of water in the resource area they encourage large-scale consumption; when there is a drought and they call upon consumers to save water, they often lack persuasion. Unfortunately the calls of water works departments to conserve water usually come to nothing. One occasionally hears that if water conservation is thoroughly carried out and is popularized, sales of piped water will decrease, hence their real inclination is against the popularization of conservation devices and the use of rainwater. The background to this dilemma is the exaggerated water supply and demand plan. This over-development of water resources encourages denser population and more consumption of water, which in turn calls for new water resource development, and so the vicious circle continues. Tokyo is a classic example of this.

As previously explained, originally in cities there was water cycle capacity. In the future if we aim for a city that takes into account of water cycle capacity, the water supply plan must include a change from coping with water supply without controlling demand, to coping with supply by controlling demand. Also it is important to foster a consciousness of water resource utilization self-control in citizens, based on supplying water from the regional watershed to the extent possible. If lifestyle based on the large scale consumption model of using as much water as one likes is not corrected, it will be difficult to bring about a sustainable development in cities. Beyond the popularization of devices to conserve water, if citizens themselves do not adopt a water conservation model, restrictions in water demand will not succeed. In connection with the move toward using rainwater, it is interesting that citizens who have come to use rainwater point to a change in thinking from their previous idea that rainwater is unpleasant and nuisance to the idea that rainwater is a blessing.

Furthermore, when they turn their eyes to the distant upstream dams, they become more interested in the use of water and the idea of water close at hand.

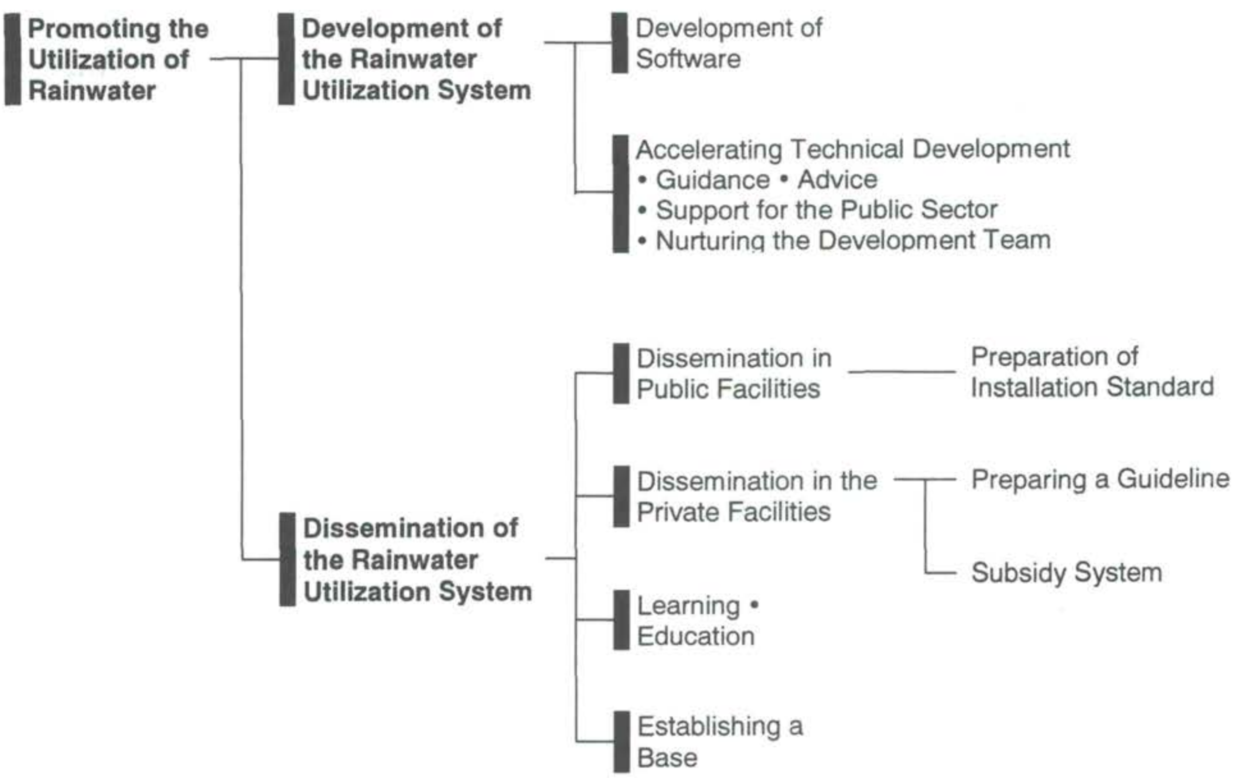
The objectives for the supply of Japanese water determine that water should be supplied "purely", "cheaply" and "plentifully". But now, when the network of water distribution infrastructure has reached almost 100% it seems that the time has come for a change in policy. It is time for a fundamental reappraisal of water supply objectives within the context of water cycle capacity and control of demand.

3 What should be done?

Within context of the new paradigm described above, as cities plan for greater independence in the supply of water resources and the restoration of regional water circulation, practical themes such as the following should be considered.

(1) Systemization

Policy System for the Utilization of Rainwater



First of all, the use of rainwater, conservation of water and reclamation of wastewater should be codified into ordinances and regulations, and systemized so that they can be incorporated into the fabric of society.

In 1982, Sumida City, located in the east of Tokyo, directed the Japanese Sumo Association to use rainwater at the Kokugikan National Sports Stadium. The implementation of this was seen as an opportunity, and almost all the public new facilities in the city are now using rainwater. At the community level, a unique rainwater utilization facility, "Rojison" has been set up by local residents. Rainwater utilization is now flourishing at both the public and private level.

Sumida City has been promoting rainwater utilization for 17 years. Over a two year period beginning in 1993, Sumida City carried out an analysis of the effectiveness of the spread in rainwater utilization in the city. The analysis concluded that the rainwater utilization had spread throughout the whole city, for the purposes of water conservation, flood control and disaster prevention. The effectiveness of "mini dams" was observed. Based on fixed requirements, it has been estimated that if the rainwater utilization spreads to 30 % of facilities within the city, the number of times that sewage is discharged into the river from existing sewage pumping stations would be cut in half; further more during drought or disaster conditions, water would not have to be brought from outside Sumida City for about one month in order to give the citizens of the city 11 liters of water each day.

In response to this, in March 1995, the city decided to implement "Rainwater Utilization Promotion Guidelines". The gist of these guidelines is as follows: First, in the future construction of city facilities, rainwater utilization systems should be installed. Second, for large scale development, the developer should be directed and encouraged to use rainwater. Third, rainwater tank facilities for citizens should be subsidized. In the same year from October, the subsidization of rainwater tanks for citizens began. Thus far, 113 rainwater tanks have received subsidies and are set up. The combined holding volume of facilities using rainwater in Sumida City is now about 8000 m^3 and rainwater mini dams are gradually spreading through the city.

(2) Implementation policy

Various implementation policies must be devised to make rainwater utilization and other measures a part of the social system. Leadership is very important. Public administration must take the initiative and promote the concept of water resource independence and restoring the regional water cycle. Public administration must also support the efforts of citizens and make plans to implement these ideas as part of the social system. Specific consideration should be given to subsidizing facilities for rainwater utilization, devices for rainwater to seep underground, devices for water conservation and facilities for using reclaimed water.

Measure to rebate sewerage service charges should be examined. Local governments that subsidize rainwater tanks, besides Sumida City mentioned before, already number 25 throughout Japan. These include Takamatsu City, Fujisawa City, Kawaguchi City, Tama City and Katsushika City. In Germany one objective of subsidizing the use of rainwater is to conserve ground water. Hence they subsidize not only rainwater use facilities but also facilities for the permeation of rainwater underground. New York City subsidized water conserving toilets, and is having success in popularizing them. Regarding measures to rebate the sewerage service charges, in Germany, when rainwater is discharged into drains, drain fees are collected; but when rainwater is used, the local government rebates the sewerage service charge. Although such a system currently does not operate in Japan, it will be necessary to examine such approaches.

(3) Development of technology and the education of specialist technicians

Encouraging the development of technology and the development of human to support rainwater utilization is very important. It is also important to promote the development of cheap and efficient devices to conserve water, facilities to use rainwater and devices to promote the underground seepage of rainwater. Together with this is need to develop specialist technologists with a thorough grasp of these technologies and devices. At the present time the amount of water consumed in one flush of Japanese toilets is 12~13 liters, in Germany it is 6 liters and the target for the future is 4 liters. In the future the national government and local governments will have to appeal to manufacturers of product which dominate a great deal of the demand for water, such as toilets and washing machines, to improve the efficiency of their product. Superior products should be recognized by administrators, types fixed by rules and regulations, and a positive promotion carried out. The same thing can be said about rainwater utilization facilities and devices for seepage of drain water underground. Previously in Fukuoka City, using the unusual drought of 1978 as an opportunity, the City set up its "Outline measures relating to Fukuoka City water conservation model usage" and achieved success in popularizing the use of water conservation devices.

Also in Germany there is a group specializing in the use of rainwater called "fbr" composed of architects and others, who convene seminars aimed at developers from various parts of Germany. These seminars relate to the rainwater utilization. The energetic activities of this group also include design consultations for the general public about facilities for rainwater utilization. In Japan there is not yet this kind of activity by people in the industry. Nevertheless there is now an urgent need for the development of groups of technicians well versed in design construction and maintenance management in the fields of rainwater management, the underground seepage of rainwater, conservation of water and the cascading use of gray water, together with wastewater reclamation.

(4) Development of networks

Finally, in order for this kind of social system to continue in a sustainable way, a network should be promoted made up from government administration, citizens, architects, plumbers and the representatives of equipment manufacturers. It is essential to combine the efforts of public servants, citizens and industry representatives involved in the fields of rainwater storage, seepage and use, conservation and wastewater reclamation. This is not only true in Japan but also in every region throughout the world. In order to bring about a sustainable development on a global scale, it is important to encourage regional interchanges and networking of these groups throughout the world. To do this, it will be necessary to plan for the creation of a structure to encourage common activities and the exchange of information amongst these groups internationally. Japan is carrying out advanced activities in the areas of rainwater utilization, the practical application of seepage of rainwater underground, and water conservation. In the future, Japan must make a positive international contribution in these areas.

Reference

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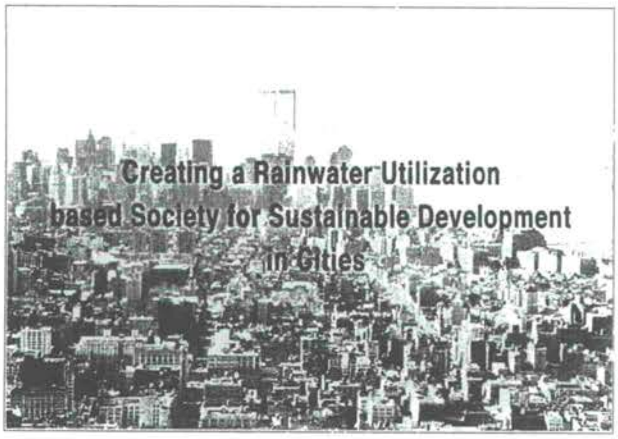
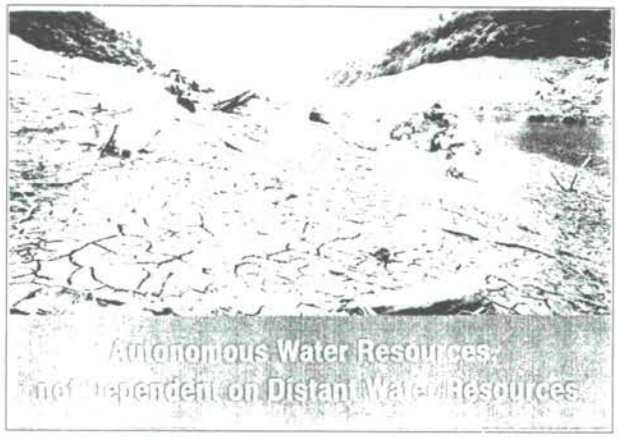
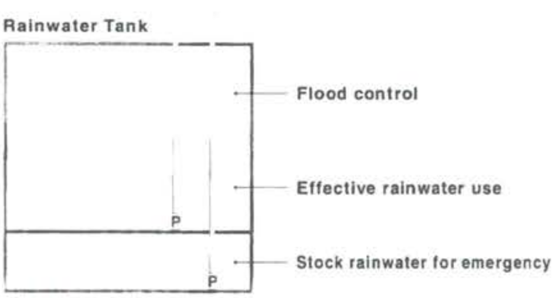




The Concept of Rainwater Utilization



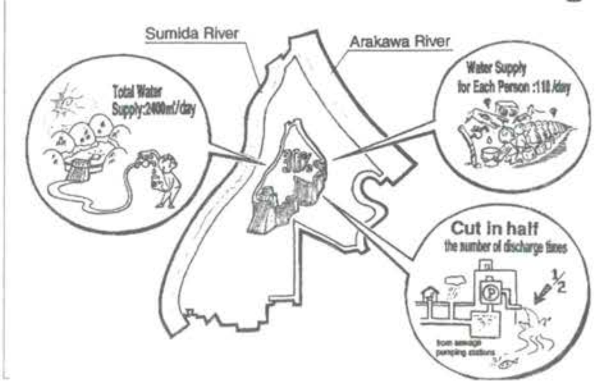
Reclamation of Rainwater in Sumida City Office Building

	1995	1996	1997
1) Piped water	23,549m³	20,637m³	18,261m³
2) Reclaimed water	11,110m³	10,309m³	11,500m³
3) Reuse of Rainwater	4,585m³	3,571m³	6,466m³
4) Supplemented piped water	4,805m³	5,091m³	3,269m³
5) Drained water from cooling towers	1,162m³	673m³	1,071m³
1+2	34,029m³	30,946m³	129,761m³
2÷(1+2)	32.1%	33.3%	38.6%
3÷2	41.3%	34.6%	56.2%
4÷2	43.2%	49.4%	28.4%
5÷3	25.3%	18.8%	16.6%
3÷(2+4) Coefficient of Used Rainwater	28.8%	23.1%	43.7%

Analysis of water quality of rainwater in rainwater utilization facilities

	Sumida City Office		Sotode child institution		Rojison			Large scale (private facilities)	Medium scale (private facilities)	Small scale (private facilities)	The water quality standard of piped water
Sampling date	99. 1.19	95. 5.24	99. 1.19	95. 4.19	99. 1.19	96. 8.4	95. 4.19	99. 1.19	99. 1.19	99. 1.19	
N-NO₃ and N-NO₂	2.0	2.9	3.0	1.6	1.2	1.4	2.1	3.2	3.0	1.5	10mg/l ↓
Cl⁻	7.1	44.7	31.2	7.8	5.7	7.1	25.2	32.0	32.6	3.5	200mg/l ↓
KMnO₄ consumption	3.6	13.1	2.8	4.2	1.9	2.2	3.9	3.0	2.8	2.5	10mg/l ↓
Heterotrophic plate count	6	90	5	7	2	8	0	8	1	10	100/ml ↓
Coliform group	+	−	−	+	−	−	−	−	−	−	−
pH	7.9	7.5	7.4	7.3	9.8	10.2	8.1	8.4	6.9	5.9	5.8~8.6
Odor	−	+	−	+	−	+	−	−	−	+	−
Color unit	5	15	3	7	5	4	1	2	5	3	5↓
turbidity	1↓	1	1	1	1↓	1↓	1	1	1	1↓	2↓

Mini Dam effect in Sumida City



Subsidy System for Promoting Rainwater Utilization in Sumida City

● Large scale (Basement tank type)
Capacity of rainwater storage tank : 5m³ and over

Subsidy	¥40,000/m³
Maximum subsidy	¥1000,000

● Medium scale
Capacity of rainwater storage tank : 0.5m³ and over

Subsidy	FRP tank and Stainless steel tank ¥120,000/m³
	Polyethylene tank ¥45,000/m³
Maximum subsidy	¥300,000

● Small scale
Capacity of rainwater storage tank : under 0.5m³

Subsidy	1/2 × total cost of tank
Maximum subsidy	¥2,5000

What should be done ?

1 Systemization
2 Implementation policy
3 Development of technology and the education of specialist technicians
4 Development of networks

No More Tanks for War, Tanks for Peace !

Rainwater Utilization Saves the Earth

International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
Kobe, Japan, 8-10 June 1999

Session 3: Water Reuse for Non-potable Applications

WASTEWATER REUSE FOR NON-POTABLE APPLICATIONS: AN INTRODUCTION

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ABSTRACT

The role of wastewater reclamation and reuse in the context of efficient water use in urban areas is reviewed. Over the past few decades, the use of water increased rapidly and significantly. Frequent droughts, increasing water development costs, institutional and environmental concerns, and a growing conservation philosophy are key factors accounting for current surge of interest in wastewater reclamation and reuse throughout the world. Reclaimed water is, after all, a water resource existing right at the doorstep of the urban environment where water resources are needed most and priced the highest. Furthermore, reclaimed water provides a reliable source of water even in drought years because the generation of urban wastewater is affected little by drought. In this paper, fundamental concepts of wastewater reclamation and reuse are reviewed which include applicable wastewater treatment processes and operations, categories of water reuse, emphasizing the role of water reclamation and reuse in the context of more sustainable water resources development.

In every wastewater reclamation and reuse operation, however, there is some risk of human exposure to infectious agents. Because of the public health concerns, special attention is paid to wastewater treatment systems that are capable of producing essentially pathogen-free effluent for variety of beneficial uses. Finally, regulatory aspects of wastewater reuse in developing countries are discussed.

KEYWORDS

Pathogens, planning, public health, water quality regulations, water resources, wastewater reclamation and reuse, wastewater treatment.

INTRODUCTION

As the worldwide demand for water increases, wastewater reclamation and reuse have become increasingly important in water resources management by allowing a water supply agency to plan for increasing long-term water supply reliability in agriculture, industry, and municipality. In industrialized countries, there are growing problems of providing dependable water supply, and municipal and industrial wastewater disposal. In developing countries, particularly those in arid parts of the world, there is a need to develop economically feasible new water supplies and protect existing water sources from pollution. The water pollution control efforts in many countries have made treated effluent available that may be an economical augmentation to the existing water supply when compared to the increasingly expensive and environmentally destructive new water resources development. However, wastewater reuse is only one alternative in planning to meet future water resources needs. Water conservation, water recycling in industries, efficient management and use of existing water supplies, and new water resources development based on environmentally conscious watershed management are the examples of other alternatives.

The advantages as well as motivating factors for wastewater reuse are identified as follows:

- Water pollution abatement, not discharging into receiving waters

- Availability of highly treated effluents for various beneficial uses enforced by increasingly stringent water pollution control requirements
- Providing long-term water supply reliability within the community by substituting freshwater
- Water demand and drought management in overall water resources planning
- Responsible public policy encouraging resources conservation including water conservation and wastewater recycling and reuse

However, a common misconception in planning for wastewater reclamation and reuse is that reclaimed wastewater represents a low-cost new water supply. This assumption is generally true only when wastewater reclamation facilities are conveniently located near large agricultural or industrial users and when no additional treatment is required beyond the existing water pollution control facilities from which reclaimed water is delivered. The conveyance and distribution systems for reclaimed water represent the principal cost of most proposed water reuse projects. Recent experience in California indicates that approximately four million U.S. dollars in capital cost are required for each one million m^3 per year of reclaimed water that made available for reuse. Assuming a facility life of 20 years and a nine percent interest rate, the amortized cost of this reclaimed water is about $0.45/$m^3$, excluding O & M costs.

Wastewater reclamation and reuse involves considerations of public health and also requires close examinations of infrastructure and facilities planning, wastewater treatment and plant siting, treatment process reliability, economic and financial analyses, and water utility management involving effective integration of domestic water supply and reclaimed wastewater distribution. Whether wastewater reuse will be appropriate in a community depends upon careful economic considerations, potential uses for the reclaimed water, stringency in environmental protection and waste discharge, and public policy wherein the desire to conserve rather than develop new water resources with considerable environmental impacts. Today, technically proven wastewater treatment or purification processes exist to provide water of almost any quality desired. Thus, wastewater reuse has a rightful place and an important role in optimal planning and more efficient management and use of water resources in many countries.

Wastewater reclamation is the treatment or processing of wastewater to make it reusable, and *water reuse* is the use of treated wastewater for a beneficial use such as agricultural irrigation and industrial cooling. In addition, *direct* wastewater reuse requires existence of pipes or other conveyance facilities for delivering reclaimed water. *Indirect* reuse, through discharge of an effluent to a receiving water for assimilation and withdrawals downstream, is recognized to be important but does not constitute *planned direct water reuse*. In contrast to direct water reuse, *water recycling* normally involves only one use or user and the effluent from the user is captured and redirected back into that use scheme. In this context, water recycling is predominantly practiced in industry such as in pulp and paper industry (Metcalf & Eddy, 1991).

WASTEWATER TREATMENT TECHNOLOGIES FOR WATER REUSE

In evaluating wastewater reclamation technologies, the overriding considerations are the operational reliability of each wastewater treatment process and operation, and the overall capability of complete treatment system to provide a reclaimed water that meets established water quality standards and/or criteria. As a result, additional treatment processes and operations may be required in certain water reuse applications for removal of chemical contaminants and removal or inactivation of microbiological pathogens.

In conventional wastewater treatment, the general terms used to describe different degrees of treatment, in order of increasing treatment level, are preliminary, primary, secondary, and tertiary/advanced treatment. A disinfection step for removal or inactivation of pathogenic organisms is often the final treatment prior to storage and distribution for reuse. Because of cost considerations, preliminary and primary treatment in developing countries, and secondary treatments in industrialized countries are generally considered as water pollution control requirements; the additional treatment required for water reuse is normally designated as tertiary or advanced wastewater treatment. The goal in designing a wastewater reclamation and reuse system is to develop integrated cost-effective process combinations that are capable of reliably meeting the water quality objectives required for wastewater reuse.

Figure 1 shows a generalized view of wastewater treatment processes and operations as well as effluent reuse schemes. Based on water quality requirements, any effluent stream can be used as reclaimed water for various beneficial uses. The range of applicable technologies may include: 1) septic tanks, lagoons, wetland, and natural treatment systems, 2) secondary wastewater treatment systems, 3) advanced physical-chemical treatment, 4) advanced biological treatment including biological nutrient removal (BNR), 5) advanced oxidation processes, 6) membrane separation and membrane bioreactors, 7) disinfection technologies, and 8) innovative reactor designs such as sequencing batch reactors and advanced mixing devices.

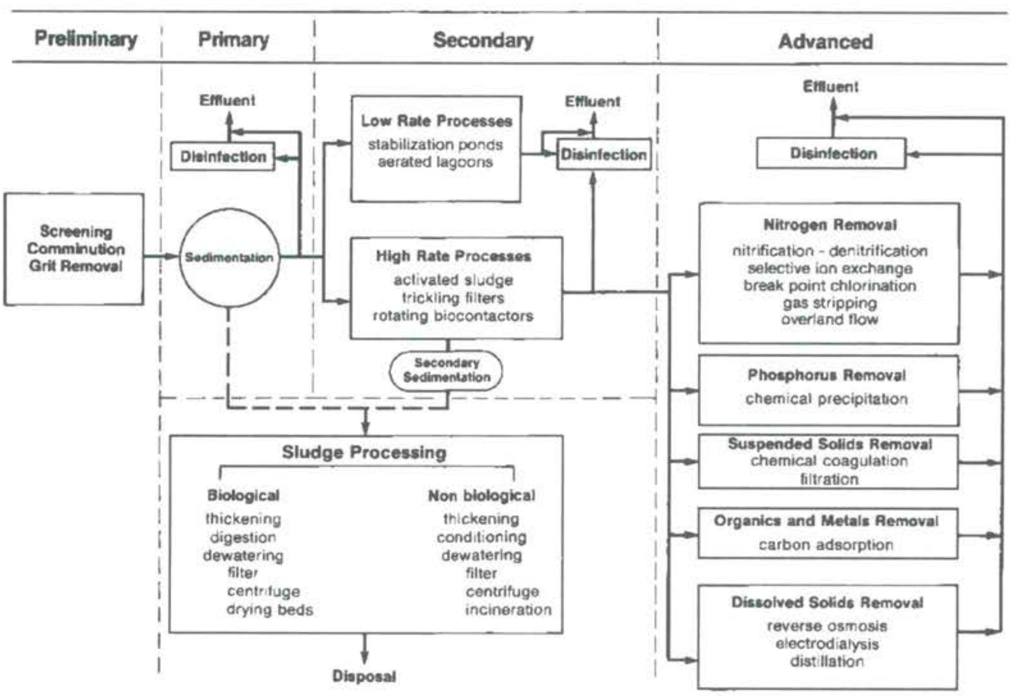

Figure 1. Generalized wastewater treatment processes and operations, and effluent reuse schemes (Adapted from Asano, Smith, and Tchobanoglous, 1985).

Advanced treatment plays a critical role in the effective treatment of municipal and industrial wastewater to meet higher water quality objectives for water reuse and to protect public health. Conventional and advanced wastewater treatment consist of a combination of physical, chemical, and biological processes and operations to remove settleable, suspended, and dissolved solids, organic matter, metals, nutrients, and pathogens from wastewater. Most of the current wastewater reclamation and reuse technologies are essentially derived from those used in water and wastewater treatment. However, opportunities for adopting technological innovations are much greater for water reuse applications, because reclaimed water will have an economic value as an alternative water supply. Furthermore, contrary to the disposal of treated effluent, where federal or national regulations are enforced by "command and control" methods of water pollution control, water reclamation and reuse allow more flexibility in water quality management, and consequently more possibilities for adopting innovative technologies.

Table 1 shows a summary of major unit operations and processes used for wastewater reclamation. At present, the dominant wastewater reuse applications, worldwide, are irrigation of agricultural lands, parks and golf courses. However, there has been considerable progress in reclaimed water applications in the urban setting such as toilet flushing, cooling, fire fighting, and stream flow augmentation. Furthermore, future use of reclaimed water may involve a completely controlled "pipe-to-pipe" system with an intermittent storage step, or it may include blending of reclaimed water with non-reclaimed water, either directly in an engineered system or indirectly through a surface water supply reservoir or a groundwater recharge scheme.

Tertiary and Advanced Wastewater Treatment

After conventional biological treatment processes (e.g., activated sludge process, trickling filters, and oxidation ponds), tertiary or advanced treatment can be applied to remove additional dissolved and suspended contaminants, nutrients, specific metals, and other harmful constituents (see Fig. 1).

Filtration. Filtration is a solid/liquid separation process that effectively removes suspended particles larger than about 3 μm. When wastewater passes through a column of granular media, particles are removed by impaction, interception, and physical straining. As particles accumulate in the filter media, headloss through the filter increases, making necessary for the filter to be cleaned by backwashing using a combination of air and water scour. To avoid rapid build-up of headloss and reduction of run time, filtration is most effective if the particle concentration (as TSS) is lower than 20 mg/L. Filtration can be used downstream of primary sedimentation (primary effluent filtration), or downstream of secondary sedimentation (tertiary filtration).

As pathogenic organisms are associated with particles, filtration is an effective process for reducing pathogen concentration in wastewater streams, and provides an excellent pre-treatment for disinfection. Filtration is stipulated as a required treatment process in many applications, because its favorable effect on aesthetics, particle removal, and disinfection effectiveness. If water is to be treated by activated carbon, ion exchange, or reverse osmosis, filtration is used to reduce solids loading on these processes and improve their overall effectiveness.

Adsorption. Activated carbon adsorption is effective in removing hydrophobic organic compounds from surface and groundwater sources. Compounds with low water solubilities, such as organic solvents and chlorinated organic solvents, are adsorbable because of their low water solubility. Water soluble compounds and larger compounds are better removed by oxidation or ultrafiltration. In most cases testing is necessary (isotherm evaluation, dynamic adsorption testing) to determine the applicability of activated carbon treatment to a water of specific quality.

Membrane Processes. Among advanced treatment processes, membrane applications have clearly emerged as one of the promising alternatives to conventional advanced physical-chemical treatment, which usually includes chemical coagulation, flocculation, and granular-medium filtration. Membrane processes, ranging from microfiltration to reverse osmosis, are finding their way to cost-comparable applications for removal of microorganisms in membrane bioreactors, and for removal of trace organic substances, specific ions, and dissolved solids.

Membrane processes include microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and electrodialysis. Microfiltration is effective for removal of particles, and can be competitive with conventional granular medium filtration. Ultrafiltration is effective for removal of particles and macromolecules. Nanofiltration and reverse osmosis are effective for removal of dissolved ions from liquids. While membranes have multiple applications, the useful life of a membrane closely depends on avoiding conditions that will cause fouling, scaling, or chemical interactions. Membrane process success is highly dependent on appropriate pretreatment. Pretreatment options include filtration for coarse particle removal, scale control, and chemical addition. Post treatment includes water pH stabilization to prevent corrosion, and air stripping.

Table 1. Unit operations and processes used in wastewater reclamation (Adapted from Asano, and Levine, 1998).

Process	Description	Application
Solid/liquid separation		
Coagulation	Addition of chemicals to destabilize colloids and suspended matter	Promote particle destabilization to improve flocculation and solids removal
Flocculation	Particle aggregation	Particle agglomeration upstream of liquid/solid separation operations
Filtration	Particle removal by granular medium	Removal of particles larger than about 3 μm
Sedimentation	Gravity settling of particulate matter, chemical floc, and precipitates	Liquid/solids separation
Biological treatment		
Aerobic biological treatment	Biological metabolism of wastewater and solids by microorganisms in an aeration basin	Incorporation and removal of organic matter from wastewater by synthesis into microbial cells and CO_2 and H_2O
Oxidation Pond	Ponds with 2 to 3 feet of water depth for mixing and sunlight penetration and oxidation and synthesis by algae	Reduction of suspended solids, BOD, fecal bacteria and ammonia
Disinfection	The inactivation or removal of pathogenic organisms using oxidizing chemicals, ultraviolet light, caustic chemicals, heat, or physical separation processes	Protection of public health
Advanced treatment		
Activated Carbon	Process by which contaminants are physically adsorbed onto the carbon surface	Removal of hydrophobic organic compounds
Air Stripping	Wastewater is distributed over a packing through which forced air is drawn to extract ammonia and volatile organics from the water droplets	Removal of ammonia nitrogen and some volatile organics
Ion Exchange	Exchange of ions between an exchange resin and water using a flow through reactor	Softening and removal of selected ionic contaminants; Effective for removal of cations such as calcium, magnesium, iron and anions such as nitrate
Lime treatment	The use of lime to precipitate in high pH various cations and metals from water and wastewater	Used to stabilize lime-treated water, to reduce its scale forming potential

Membrane processes and reverse osmosis	Pressure driven membrane processes to separate impurities, colloids, ions from water, based on size exclusion or molecular diffusion	Removal of impurities, bacteria and viruses, dissolved salts from water and wastewater

Disinfection. Disinfection is an essential component of many wastewater reclamation and reuse treatment systems. The objective of disinfection processes is to inactivate/destroy pathogenic organisms. Disinfection is typically used as one of the final treatment processes in a treatment system. Chemical disinfection practices are based on addition of a strong oxidizing chemical such as chlorine, ozone, hydrogen peroxide, or bromine. Ultraviolet radiation is an alternative to oxidation process that can achieve disinfection. Other methods for decreasing the microbial content of reclaimed wastewater include exposing pathogenic organisms to high pH environments as in lime treatment. Alternatively, organisms can be effectively removed by physical methods, such as membrane filtration systems.

The most common type of disinfection system is chlorine at dosages ranging from 5 to 15 mg/L, with a recommended contact time of 30 minutes to 2 hours. For wastewater reuse, it is important to remove residual chlorine to prevent complications in downstream beneficial uses. Dechlorination is often used as a final step, and is accomplished using sulfur dioxide or other reducing agents. Activated carbon adsorption is also effective for removal of residual chlorine.

Ultraviolet disinfection has been demonstrated to provide a viable alternative to chemical disinfection processes, at doses ranging from 100 to 120 mWs/cm^2, and higher. The performance of UV disinfection is influenced by water turbidity and UV lamp intensity, which in turn can be reduced by lamp age and the fouling characteristics of the wastewater. Upstream filtration is usually essential to prevent particle shielding of pathogenic microorganisms and thus reducing the effectiveness of UV disinfection.

CATEGORIES OF WASTEWATER REUSE

In the planning and implementing a wastewater reuse project, the intended wastewater reuse applications govern the degree of wastewater treatment required and the reliability of wastewater treatment processing and operation. In principle, wastewater or any marginal quality waters can be used for any purpose provided that they are treated to meet the water quality requirements for the intended use. Seven categories of reuse of municipal wastewater are identified in Table 2, along with the potential constraints. Large quantities of reclaimed municipal wastewater can be used in four reuse categories: agricultural irrigation, landscape irrigation, industrial recycling and reuse, and groundwater recharge.

In California, where the largest number of wastewater reclamation and reuse facilities has been developed in the United States, at least 330 million m^3 of municipal wastewater are currently reused. This figure corresponds to around 8 percent of municipal wastewater generated in the State (State of California, 1990). According to the only available national survey on wastewater reclamation and reuse projects, 536 wastewater reuse projects were in existence in the United States in 1975. The estimated total volume of wastewater reuse was 2.6×10^{12} m^3/d (Metcalf & Eddy, 1991). A considerably greater quantity of reclaimed water has been in use nationwide since 1975, but, unfortunately, there is no national summary of such data.

Agricultural and landscape irrigation is the largest current and projected use of reclaimed wastewater in the United States. Irrigation uses can offer significant opportunity for wastewater reuse since, in many arid and semi-arid regions of the world, approximately 70 to 80 percent of applied water is used for irrigation. Much of the attention focused on reclaimed water over the last two decades has been for its use in the urban environment, such as for landscape irrigation, and its potential for groundwater recharge. Nonetheless, the historical application for agricultural purposes continues to dominate worldwide; for example, wastewater reuse for agricultural irrigation amounted to 63 percent of the total reclaimed water used in California in 1987. At least 20 different food crops were irrigated with reclaimed water, as well as at least 11 other crops and nursery products in California.

Table 2. Categories of municipal wastewater reuse and potential constraints*

Wastewater reuse categories	Potential constraints
Agricultural irrigation:	
crop irrigation commercial nurseries	Effect of water quality, particularly, salts on soils and crops
Landscape irrigation: park school yard freeway median golf course cemetery greenbelt residential	Public health concerns related to pathogens (bacteria, viruses, and parasites) Surface and groundwater pollution if not properly managed Marketability of crops and public acceptance
Industrial reuse:	
cooling boiler feed process water heavy construction	Reclaimed wastewater constituents related to scaling, corrosion, biological growth, and fouling Public health concerns, particularly aerosol transmission of organics and pathogens in cooling water and pathogens in various process waters
Groundwater recharge:	
groundwater replenishment salt water intrusion subsidence control	Trace organics in reclaimed wastewater and their toxicological effects Total dissolved solids, metals, and pathogens in reclaimed wastewater
Recreational and environmental uses:	
lakes and ponds marsh enhancement streamflow augmentation fisheries snowmaking	Health concerns of bacteria and viruses Eutrophication due to nutrients Esthetics including odor
Nonpotable urban uses:	
fire protection air conditioning toilet flushing	Public health concerns about pathogen transmission by aerosols

	Effects of water quality on scaling, corrosion, biological growth, and fouling
	Potential cross-connections with potable water systems
Potable reuse (repurified water) blending in water supply pipe to pipe water supply	Trace organics in reclaimed wastewater and their long-term toxicological effects
	Esthetics and public acceptance
	Public health concerns on pathogen transmission including viruses

*Arranged in descending order of volume of use.

The largest industrial application of reclaimed water in California was for paper manufacturing. Other significant industrial uses were power plant cooling, watering of log decks, and cooling water in a steel manufacturing plant (State of California, 1990).

WASTEWATER REUSE IN DEVELOPING COUNTRIES

Reclaimed wastewater regulations for conserving water resources and protecting health in developing countries are often established in relation to the limited resources available for public works, piped water supply, sewers, and water and wastewater treatment. Confined wastewater collection systems and wastewater treatment facilities are often nonexistent, and wastewater often provides an essential irrigation water and fertilizer source. The greatest concern with the use of wastewater for irrigation is that untreated or inadequately treated wastewater contains numerous enteric helminthes such as hookworm, ascaris, trichuris, and, under certain circumstances, the beef tapeworm. These infectious agents as well as other pathogens can damage the health of field workers, and the general public consuming the contaminated crops.

The *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture* published by the World Health Organization in 1989 have been accepted as reasonable goals for protecting public health in agriculture in developing countries. In several Middle Eastern countries that have recently developed facilities for wastewater reuse, the tendency has been to adopt more stringent wastewater treatment and reuse regulations, similar to the State of California regulations. Adoption of more stringent regulations was chosen to promote public acceptance and to protect an already high standard of public health by preventing, at any expense, the introduction of pathogens into the human food chain. In less affluent countries, a critical evaluation on wastewater reclamation and reuse should be carried out in relation to other health delivery systems such as domestic water supply, food sanitation, and hospital care – a difficult decision.

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CASE STUDIES OF DOMESTIC AND INDUSTRIAL WATER REUSE FOR NON-POTABLE APPLICATIONS

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ABSTRACT

The lack of an adequate water supply and the cost of water are the two most significant driving forces in the implementation of a water reuse program. Four case studies addressing various options for implementation of successful water reuse programs are presented in this paper. The SUTRANE Integrated Wastewater Treatment System for reuse of water, nutrients and energy represents a low cost option for treatment and reuse of wastewater from domestic and industrial sources. The Monterrey, Mexico water reuse program represents an example of a very large water management program where virtually all of the wastewater from the city is treated and reused either directly for non-potable industrial reuse or indirectly for potable water reuse throughout the city. The Oneida Industrial Park project represents a full scale demonstration of a total water reuse program for an industrial park which does not have access to water distribution and wastewater collection systems. The fourth case study is the presentation of a conceptual model which addresses water reuse issues within industrial park complexes.

KEYWORDS

Industrial water reuse; industrial wastewater reuse; water management planning; water reuse; water reclamation; SUTRANE treatment system; wastewater treatment.

INTRODUCTION

In locations where the quantity of water is limited or an adequate water supply is not available, treated wastewater becomes a viable option for non-potable reuse applications. The wastewater source may be of domestic or industrial origin with rainwater representing a significant source to supplement the volume required. An important consideration is the consistency of the quantity and quality of the wastewater source stream. The quality of the product being reused must also be well defined as inadequate treatment may limit the acceptability for the end user while over treatment could substantially increase the cost per unit of production.

The technology for the treatment of the wastewater to appropriate reuse standards is well defined. Optimization of system design and operation for the more conventional technologies has resulted in improved process performance and a reduction in the total cost of production of a unit volume of water. A wide range of technologies is being applied with further refinements and modifications being made to continually improve the quality and reduce the costs. As a result, the factor limiting the use of wastewater in water reuse applications is not the acceptability of the treatment technology, but is primarily related to the acceptability of the product water and more importantly the cost of producing the water for reuse.

In this presentation, four case studies involving the use of wastewater for non-potable water reuse will be described. They are as follows:

- The SUTRANE Integrated Wastewater Treatment System, a low cost option for treatment of wastewater from domestic and industrial sources.
- A description of the extensive water reuse program for Monterrey, Mexico, a city with a heavy industrial base and totally inadequate raw water supply.

- Oneida Industrial Park, an industrial park being established with total water reuse within the industrial complex, because water distribution and wastewater collection systems are not available.
- The presentation of a conceptual model for water reuse within industrial park complexes with emphasis on recovery of product losses, treating of residual wastewater flows, and on-site reuse of the treated effluent.

CASE STUDY NUMBER 1: THE SUTRANE SYSTEM

Process Description

The SUTRANE system incorporates a low cost version of a constructed wetland which functions best in warm climates and is ideally suited for developing countries. The technology was developed using a total system approach which provides reuse of water, nutrients and energy for industrial and municipal applications. The SUTRANE Integrated Wastewater Treatment System was developed by Professor Jesús Arias Chavez of the University of Chapingo in Texcoco, the State of Mexico. The technology has been further developed and marketed by the Xochicalli Eco-Development Foundation, A.C., Mexico D.F.

The English translation for SUTRANE is the Unit Treatment System for the Reuse of Water, Nutrients and Energy at the domestic level. As illustrated in Figure 1, the system provides primary and secondary treatment. The primary system includes an anaerobic digester for the treatment of black water and a two-stage reactor for the treatment of grey water, a pre-oxygenator (a box filled with stone and gravel) followed by a grease trap. Both primary effluents flow into a channel with aquatic plants. These effluents sub-irrigate a secondary filtration field constructed of stone, gravel and sand, with the entire bed placed on an impermeable film. Selected plants are grown on the filtration bed. A multi-purpose greenhouse can be used to provide optimal growth for the plants in both stages of secondary treatment.

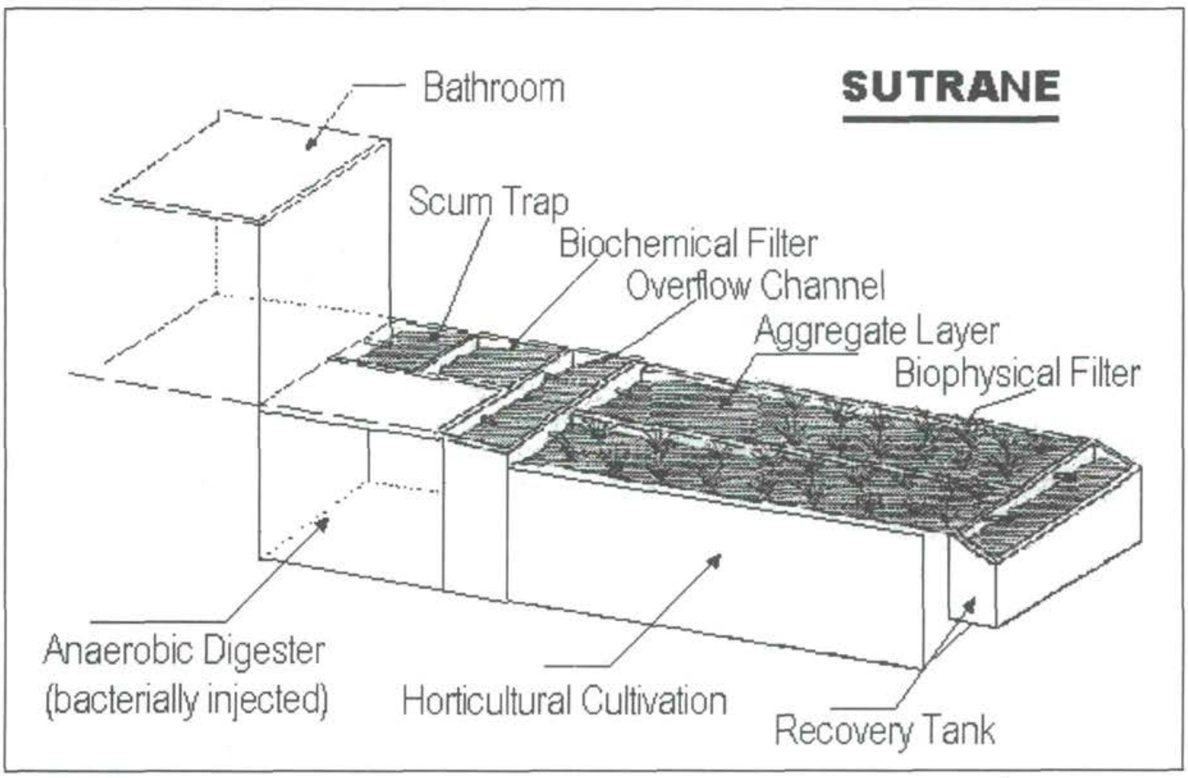

Figure 1 - Schematic of SUTRANE System

For larger systems, the SUTRANE system concepts have been incorporated into a design referred to as the Dual Microplant system. The components of this system are presented in Figure 2. Blackwater combined with the biodegradable organic fraction of solid wastes is treated in a three-stage anaerobic reactor followed by solid/liquid separation and effluent polishing. The selection of the effluent polishing tertiary treatment technology is based on the water quality reuse requirements.

The anaerobic digesters decompose complex organic material, thereby generating methane gas and liberating essential nutrients for plant growth in the secondary treatment system. The methane gas is used as a fuel source for cooking or heating.

Pre-treatment, including the pre-oxygenator, provides film flow on the surface of the rock media, absorbing oxygen necessary to counteract the harmful effect of the detergents. This effluent flows to the grease trap where the oil and grease floats to the surface; the grease is reused for soap production or placed in the anaerobic digesters to enhance digester loading and performance.

The plants in the secondary process consume the available nutrients and, with the assistance of the soil micro-organisms in the filtration bed, provide a relatively high degree of treatment.

Status of application of the technology

The SUTRANE technology for the treatment of wastewater was reviewed by a Canada-Mexico team (Jank, 1995). The technology has application in treating both municipal and industrial wastewater under conditions where decentralized applications are required. Compared to other technologies with similar applications, the SUTRANE system offers numerous advantages. The process includes simple primary and secondary treatment components. Its modular design allows the system to be tailored to a variety of operating environments. The SUTRANE technology is best applied in warm climates and is ideal for developing countries. Capital and operating costs are very low in comparison to other systems.

The initial system was developed and installed in early 1970 in Mexico. There is a limited amount of performance data available, mainly due to the simplicity and size of the process. Design data for the larger Dual Microplant systems should be developed with the assistance of Professor Jesús Arias Chavez. For systems of ten dwellings or less, design could be based on technical descriptions provided by individuals that have participated in the construction and operation of systems of such size.

An entire SUTRANE system and Dual Microplant systems can be constructed using local material and labour. An organization similar to the Xochicalli Eco-Development Foundation, A.C., could be established to market, design and construct the technology, or a local firm could provide the same services on a fee for service basis. In all cases, an agreement should be reached with Xochicalli Eco-Development Foundation, A.C., with respect to the utilization/marketing of technology.

Emphasis has been placed on marketing the technology within Mexico, while research, development, and full-scale performance assessment have not been a high priority. Since the systems are very effective in warm weather conditions, and resources are not available for research and development, efforts have been focused on the commercialization of the technology. This has been highly successful, as the developers estimate that there are now thousands of systems operating in Mexico and other countries in Central and South America and the Caribbean. While the majority of these systems are for single dwellings, a number of larger systems provide treatment for industries, institutional facilities, and residential subdivisions. The two largest systems are Dual Microplants, located at the Iberoamericana University in Puebla, and at the University of Chapingo in Texcoco. The former serves a population of approximately 2 000, and the latter a population of approximately 8 000.

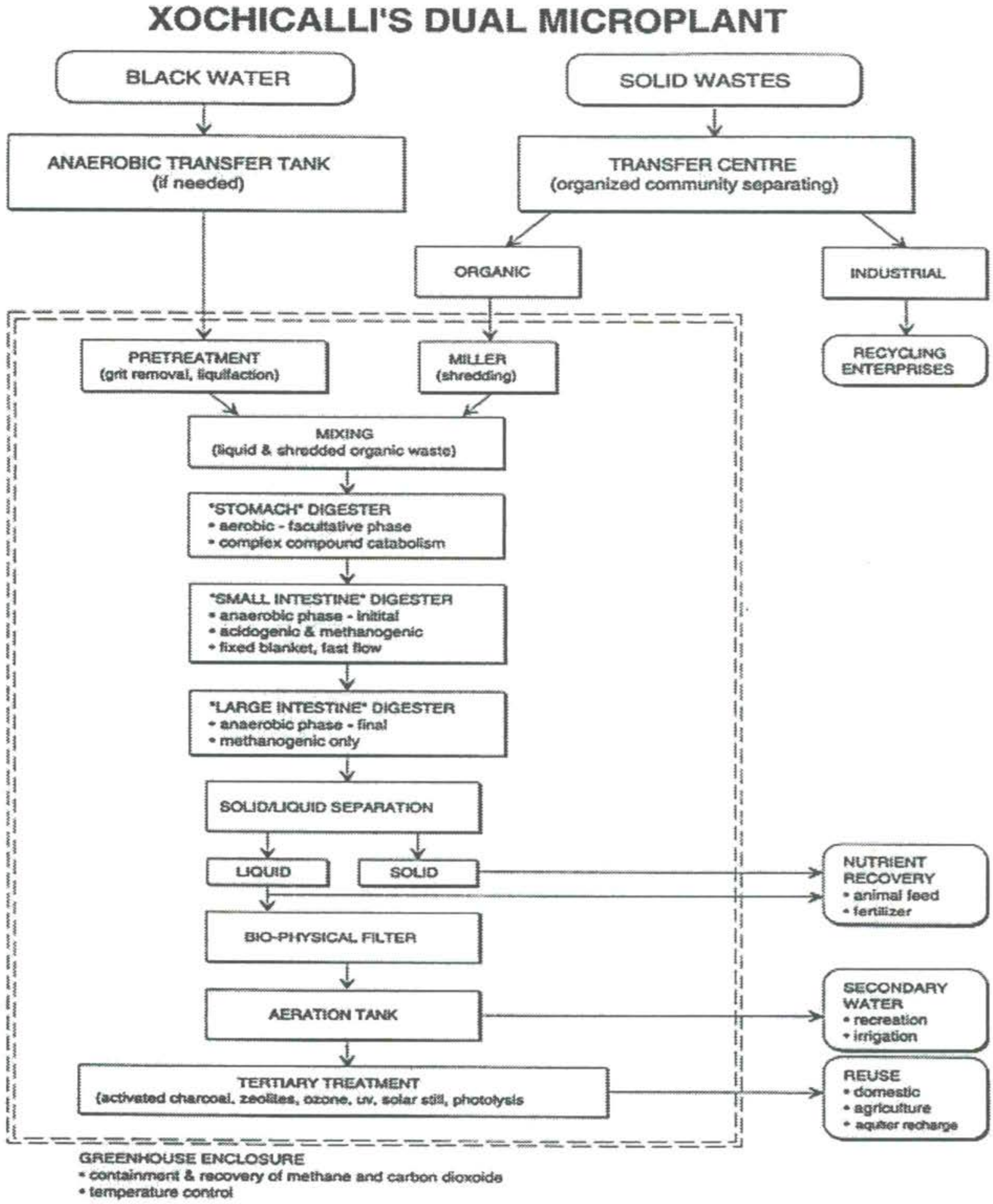

Figure 2. Schematic of Dual Microplant System

Assessment of SUTRANE performance

The effluent quality for the three litres/second Dual Microplant system treating the wastewater from approximately 2 000 inhabitants at the Universidad Iberoamericana in Puebla is given in Table 1. This data is representative of the performance of the SUTRANE systems.

A limited amount of heavy metals and bacteriological data is available. The results indicate that the quality is relatively comparable to an effluent from a conventional secondary activated sludge process. The limited data makes it difficult to conduct a statistically valid comparison with other technologies. However, the effluent quality appears to be much better than what is generally obtained from low cost technologies.

Table 1. **Performance - SUTRANE system**

Parameter	Influent (mg/l)	Effluent (mg/l)
BOD_5	260	20
Oil and grease	430	1
Organic N	84	0.5
TSS	223	48

Source: Jank, 1995.

Operation of the SUTRANE system

The operational requirements for the SUTRANE system are clearly less than 25% of those for a conventional mechanical system, and maybe under 10%. For the larger Dual Microplant systems serving 8 000 inhabitants, the operator would spend two hours per shift. This time would be spent on cleaning and housekeeping responsibilities in addition to operational functions. The aquatic plants are harvested and shredded in a mechanical device developed, manufactured and marketed by the Xochicalli Eco-Development Foundation. The plants are fed to the first stage of the three-stage anaerobic reactor in order to increase methane gas production, a valuable energy by-product of the treatment system.

The SUTRANE system operates best in warm climate situations. The complete SUTRANE system could only be utilized in colder climates if the primary grey water treatment unit and the secondary treatment units were enclosed in a greenhouse. Energy requirements would likely invalidate this approach. However, if methane generation from the anaerobic reactor was optimized, the energy costs may be substantially reduced.

The anaerobic digester concept and design is directly applicable in rural areas and could be considered as a replacement for a septic tank or similar pre-treatment system. Operating the digester at loadings which ensure methane gas production (and gas utilization) is essential for optimal process efficiency and reduced operating costs.

Economic assessment of SUTRANE technology

The SUTRANE technology is definitely lower in capital and operating cost than competing technologies generating a similar quality effluent. SUTRANE systems have been designed so that the individual homeowners, multiple dwelling owners, or communities, can construct the plants using their own labour. The capital cost of construction is the cost of building materials, and every effort has been made to reduce this cost through optimal process design. Capital costs estimates of $0.06-0.12/m^3* have been provided by Prof. Arias Chavez for communities of 10 000 inhabitants. Data from CNA, the Comisión Nacional del Agua, would indicate that comparable costs for conventional technologies providing a similar effluent quality would range from $0.30 to 0.60/m^3* or five times the cost of SUTRANE systems. SUTRANE operational costs are a small fraction of the cost of the conventional mechanical systems.

Xochicalli Eco-Development Foundation has expended considerable effort on cost reduction initiatives. Reactor design is based on the efficient use of reused waste products.

As with the performance data, there is a limited amount of cost data available. Since cost is specific to the individual sites, it is difficult to make cost comparisons using similar population numbers for different sites. However, there is no question that trends presented and cost estimates indicate that these technologies will cost significantly less than a competitive technology providing a similar effluent quality.

A comparison of SUTRANE and competing technologies

Environment Canada's Wastewater Technology Centre completed a critical assessment of appropriate technologies for wastewater treatment and disposal for rural communities. The study evaluated both on-site and off-site wastewater treatment technologies. All appropriate technologies were considered and evaluated against the following criteria: principles of operation, status of the technology, suitability to local conditions and maintenance requirements, capital and installation costs, effluent quality from full scale plants, and utilization of local resources for construction and operation. The study (Wastewater Technology Centre and Davis Engineering & Associates, 1995a and 1995b) was carried out for the Province of Newfoundland and Environment Canada.

The SUTRANE system was one of the technologies evaluated. It was not selected as an appropriate wastewater treatment system for the Province of Newfoundland only because it would be adversely affected by the low ambient air temperatures encountered during the Canadian winters.

Socio-cultural impact of technology implementation

The Xochicalli Eco-Development Foundation is an Organization which promotes a holistic approach involving environmentally sustainable economic development and the conservation of natural resources. The Foundation understands these ecological principles, and is able to provide integrated solutions to environmental issues related to air, water, solid waste, environmental hygiene and environmental health.

Another unique attribute of Xochicalli Eco-Development Foundation is its marketing philosophy. Each participant in the Foundation's program agrees to transfer his new knowledge to at least four new participants. This concept allows for effective dissemination of the Foundation's ecological principles. The promotion and the implementation of the principles of ecological sustainability have created a powerful marketing approach. This has resulted in the widespread acceptance of the treatment systems, in both rural and urban communities.

The Xochicalli Eco-Development Foundation has developed an integrated ecological approach to the management of environmental issues. The approach has resulted in the installation of thousands of SUTRANE systems in Mexico, Central and South America, and the Caribbean, providing a high quality effluent at reduced capital and operating costs. Because of its simplicity and reduced cost, it should be identified as an appropriate technology for developing countries.

CASE STUDY NUMBER 2: WATER REUSE IN MONTERREY, MEXICO

The capital of the state of Nuevo León, Monterrey, is situated in the north east corner of Mexico approximately 240 kilometres from the Texas border. It has a population in excess of 3.5 million and is Mexico's third largest city, and second most important industrial centre. Iron and steel, glass production, textiles and petrochemicals are the principal manufacturing activities.

Ground and surface water sources in this area of Mexico are in short supply. The water demand is significantly increased by the requirements of the heavy industrial manufacturing plants. To compensate for this water supply shortage, the industries have either on their own or as a consortium of companies, constructed wastewater treatment plants which provide treated effluent for industrial process water.

Wastewater is purchased from the city, pumped from the sewer, into a treatment plant, and the treated water distributed to the industries. For individual industrial owners the treated water is reused on the plant property. Where there is a consortium, the treated water is distributed through a water distribution system to the industrial plants with as many as 12 industrial sites connected to one distribution network.

The first industrial water reuse plant was constructed in the 1950's. This wastewater treatment plant was a conventional activated sludge plant with primary clarification and secondary effluent chlorination. The treated effluent is stored in a storage pond on the industrial property and distributed to the various manufacturing processes on the site. Although the plant has undergone significant upgrades the components of the original plant are still in use.

The majority of the water reuse plants have utilized the conventional activated sludge process for the combined domestic/industrial wastewater treatment. The untreated wastewater is pumped from the sewer and the primary and secondary sludges combined and discharged directly back to the sewer. Direct discharge of the sludges to the sewer represented a significant capital and operating cost saving for the industrial water reuse plants.

In the last 5 years, the Monterrey water and wastewater authority (Servisios de Agua y Drenaje de Monterrey–SADM) has constructed three relatively large wastewater treatment plants, Norte, Noreste and Dolces Nombres, with approximate flows of 0.5, 2.5 and 4 m^3/sec, respectively. The treated effluents from these plants are discharged into streams which flow into a water supply reservoir, with stored water pumped back to the city for treatment and distribution to domestic and industrial users. As a result, virtually all of the wastewater from the city is treated and reused either directly for non-potable industrial reuse or indirectly for potable water reuse throughout the city.

Following the construction of the three city owned plants, SADM has requested that the industrial water reuse plants should stop discharging their sludges to the sewer. The capital and operating costs for sludge treatment, handling and disposal facilities at the industrial water reuse treatment plants will represent a substantial increase in the cost of water presently marketed to the network of industrial plants. The three SADM owned plants have state-of-the-art sludge treatment, handling and disposal facilities.

SADM should charge the industrial plants an appropriate fee to discharge the sludge to the sewer rather than insisting that separate sludge processing facilities be constructed. It is my opinion that a life cycle cost analyses would verify that the least cost option for everyone would be the discharge of sludge to the sewer, with sludge treatment at the three SADM owned plants.

In addition to the increased cost for sludge treatment, SADM has increased the cost to purchase the wastewater from the city. The cost will be increased incrementally, and within two years the cost of untreated wastewater for some of the plants will be so high that the plants will have to cease operation. As a result, components of this very efficient water reuse system involving 16 wastewater treatment plants, may have to be shut down. If it has not already done so, SADM should definitely reassess its pricing policy, to ensure that all plants can continue to operate providing an acceptable product at a competitive cost.

There are two additional issues which could be addressed to further enhance the city of Monterrey's very efficient water management system. They involve upgrading effluent quality and beneficial reuse of biosolids.

The quality of water produced by the various industrial consortia treating wastewater for industrial reuse could be improved by the optimization of treatment process operations and by the provision of post treatment of the effluent. The latter would include the introduction of technologies such as membrane systems for effluent filtration; ozonation for colour removal, trace organics removal and disinfection; and granular activated carbon systems for removal of residual trace organics. Demonstration projects are required to verify the acceptability and cost effectiveness of these options.

The issue of sludge management for the city could be addressed by implementing a biosolids management program. A Canadian International Development Agency (CIDA) funded project recommended that an extensive developmental demonstration program be implemented to verify that the biosolids generated from the 3 large SADM owned treatment plants could be effectively integrated into an agricultural beneficial reuse program. The proposed 5 year program would have established land application guidelines for agricultural crops in the vicinity of Monterrey. These developmental demonstration programs involving local participants are extremely important educational training initiatives.

CASE STUDY NUMBER 3: WATER REUSE AT ONEIDA INDUSTRIAL PARK

Six Nations Council at Ohsweken, Ontario, Canada has purchased a 50 hectare property to be used as an industrial business park. The property has been sub-divided providing sites for 15 industrial manufacturing plants. Although there is not a shortage of ground or surface water in the area, the property is not serviced, i.e., water distribution and sewage collection are not available.

The Six Nations Council has established an environmental services company, NovaSix Water Treatment Inc., to provide cost effective environmentally acceptable technologies for their reserve. The decision was made by this group to provide a self contained water management system which could be marketed to the aboriginals of Canada and United States. The beta test site was to provide a total water supply system from rainwater storage ponds. Although it is not considered to be required, a drilled well has been added to provide the potable water supply which represents approximately 5% of the total water supply requirements of the industrial park complex.

The layout for a portion of the industrial park is presented as Figure 3. Rainwater will be collected in storage pond # 2 and pumped at $25m^3/d$ into a $114m^3$ storage tank. To remove suspended solids and trace levels of organics, and oil and grease, a granular media filtration unit and an adsorption column using a modified clay formulation supplied by novaaqua is being installed. The contents of the $114m^3$ tank will be ozonated using novaaqua's ozonator and hypersonic venturi injection system. A contactor will be provided to provide a 90 second retention time for the ozonation reactions to go to completion. The ozonated water from the $114m^3$ storage tank will be pumped through a granular activated carbon column and distributed under pressure to the industrial manufacturing plants. This utility water supply system provides a low mineral content water for all of the applications except potable water.

A separate water supply has been provided for the drinking water fountains and cold water faucets at all of the sinks in the buildings. A well has been drilled on the property with pumping tests confirming a capacity of $400m^3/d$. The drilled well water has a hardness in the range of 1100 to 1300 mg/l as $CaCO_3$ and 700 to 800 mg/l of sulphate. It must be treated to remove the sulphates, as it is presently non drinkable. An ion exchange column provided by novaaqua will be used to remove the sulphate. This will be followed by a second ion exchange column, an ozonation unit and a granular activated carbon column.

This is a package unit provided by novaaqua at a rated capacity of $3m^3/d$. The ozonated water will be stored in a small holding tank prior to distribution to the various buildings. A chlorination system has been specified

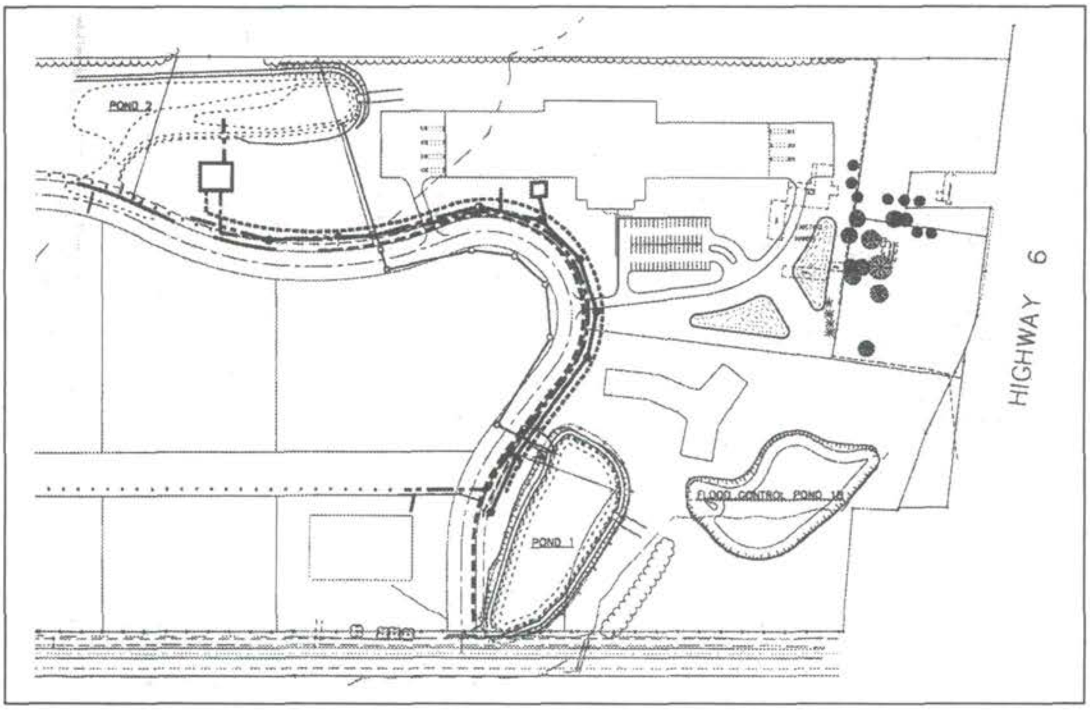

Figure 3 Layout Phase 1 Oneida Industrial Park

and the space required for installation included in the piping. However, the system will not be purchased as NovaSix is confident that it will not be required. Because of the high hardness, it is recommended that the well water be blended with the water from the storage pond. Once the system is in operation the blending option can be evaluated. It is anticipated that with the blending option in place, less than 10% of the potable water would come from the drilled well, and thus, the well water would account for less than 1% of the total water consumption at the industrial park.

The wastewater treatment system has been designed to provide an effluent which exceeds normal dry ditch discharge standards. The limits are as follows: BOD_5 and TSS as non detect, total phosphorous 0.1 mg/l, ammonia less than 1mg/l and the bacterial count zero. The effluent will be stored in storage pond # 1 which will be used as the source of water for fire protection. The pumps used for fire protection will be used to pump water from storage pond #1 to pond # 2 in the event that there is a shortage of water in the rainwater storage pond.

The wastewater from each building at the industrial park will be discharged to a septic tank. The effluent from the septic tanks flows by gravity to a wastewater holding tank. The settled sewage is pumped at a flow rate of 2 m^3/h through a physical/chemical treatment unit which uses a modified clay formulation for removal of suspended solids, colloidal material, heavy metals, oil and grease and trace organics. The effluent is filtered and discharged into a second holding tank. The contents of the second tank are ozonated and filtered through a series of effluent polishing columns including clinoptilolite for ammonia removal, and granular activated carbon for final effluent polishing. Other units are used on an as required basis. A flow diagram for the novaaqua wastewater treatment system is presented as Figure 4. The contents of the reactor are monitored and when the effluent has achieved the targeted limit, it is discharged to the fire protection storage reservoir, storage pond #1 on Figure 3.

The wastewater treatment system, having a design capacity of 50 m^3/d will initially be operated at an average flow rate of 25 m^3/d. The water and wastewater treatment plants were provided to NovaSix Water Treatment Inc. by novaaqua, Toronto , Canada. The Oneida Industrial Park Water reuse system will be operated as a developmental demonstration facility, and further refinements of the technology will be incorporated into the operating system as they become available.

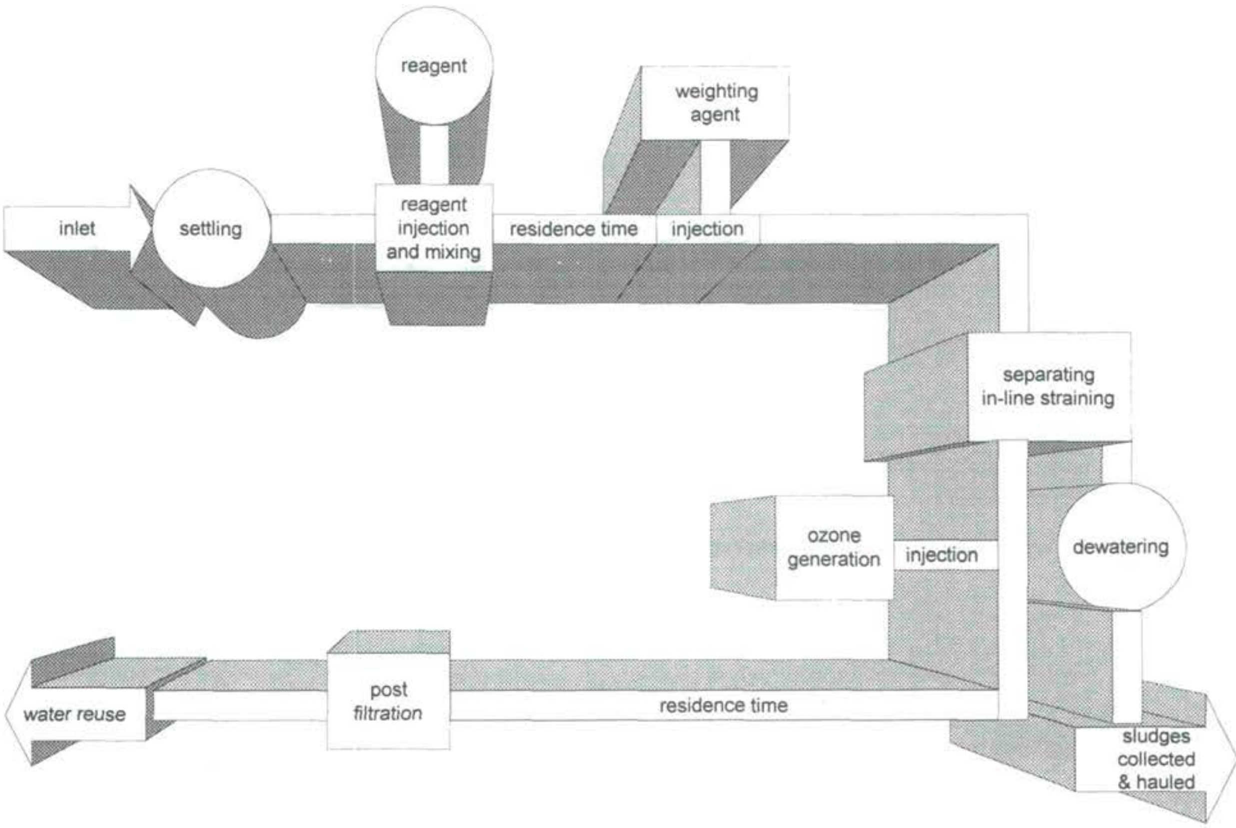

Figure 4 Flow Diagram novaaqua Wastewater Treatment System

CASE STUDY NUMBER 4 : WATER REUSE WITHIN EXISTING INDUSTRIAL PARKS

The potential for water reuse within existing industrial park complexes represents an important component of the overall environmental management strategy. The reuse of water within specific manufacturing facilities should be a primary objective, while reuse of water from other plants or a centralized wastewater treatment plant is of secondary importance. The water reuse program is an integral component of an overall management strategy which provides the least cost per unit of manufactured product.

In most manufacturing plants, the pollutant discharged in the wastewater represents product loss. Recovery or elimination of product loss must be given the highest priority in the management strategy. In most cases, eliminating product loss will have a direct impact on wastewater quality which should enhance the potential for water reuse within the system. The potential for at source treatment and reuse should also be assessed for all streams.

When recovery and reuse options have been exhausted and the remaining waste stream discharged to a centralized treatment plant, the potential for energy recovery and reuse must be assessed again. The characterization of the combined waste streams and the selection of the treatment process should be based on a selection procedure which will include the assessment of the reuse options.

A feasibility study was undertaken for one of the large industrial parks in Mexico. The centralized external treatment plant was substantially overloaded and a request was made for a plant expansion to alleviate the problem. Following an assessment of existing conditions, the owners of the industrial park were informed that a source control program would eliminate the overloading problem.

The proposed approach involved characterization of all significant streams at every manufacturing plant in the industrial park. Although the main economic benefits were gained through recovery of product loss, the water management strategy was of the second highest priority. All aspects of water reuse within the plants were considered in order to reduce the loading on the centralized treatment plant. For some of the industrial plants, treatment plants were installed at the source to provide a supply of water which could be reused within the plant production units.

Although this approach to water reuse may not be considered as significant as the Monterrey, Mexico, city wide industrial reuse program, when all industrial sectors are considered, the impact on water reuse is very significant. For the Oneida Industrial Park demonstration project, an industry with a high water usage and the potential for reuse will be selected as proof of the concepts presented in this case study.

SUMMARY

The four case studies on water reuse for non-potable applications all have a very significant industrial component. Industrial process water requirements can be satisfied either by internal reuse of selected streams, partial or complete treatment and reuse at the industrial plant, or within an industrial park, treating at a centralized wastewater treatment plant to standards acceptable for reuse by the industries within the park. For industries located within a city, such as Monterrey, Mexico, the treatment of the municipal sewage to specific water quality standards for distribution and reuse at industrial plants represents an environmentally acceptable cost effective solution to water management.

The paper has not focused on agricultural reuse even though, most of the treated water from the SUTRANE systems is utilized for irrigation purposes, and a significant percentage of the treated water from the 13 industry owned wastewater treatment plants in Monterrey is used for golf courses and agricultural land.

The case studies confirm that the lack of an adequate water supply and economic factors including the cost of water, are the driving forces for the implementation of water reuse programs.

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Case Studies of Domestic and Industrial Water Reuse for Non-Potable Applications

by Dr. Bruce Jank

Canadian Global Environmental Technologies

presented at: International Symposium on Efficient Water Use in Urban Areas

Innovative Ways of Finding Water for Cities

Kobe, Japan June 8-10, 1999

Sponsored by:

United Nations Environmental Programme

International Environmental Technology Centre

Case Studies

1. SUTRANE Integrated Wastewater Treatment System
2. The Water Reuse Programme - Monterrey Mexico
3. Oneida Industrial Park Water Reuse
4. Conceptual Model for Water Reuse at Industrial Park Complexes

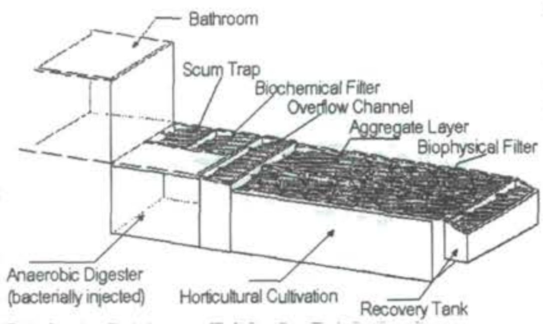
SUTRANE

Dual

Microplant

System

SUTRANE



SUTRANE System Performance

Parameter	Influent (mg/l)	Effluent mg/l
BOD_5	260	20
Oil and grease	430	1
Organic N	84	0.5
TSS	223	48
Source: Jank, 1995		

SUTRANE Systems

Construction mutiple home complex

Iberoamericana University, Puebla

University of Chapingo, Texcoco

SUTRANE System Performance

Parameter	Influent (mg/l)	Effluent mg/l
BOD_5	260	20
Oil and grease	430	1
Organic N	84	0.5
TSS	223	48

Source: Jank, 1995

SUTRANE System Advantages

low cost constructed wetlands

functions best in warm climates

system provides reuse of water, nutrients and energy

provides relatively high degree of treatment

treated effluents readily amenable to upgrade

capital cost is basically cost of materials

solid waste materials converted to materials of construction

operating costs minimal

Socio-cultural Impact of Technology Implementation

Technology promoted by Xochicalli Eco-Development Foundation

Concept promotes principals of ecological sustainability

Marketing philosophy encompasses holistic educational / training approach including environmental hygiene and environmental health

Water Reuse - Monterrey Mexico

Problem Definition

The Solution

- 13 treatment plants purchasing sewage, treating and selling industrial process water
- 3 Monterrey Water and Wastewater Authority Plants (SADM)
  - Norte 0.5 m^3/s
  - Noreste 2.5 m^3/s
  - Dulces Nombres 4.0 m^3/s

Technologies for Water Reuse

Issues to be addressed by SADM

water quality

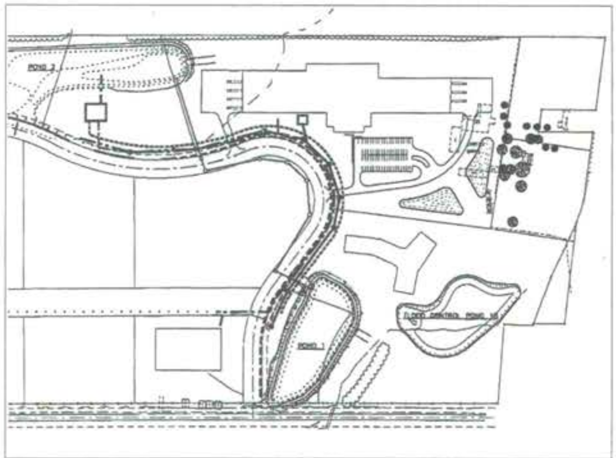
sludge disposal from the 13 water company plants

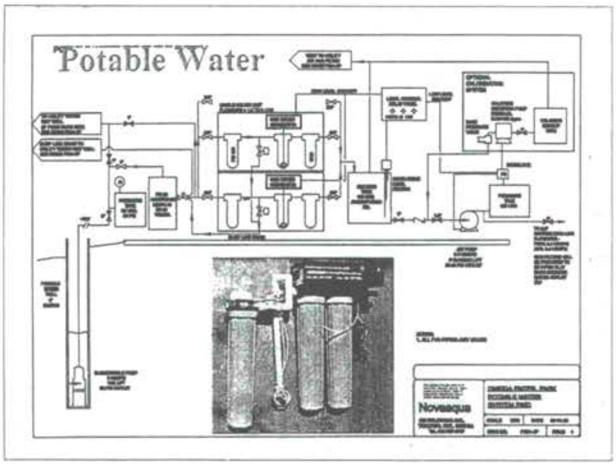
cost of wastewater purchased

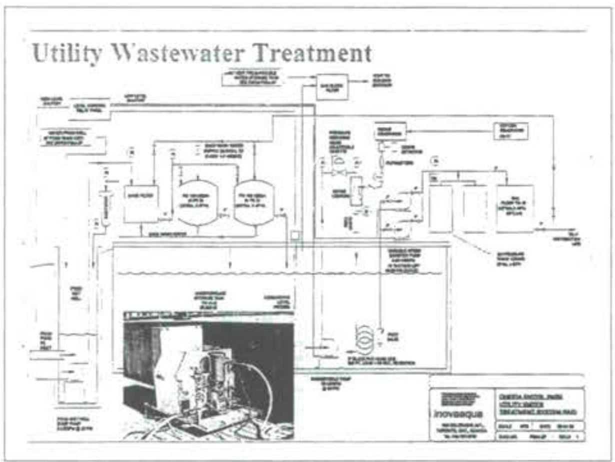
biosolids management

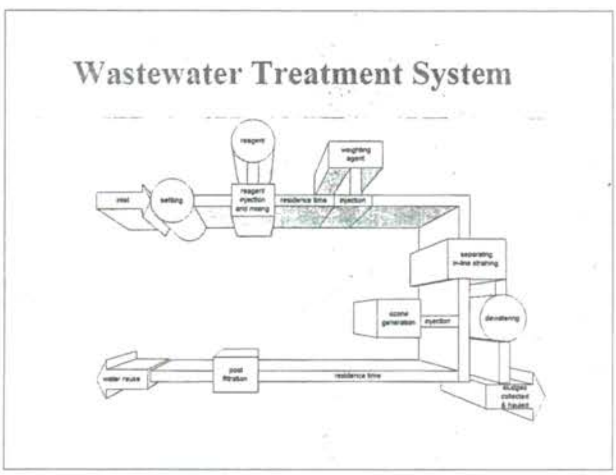
Oneida Industrial Park

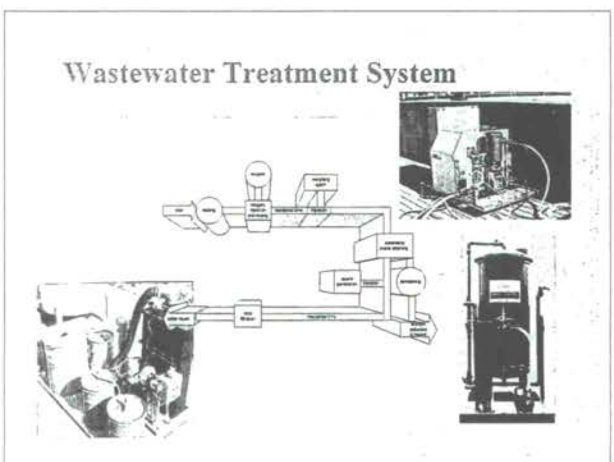

Oneida Business Park -
Water Reuse
potable water
utility water
wastewater
treatment
fire protection




Potable Water


Utility Wastewater Treatment


Wastewater Treatment System
reagent
weighting agent
inlet
settling
reagent injection and mixing
residence time
injection
separating in-line straining
ozone generation
injection
dewatering
water reuse
post filtration
residence time
sludge collected & hauled


Wastewater Treatment System

Case Study No. 4 - Water Reuse for Industrial Park Complexes

- The problem
- The solution
- Economic benefits

Case Study No. 4 - Water Reuse for Industrial Park Complexes

- recover product loss
- internal reuse of selected streams
- onsite partial or complete treatment
- external centralized industrial park wastewater treatment
- municipal sewage → industrial process water

Water Reuse for Non-potable Applications

- industrial reuse
- agricultural reuse
- driving forces for water reuse
  - lack of adequate water supply
  - cost of water

Thank you

Health Protection Measures and Health Safeguards in Water Re-Use for Non-potable Applications

Dr. G. Goldstein
Coordinator, Healthy Cities Programme, Department of Health Promotion, WHO

Introduction

Land applications of wastewater and sewage sludge have been common practices around the world for centuries. Three common practices are:

- use of wastewater for crop irrigation
- use of excreta for soil fertilization and soil structure improvement
- use of wastewater and excreta in aquaculture

Efforts to ensure the safe use of wastewater must consider the protection of the health of workers involved, crop handlers, those living near treated fields, and the public at large. I will focus on the re-use of wastewater and excreta in agriculture and aquaculture. The term wastewater refers to domestic sewage and municipal waste waters that do not contain substantial quantities of industrial effluent; by excreta I refer to nightsoil and to excreta-derived products such as sludge and septage. I shall propose that health protection considerations will generally require that some treatment be applied to these wastes to remove pathogenic organisms. Apart from treatment of waste water and excreta, other control measures considered will include crop restriction, waste application techniques and human exposure control.

Until recently the focus in re-use of waste water has been the prevention of transmission of communicable diseases and the control of microbiological contamination. The health hazards of chemical pollution have been considered comparatively of minor importance. However Chang et al (1995) reported that large-scale irrigation of crops with mostly untreated municipal wastewaters - containing industrial wastewater - could be harmful to crops and cause injuries to humans. Poorly controlled toxic and hazardous waste dumping and discharges into drains is an increasing problem that leads to significant amounts of chemical pollutants in municipal wastewater and sewage sludge, and land application may be restricted because of the potential for food chain transfer of pollutants.

Urbanization fundamentally involves a change in the mode of production, from agriculture to industry, and in our rapidly urbanizing world industrialization proceeds unchecked. In many cities in developing countries, estimates are:

- that 50% of industrial production are small-scale or informal enterprises

- that in many slums and houses in peri-urban settlements, 50% or more of households may have domestic cottage industries, involving chemicals and a risk of toxic discharges or spills.

If we consider a peri-urban settlement with crowding and lack of organized protection of water sources, it seems likely that the greatest toxic chemical hazard to humans is direct contamination of water sources from indiscriminate dumping, and not the food chain transfer of pollutants via the waste – soil – plant - human route. Wastes from improperly managed informal enterprises may directly contaminate groundwater and wells, however the focus of this paper is the health hazards from chemicals that result from re-use of waste water.

Disorders caused by chemical toxicants are harder to identify than water-borne diseases, which have short latency, unique clinical symptoms, readily identifiable exposure route and unambiguous dose-response relationship. The prevalence of diseases of chemical aetiology is not well documented. Some diseases may result from a single chemical compound, eg methyl mercury and Minamata disease. More often chemical agents act as one of the co-factors in a multi-causal relationship , eg the Itai-Itai disease in which Cd toxicity is only one of the causal factors.

Hundreds of chemical toxicants known or suspected to be carcinogenic, mutagenic or teratogenic appear in the priority pollutant lists of the US and the Council of European Communities, and they are ubiquitous in the environment. Because of the long latency period, and because chemicals are common in the environment, the exposure due to a given pathway cannot always be separated from the background exposure.

Given the ambiguous cause-effect relationship and the lack of epidemiological evidence, a dose-response relationship for chemical toxicants must be derived from animal bioassays or other means. There is a major challenge to develop criteria that are not overly restrictive to beneficial use of wastewater and sewerage sludge, and yet protect human health that is vulnerable to hundreds of toxic chemicals that may be present in municipal wastewater and sewerage.

Health Risks from microorganisms in waste water

An actual risk to public health is present only when all the following conditions are met in the re-use of waste water:

either an infective dose of an excreted pathogen reaches a field or pond, or the pathogen multiplies in the field or pond to form an infective dose

the infective does reaches a human host

the host becomes infected

the infection causes disease or further transmission

A review of studies on wastewater irrigation has concluded that:

(a) when **untreated** wastewater is used to irrigate crops there is a high actual health risk from intestinal nematodes and bacteria, but little or no risk from viruses, and (b) treatment of wastewater is highly effective in safeguarding health. In particular:

- crop irrigation with untreated wastewater causes excess intestinal nematode infection in crop consumers and field workers. Field workers, especially those who work barefoot, are at higher risk of hookworm infection than those not working in waste-water irrigated fields

- irrigation with adequately treated wastewater does not lead to excess intestinal nematode infection in field workers or crop consumers

- cholera and probably typhoid can be effectively transmitted by irrigation of vegetable crops with untreated wastewater

- cattle grazing on pasture irrigated with raw wastewater may become infected with beef tapeworm but there is little risk to humans

- some health impacts have been observed on the health of people living near fields irrigated with raw wastewater, due to direct contact with the soil or indirectly by contact with farm workers

- sprinkler irrigation with treated wastewater may promote aerosol transmission of excreted viruses, although in practice transmission is rare

In the aquacultural use of excreta and wastewater, there is evidence of transmission of trematode diseases (Clonorchis, oriental liver fluke, and Fasciolopsis, giant intestinal fluke). Also, schistosomiasis is a potential risk for those who work in excreta-fertilized ponds.

Microbiological Guidelines

The very strict microbial standards developed by the California State Health Department and others some 50 years ago, (2 coliforms per 100 ml for effluent irrigation of vegetables and salad crops eaten uncooked) was based on a "zero risk" concept. This standard was not feasible with common wastewater treatment technologies, even in developed countries, and as well was not based on epidemiological evidence. Nonetheless the California standard became the most commonly accepted guideline around the world.

The irrational application of unjustifiably strict microbial standards for waste water irrigation of treated wastewater for crop irrigation contributed to a situation where standards were not enforced, and the hazardous irrigation of salad crops with raw wastewater was widely practiced in many developing countries.

The Engelberg standard was based on a critical evaluation of the massive amount of epidemiological data reviewed and analysed by the World Bank study (Shuval et al, 1986) and the IRCWD/WHO Study (Blum and Feachem, 1995) on credible health effects associated with wastewater and excreta use in agriculture. They concluded that:

- the risks of irrigation with treated wastewater were minimal and that the California standard was unduly restrictive
- the main risk in many developing countries was associated with helminthic diseases and a high degree of helminth removal was necessary.

Waste stabilization ponds are particularly effective in achieving the helminth goal, and are usually the wastewater treatment method of choice in warm climates wherever land is available at reasonable cost. It was understood that the strict helminth standard recommended is an indicator for all of the large pathogens (that settle readily) including the protozoa Amoeba and Giardia.

Table 1: Microbiological Quality Guidelines for Treated Wastewater Reuse in Agricultural Irrigation (Engelberg Standard)

	Reuse Process	
	Restricted	Unrestricted
	trees, industrial crops, fodder crops, fruit trees and pasture	edible crops, sports fields and public parks
Intestinal nematodes	≤ 1	≤ 1
fecal coliforms	not applicable	≤ 1000
requirements for treatment in stabilization ponds to meet standard		
number of ponds	3	4-6
total retention time	12 days	20 days

Intestinal nematodes include Ascaris, Trichuris and hookworms, and are expressed in arithmetic mean no. of viable eggs per liter
Fecal coliforms are expressed as geometric mean no. per 100 ml.

The "requirements for treatment in stabilization ponds to meet standard" may vary from the indicative figures given, but the guidelines note that a minimum degree of treatment for restrictive use is equivalent to at least a 1-day anaerobic pond followed by a 5-day facultative pond or its equivalent. Mara and Silva (1986) note that in many cases the most appropriate treatment option for restrictive use will be a waste stabilization pond system comprising a 1-2 day anaerobic pond followed by a facultative pond (5 days) and a maturation pond (5 days).

For **aquacultural** use, guidelines for the microbiological quality of treated excreta and wastewater were:

> zero viable trematode eggs per litre or per kilogram (on an arithmetic mean basis) and less than 10 000 fecal coliform bacteria per 100 millilitres or 100 grams (on a geometric mean basis)

The stringent trematode guideline is necessary as these pathogens multiply greatly in their first intermediate host. The value for fecal bacteria assumes a 90% reduction of these bacteria in the pond, so that fish and aquatic vegetables are not exposed to more than 1000 fecal coliforms per 100 millilitres.

Options for Health Protection

I shall briefly consider the following options:

Treatment of waste

As already noted, **waste stabilization ponds** are the treatment of choice, because of high effectiveness in meeting the guidelines, as well as low cost and simple operation. **Disinfection** – usually chlorination is usually effective in reducing the numbers of bacteria in the effluent from a conventional treatment plant, but it leaves most helminth eggs unharmed and is expensive.

Crop restriction may allow growth of selected crops even if the Engelberg standard is not fully met. Crop restriction provides protection to consumers but not to farm workers and their families. Therefore crop restriction should be complemented by measures to protect workers, including partial waste treatment, controlled waste application and human exposure control. Partial waste treatment to meet the helminthic standard of the Engelberg guideline would be effective in many circumstances and is cheaper than full treatment. Crops are categorized according to the required protection measures:

Category A – protection needed only for field workers. Includes industrial crops such as cotton, sisal, grains and forestry, as well as food crops for canning.

Category B – this intermediate category requires further measures, and applies to pasture, green fodder and tree crops, and to fruit and vegetables that are peeled or cooked before eating.

Category C – Engelberg "unrestricted" guidelines essential, and the category applies to fresh vegetables, spray-irrigated fruits, parks, lawns and golf courses.

Not suprisingly, crop restriction works best when there is an adequate market demand for allowed crops and they fetch a reasonable price, and as well there is little market pressure in favor of excluded crops.

Waste application methods are a factor in determining health risk. Irrigation water, including treated waste water, can be applied to the land in the following five ways:

By flooding (border irrigation), wetting almost all the land surface

By furrows, wetting only part of the ground surface

By sprinklers, in which the soil is wetted in much the same way as by rain

By subsurface irrigation, in which the surface is only slightly wetted but the subsoil is saturated

By localized irrigation, (trickle, drip or bubbler irrigation), in which water is applied to each individual plant at an adjustable rate

Flooding involves the least investment but is probably poses the greatest risk to field workers. It should not be used for vegetables. Sprinkler irrigation should not be used for tree crops and for fruit and vegetables that are peeled or cooked before eating, unless the Engelberg bacterial quality standard is met.

Subsurface irrigation can give the greatest degree of health protection, as well as using water more efficiently and producing the best yields. However it is expensive, and water must be treated extensively to prevent clogging of the small holes through which water is slowly released into the soil.

In aquaculture, exposing the fish to clean water for at least 2 –3 weeks before harvest ill remove any residual odors and reduce contamination with fecal microorganisms.

Control of human exposure

Four groups to consider are the workers involved, crop handlers, those living near treated fields, and the public at large. Exposure of field workers to hookworm infection can be reduced by continuous in-field use of footwear. Immunization against helminthic infections and most diarrhoeal diseases is not feasible, but exposed groups may be immunized against typhoid and hepatitis A. Additional protection may be afforded by adequate medical facilities, by regular chemotherapeutic control of intense nematode infections in children, and by control of anemia. Risks to consumers can be reduced by good food preparation practices to reduce existing contamination. Tapeworm transmission can be controlled by meat inspection.

Local residents should be fully informed of the location of all fields where human wastes are used so that they and their children can avoid them. Sprinkler irrigation should not occur within 50 to 100 metres of houses or roads, although there is no evidence that those living near wastewater treated fields are at risk.

In aquaculture, groups of people at potential risk include aquacultural pond workers, fish and macrophyte (plant) handlers, fish and macrophyte consumers, and those living near ponds fertilized with excreta or wastewater. Pond workers are at high potential risk of parasitic infections. Schistosomiasis can be best dealt with by treatment of infected persons and by snail control. However wearing of boots or body-waders can reduce exposure. Local residents should be informed which ponds are fertilized, and should prevent their children playing or swimming in them. Produce handlers can reduce exposure by the wearing of gloves and a high level of personal hygiene.

Planning and implementation

The incorporation of wastes reuse planning protocols into national water plans is important, especially under conditions of water scarcity, in order to

- protect water quality
- minimize treatment costs
- safeguard public health
- obtain increased agricultural and aquacultural benefits from nutrients

It is clear that many sectors must be involved in developing a protocol, including ministries of agriculture, fisheries, health, water resources, public works and local government, finance and economic planning, and others. An intersectoral body may be formed, whose main tasks are:

- develop a coherent national or regional policy and monitor its implementation

- define division of responsibilities between ministries and other bodies involved in the sector, and liaison between them

- appraise major proposed new schemes (including economic appraisal), from health and environmental protection standpoints oversee the promotion and enforcement of national legislation and codes of practice

development of human resources policy.

For a detailed consideration, the reader is referred to Mara and Cairncross (1989). Policy options may be developed for existing and new schemes, to address technical aspects, the management of schemes and the operation and maintenance. The planning requirements for excreta and wastewater reuse are similar in many respects to those for other irrigation and fertilization schemes. Experience has shown the value of a joint planning board that includes representatives of farmers or pond-owner associations, the authorities that collect and distribute the wastes, and local health authorities.

In implementing an economic appraisal, a calculation is made of the marginal costs and benefits of the new project – the differences between the costs and benefits of the project and the costs and benefits of the alternative. Appraisal must take into account that the alternative to a wastewater irrigation scheme may be:

no agriculture at all

no irrigation at all (that is, rain-fed agriculture)

irrigation with water from an alternative source **without** fertilizer application

irrigation with water from an alternative source **with** fertilizer application

The marginal benefit from wastewater irrigation is different in each case.

Greater emphasis may have to be given to the principle that human behaviors are key determinants in the transmission of excreta-related diseases. The introduction of waste-water re-use schemes, or measures to reduce transmission in existing schemes will usually involve a change in behaviors and practices. Whether a change is socially feasible depends on social preferences and cultural beliefs that vary widely in different parts of the world. It is not safe to assume that excreta or waste-water re-use practices that have evolved in one part of the world can be readily be transferred to another.

Avoidance of Chemical Pollution

There are 2 general theoretical approaches:

1. Preventing pollutant accumulation in waste-receiving soil. No net accumulation of pollutants is permitted in the soil, and numerical limits are set to prevent a rise in pollutant concentration during the course of the land application. Guidelines based on this approach are in use in some European countries, however many countries lack sufficiently advanced wastewater collection and treatment infrastructure to adopt such guidelines.

2. Taking maximum advantage of the soil's capacity to assimilate, attenuate and detoxify pollutants. Accumulation of pollutants in the soil is managed so that they will not reach levels that are harmful to human health. Land application guidelines set the maximum permissible pollutant loadings and provide users with the flexibility to develop suitable management practices for using wastewater and sewerage sludge. This approach causes pollutant concentrations in the soil to rise higher than background levels which may restrict future use of the land.

Chang et al argue that the **pollutant concentration** in the soil is a more suitable global reference point than the **pollutant loading rate** in the assessment of potential negative impacts of pollutants in soil. A detailed examination of their model, its assumptions and conditions is beyond the scope of this paper. Their model has produced numerical values for maximum pollutant concentrations in soils.

Maximum Pollutant Concentrations In Soils

(a) Inorganic Elements

Constituent	Concentration in soil (mg/Kg/DW)
Arsenic	9
Barium	2900
Beryllium	20
Cadmium	7
Chromium	3200
Fluorine	2600
Lead	150
Mercury	5
Nickel	850
Selenium	140
Silver	3

Source: Chang et al 1995

(b) Organic Compounds

Compound	Concentration in soil (mg/Kg/DW)
Aldrin	0.2
Benzene	0.03
Benzo (a) pyrene	3
Chlorodane	0.3
Chlorobenzene	ND
Chloroform	2
Dichlorophenols	ND
2,4-D	10
DDT	ND
Dieldrin	0.03
Heptachlor	1
Hexachlorobenzene	40
Hexachloroethane	2
Pyrene	480
Lindane	0.6

Methoxychlor	20
Pentachlorophenol	320
PCBs	30
Tetrachloroethane	4
Tetrachloroethylene	250
Toluene	50
Toxaphene	9
2,4,5-T	ND
2,3,7,8 TCDD	30

Source: Chang et al, 1995

In developing these guideline limits, many methodological cautions were expressed, given the complexity of pollutant transport through various environmental exposure routes and the inherent variability of diets, environmental exposures to pollutants and soil and plant partition coefficients.

Chang has concluded that communities that have a comprehensive and effective industrial waste pretreatment program can apply secondary and tertiary treated wastewater effluents without any restriction, provided the amount used is in accordance with the water requirement of crops.

Conclusions

The health hazards of the use of inadequately treated municipal wastewater are mainly microbiological, however rapid industrialization is increasing the load of chemical pollutants in municipal wastewater. While health measures and guidelines are well-established for microbiological hazards, chemical guidelines based on routine monitoring of soil concentrations of chemical pollutants (as discussed above) may be difficult to promote and apply widely. Relatively few countries presently have the capacity to routinely monitor soil concentrations of chemical pollutants. WHO is launching an international effort to collect data and analyze technical information to develop reliable chemical guidelines for wastewater reuse. Chemical guidelines may be integrated with the microbial guidelines in one guidebook to better assist personnel involved in wastewater reuse. A profile of likely chemical pollutants for waste-water in a given municipality may be constructed based on the profile of the existing industries – formal, and small-scale and informal, together with a rapid assessment of their methods for handling wastes. If a technical databank was developed in this initiative, it could support an expert system-based computer program that could give advice and make informed judgements in assessing the hazards in various locations. Using such a methodology, human health risks associated with land application of wastes worldwide could be evaluated independently with a more consistent and systematic procedure.

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Health Protection Measures and Health Safeguards in Water Re-Use for Non-potable Applications

- use of wastewater for crop irrigation
- use of excreta for soil fertilization and soil structure improvement
- use of wastewater and excreta in aquaculture

- protect water quality
- minimize treatment costs
- safeguard public health
- obtain increased agricultural and aquacutural benefits from nutrients

protection of the health of:

- workers involved
- crop handlers
- those living near treated fields, and
- the public at large

Disorders caused by chemical toxicants are harder to identify than infectious water-borne diseases

Infectious water-borne diseases:

- short latency
- unique clinical symptoms
- readily identifiable exposure route and
- unambiguous dose-response relationship

There is a major challenge to develop criteria that are not overly restrictive to beneficial use, and yet protect human health that is vulnerable to hundreds of toxic chemicals that may be present in municipal wastewater and sewerage.

Health Findings

crop irrigation with **untreated** wastewater causes excess intestinal nematode infection in crop consumers and field workers who if barefoot, are also at higher risk of hookworm infection

irrigation with **adequately treated** wastewater does not lead to excess intestinal nematode infection in field workers or crop consumers

cholera and probably typhoid can be transmitted by irrigation of vegetable crops with **untreated** wastewater

cattle grazing on pasture irrigated with **raw** wastewater may become infected with beef tapeworm but there is little risk to humans

Health Findings (cont.)

some health impacts have been observed on the health of people living near fields irrigated with raw wastewater, due to direct contact with the soil or indirectly by contact with farm workers

sprinkler irrigation with **treated** wastewater may promote aerosol transmission of excreted viruses, although in practice transmission is rare

Table 1: Microbiological Quality Guidelines for Treated Wastewater Reuse in Agricultural Irrigation (Engelberg Standard)

	Reuse Process	
	Restricted	Unrestricted
	trees, industrial crops, fodder crops, fruit trees and pasture	edible crops, sports fields and public parks
Intestinal nematodes	≤ 1	≤ 1
fecal coliforms	not applicable	≤ 1000
requirements for treatment in stabilization ponds to meet standard		
number of ponds	3	4-6
total retention time	12 days	20 days

treatment of waste

waste stabilization ponds

disinfection

crop restriction

- Category A – protection needed only for field workers
- Category B – intermediate category applies to pasture, green fodder and tree crops, and to fruit and vegetables that are peeled or cooked before eating.
- Category C – Engelberg "unrestricted" guidelines essential, applies to fresh vegetables, spray-irrigated fruits, parks, lawns and golf courses.

Waste application methods

five ways:

- by flooding (border irrigation)
- by furrows, wetting only part of the ground surface
- by sprinklers, wet soil as by rain
- by subsurface irrigation, subsoil is saturated
- by localized irrigation, (trickle, drip or bubbler irrigation) apply to each individual plant at an adjustable rate

Chemical Guidelines

1. Preventing pollutant accumulation in waste-receiving soil.

2. Taking maximum advantage of the soil's capacity to assimilate, attenuate and detoxify pollutants.

pollutant concentration in the soil is a more suitable global reference point than the **pollutant loading rate** in the assessment of potential negative impacts of pollutants in soil

communities that have a comprehensive and effective industrial waste pre-treatment program can apply secondary and tertiary treated wastewater effluents without any restriction

Maximum Pollutant Concentrations In Soils

(a) Inorganic Elements

Constituent	Concentration in soil (mg/Kg/DW)
Arsenic	9
Barium	2900
Beryllium	20
Cadmium	7
Chromium	3200
Fluorine	2600
Lead	150
Mercury	5
Nickel	850
Selenium	140
Silver	3

Source: Chang et al 1995

Maximum Pollutant Concentrations In Soils (cont.)

(b) Organic Compounds

Compound	Concentration in soil (mg/Kg/DW)
Aldrin	0.2
Benzene	0.03
Benzo (a) pyrene	3
Chlorodane	0.3
Chlorobenzene	ND
Chloroform	2
Dichlorophenols	ND
2,4-D	10
DDT	ND
Dieldrin	0.03
Heptachlor	1
Hexachlorobenzene	40
Hexachloroethane	2
Pyrene	480
Lindane	0.6
Methoxychlor	20
Pentachlorophenol	320
PCBs	30
Tetrachloroethane	4
Tetrachloroethylene	250
Toluene	50
Toxaphene	9
2,4,5-T	ND
2,3,7,8 TCDD	30

Source: Chang et al. 1995

Conclusions

health hazards mainly microbiological

rapid industrialization increasing load of chemical pollutants in municipal wastewater

health measures and guidelines are well-established for microbiological hazards

chemical guidelines based on routine monitoring of soil concentrations of chemical pollutants difficult to promote and apply widely

international effort to collect data and analyze technical information to develop reliable chemical guidelines for wastewater reuse

chemical guidelines may be integrated with the microbial guidelines in one guidebook

Conclusions

profile of likely chemical pollutants for waste-water in a given municipality based on the profile of the existing industries - formal, and small-scale and informal, together with a rapid assessment of their methods for handling wastes

if a technical databank was developed in this initiative, it could support an expert system-based computer program that could give advice and make informed judgements in assessing the hazards in various locations. Using such a methodology, human health risks associated with land application of wastes world-wide could be evaluated independently with a more consistent and systematic procedure

Session 4: Augmentation of Groundwater Resources through Aquifer Recharge

ADVANTAGES OF AQUIFER RECHARGE FOR A SUSTAINABLE WATER SUPPLY

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INTRODUCTION: Aquifer recharge is becoming an integral part of water resources planning as urban areas recognize the need for developing sustainable water supplies. Traditional approaches to meet growing water demand in urban areas require exploitation of surface and subsurface resources to the maximum extent possible. Future sustainable development of urban areas is dependent on solutions that provide sustainable water supplies without associated negative environmental impacts. Negative environmental impacts include damage to fisheries and ecosystems from dams, increased salinity from evaporation during surface water storage and land subsidence from decreasing groundwater levels. Aquifer recharge has many advantages as compared to conventional surface water storage. Groundwater recharge is preferred because there are negligible evaporation losses, the water is not vulnerable to secondary contamination by animals or humans, and there are no algae blooms resulting in decreasing surface water quality (Crook, 1998). Other benefits include prevention and minimization of land subsidence and reduced groundwater pumping costs. Additionally, passage of water through the subsurface provides soil-aquifer treatment (SAT) and the aquifers may offer seasonal or longer-term storage (Bouwer, 1985). Aquifer storage and recovery systems can allow for the storage of excess surface water during periods of high surface water flow combined with the recovery of stored surface water during periods of low surface water flows or drought (Pyne, 1994). In many cases, aquifers provide large amounts of storage capacity that can be made available through aquifer recharge. Public acceptance of groundwater recharge for indirect potable reuse of reclaimed waters has been favorable as compared to other forms of proposed potable reuse. As with the development of any water resource, the major costs are often associated with distributing the water and these costs can be exacerbated in urban areas that were developed to primarily utilize surface waters. Water resources planning including aquifer recharge provides many options to develop a sustainable water supply while reducing the costs associated with expensive distribution systems.

METHODOLOGY AND ECONOMICS: The most common and widely accepted method for aquifer recharge is the use of percolation basins. Another method for groundwater recharge includes direct injection into the saturated zone. An emerging method for groundwater recharge is the used of vadose zone injection wells which are analogous to trenches (Close et al., 1997). The three technologies are illustrated in Figure 1. The major characteristics of the three technologies are summarized in Table 1. Both recharge basins and vadose zone injection wells require the presence of an

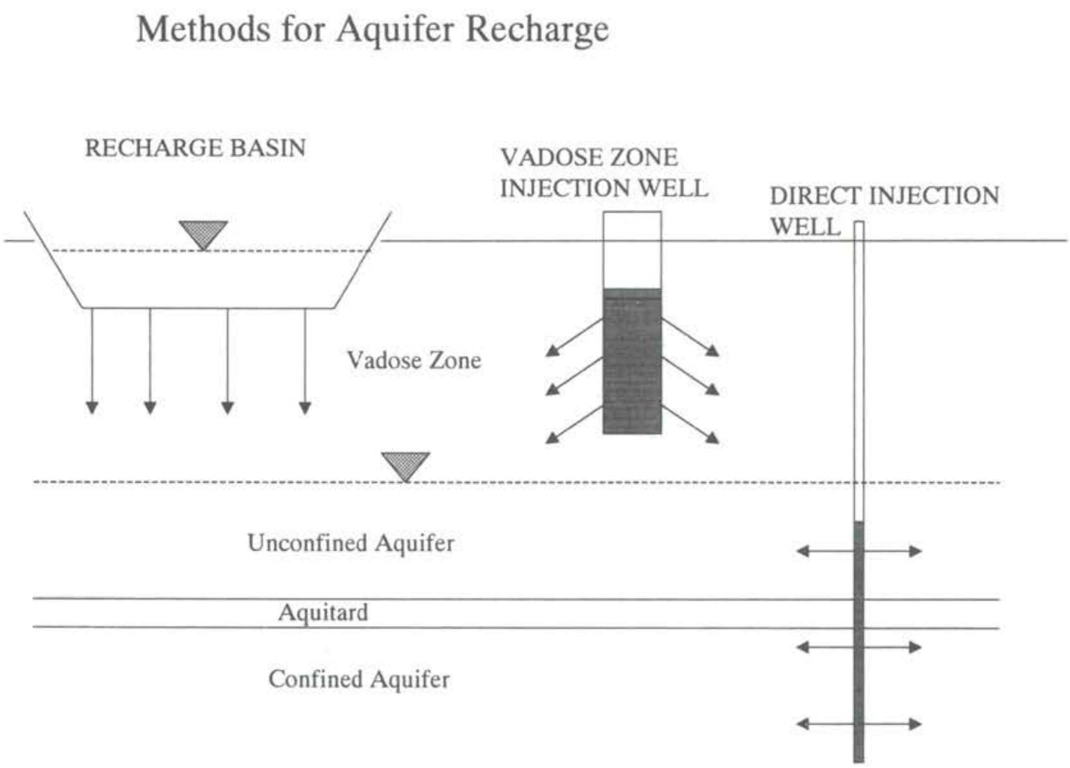

Figure 1. The three commonly used methods for aquifer recharge. Recharge basins are the most common low technology method that require large amounts of land. Direct injection wells allow for injection into confined aquifers and require high technology pre-treatment. Vadose zone injection wells are an emerging technology that provides some of the advantages of both recharge basins and direct injection wells

unconfined aquifer with sufficient storage capacity. Direct injection wells can inject water directly into unconfined aquifers or confined aquifers. When unconfined aquifers are unavailable, direct inject wells are the only alternative for groundwater recharge and are capable of simultaneously injecting water into several aquifers. However, direct injection wells are expensive, require advanced pre-treatment technology and advanced technology for maintenance. Therefore, direct injection is not a viable option when low technology solutions are desired. The major costs associated with recharge basins are the required land and the conveyance system to deliver water to the recharge basins. Therefore, it is often desirable to locate recharge basins near water conveyance systems where land that is located in floodplains might be available.

Table 1. Major Characteristics of Aquifer Recharge Methodologies

	Recharge Basins	**Vadose Zone Injection Wells**	**Direct Injection Wells**
Aquifer Type	Unconfined	Unconfined	Unconfined or Confined
Pre-Treatment Requirements	Low Technology	Removal of Solids ???	High Technology
Estimated Major Capital Costs US$	Land and Distribution System	\$25,000-75,000 per well	\$500,000-1,500,000 per well
Capacity	1000-20,000 m^3/ha-d	1000-3000 m^3/well-d	2000-6000 m^3/well-d
Maintenance Requirements	Drying and Scraping	Drying and Disinfection ??	Disinfection and Flow Reversal
Estimated Life Cycle	>100 Years	5-20 Years	25-50 Years
Soil Aquifer Treatment	Vadose Zone and Saturated Zone	Vadose Zone and Saturated Zone	Saturated Zone

The estimated costs associated with the use of recharge basins are highly variable since they depend on both infiltration rates and land values. Infiltration rates are a function of the soil hydraulic conductivity and the development of mounding on the groundwater table. Average infiltration rates must consider the cyclic operation of the recharge basins that includes both wetting and drying periods. Average infiltration rates can vary from 8 to 150 cm/d depending on the soil type and development of clogging layers. When groundwater levels are shallow, mounding below the recharge basins can increase groundwater levels to near the bottom of the infiltration basins thus decreasing infiltration rates. Under such conditions, extended drying periods are required to allow for dissipation of the mounds. Estimated land requirements for a recharge project using recharge basins depends on the volumetric rate of recharge and the average infiltration rate.

Land Required = Flowrate (m^3/d) ÷ Infiltration Rate (m^3/ha-d)

And the estimated costs are dependent on the land values.

Costs for Land = Land Required (ha) x Land Cost (\$/ha)

For example, a 20,000 m^3/d project with an average infiltration rate of 5,000 m^3/ha-d will require 4 ha of recharge basins. If the land costs \$20,000 per ha the total cost for the land will be \$80,000. These costs do not consider the costs for a conveyance system to supply the water to the recharge basin. The City of Phoenix, Arizona, USA investigated a plan to recharge groundwater in recharge basins using reclaimed water from the 91st Avenue Wastewater Treatment Plant. A system with a capacity to deliver 400,000 m^3/d for a distance of 11.5 km was prohibitively expensive (\$50,000,000). Therefore, a smaller project was designed to reduce the costs of the conveyance system and the remaining reclaimed water will be used to restore the ecosystem of receiving waters. An alternative surface water source was found to keep the capacity of the recharge project at greater than 400,000 m^3/d of which less than 50% will be reclaimed water.

The high cost of land in some urban areas has provided the motivation for the development of vadose zone injection wells. As land prices escalate to greater than $100,000 per ha, the land costs associated with large recharge projects can become prohibitive. While still an unproven technology, vadose zone wells are rapidly becoming part of water resources planning in urban areas. The other key advantage to vadose zone injection wells is they can often be located near a water supply that eliminates the need for expensive conveyance systems. Pre-treatment requirements usually include removal of solids and disinfection with chlorine to prevent clogging. Vadose zone injection wells have been used for recharging filtered surface waters and for recharging reclaimed waters treated by secondary biological treatment followed by filtration and disinfection. Improvements in water quality as water percolates through the vadose zone and enters the saturated zone are expected but have not been well documented as compared to recharge basins. The life cycle of vadose zone injection wells is very uncertain since they are an emerging technology. Once a vadose zone injection well is clogged, they are very difficult to redevelop since there is no technique to backwash the well or to rapidly dry the well. Systems are being designed to allow for alternating flow patterns such that wells located adjacent to one another are never operated simultaneously (Small and Vernon, 1999). This operating scheme will allow wells to dry and to possibly be backwashed by horizontal flows from adjacent wells. Even when systems are designed with a life cycle of only five years, they are more economical than alternative recharge basins or direct injection wells when land is expensive.

Recharge basins are still the most common method of recharge and provide excellent versatility for water resources planning. In the Montebello Forebay of Los Angeles County, California, USA, recharge basins are located adjacent to major water conveyance channels. Depending on the available water source, the basins are used to recharge stormwater, surface water from either the Colorado River or the State Water Project, or reclaimed water. Pre-treatment requirements for the stormwater and surface waters are essentially non-existent. Stormwater or surface waters are passed through stilling basins to reduce the sediment loading on the recharge basins. Reclaimed water is treated by secondary biological treatment followed by filtration and chlorination. Filtration and chlorination are primarily for the control of pathogens and are not required for many recharge projects applying reclaimed water on recharge basins. The versatile infrastructure available to deliver different waters to the recharge basins combined with effective water resource planning allows for efficient water use and maintenance of groundwater levels in the region. The Montebello Forebay also provides an example of indirect potable reuse since reclaimed water becomes part of the drinking water supply. Epidemiological studies have found no negative impact from over thirty years of indirect potable reuse at the Montebello Forebay (Nellor, 1984).

A combination of low technologies can be used to accomplish groundwater recharge with reclaimed water or other poor quality water sources. For example, a sequence of lagoons followed by constructed wetlands is used as pre-treatment for groundwater recharge basins located in Kingman, Arizona, USA. Periodic high solids loadings from the wetlands do not have a permanent negative impact on infiltration rates since drying cycles dessicate the solids that are primarily organics. In Morroco, a sequence of lagoons followed by intermittent sand filtration was used prior to groundwater recharge using trenches. The intermittent sand filters clogged rapidly and were consequently labor intensive, however, an abundant supply of labor made the intermittent sand filters a feasible technology. The intermittent sand filters effectively prevented clogging of the groundwater recharge trenches.

Regulations and laws have been developed to stimulate aquifer recharge in many urban areas. Laws that require assured water supplies, encourage groundwater recharge through water banking, and require irrigation with reclaimed water effectively promote water resource planning with aquifer recharge as an important component. Laws that require assured water supplies, as is the case in Arizona, USA, promote decentralization to reduce the costs associated with fully utilizing reclaimed water as a water resource. Water reclamation plants are located near sites where water is reused and where water is recharged into the ground. In Arizona, a typical water reclamation plant will provide reclaimed water for irrigation of parks and golf courses throughout the year. In the winter when irrigation water demand is less than the supply of reclaimed water, the reclaimed water is used to recharge groundwater. The net impact is an increase in groundwater levels providing that the primary drinking water source is a surface water. Groundwater is stored for future use and will be available during droughts and other periods of low surface water supply. The recharged groundwater is presently used primarily for non-potable purposes; however, many underground storage and recovery systems include plans for potable reuse. Another potential benefit of a decentralized system is reduced environmental impacts on receiving surface waters since discharge of reclaimed water into surface waters is eliminated.

Laws that establish groundwater banks provide genuine economic motivation for groundwater recharge. Entities that recharge groundwater receive credit for the amount of groundwater that is recharged. These entities can then sell the groundwater to groundwater users in the future and the recharged groundwater can be viewed as money in the bank. A system of buyers and sellers can be established to effectively maintain or increase groundwater levels in an economically sound fashion. Banking of groundwater can also be integrated with the allocation of surface water supplies to allow for trading of groundwater with surface waters. Advantages of this strategy include the utilization of poor quality surface waters or reclaimed waters for irrigation while high quality groundwater is dedicated for drinking water purposes. The Groundwater Management Act (GMA) established a goal of zero groundwater mining by the Year 2025 in the State of Arizona, USA. The GMA established a groundwater banking systems combined with a system of penalties and incentives. Groundwater users are penalized on an escalating scale for withdrawing groundwater without recharging groundwater. The penalties force the groundwater user to either recharge groundwater or purchase recharged groundwater from a groundwater supplier. Increased groundwater reserves can also be used to protect baseline stream flows for environmental purposes.

Laws that establish groundwater banks and provide incentives for groundwater recharge do not guarantee that water will be recharged adjacent to areas where groundwater overdraft is most severe. For example, the Groundwater Management Act in Arizona, USA, established Active Management Areas (AMA) and each AMA is viewed as one large aquifer. Therefore, groundwater can be recharged 40 km from an area where groundwater overdraft is severe. Groundwater users can continue to extract groundwater from an area where groundwater overdraft is severe by purchasing recharged groundwater regardless of the location of the recharge project. While decentralization tends to evenly distribute the recharge of reclaimed water as discussed above, large recharge projects that use surface water supplies are typically located adjacent to canals or rivers for economic reasons. The location of large recharge projects can causes increasing groundwater levels locally while doing very little to alleviate groundwater overdraft in other areas. Rising groundwater levels can also be a problem for adjacent industries and municipalities.

LAND SUBSIDENCE: Land subsidence due to groundwater overdraft is an important consequence of groundwater overdraft. Subsidence is caused by compression of underground materials when water tables decline (Bouwer, 1977). Also, lateral flow of groundwater can cause lateral compression of the aquifer and, consequently, lateral movement of land surface. Movements from groundwater flow or overdraft are normally small, however, they become significant where underground materials are compressible and groundwater levels decline. Observed land subsidences vary from several centimeters to greater than 10 m (Poland, 1969) and the amount of subsidence depends on the thickness and compressibility of underground formations. Nonuniform subsidence results when different rates of groundwater declines exist or from differences in compressibility of formations and can lead to the production of cracks and fissures at the land surface.

Land subsidence from groundwater overdraft is essentially irreversible. Land subsidence can be prevented or minimized by eliminating groundwater overdraft. Since subsidence is a slow process, groundwater replenishment can prevent residual compression of clay layers. However, increases in the land surface are normally insignificant, even when groundwater levels are returned to levels prior to land subsidence. As stated above, groundwater recharge to prevent continued damage from land subsidence must occur in the area of the overdraft. A groundwater depression created by overdraft will provide a gradient to enhance groundwater flow into the depression. Nevertheless, replenishing groundwater levels when overdraft is severe is a process that can take years or decades.

Land subsidence can also occur in recharge basins as a consequence of infiltration of large water volumes. There are several possible reasons for this phenomena but regardless of the mechanism, the effect is local and is not related to land subsidence from overdraft. One mechanism is associated with collapsible soils where calcium carbonate or other cementing agents dissolve resulting in compaction of the soil. Hydrocompaction can occur in the vadose zone as the intergranular pressure increases the compaction of compressible layers below. Presettling soils can be done to prevent hydrocompaction during the operation of recharge basins. Finally, clays can shrink and swell if changes in the sodium and calcium concentrations occur. This can result in either compaction of fines migration. In most cases, land subsidence in a recharge basin will result in a permanent but small reduction in infiltration rates. If fines migrate to less permeable layer, a larger reduction in infiltration rates might occur requiring maintenance to remove the impeding layer.

IMPACTS ON UNDERGROUND ECOLOGY: The impacts on underground ecology can be discussed in terms of microbial ecology and related geochemical interactions. The microbial activity within an aquifer is strongly related to the redox potential of the aquifer. Aquifers that contain dissolved oxygen are considered to be aerobic and have a high redox potential similar to aerobic surface waters. Aquifers that are depleted in molecular oxygen but contain chemical oxygen in the form of nitrate are considered to be anoxic and have an intermediate redox potential. Aquifers that are anaerobic have low redox potentials and a variety of electron acceptors might be used including sulfate, carbon dioxide, iron or manganese. The impact of groundwater recharge on underground ecology depends on the prior redox potential of the aquifer, the type of water that is used for recharge and the method of recharge. Both microbial and geochemical interactions are difficult to predict without conducting tests to evaluate the interactions prior to groundwater recharge.

Groundwater recharge using surface waters containing biodegradable organics or reclaimed water will generally result in depletion of molecular oxygen as the groundwater is recharged. When recharge basins are used, high levels of aerobic microbial activity consume oxygen at the soil/water interface resulting in anoxic or anaerobic conditions below the recharge basin and in areas dominated by the recharged water. When reclaimed water is used, there is generally some residual nitrogen in the form of nitrate and the aquifer becomes anoxic. The presence of some nitrate will prevent the development of anaerobic conditions and the potentially undesirable effects of anaerobic conditions on groundwater quality. Since many soil microorganisms are facultative, the enzymatic activity of soil microorganisms is similar under either anoxic or aerobic conditions and long term transformations of organics should proceed in similar fashions under either aerobic or anoxic conditions. Anoxic conditions dominate many aquifers influenced by recharge activity in the Southwestern United States.

Anaerobic conditions in an aquifer influenced by groundwater recharge can develop as a consequence of groundwater recharge and pre-existing anaerobic conditions are likely to remain anaerobic after groundwater recharge. An aerobic or anoxic aquifer can become anaerobic if the applied water for groundwater recharge is depleted in molecular oxygen and nitrate while containing some residual biodegradable materials. This situation is most likely to occur if reclaimed water or poor quality surface water is applied for extended periods to recharge basins without drying cycles to permit for reaeration of soils and subsequent nitrification of adsorbed ammonia. This has been observed under a combined wetlands/percolation system where anaerobic conditions develop in the wetland sediment and persist in the underground environment (Nahar et al., 1998). If an aquifer is naturally anaerobic, the biogeochemical mechanisms for the development of anaerobic conditions tend to prevail throughout the aquifer. Therefore, when oxygen or nitrate is introduced into an anaerobic aquifer, the oxygen or nitrate is rapidly consumed through a biogeochemical pathway that maintains anaerobic conditions in the aquifer. This has been observed for both groundwater recharge and for bank filtration when aerobic surface waters are drawn through an anaerobic aquifer. Anaerobic aquifers tend to have elevated concentrations of sulfide, reduced iron and manganese that can have a negative impact on water quality. When these reduced elements are exposed to oxygen or strong oxidants such as disinfectants, they are oxidized to forms that precipitate and can foul distribution systems. Therefore, groundwaters extracted from anaerobic aquifers typically require treatment for the removal of reduced compounds prior to distribution.

When oxygen or strong oxidants such as chlorine are introduced to anaerobic aquifers, rapid oxidation of reduced compounds occurs at the point of contact between the recharge water and the anaerobic aquifer. This can result in the accumulation of precipitates and clogging of the aquifer. For recharge basins, the interfacial area between the recharge water and the anaerobic aquifer is large preventing a concentrated accumulation of precipitates. When direct injection is used, clogging around the wells can be a serious problem.

CONTAMINATION OF SOIL AND GROUNDWATER: Groundwater recharge will impact pre-existing contaminated conditions and geochemical interactions between recharge waters and soils can also impact groundwater quality. If recharge basins are located above contaminated soils, there is a strong possibility contaminants will rapidly migrate into the groundwater resulting in groundwater contamination when the contaminants were previously present only in the soil. In some cases, natural migration of contaminants in the soil could take decades or centuries before groundwaters will be impacted by the contaminants and natural attenuation could greatly reduce the future impact on groundwater quality. In such cases, groundwater recharge should not be practiced or thorough soil remediation should be completed prior to groundwater recharge. Contaminated soils adjacent to recharge basins could also be affected by lateral flows or rising groundwater tables resulting in groundwater contamination. In Mesa, Arizona, USA, groundwater recharge with reclaimed water in an area of contaminated soils has resulted in no negative impact on groundwater quality since the soils above the groundwater were successfully remediated by vapor extraction. The lack of impacts on groundwater quality is surprising since the groundwater table has risen over 10 meters since 1990. Groundwater recharge will also influence local gradients and groundwater flow patterns. Therefore, the consequences of groundwater recharge on groundwater contamination in the vicinity of a recharge project must be considered. A recharge project could cause movement of contaminated groundwater towards a potable well resulting the loss a potable well and a contaminated groundwater plume that is more difficult to contain. Therefore, the siting and planning of groundwater recharge systems should always consider pre-existing contaminated conditions, particularly when the contaminants are mobile organics or inorganics.

Geochemical interactions between soils, aquifer materials and recharge waters can dictate final water quality. In Orange County, California, USA, recharge waters low in total dissolved solids are used and after several years of contact with native aquifer materials, the recharged groundwater comes to equilibrium with the native aquifer materials resulting in a significant increase in the total dissolved solids of the recharged groundwater. Similar to the case for anaerobic aquifers, the recharged groundwater does not improve the quality of the receiving aquifer. When groundwaters are recharged that are higher in total dissolved solids than the receiving aquifer, the recharged groundwater tends to maintain the higher total dissolved solids concentration since the total dissolved solids are stable and often do not interact to form precipitates with the native aquifer materials. Ion exchange reactions with clays can result in an exchange of dissolved sodium for calcium when the recharge waters have high levels of sodium and low levels of calcium. This effect does not significantly impact water quality unless dispersed clays migrate to recovery wells.

The impact of geochemical interactions with native soils and soils strongly influenced by prior agricultural activities can result in short-term groundwater contamination. When vadose zone soils in arid regions have not been contacted with significant quantities of water for many years, salts and minerals on the soil surface will rapidly dissolved when exposed to recharging groundwater. This can result in temporarily high concentrations of natural contaminants such as fluoride, arsenic, barium, lead or chromium (Johnson et al., 1999). These contaminants can be present at concentrations above maximum contaminant levels, however, the contaminants are only present as a spike of elevated concentrations. After longer-term storage of the groundwater, dispersion will reduce the contaminant concentrations to acceptable levels before the groundwater is recovered. Similarly, salts and nitrate accumulated in the vadose zone from prior agricultural activity can be rapidly dissolved as a consequence of groundwater recharge. Since agricultural activity can result in large quantities of salts and nitrates accumulated in the vadose zone, the impact of recharging groundwater with might not be a short-term effect. In most cases, the receiving groundwater already has elevated levels of salts and nitrates from the prior agricultural activities and groundwater recharge will eventually reduce the salinity and nitrate concentrations in the receiving aquifer. This phenomena has been observed at several sites in the Southwestern US where nitrate and salinity concentrations increased for time periods ranging from months to several years after groundwater recharge was initiated before beginning to decrease.

SUMMARY AND CONCLUSIONS: Groundwater recharge should be considered as an integral part of water resources planning. The advantages of groundwater recharge far outweigh the potential disadvantages of groundwater recharge. Groundwater recharge provides greater flexibility in water resources planning and groundwater banking systems provide economic incentives for groundwater recharge projects. Prevention of land subsidence is difficult even when systems for groundwater banking have been developed. As with most water resources projects, the development of infrastructure for the conveyance of water for groundwater recharge projects can be prohibitively expensive. Consideration of groundwater recharge in the initial stages of water resources planning will reduce large expenditures by optimizing the location of projects.

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GROUNDWATER RECHARGE WITH RECLAIMED MUNICIPAL WASTEWATER - REGULATORY PERSPECTIVES -

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ABSTRACT

Groundwater recharge with reclaimed municipal wastewater presents a wide spectrum of technical and health challenges that must be carefully evaluated. In this paper, regulatory aspects of groundwater recharge with reclaimed municipal wastewater are reviewed. Rationale and scientific basis for the proposed California groundwater recharge regulations are discussed. At present, several health constraints limit expanding use of reclaimed municipal wastewater for groundwater recharge when a large portion of groundwater contains recharged reclaimed wastewater that may affect domestic water supply. Two case histories are presented for the soil aquifer treatment and non-potable water reuse with less stringent water quality requirements.

KEYWORDS

Groundwater, pathogens, planning, public health, recharge, water quality regulations, water resources, wastewater reclamation and reuse, wastewater treatment.

INTRODUCTION

Natural replenishment of the vast supply of underground water occurs very slowly; therefore, excessive continued exploitation of groundwater at a rate greater than this replenishment causes declining groundwater levels in the long term and if not corrected, leads to eventual mining of groundwater. To increase the natural supply of groundwater, artificial recharge of groundwater basins is becoming increasingly important in groundwater management and particularly in situations where the conjunctive use of surface water and groundwater resources is being considered.

Groundwater recharge with reclaimed municipal wastewater is an approach to water reuse that results in the planned augmentation of groundwater for various beneficial uses. The beneficial uses are the many ways water can be used, either directly by people, or for their overall benefit. Groundwater is used as a source of water supply, and its major beneficial uses include municipal water supply, agricultural irrigation, and industrial water supply. The purposes of artificial recharge of groundwater have been (Bouwer, 1978; Todd, 1980; Asano, 1985):

- To reduce, stop, or even reverse declines of groundwater levels
- To protect underground freshwater in coastal aquifers against saltwater intrusion from the ocean
- To store surface water, including flood or other surplus water, and reclaimed municipal wastewater for future use.

Groundwater recharge is also incidentally achieved in land treatment and disposal of municipal and industrial wastewater via percolation and infiltration.

There are several advantages to storing water underground:

- The cost of artificial recharge may be less than the cost of equivalent surface water reservoirs
- The aquifer serves as an eventual distribution system in underground and may eliminate the need for transmission pipelines or canals for surface water
- Water stored in surface reservoirs is subject to evaporation, potential taste and odor problems due to algae and other aquatic productivity, and to pollution; these may be avoided by underground storage
- Suitable sites for surface water reservoirs may not be available or environmentally acceptable
- The inclusion of groundwater recharge in a wastewater reuse project may provide psychological and esthetic benefits as a result of the transition between reclaimed municipal wastewater and groundwater. This aspect is particularly significant when a possibility exists in the wastewater reclamation and reuse plan to augment substantial portions of domestic or potable water supplies.

TECHNIQUE OF GROUNDWATER RECHARGE

Two types of groundwater recharge are commonly used with reclaimed municipal wastewater: surface spreading or percolation, and direct injection.

Groundwater Recharge by Surface Spreading. Direct surface spreading is the simplest, oldest, and most widely applied method of artificial recharge (Todd, 1980). In surface spreading, recharge waters such as treated municipal wastewater percolates from spreading basins through the unsaturated groundwater (vadose) zone. Infiltration basins are the most favored methods of recharge because they allow efficient use of space and require only simple maintenance. In general, infiltration rates are highest where soil and vegetation are undisturbed.

Where hydrogeological conditions are favorable for groundwater recharge with spreading basins, wastewater reclamation can be implemented relatively simply by the soil-aquifer treatment (SAT) process. The necessary treatment can be obtained by the filtration process as the wastewater percolates through the soil and the vadose zone, down to the groundwater and then some distance through the aquifer. Recommended pretreatment for municipal wastewater for the SAT process includes primary treatment or stabilization pond. Pretreatment processes that leave high algal concentrations in the recharge water should be avoided. Algae can severely clog the soil of infiltration basins. While renovated wastewater from the SAT process is much better water quality than the influent wastewater, it could be lower quality than the native groundwater. Thus, the SAT process should be designed and managed to avoid encroachment into the native groundwater and to use only a portion of the aquifer. The distance between infiltration basins and wells or drains should be as large as possible, usually at least 50-100 m to give adequate soil-aquifer treatment (Bouwer, 1978 and 1988).

The advantage of groundwater recharge by surface spreading is:

- Groundwater supplies may be replenished in the vicinity of metropolitan and agricultural areas where groundwater overdraft is severe
- Surface spreading provides the added benefits of the treatment effect of soils and transporting facilities of aquifers.

Direct Injection to Groundwater. Direct subsurface recharge is achieved when water is conveyed and placed directly into an aquifer. In direct injection, generally, highly treated wastewater is pumped directly into the groundwater zone, usually into a well-confined aquifer. Groundwater recharge by direct injection is practiced:

- Where groundwater is deep or where the topography or existing land use makes surface spreading impractical or too expensive
- When direct injection is particularly effective in creating freshwater barriers in coastal aquifers against intrusion of saltwater.

- Both in surface spreading and direct injection, locating the extraction wells as great a distance as possible from the spreading basins or the injection wells increases the flow path length and residence time of the recharged water. These separations in space and in time contribute to the mixing of the recharged water and the other aquifer contents, and the loss of identity of the recharged water originated from municipal wastewater. The latter is an important consideration in successful wastewater reuse facilitating public acceptance.

In arid climates where the practice of groundwater recharge is most imperative, recharge will occur through such means as dry riverbeds and spreading basins, and in most situations there will be an unsaturated zone between the surface and the aquifer.

PRETREATMENT FOR GROUNDWATER RECHARGE

Four water quality factors are particularly significant in groundwater recharge with reclaimed wastewater: (1) microbiological quality, (2) total mineral content (total dissolved solids), (3) presence of toxicant of the heavy metal type, and (4) the concentration of stable organic substances. Thus, groundwater recharge with reclaimed wastewater presents a wide spectrum of technical and health challenges that must be carefully evaluated. Some basic questions that need to be addressed include (Asano and Wassermann, 1980; Roberts, 1980; NRC, 1994):

- What treatment processes are available for producing water suitable for groundwater recharge?
- How do these processes perform in practice?
- How does water quality change during infiltration-percolation and in the groundwater zone?
- What do infiltration-percolation and groundwater passage contribute to the overall treatment system performance and reliability?
- What are the important health issues?
- How do these issues influence groundwater recharge regulations at the points of recharge and extraction?
- What benefits and problems have been experienced in practice?

Pretreatment requirements for groundwater recharge vary considerably, depending on purpose of groundwater recharge, sources of reclaimed wastewater, recharge methods, and location. Although the surface spreading method of groundwater recharge is in itself an effective form of wastewater treatment, a certain degree of pretreatment must be provided to untreated municipal wastewater before it can be used for groundwater recharge.

A variation of the SAT process in Ben Sergao (a suburb of Agadir, Morocco) is described in the following Case History 1. The pilot study is of interest not only for the Greater Agadir where water resources are limited but also for a number of cities in Morocco where reuse of treated wastewater constitutes an essential option in wastewater treatment and disposal. Case History 2 deals with infiltration percolation as a tertiary treatment to meet the World Health Organizations (WHO) microbiological standards applying to unrestricted agricultural reuse (WHO, 1989).

Case History 1: Wastewater Treatment of Greater Agadir, Morocco (Bennani, *et al.*, 1992)

Today with its population of over 350,000, the rapidly growing Greater Agadir faces need for wastewater treatment and increased demand for water supply. The two main discharges of raw sewage, one into the port area, the other into the bed of the Souss wadi, at a few kilometers of its mouth, become less and less compatible with valuable tourist attraction.

In the Moroccan-French cooperation project, pilot wastewater treatment through dune sand infiltration-percolation is underway at Ben Sergao (a suburb of Agadir). After treatment by anaerobic stabilization pond (chemical oxygen demand, COD, of raw sewage=1,190 mg/L), the pilot wastewater treatment by infiltration-percolation plant treats 1,000 m^3/d of highly concentrated effluents in five infiltration basins of 1,500 m^2 each, consisting of two-meter thick eolian sand. The anaerobic stabilization pond (1,500 m^3 for a theoretical residence time of 2 days; depth of the pond: 3-4 m) is used to reduce suspended solids (40-50 %) and organic matter (50-60 %); thus, reducing the surface areas necessary for the infiltration basin. The basin is submerged for 8 hours and stays dry for 16 hours.

The wastewater was infiltrated at the rate of one meter per day. With this process nearly 100 percent of suspended solids and 95 percent of COD are removed, and 85 % of nitrogen is in oxidized forms and 56 % removed. Microbiological quality of raw sewage, pond effluent, and percolated water are shown in Table 1. The percolated water will be used in growing tomatoes (a vegetable extensively cultivated in the Agadir region), public gardens, and future golf courses.

Table 1. Microbiological quality of raw sewage, pond effluent, and percolated water (Bennani, *et al.*, 1992)

	Raw sewage	Pond effluent	Percolated water	Overall removal efficiency
Fecal coliforms, Numbers/100 mL	$6x10^6$	$5x10^5$	327	4.26 logs
Fecal streptococci, Numbers/100 mL	$2x10^7$	$1.6x10^6$	346	4.78 logs
Nematode eggs, Numbers/L	139	32	0	100 %
Cestode egg, numbers/L	75	18	0	100 %
Total helminths egg, Numbers/L	214	47	0	100 %

Inasmuch as recharged groundwater may be an eventual source of potable water supply, groundwater recharge with reclaimed municipal wastewater may often involve treatment beyond the conventional secondary wastewater treatment. In the past, prior to the recent concerns about protozoan cysts, enteric viruses, and trace organics in drinking water, several apparently successful groundwater recharge projects were developed and operated using primary and secondary effluents in spreading basins. However, because of the increasing concerns for these contaminants, groundwater recharge with reclaimed wastewater normally entails further treatment following conventional secondary treatment. For example, for surface spreading operations practiced in the United States, common wastewater reclamation processes include primary and secondary wastewater treatment, and tertiary granular-medium filtration followed by chlorine disinfection. The following Case History 2 deals with infiltration percolation as a tertiary treatment to meet the World Health Organizations (WHO) microbiological standards applying to unrestricted agricultural reuse.

Case History 2: Disinfection of Secondary Effluents by Infiltration and Percolation (Brissaud, *et al.*, 1998).

Effluent from conventional wastewater treatment cannot be directly used without disinfection for irrigation of public parks, sports fields, golf courses and edible crops. They have to be disinfected prior to reuse in order to comply with relevant regulations. When the object is to meet WHO's unrestricted irrigation criteria (WHO, 1989), the additional treatment can be achieved through infiltration peroration. Infiltration peroration plants were intermittently fed with secondary effluents which percolate through 1.5 to 2 m unsaturated coarse sand, and recovered by underdrains.

Infiltration percolation allows oxidizing and disinfecting wastewater. These are the reasons why soil aquifer treatment is used, in Spain and France, as a tertiary treatment with the aim of removing pathogens from the effluents of conventional wastewater treatment plants. It is a low-technology method that can be used to prepare wastewater for unrestricted irrigation (Brissaud, *et al.*, 1998). However, the reported disinfection performances provided by infiltration percolation are uneven dependent on the hydraulic loading of the system. The average water quality of secondary effluents and the percolated water is shown in Table 2.

Table 2. Water quality of secondary effluent and percolated water (Brissaud, *et al.*, 1998).

	Secondary effluent	Percolated water
Suspended solids, mg/L	18	1.2
COD, mg/L	97	51
NH_3-N, mg/L	28	0.5
NO_3-N, mg/L		47
Fecal coliform, CFU/100 mL	$6.1 \times 10^5 \sim 7.3 \times 10^6$	Variable, in the range of 100 to 500 dependent on the hydraulic loading

REGULATORY ASPECTS OF GROUNDWATER RECHARGE WITH RECLAIMED WASTEWATER

As discussed in the previous sections, groundwater recharge with reclaimed municipal wastewater presents a wide spectrum of health concerns. It is essential that water extracted from a groundwater basin for domestic use be of acceptable physical, chemical, microbiological, and radiological quality. Main concerns governing the acceptability of groundwater recharge projects are that adverse health effects could result from the introduction of pathogens or trace amounts of toxic chemicals into groundwater that is eventually consumed by the public. Because of the increasing concern for long-term health effects every effort should be made to reduce the number of chemical species and concentration of specific organic constituents in the applied water (National Research Council, 1982 and 1994; State of California, 1987).

A source control program to limit potentially harmful constituents entering the sewer system must be an integral part of any groundwater recharge project. Extreme caution is warranted because of the difficulty in restoring a groundwater basin once it is contaminated. Additional cost would be incurred if groundwater quality changes resulting from recharge necessitated the treatment of extracted groundwater and/or the development of additional water sources.

In the United States, federal requirements for groundwater recharge with reclaimed municipal wastewater have not been established. As a consequence, water reclamation and reuse requirements for groundwater recharge are established by the state agencies such as the California Regional Water Quality Control Boards with a case-by-case determination of the project (State of California, 1978). Considerably higher wastewater treatment prior to groundwater recharge is advocated in general because of the health concerns related to potential chronic effects of trace organics, and waterborne pathogens, particularly, enteric viruses upon human health.

Proposed California Groundwater Recharge Criteria

The proposed criteria for groundwater recharge with reclaimed municipal wastewater rightly reflect cautious attitude toward such short-term as well as long-term health concerns. Proposed Criteria (State of California, 1992) are shown in Table 3. The criteria rely on a combination of controls intended to maintain a microbiologically and chemically safe groundwater recharge operation. No single method of control would be effective in controlling the transmission and transport of contaminants of concern into and through the environment. Therefore, source control, wastewater treatment processes, treatment standards, recharge methods, recharge area, extraction well proximity, and monitoring wells are all specified.

The requirements in Table 3 are specified by "project category" which identify a set of conditions that constitute an acceptable project. An equivalent level of perceived risk is inherent in each project category when all conditions are met and enforced. Main concerns governing the acceptability of groundwater recharge projects with reclaimed municipal wastewater are that adverse health effects could result from the introduction of pathogens or trace amounts of toxic chemicals into groundwater that is eventually consumed by the public.

Table 3. Proposed requirements for groundwater recharge with reclaimed municipal wastewater (State of California, 1992)

Treatment and recharge site requirement	Project category			
	Surface spreading			Direct injection
	I	II	III	IV
Level of wastewater treatment:				
Primary/secondary	X	X	X	X
Filtration	X	X		X
Organics removal	X			X
Disinfection	X	X	X	X
Max. allowable reclaimed wastewater in extracted well water (%)	50	20	20	50
Depth to groundwater (m) at initial percolation rate of:				
50 mm/min.	3	3	6	na[1]
80 mm/min.	6	6	15	na[1]
Retention time in underground (months)	6	6	12	12
Horizontal separation[2] (m)	150	150	300	300

[1]Not applicable.
[2]From the edge of the groundwater recharge operation to nearest potable water supply well.

Microbiological Considerations. Of the known waterborne pathogens, enteric viruses have been considered most critical in wastewater reuse in California because of the possibility of contracting disease with relatively low doses and difficulty of routine examination of reclaimed wastewater for their presence. Thus, essentially virus-free effluent via the full treatment process (primary/secondary, coagulation/flocculation, clarification, filtration, and disinfection) is deemed necessary by the California Department of Health Services (State of California, 1978) for reclaimed wastewater applications with higher potential exposures, e.g., spray irrigation of food crops eaten uncooked, or most of groundwater recharge applications such as Project Categories I, II, and IV in Table 3.

The wastewater treatment requirements in Table 3 are designed to provide assurance that reclaimed water is essentially pathogen-free prior to extraction from the groundwater. The pathogen, e.g., enteric viruses, removal capabilities of an individual or a combination of treatment processes have been estimated (Hultquist, *et al.*, 1991) and the virus removals achieved by various combinations of wastewater treatment is reported in Table 4.

In addition to the treatment processes shown in Table 4, passage through an unsaturated zone of significant depth (> 3 m) reduces organic constituents and pathogens in treated effluents. At low infiltration rates of less than 5 m/day in sands and sandy loams, the rates of virus removal are approximated by a semi-log plot (k = -0.007 log/cm) against infiltration rates, resulting approximately 99.2 % or 2.1 logs removal for 3 m depth soils. The overall estimate for the removal of enteric viruses by the treatment processes, unsaturated zone, and horizontal separation (retention time in groundwater) as specified in the proposed requirements is shown in Table 5.

Trace Organics Removal. The regulations intend to control the concentration of organics of municipal wastewater origin as well as anthropogenic chemicals that have an impact on health when present in trace amounts. Thus, the dilution requirements and the organics removal specified in Project Categories I and IV in Table 4 are to limit average concentration of unregulated organics in extracted groundwater affected by the groundwater recharge operation. The concentration of unregulated and unidentified trace organics is of great concern since other constituents and specific organics are dealt with through the established maximum contaminant levels and action levels developed by the California Department of Health Services (CDHS).

Approximately 90 percent by weight of the organics comprising the total organic carbon (TOC) in treated municipal wastewater are unidentified (State of California, 1987). One of the health concerns related to the unidentified organics is that an unknown but small fraction of them are mutagenic. Regulation of the presence of trace amount of organics in reclaimed water can be accomplished by dilution using surface water or groundwater of less contaminated source. When reclaimed water makes up more than 20 percent of the water reaching any extraction well for potable water supply, treatment to remove organics must be provided. Because of lack of an ideal measure for trace amount of organics in reclaimed water as well as in the affected groundwater, total organic carbon (TOC) was chosen, as a surrogate, to represent the unregulated organics of concern. Although TOC is not a measure of specific organic compounds, it is considered at present to be a suitable measure of gross organics content of reclaimed water as well as groundwater for the purpose of determining organics removal efficiency in practice. However, there is insufficient basis for the establishment of a gross organics standard for the recharge water that protects public health.

Table 4. Estimated log virus removal by wastewater treatment in different project category[1]

Project category	Treatment requirements	Log virus removal[3]
I	Primary/secondary/filtration/ Organics removal/disinfection	7
II	Primary/secondary/filtration/ Disinfection	6
III	Primary/secondary/disinfection	3
IV	Primary/secondary/filtration/ Organics removal/disinfection	6

[1]Adapted from State of California, 1992 and Hultquist, *et al.*, 1991.
[2]Refer to Table 3 for the Project category.
[3]Log removal is the negative log of the fraction remaining. Thus, the fraction remaining is 0.10, it is equivalent to one log removal. Conversely, 99.999% removal or 0.00001 remaining is the equivalent of 5 logs removal.

Inorganic Chemicals. Inorganic chemicals, with the exception of nitrogen in its various forms, are adequately under control if all maximum contaminant limits (MCLs) regulated by CDHS are met. By limiting the concentration of total nitrogen in the reclaimed water, detrimental health effects such as methemoglobinemia can be prevented. In those recharge operations where adequate nitrogen removal cannot be achieved by treatment processes or passage through an unsaturated zone, the criteria provide the alternative method such as well head treatment to reduce the total nitrogen concentration to below the allowable concentration of 10 mg/L as N.

Table 5. Estimate of overall removal of enteric viruses in groundwater recharge systems due to the combined effects of treatment processes, soil systems, and retention in groundwater[1,2]

Project category	Treatment requirements	Log virus removal[3]
I	Primary/secondary/filtration/ Organics removal/disinfection	17
II	Primary/secondary/filtration/ Disinfection	16
III	Primary/secondary/disinfection	14
IV	Primary/secondary/filtration/ organics removal/disinfection	13

[1]Adapted from State of California, 1992 and Hultquist, et al., 1991.
[2]Infiltration rate of 7.3 m/day was assumed for virus removal with soils in unsaturated zone.

SUMMARY AND CONCLUSIONS

To increase the natural supply of groundwater, artificial recharge of groundwater basins is becoming increasingly important in groundwater management and particularly in situations where the conjunctive use of surface water and groundwater resources is considered.

Several constraints limit expanding use of reclaimed municipal wastewater for groundwater recharge. The lack of specific criteria and guidelines governing the artificial recharge of groundwater with reclaimed municipal wastewater is currently hampering the implementation of large-scale groundwater recharge operations; thus, the establishment of policy and regulations for the planning and implementing new groundwater recharge projects has been proposed. The rational basis and other background information for the proposed groundwater recharge regulations are presented in this paper. These regulations will serve as a basis with which future groundwater recharge projects are evaluated. Two case histories are presented for the soil aquifer treatment and non-potable water reuse with less stringent water quality requirements.

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Aquifer Storage and Recovery in Urban Areas - Technology, Risks, and Implementation Issues

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SUMMARY

An underground water banking technique known as Aquifer Storage and Recovery (ASR) has emerged as a means of expanding urban water resources by harvesting waters that would otherwise be foregone. Where peri-urban areas are endowed with suitable aquifers, even those where groundwater may be saline, these present opportunities for generating new water resources. Injecting stormwater or treated effluent may restore saline aquifers so that they become underground reservoirs for irrigation supplies. With appropriate pretreatment these supplies can even be made potable. In South Australia, five years of experience with stormwater recycling has led to the development of an ASR trial for reclaimed municipal effluent for recovery as an irrigation supply in the dry season. Some of the issues to be addressed are; can the quality of groundwater be adequately protected?, will the quality of the recovered water be fit for its intended use?, how can we prevent clogging of the injection well?, how much can we store? The research project at Bolivar near Adelaide is currently underway to answer these questions, and to assess technical viability, environmental sustainability, and commercial/economic feasibility at this site, and where possible in a generic sense. Injection of potable water to aquifers in years of plenty could add even more value to our natural urban water infrastructure below ground, by buffering seasonal peak demands that exceed the capacity of water treatment plants, and providing emergency or drought supplies of drinking water. This paper briefly describes the motivations for these developments, the types of artificial recharge methods available, some experience with stormwater ASR and some of the research being performed to address the risks identified in ASR with recycled water. Legal, social and economic aspects of implementing ASR with reclaimed waters are also mentioned.

1. INTRODUCTION

Many cities and agricultural areas rely on conjunctive use of surface water and groundwater. However for some cities which depend solely on surface water, there comes a time when the most economic next source of supply, taking into account the environmental cost of increased diversions or new dams, is groundwater. Where the groundwater quality is unsuitable for supply, artificial recharge of water in times of excess surface water, can produce new groundwater supplies of suitable quality.

Two developments are occurring that will enable more flexibility in future urban water supply. (1) Wastewater treatment processes are improving and reducing in cost, and in some locations, reclaimed effluent is now more economic than developing new resources for some classes of use, such as irrigation. (2) Utilities that differentiate the demand for water across several water quality types can economise on treatment costs. For example only a small fraction of the use of reticulated water is for drinking and human contact, so that dual reticulation systems, especially at smaller than traditional scales of water supply and effluent collection and treatment systems, may be commercially attractive. This flexibility presents opportunities for more holistic urban water management, recycling more water and reducing water imports and discharges of polluted water.

CSIRO, in sympathy with the Council of Australian Governments (COAG) water reform agenda (Thomas *et al*, 1997) which encourages competition within the water industry, and in partnership with members of the Water Services Association of Australia, is providing research support for implementation of full scale experimental urban water management systems. Quantifying actual costs, risks, operating requirements, public acceptance, and financial and environmental benefits through such trials, will encourage appropriate innovation by infrastructure investors. This also gives opportunities for small-scale investors to profit from provision of alternative water supplies, while generating environmental benefits. Artificial recharge and recovery of stormwater, reclaimed effluent, and mains water are vehicles, among others, to realise system flexibility, augment water resources, expand supply capacity, improve the efficiency of use of water infrastructure, and reduce adverse environmental impacts of urban water systems.

2. ARTIFICIAL RECHARGE METHODS

There are various methods for storing water in aquifers, known collectively as artificial recharge.

(1) Aquifer storage and recovery involves injecting water into a well and later recovering it from the same well. This can be performed even where the native groundwater is not fit for the intended use, such as where aquifers are saline or suffering from relic pollution, so long as the injected water after a period of storage is of suitable quality for its intended use.

(2) Injection and recovery from different wells has the advantage of filtration provided by passage through the aquifer. However this is usually only used when the native water in the aquifer is of suitable quality for reuse, and injection helps to maintain the supply.

(3) Pond infiltration is used when water can be stored in an unconfined aquifer, and leakage from the pond through the unsaturated zone recharges an aquifer, which is subsequently pumped to provide a water supply. Percolation through the unsaturated zone provides relatively rapid attenuation of some contaminants in comparison with passage through the aquifer. Soil aquifer treatment (SAT) is a form of intermittent pond filtration, in which recycled water undergoes alternate nitrification and denitrification beneath a leaky pond.

(4) Induced infiltration describes pumping of groundwater from aquifers that are hydraulically connected to ponds or streams. The hydraulic gradient induces seepage from the surface water into groundwater and provides filtration of the water en-route to the water supply well. This is commonly used in alluvial aquifers in Europe for purifying water supplies.

(5) All forms of irrigation are unintentional artificial recharge. Salt is more concentrated in recharge water than in the irrigation water, and therefore this is not a preferred way to achieve artificial recharge.

The best technique to use depends on local needs, conditions and contraints. However the rest of this paper focuses on aquifer storage and recovery (single well systems), as

- this makes the least demanding assumptions on the ambient quality of groundwater,
- recovery from the injection well helps to keep it from clogging, and
- this has the smallest requirement for land area, which can be an important factor in urban areas.

A number of the risks and implementation issues for ASR are common to the other techniques.

3. ASR WITH STORMWATER, RECLAIMED EFFLUENT AND MAINS WATER

Artificial recharge ponds have been used extensively throughout the world, including Australia, and injection of water into aquifers using wells is much less common. However the number of operational ASR sites has grown remarkably in recent years (Pyne, 1995). In an international context, use of urban stormwater for ASR is relatively unique. A review of international experience in ASR (Pavelic and Dillon, 1997) identified 45 case studies, including 70 known sites in 12 countries, with published information on; site characteristics and recharge techniques; operational problems such as clogging, and means to resolve these; and monitoring of impacts on groundwater quality or the quality of recovered water. Of the 45 case studies, 71% use "natural" source waters (rivers, lakes and groundwater), and the remainder use treated sewage effluent (20%) or urban stormwater runoff (9%) (Figure 1). Highly treated sewage effluent is commonly used in the United States of America. This yields a very consistent, high quality (but expensive) water at a relatively uniform flow rate, making this attractive as a source of water for ASR (National Research Council, 1994). Retention in an aquifer provides the necessary contact with the natural environment to make recovery for potable reuse palatable to consumers. The sustained injection of urban stormwater was found in only four documented cases, three of which were in South Australia.

The question of whether the quality of stormwater and treated effluent is adequate for ASR has been addressed and a survey of the characteristics of these classes of water, and the effects of passive treatment in wetlands reported (Pavelic and Dillon, 1995). Stormwater quantity and quality are determined by rainfall, catchment processes and human activities, which cause its flow and composition to vary in space and time. Municipal treated effluent on the other hand, is much more consistent in flow and composition, and water quality is determined by source water, the nature of industries connected to sewer, and their proportion of sewer discharge, and the effluent treatment processes. For the set of Australian samples considered stormwater had higher suspended solids, heavy metals and bacterial numbers, and lower dissolved solids, nutrients and oxygen demand than secondary treated sewage effluent. Guidelines on the quality of water for injection have been developed subsequently, as explained later in this paper.

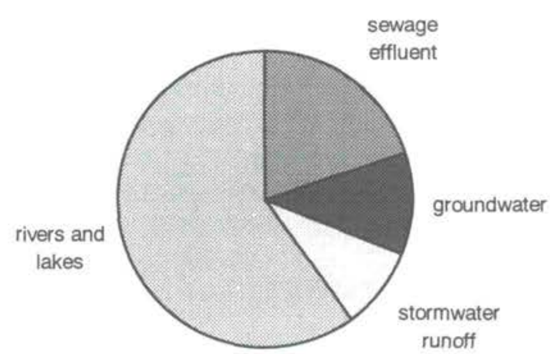

Figure 1. Types of ASR source waters *(n=45)*

Much has already been written about the benefits of ASR with stormwater (eg Dillon *et al* 1997, Gerges and Howles 1998). These have demonstrated that saline and brackish aquifers can be freshened for use as irrigation water supplies. ASR takes two un-utilised water resources, and adds value to them both by blending them at times of excess supply, storing until times of peak demand, and then recovering the water for the highest valued uses to which it can be applied. The economic viability of ASR with stormwater may depend on the establishment of urban stormwater detention ponds for flood mitigation or other purposes.

The viability of ASR with post-secondary treated effluent is currently being evaluated on the Northern Adelaide Plains. This will make use of installed effluent treatment capacity for direct reuse of reclaimed effluent for irrigation of food crops. Effluent supply is relatively constant throughout the year, but irrigation demand varies, and effluent supply in winter exceeds irrigation demand. Storage of surplus treated effluent in depleted aquifers over winter will enable it to be recovered in summer to meet peak demand, and thereby allow expansion of the irrigated area. A distributed network of ASR wells will enable this expansion without increasing the capacity of trunk pipelines in the irrigation distribution system (Gerges, 1996).

In USA, UK, Netherlands and Israel, ASR with mains water or its equivalent is practised. This is used to serve peak water demand where this exceeds water treatment capacity, and storage within the distribution system is small. Surplus treatment capacity in the off-peak season is used to treat water for injection into an aquifer, for subsequent recovery and return to the distribution system at times of peak demand, usually with minimal post-treatment (eg chlorination). In one system in UK, ASR is used for mains pressure compensation even on a daily basis.

An unexploited aquifer underlying or near a city is latent water resources infrastructure, which has a capacity to store, treat, and distribute water. A good aquifer, can be considered therefore as both a dam, treatment plant, and reticulation network, for which the capital cost is a comparatively trivial access and restoration charge, and the operating costs involve pre- and post- treatment, pumping, and monitoring costs. The access charge is simply the cost associated with drilling a well. Restoration costs are negligible where the groundwater is of suitable quality for the intended use of the recovered water. However in arid and semi-arid areas aquifers are commonly brackish or saline, and some injection of water is required to establish a water quality buffer zone.

As a principle, improving the environmental value of the groundwater resource should be an aim of ASR. As drinking water has a higher resale value than lower classes of water such as irrigation, it has been suggested that the utility of an aquifer would be improved most by insisting that injected water needs to be of potable standard. In reality, treatment of reclaimed waters to potable standards is rarely economically viable. Furthermore, this is not precluded as a future option so long as the principle of improving the environmental value of the resource is adopted. In addition, the needs of existing environmental values of the groundwater system need to be taken into account, including existing beneficial extractive uses of the groundwater and ecosystem support values. That is, the potential for negative aspects of ASR on groundwater quality and pressures should not be overlooked.

This paper advocates ASR not disposal of unwanted water into aquifers without thought of reuse. The latter may have significant and undesirable impacts on groundwater quality and pressures. The recovery element is important for maintaining a longer term hydrologic equilibrium in the aquifer and ensuring that there is an ongoing vested interest in the quality of the injectant.

3. EXPERIENCE WITH ASR OF STORMWATER

In South Australia research and development has concentrated until recently on injection of stormwater into limestone and fractured rock aquifers. A series of ASR sites has been established by Primary Industries and Resources, SA (Table 1). Drainage wells in Mount Gambier have been in operation for more than 100 years, and a water quality assurance program is being led by EPA to ensure that injected stormwater will not irreversibly contaminate the unconfined Gambier limestone aquifer which contains potable water in this area.

Previous accounts (Dillon *et al* 1997, 1998, Pavelic *et al* 1998) describe ASR operations at Andrews Farm a northern suburb of Adelaide. These commenced in 1993 and have been intensively monitored from 4 wells over a period of five years. Water was harvested from a stormwater detention basin, and injected into a Tertiary limestone confined aquifer containing brackish groundwater which in that locality was considered too saline for irrigation. A total of 240,000 m^3 (240 ML) stormwater was injected over four winter seasons, and the first major recovery of 100,000 m^3 was undertaken in 1997-98. The results are most promising, as clogging problems have been overcome, water quality in the aquifer has been protected, and the quality of recovered water is satisfactory for irrigation.

Results from Andrews Farm and the other SA sites, together with international reviews of ASR practice and regulations, and various fundamental guidelines of the National Water Quality Management Strategy were used to produce Australian guidelines for the quality of stormwater and treated effluent for injection into aquifers for storage and reuse (Dillon and Pavelic, 1996). These are different to other guidelines in use elsewhere in the world as they allow other beneficial uses besides drinking water, and they allow for the sustainable capability for treatment (notably for pathogen attenuation) within the aquifer. These guidelines were disseminated, along with other information including how to assess the suitability of prospective ASR sites at a two day workshop held at Glenelg in Oct 1996 (CGS, 1996), and further similar workshops are planned. An overview of the development of the guidelines is presented in Dillon and Pavelic (1998).

Table 1. Summary of Aquifer Injection Operations in South Australia

Site (Year commenced)	*Aquifer Type (Reference)*	*Source of Water*	*Infrastructure*	*Bore Recharge Rate L/sec*	*Annual Recharge Volume ML*
Mt Gambier (late 1800's)	Tertiary Limestone (Telfer, 1995)	Stormwater	300 drainage wells		2800
Andrews Farm (1993)	Tertiary Limestone Confined (Pavelic & Dillon, 1996; Dillon *et al*., 1997; Gerges *et al*,1996, Pavelic *et al*, 1998a)	Stormwater	wetland 1 injection well 3 obs. wells	15 - 20 (gravity or pressure)	100
Greenfields (1995)	Tertiary Limestone Confined (Gerges *et al.,* 1996)	Stormwater	wetland 1 drainage well 1 obs. well	10 -15 (gravity)	100
The Paddocks (1995)	Tertiary Limestone Confined (Gerges *et al.,* 1996)	Stormwater	wetlands 1 injection well	8	75
Angas Bremer (mid 1970's)	Tertiary Limestone (Gerges *et al.,* 1996)	River flow	~30 drainage wells	5-40 (gravity)	1000
Clayton (1995)	Tertiary Limestone Confined (Gerges *et al.,* 1996; Gerges & Howles, 1998)	Lake	1 injection well 7 obs. wells	40	70
Northfield (1993)	Fractured Rock (Stevens *et al.,* 1995)	Stormwater	wetland 1 drainage well 1 obs. Well	10-15 (gravity)	40
Scotch College (Torrens Park) (1989)	Fractured Rock (Armstrong, pers. com.)	Creek flow	1 injection well 1 production well	15 (gravity)	40

In Bandung, Indonesia, CGS and local partners have commenced preliminary research on the potential for reversing groundwater declines by injection of roof runoff. There are numerous other opportunities for ASR to prevent land subsidence and saline intrusion for cities located on deltas and over-using groundwater from confined aquifers. The main limitation in Asia is the quality of the water available for injection, but by being selective with sources of water, such as in Bandung, and with the type of aquifers into which to inject, or to exclude drinking as a potential use of recovered and affected water, it is possible to manage ASR so that substantial benefits can accrue safely and sustainably.

4. RESEARCH ON ASR WITH RECYCLED WATER

A three stage research project commenced in July 1997 to assess the potential for ASR with post-secondary treated effluent. A description of the project and its context is given in Bosher and Kracman (1998). The first stage was to determine through laboratory experiments on cores of aquifer material, using water like that intended to be injected near the Bolivar STP, whether such injection would be technically, environmentally, and economically sustainable. It was recognised that treated effluent differed from stormwater in its nutrient and microbiological content, and these may affect clogging (Rinck-Pfeiffer *et al*, 1998), transport and viability of pathogens (Pavelic et al, 1996,1998b), and biogeochemical reactions within the aquifer (Rattray *et al*, 1996). Furthermore the potential impacts of ASR on adjacent aquifers and on pressures and quality in wells of other groundwater users in the area needed rigorous assessment. This work is currently underway.

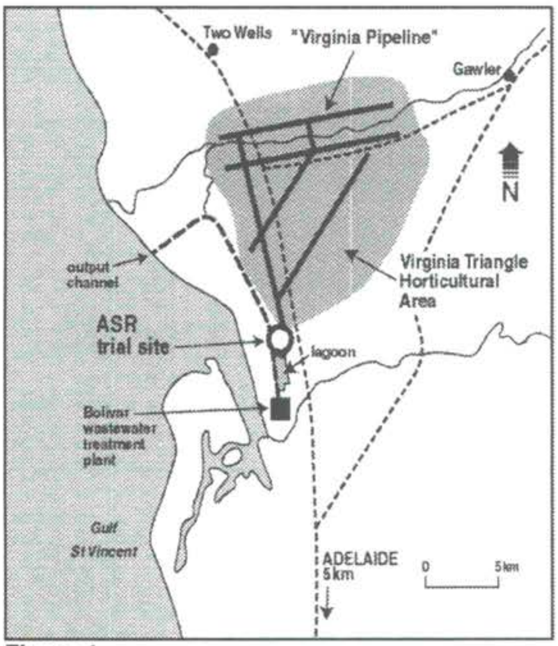

Figure 1
Northern Adelaide Plains location map showing Bolivar WWTP, ASR trial site, the Virginia Pipeline Scheme and Virginia horticultural area.

A sound understanding of the physical, chemical and microbiological processes occurring within the aquifer is important to manage ASR systems with confidence. The results from a well-instrumented and monitored injection trial at this site will be used to test models of these processes, with the intention of using these to assist in the design of treated effluent ASR operations at other sites, using site-specific data.

Risks that were identified for the Bolivar ASR project, and on which the project focused were specifically related to subsurface processes. These may affect groundwater quality or pressure in the aquifer, the quality of recovered water, the quality of water in an overlying aquifer, and the stability and integrity of the well and aquitard.

The broader issues associated with water recycling and reuse have been fully explored by many researchers, eg see Asano (ed.) (1998). Recycled water in comparison with typical stormwater at Andrews Farm has higher nutrient and organic concentrations, higher partial pressure of CO_2 and, like stormwater, has a possibility of containing pathogenic microorganisms. Unlike stormwater, there is significantly more control on the quality of water available for ASR, which has been seen in USA as a reason for preferring recycled water to stormwater for artificial recharge intended to create potable water supplies (NRC, 1994). Most ASR sites in USA have been constructed for potable water supplies with potable or near-potable source waters (Pyne, 1995). Some of the perceived risks associated with ASR of recycled water at Bolivar include the possibility of:

- growth or survival in the aquifer of injected pathogens
- injected water reaching existing water supply wells
- irreversible clogging of the well, or nearby aquifer
- growth of opportunistic pathogens indigenous to the aquifer
- well or aquitard instability due to aquifer dissolution or pressure changes
- recovered water having an excessive proportion of brackish native groundwater, and
- aquifer storage capacity being inadequate for economic ASR.

A summary of the research addressing these risks is given in Dillon *et al* (1999).

5. EXPERIENCE WITH ASR OF MAINS WATER

Early experience with mains water ASR was obtained by Miles (1952) who injected mains water into aquifers via several wells in the Adelaide metropolitan area. (This followed several droughts during which groundwater was pumped into the mains to supplement supplies.) Miles' results for pressure injection were promising, but presumably due to the low frequency of reservoir spills, the costs of setting up injection wells, and the uncertainty over water quality which could be recovered after a period of storage in the aquifer, his plan for ASR wells established on a 3 km grid across the Adelaide Plains languished. The concept of restoring aquifers was not considered and opportunistic recharge of brackish or depleted aquifers using mains water in occasional wet years has considerable merit. This would create emergency supplies and increase groundwater reserves where they have economic value.

Experience in injecting raw drinking water into a highly saline (35,000 mg/L) unconfined aquifer at Clayton (Gerges and Howles, 1998) has revealed that the recovered water, although marginally more saline than the injectant, is still within NWQMS guidelines for raw water for drinking supplies, and has substantially lower turbidity than the lake water. Filtration within the aquifer is an appealing aesthetic benefit of ASR. Opportunities for ASR adjacent long pipelines are also being explored in SA as a means of augmenting water supplies to remote towns in arid areas at times of peak demand.

In wetter areas of Australia, where spill may be more frequent, mains water ASR could be more attractive than reclaimed water ASR as a water resource conservation strategy, especially if water treatment capacity is limited. Mains water ASR may also be a practical strategy to reduce land subsidence in coastal areas drawing groundwater for drinking supplies, industry, or aquaculture, such as commonly occurs in overexploited delta deposits in South East Asia. Where aquifers are used for drinking water supplies, mains water ASR is recommended in preference to the other methods, for which restrictions may be imposed on the recovery of water for drinking supplies.

To capture these opportunities and develop economic strategies will require a good working model of the groundwater system, a forecast of the amount and frequency of availability of surplus mains water, and an assessment of the economic and environmental benefits which would be produced, including reduced risks of failure, and relate these to the capital and operating costs. Models of mixing and recovery efficiency which are currently being developed, would be an important part of such economic and technical assessments.

6. LEGAL, SOCIAL AND ECONOMIC ASPECTS OF ASR IMPLEMENTATION

Implementation of an ASR operation in South Australia requires a series of approvals. These include the rights :

- to take water from a watercourse or drain
- to inject water into an aquifer, and
- to extract water from an aquifer.

These take account of the rights to water of others in the catchment (including environmental flows), protection of groundwater quality, and the sustainability of the groundwater resource, and are based on two acts, the Water Resources Act and the Environment Protection Act..

There is a requirement that proponents submit an environmental management plan, consisting of protection measures, monitoring to demonstrate compliance with the plan, and contingency plans in the event of a failure. Protection measures may consist of:

- prevention of the harvesting of contaminated water,
- monitoring of the quality of incoming water,
- shut down systems to prevent injection of contaminated water,
- restricting injection pressures to avoid breaching of any confining layer,

Prior to implementation of the recycled water ASR trial, there were six community meetings held to inform the local community about the trial, and give the opportunity for feedback. Quite clearly the community was concerned with the protection of their drinking water supplies and implications for the health of all who drink that groundwater. All were satisfied after the meetings that the issues were being addressed in our research, and their water supplies were not at risk. However we undertook to keep them informed through newsletters and an open day of the outcomes of the trial, and that there would be no expansion of the project to other sites until the results of the trial had been analysed and reported.

The cost of water from all stormwater ASR sites, taking account of depreciation, maintenance, and operating costs, was less than half the price of the city reticulated supply. This has stimulated considerable demand by local government, and racing and golf clubs who have responsibility for large areas of grass. While there are financial incentives to minimize monitoring costs, for all operators who make substantial savings or profits there is an incentive for them to maintain and monitor their operations appropriately. Marginally economic operations are discouraged as there is little incentive to keep them operational, and presumably only minimal resources could be devoted to maintenance.

7. CONCLUSIONS

Stormwater ASR has been proven to be viable and will no doubt develop as a fringe benefit of establishing stormwater detention ponds in urban areas. It has wide applications for industrial estates, and municipalities with significant irrigation demands. ASR with treated effluent, has proved viable for highly treated effluents elsewhere in the world for recovery as drinking water supplies. The Australian studies currently underway are testing viability for less highly treated effluent and other beneficial uses. This will have significant potential in generating irrigation resources from otherwise wasted winter/wet season effluent. There is also a niche for ASR with mains water as part of drought-proofing cities, or aquifer restoration or replenishment operations. This may be particularly attractive where groundwater is potable. Combinations of these techniques may be used in any city where there are suitable aquifers. Applications in Asia where there are significant environmental problems such as over-exploitation of groundwater leading to land subsidence and saline intrusion may be particularly useful, as the confined aquifers may be re-pressurised directly.

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Session 5: Leakage Control and the Reduction of Unaccounted-for Water

Advantages of Leakage Control and the Reduction of Unaccounted-for Water

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Introduction

The provision of adequate and safe drinking water supplies and the availability of appropriate wastewater facilities form a basis to improve the health and the standards of living of the developing world populations. These benefits will be accrued when the installed systems operate continuously and reliably, to the extent of their capacity and in agreement with acceptable levels of services quality.

In a number of cities of the developing world, more than 25% of the water produced is lost before reaching the consumers, with some drinking-water supply networks losing more than 50% of the total water produced. Water supply networks in several developing countries are constructed predominantly with poor quality asbestos-cement, plastic (PVC, HDP), concrete or steel. Most industries have metered water consumption whereas this is generally not the case for domestic consumption. The technological features of water and wastewater treatment plants in developing nations do not differ substantively from those in industrialized cities. However, there are still serious difficulties with regard to the lack of spare parts and technical assistance and local skills vis-à-vis imported equipment or installations, specially electronic instrumentation. The water supply systems frequently function intermittently because of deficient operation, neglected maintenance and high levels of leakage. It is not unusual that the water distributed by leaking pipelines of the distribution network is contaminated through wastewater from defective sewers.

Although many factors contribute to the situation described above, the greatest impact stems from a lack of effective management and lack of clearly defined objectives and policies and where institutional, managerial and operational adjustments would be particularly crucial to making the most of existing facilities. Such adjustments, aimed particularly at reducing the unaccounted-for water to acceptable levels, should be viewed as a pre-condition for implementing new projects dealing with rehabilitation, replacement or expansion of services.

Efforts are being made by various international institutions, including the World Health Organization (WHO) to promote better management practices and improved operation and maintenance as a strategy to make the most of existing water supply and sanitation systems and to reduce unaccounted-for water. In order to make these efforts more effective, a working group on Operation and Maintenance was established by WHO, under the framework of the Water Supply and Sanitation Collaborative Council, whose major aim is to promote and support action on this important issue. This Group has produced various useful tools (guidelines, manuals, training packages and other information materials) dealing with most of the issues affecting sector performance and unaccounted-for water.

The approach for reducing unaccounted for water includes a set of programmes and activities aimed at the optimization of water supply and sanitation facilities through improved operation and maintenance and sound management practices. These programmes are not confined to the technology aspects of the problem (leak detection, etc). They also tackle priority factors related to the <u>causes</u> of unaccounted-for water including institutional and organizational aspects, financial constraints, supplies, transport, information systems, human resources, etc.

The establishment of a process conducive to improved efficiency and effectiveness and adequate institutional and managerial adjustments aimed at the proper carrying out of water supply and sanitation services and reduction of unaccounted-for water, requires substantial changes in the managerial culture of the water agencies. The required action should be tackled in an integrated way with a view to orienting the formulation and implementation of multidisciplinary programmes intended for overcoming the identified problems and constraints. Such programmes and activities should be prioritized, scheduled and implemented as a conjunct of interrelated and interdependent action in which cost-effectiveness should be a major concern. For instance, where the water and sewerage tariffs are not realistic and the consumers' registering system is not effective, a programme to overcome the latter constraints should receive priority because this would be an important factor contributing to the feasibility of the overall programme.

Sector Constraints

Many reasons have been identified as contributing to, or causing poor services and high levels of unaccounted-for water. These range from poor organizational structures in the responsible agency, lack of spare parts, inappropriate technology, lack of trained staff, tied aid, absence of career opportunities, insufficient funds, inadequate legal framework problems, lack of motivation by sector personnel, non-involvement of the users, the low profile of actions addressing optimization of services including leakage control, inadequate tariff and collection systems and negative political interference. These causes tend to be interrelated and intertwined.

The Operation and Maintenance Working Group of Water Supply and Sanitation Systems (OMWG) identified the following key issues contributing to poor performance of water supply facilities:

Inadequate Data

There is an overall lack of data regarding the performance of the water supply and sanitation agencies. Precise, accurate data on the systems which are not performing properly are needed, together with information on the main reasons why. Detailed figures are also necessary to determine how much it costs to undertake an adequate unaccounted-for water programme for different types of facilities.

Data are also required on the rates of breakdown of different systems such as pumping stations, pipelines in distribution networks, treatment plants, etc.

Crucial indicators such as unaccounted-for water and its distinct elements are frequently unavailable or are inaccurate.

Until this information is forthcoming it will not be possible to accurately assess the performance of the water systems and compute the financial losses due to poor operation and maintenance. These exact financial data are urgently needed to demonstrate to decision makers the advisability of implementing good programmes addressing the reduction of unaccounted-for water and leakage to acceptable levels.

Insufficient and Inefficient Use of Funds

Insufficient funding has been identified as a major contributor to poor operation and maintenance performance and high levels of unaccounted-for water. This lack of funds hampers the operating and maintaining of water supply facilities as money is not available to buy spare parts, properly train staff and provide competitive salaries to attract high calibre personnel. External support agencies have traditionally been reluctant to finance operation and maintenance activities while national governments have often given it a low priority. National governments are frequently stressed for cash, especially hard currency which is needed to pay for spare parts and the water supply agencies usually lose out to other, judged more important higher profile sectors.

The users are a potential source of finance for water supply systems. They are often unable or unwilling to pay. Usually it is that they are unwilling to pay rather than unable to. Evidence is mounting that even in the poorest and most underprivileged segments of the community people are willing to pay for a reliable, adequate supply of clean water but unwilling to be charged for an unreliable and unsatisfactory service. It is a vicious cycle. As the service level drops due to high unaccounted-for water and high leakage levels the users withhold support and become less willing to pay which further constrains operation and maintenance activities.

Sometimes it is the inefficient use of funds rather than a lack of money which contributes to poor performance. The poor management of facilities results in the squandering of resources which then reduces the viability of the water supply system. Those responsible for managing water supply facilities need to look carefully at their operations to ensure that they are operating efficiently. Too often many unskilled staff and poor logistical and organizational structures are common problems.

Losses of revenue from unaccounted-for water are a problem for most systems. It is difficult to define what is an acceptable level for unaccounted for water. A figure of 25% may be appropriate as a first target for an agency working at unaccounted for water levels of 50%, but significantly lower levels can and should be achieved. What is an acceptable level of unaccounted for water has to be determined on the basis of local conditions, but true wastage should not be significantly above 10% once illegal connections, free supplies, and leakage are reduced to acceptable levels and adequate metering, billing and collection procedures are maintained. High rates of unaccounted-for water, whether they are caused by illegal connections, leakage, free water supply, or the result of inadequate commercial operations, result in significant financial losses and poor service performance.

Management of Water Supply Systems

The water supply and sanitation systems will perform poorly if they are not managed efficiently and well. Typical management-problems include:

- inefficient organizational structures;
- absence of career structures for staff;
- low salaries; and
- poor relationships between the users and management.

The inefficient organization of many water supply agencies is a serious deficiency. If the organizational structure does not promote and allow efficient use of existing resources then the overall management will function poorly.
Personnel problems are another reason for poor management performance and high levels of unaccounted-for water. Low salaries, absence of career structures, lack of trained personnel and the low profile of operation and maintenance including the required action for reducing unaccounted-for water, as compared to new construction, are all constraints. Some of these can be traced to a lack of sufficient funds in the agency but often they are the result of inadequate management.

The absence of transparent management and accountability to the users is another major issue. Often the users are not involved in the water supply agency and there is no feedback from the consumers to the management of the agency. This is particularly acute in government owned and operated agencies which tend to be bureaucratic. This non-involvement of the users in the management of the agency results in stress and in some cases the development of a confrontational relationship between the agency and the consumers. Studies of well run water supply agencies have shown that good customer relations and a sense of management responsibility to the users are common denominations in these organizations, contributing to their overall success.

Inappropriate System Design

No matter how good the management of a water supply facility is, if it is not well designed technically, it will operate inefficiently. Many water supply facilities have been badly designed, poorly constructed and use technologies which are inappropriate. When a facility is improperly designed and constructed it cannot perform satisfactorily.

There are many reasons for poor systems design. In some instances consultants are chosen by ESAs who are not familiar with suitable technologies for use in the developing world and specify equipment and/or designs which are inappropriate. In other cases, there may be political interference to promote one particular pipe material or supplier and they may not represent the optimum choice for that particular situation.

A lack of communication between the system designer and the operators of the system is a further drawback. The operators of the system need to be familiar with, approve of and be comfortable with the technology. In addition there needs to be a continuous feedback of information from the operators to the designers to pinpoint problems with the design and suggest remedial measures.

Poor quality pipes and valves used in distribution systems or pipes installed without the appropriate technical requirements will result in serious leakage problems during the whole life span of the project.

Low Profile of Operation and Maintenance

Operation and maintenance in water supply agencies has a low, and usually an inferior profile as compared to new construction and system extension. Thus, for career minded engineers the route to top management positions is recognized to be through new construction and not operation and maintenance.

The emphasis on and recognition given to new construction is partly due to its political visibility. The provision of a water supply to many developing world communities is a vote winning exercise, while efforts for the effective and efficient functioning of the system receives few political accolades.

There is also lack of accurate figures on the costs involved in operating under high unaccounted-for water levels (UFW) and the benefits of bringing UFW down to acceptable levels. An urgent priority is to collect precise figures which clearly show to decision makers, the financial benefits of sound unaccounted-for water programmes.

Inadequate Policies, Legal Frameworks and Overlapping Responsibilities

There is a need for clear sector policies, adequate legal frameworks and a clear division of responsibilities and mandates within the water and sanitation sector. The lines of responsibility between the various organizations involved are often blurred. This is particularly true of the relations between water supply and sanitation where the maintenance agencies, not rarely, have no or limited contact.

The policies of ESAs with reference to operation and maintenance are frequently different and may be at variance with the approaches of national governments. National governments and ESAs should collaborate and coordinate their approaches in order to achieve higher levels of performance for O&M and minimum levels of unaccounted-for water.

Political Interference

Political interference has been identified as a serious contributing reason for poor performance of water supply and sanitation agencies. This is most noticeable in countries where the government is directly involved in owning, operating and maintaining the water supply facilities. Political interference manifests itself in several ways. In some cases, for political reasons, water is free or is not charged according to the costs of operation and maintenance and to cover capital costs. This decision not to charge properly for water makes it difficult to run a self financing viable system, even if government provides funding. When governments are short of cash, often it is the water supply facilities which are soft targets and experience the greatest budget cuts.

Political interference is often evident in the choice of technologies. Government officials may for one reason or another support the purchase of a particular material or equipment which may not be the best or most appropriate selection. Equipment suppliers and ESAs frequently hinder the wise choice of material and equipment by lobbying politicians or through restrictive policies of tied aid.

The contracts awarded for building water supply facilities are significant and there is considerable competition between contractors to be selected. In some cases the job may be awarded for political reasons rather than on the basis of performance with the result that the completed facilities may be shoddily constructed. The consequence will be high leakage levels and poor performance.

A possible alternative for the better management of water supply facilities is to devolve the responsibility of managing systems from government to autonomous agencies which will manage the facilities under technical, financial and administrative guidelines from the government. This would greatly limit the extent of political interference by governments and allow the facilities to be managed more efficiently.

An Unaccounted-for Water Programme

The reduction and control of Unaccounted-for Water and the optimization of water supply and sanitation systems should be adopted as a priority phase in an institutional development process. The development of this process requires the formulation and implementation of priority programmes and projects.

Although several constraints are basically similar for a broad range of water agencies in developing countries, the constituent elements of these programmes as well as the strategies and resource requirements can vary widely from one institution to another. Therefore the priority projects and programmes should be selected, formulated and implemented to meet the particular requirements of each institution. These programmes are multidisciplinary. At the various stages of their promotion, formulation, implementation and monitoring, a great amount of work will be required, involving staff dealing with different expertise areas.

It is important to emphasize that this paper does not advocate the preparation of standardized projects for application in all cases. Although it is possible to make an attempt to foresee all possible, frequent and common problems and to design similar solutions to overcome these problems, each programme formulation should meet the specific requirements of each particular water agency.

A programme aimed at the reduction and control of unaccounted-for water includes the overall set of activities carried out by an agency to achieve and maintain a level at which the losses from leaks, overflow, illegal use of water, waste of water, operational consumption, special consumption, and errors in metering or consumption estimation will be the lowest possible in conditions of technical, economical, financial and institutional viability.

Lack of efficient agency management leads to an increase in the levels of unaccounted-for water, with a consequent need for the construction of new systems or expansion of existing ones well before the planned time.

The formulation and conducting of UFW programmes will require a study for the diagnosis of losses, with the formulation and implementation of actions for their reduction to technically and economically acceptable minimum values.

These actions include the coordination and cooperation of those participating in the process, including suppliers, consultants and contractors. The following are projects which are commonly included in an unaccounted-for water programme. Most of them meet the requirements and refer to constraints of a wide range of water agencies in Member States.

A. Applied Network Survey

This project includes different performance tests of the various parts of the water supply system. It allows the preparation of a hydraulic/consumption diagnosis with the identification of the real operational and hydraulic conditions of the system. This diagnosis can then be used to orient measures for the improvement of performance of the system under controlled conditions. The most common performance tests include the following: water consumption; capacity tests of distribution networks; composition of unaccounted-for water; measurement of flows and pressures in sections of mains through portable equipment; determination of the water-carrying capacity of pipelines; checking for the presence and location of obstruction in pipelines; checking the accuracy of macrometering devices; determination of characteristic curves of centrifugal pumps; performance assessment of pumping stations, etc.

B. Macrometering project

The macrometering project deals with the installation of permanent measuring devices for collecting, processing, analysing and disseminating routine operational data regarding water flows, pressures and levels in the supply systems.

Macrometering is an indispensable tool for guiding the operation of the water supply system and for obtaining statistics on both production and distribution of water including unaccounted-for water, leakage, etc., on a permanent basis.

C. Leakage control project

The major aim of this project is to reduce to a minimum the average time that elapses between the occurrence of a leak and its elimination, through the revision and improvement of management practices and adoption of effective techniques. To that end, procedures must be established for the identification, reporting, repair and accounting for visible leaks, with the active and conscious participation of both the population served and staff members of the water authority.

D. Project for the mapping and inventory of pipes and fittings in the water supply system

This project should provide for the establishment of routine procedures for the preparation and updating of the mapping and inventory of pipelines. It is recommended that a single mapping system be adopted and that it should be possible to exchange map information with other public or private utility services (electricity, telephone, etc.)

E. Project for improvement of house connections

The house connections are frequently responsible for the majority of leaks in the distribution system. Thus, the aim of the project in question is to develop a rational system for designing, sizing, standardizing, installing, inspecting, accepting and conducting sound quality control of house connections. In view of its impact on losses, high priority should be accorded to this project.

F. Project for operation control of the water supply system

The efficient and effective operation of a water supply system depends on the knowledge of the variables affecting the continuity, reliability and amount of the water supplied to the consumers. The operation control project should include both routine operation and operation planning.

Routine operation is the conjunct of activities which result from the analysis of selected variables which are continuously communicated to an operating centre with a view to establishing in the water supply system the configuration best suited to that particular moment.

Operation planning consists in the definition of criteria and options for operation in relation to anticipated configurations of the water supply system. These criteria are determined on the basis of an analysis of the effects of specific operation actions on the hydraulic configuration of the water supply system and in the light of studies of simulated operating situations. For that purpose, mathematical simulation models could be utilized after all the basic knowledge on the network being collected: maps, flow and pressure distribution and characteristics of pipelines and equipment. This approach can be very useful, particularly in the case of systems in which the size and complexity would justify this excellent tool for operators and planners. It also would prevent high-pressure in certain parts of the distribution network minimizing the risk of pipe breakdown and would minimize the amount of leakage.

G. Water Demand Project

This project should develop and implement a consumer water conservation programme. The development and use of low-consumption sanitary devices (e.g. poor flush toilets) and the education and mobilization of the population for an efficient use of water, would greatly reduce water wastage due to inadequate uses at home and due to faulty fittings and hydraulic devices within the properties.

H. Electromechanical maintenance and instrumentation project

The project should provide for the formulation and implementation of a preventive maintenance system organized so as to systematize the process. That is to say, the system should specify the date, place, equipment, and maintenance procedure. The process should include a procedure to issue a work order for the task(s) to be performed. It should also generate information whereby the quality and reliability of the process can be evaluated and the relevant decisions taken.

I. Project for maintenance of distribution networks

The objective of this project is to improve the level of maintenance of distribution networks and house connections through improved coordination and planning of office and field work and through the use of adequate techniques, equipment and materials for field interventions. Consideration must be given to aspects such as flexibility of maintenance scheduling and team action, types of vehicle used, tools, special spare parts and fittings, the coordination of activities, quality control of services, and training of the staff for better public relations in their interaction with consumers.

J. Project for review of design and construction criteria

This project deals with adjustments in design and construction criteria so as to minimize the investment, operation and control costs of distribution systems. The planning, design and construction of distribution systems should provide for the inclusion of special arrangements in the design and construction phases that would facilitate the work dealing with leakage control, district metering, operation of the network and maintenance of pipes and fittings.

K. Projects in the Commercial System

Considering the need to generate internal resources to cover operation and maintenance and capital costs, the commercial system of a water authority is of crucial importance to ensure the long term sustainability of the services. The main components of this project should include users' registering, universal metering and effective billing and collecting.

Projects in this system should have priority because they contribute substantially to reducing the extent of unaccounted-for water, inasmuch as they result in an increase in the revenues and a reduction in the costs associated with volumes which are not accounted for.

L. Materials and equipment quality project

The aim of the Materials and Equipment Quality Project is to introduce technical and administrative procedures for achieving an improvement in the processes of procurement, follow-up during manufacturing, acceptance, transport, storage, and installation of materials and equipment.

M. Water quality project

The objective of this project is to ensure that the water provided to the consumers is according to national standards and international guidelines (e.g. WHO Drinking Water Quality Guidelines).

N. Support projects

The adequate formulation of programmes for the improvement of Operation and Maintenance and reduction of unaccounted-for water should include actions to support and facilitate their implementation, as follows:

- **organizational arrangements**, particularly with regard to the units which deal with unaccounted-for water and related areas
- **development of Human Resources**, including the improvement of managerial performance; training courses; elaboration of post profiles and personnel profiles and reorientation of cadres; improvement of Human Resources Development service;

- **development of an Information System** destined to collect, process and disseminate information on operation, maintenance and related areas;
- **improvement of the Transport Service**, including the adequacy of the transport facilities, in terms of quality and quantity and the improvement of the vehicles' maintenance service;
- **improvement of the Material and Equipment Supply**, in order to ensure a timely delivery of spare parts and maintenance material;
- **community Involvement and Participation** in unaccounted-for water programmes

Conclusions

- The success of an unaccounted-for water programme, which is highly complex when dealt with in a comprehensive way, requires concerted efforts within the water agencies. It requires considerable efforts concerning promotion, generation of awareness at all levels, formulation of suitable strategies and careful formulation and implementation of integrated programmes (diagnosis, objectives, targets, activities, resources and mechanisms).

- Unaccounted-for water programmes can be of crucial importance to the provision of services to the urban-poor. By reducing wastage and leakage, it might be possible to extend water supply services to peri-urban areas without the need for constructing new production facilities. Major health benefits for this unprivileged part of the population, which is normally at major risk of water-related diseases, would be derived from reasonable levels of unaccounted-for water.

- By developing the water supply institutions and by reducing unaccounted-for water, these agencies will be in a better financial situation and will be in a stronger position to achieve its financial self-sufficiency and long term sustainability.

- A number of tools (guidelines, manuals, and training packages) have been prepared by Operation and Maintenance Working Group of the Water Supply and Sanitation Collaborative Council addressing the above issues. They might be of great help in the formulation and implementation of programmes aimed at the reduction and control of unaccounted-for water programmes.

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Advantages of leakage control and unaccounted-for water -
a managerial approach

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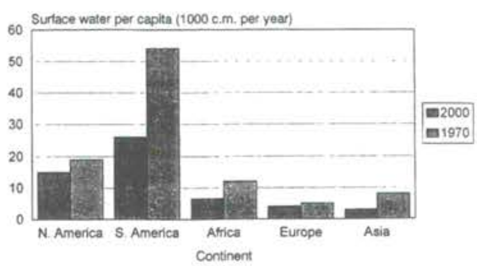
World Health Organization
Geneva, Switzerland

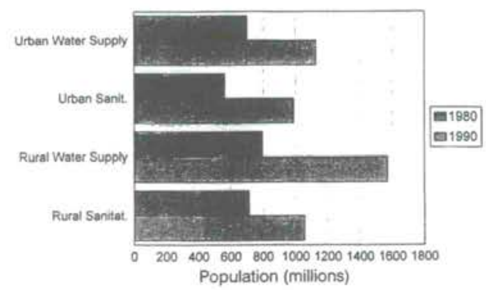
O&M Tools

- **Guidance Documents**
  - Selected case studies on O&M of water supply and sanitation systems
  - Tools for assessment of operation and maintenance status of urban and rural water supply and sanitation (position paper)
  - Management of O&M of urban water supply and sanitation systems
  - Applied network survey
  - Optimization of drinking water treatment plants
  - Characterization and evaluation of models of management systems for the operation and maintenance of rural water supply and sanitation facilities
  - Linking technology choice to Operation and Maintenance
  - Manual on O&M of handpumps
- **Training packages**
  - Training course package on leakage control
  - Training course package on management of O&M of rural water supply and sanitation.

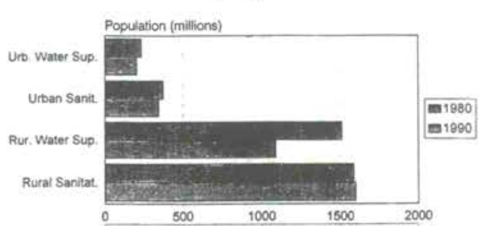
Water Resources Available



Coverage Levels 1980 and 1990 in Developing Countries

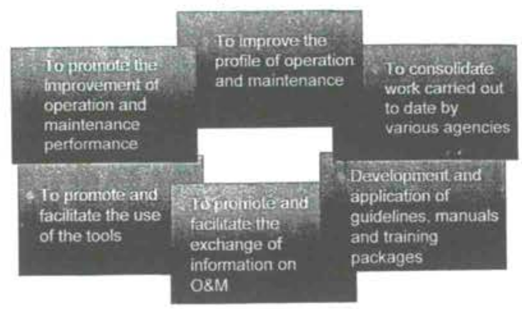


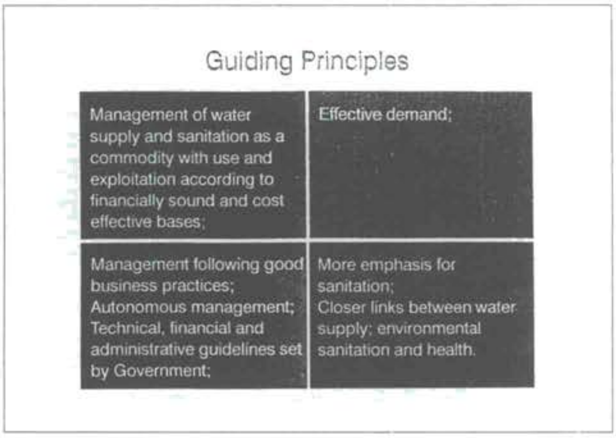
Population not Served 1980 and 1990 in Developing Countries



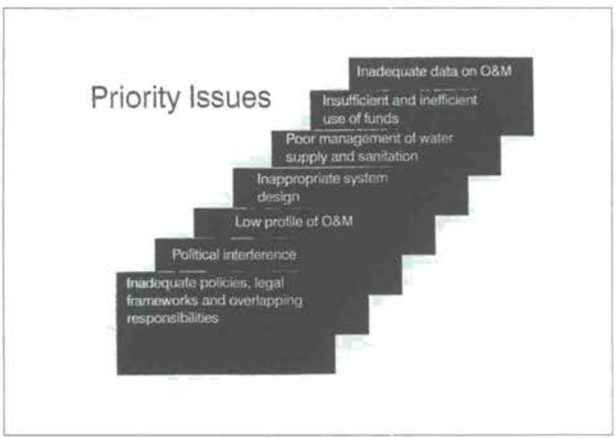
	Urb. Water Sup.	Urban Sanit.	Rur. Water Sup.	Rural Sanitat.
1980	235	374	1511	1591
1990	204	345	1088	1602

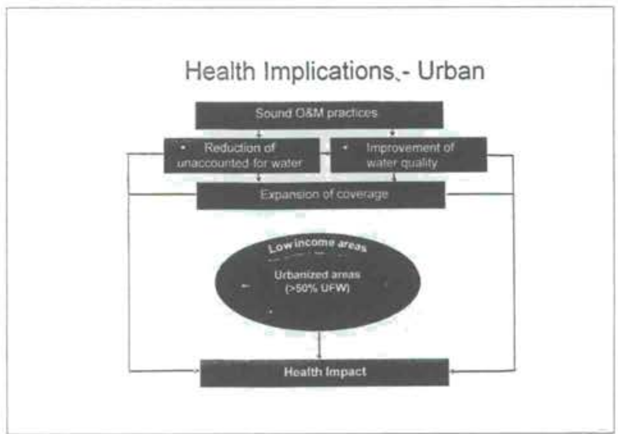
Scope of Work

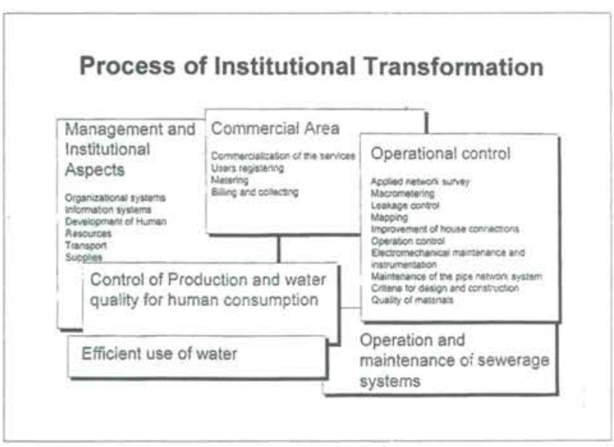


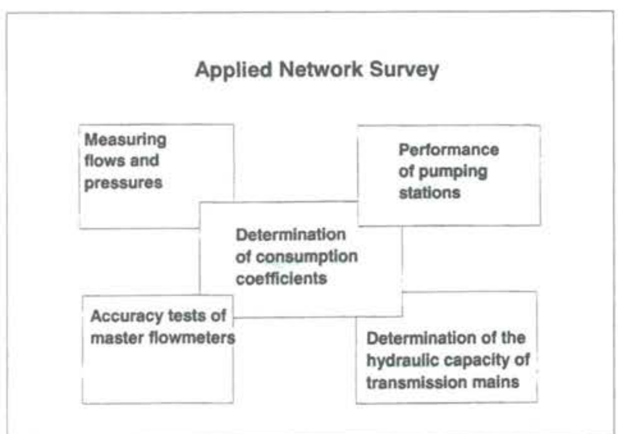

Guiding Principles
Management of water supply and sanitation as a commodity with use and exploitation according to financially sound and cost effective bases;
Effective demand;
Management following good business practices;
Autonomous management;
Technical, financial and administrative guidelines set by Government;
More emphasis for sanitation;
Closer links between water supply; environmental sanitation and health.

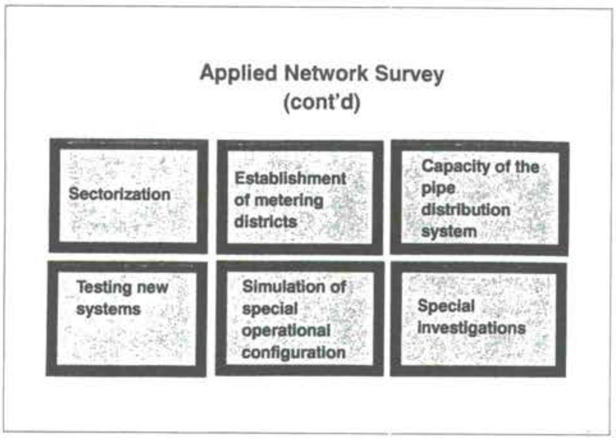

Operation and Maintenance Interlinkages
Planning
Project management
Human resources development
Operations
Services delivery
Maintenance
Community involvement
Information
Administrative aspects (supplies, transport)
Public/ private partnership
Financial (cost-recovery)

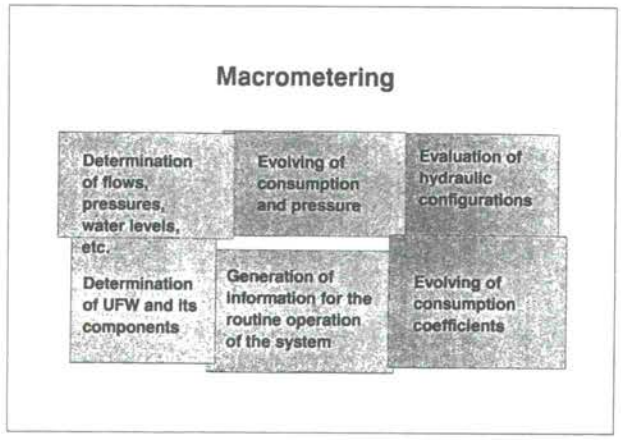

Priority Issues
Inadequate data on O&M
Insufficient and inefficient use of funds
Poor management of water supply and sanitation
Inappropriate system design
Low profile of O&M
Political interference
Inadequate policies, legal frameworks and overlapping responsibilities

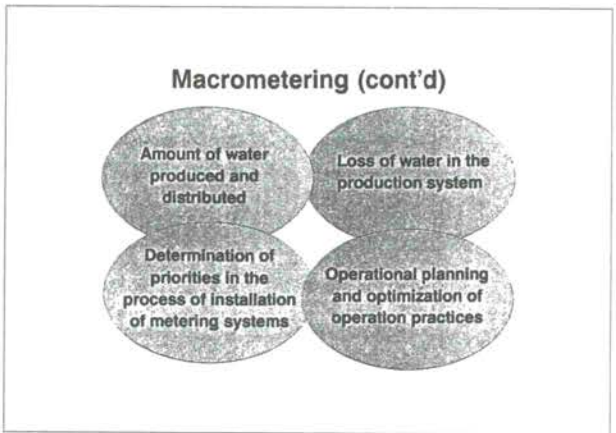

Health Implications - Urban
Sound O&M practices
Reduction of unaccounted for water
Improvement of water quality
Expansion of coverage
Low income areas
Urbanized areas (>50% UFW)
Health Impact

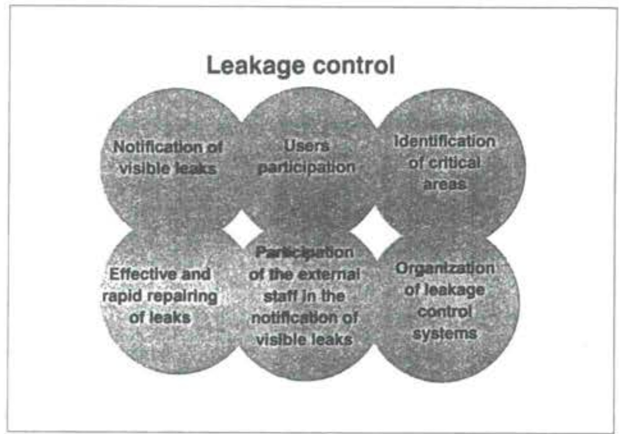

Process of Institutional Transformation
Management and Institutional Aspects
Organizational systems
Information systems
Development of Human Resources
Transport
Supplies
Commercial Area
Commercialization of the services
Users registering
Metering
Billing and collecting
Operational control
Applied network survey
Macrometering
Leakage control
Mapping
Improvement of house connections
Operation control
Electromechanical maintenance and instrumentation
Maintenance of the pipe network system
Criteria for design and construction
Quality of materials
Control of Production and water quality for human consumption
Efficient use of water
Operation and maintenance of sewerage systems

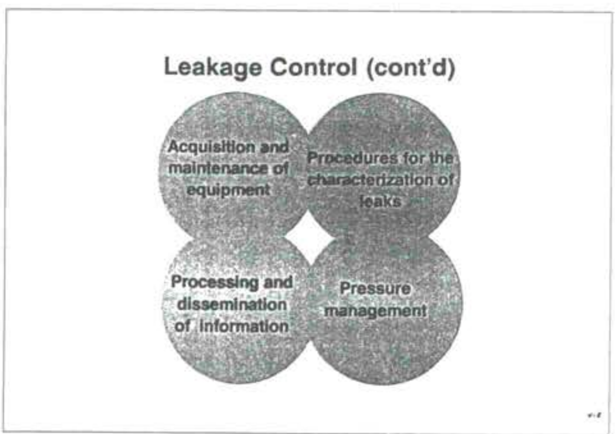

Applied Network Survey
Measuring flows and pressures
Performance of pumping stations
Determination of consumption coefficients
Accuracy tests of master flowmeters
Determination of the hydraulic capacity of transmission mains

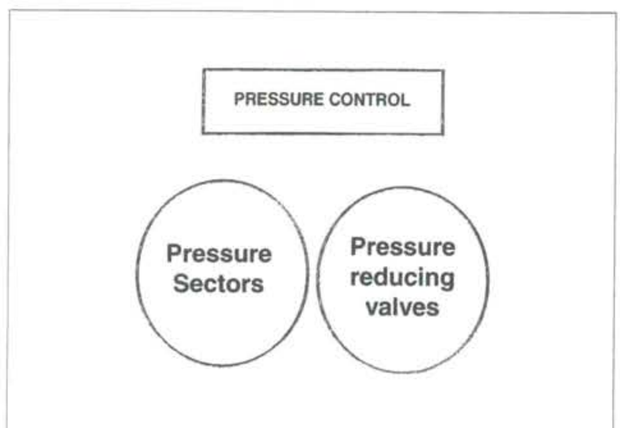

Applied Network Survey
(cont'd)
Sectorization
Establishment of metering districts
Capacity of the pipe distribution system
Testing new systems
Simulation of special operational configuration
Special investigations


Macrometering
Determination of flows, pressures, water levels, etc.
Evolving of consumption and pressure
Evaluation of hydraulic configurations
Determination of UFW and its components
Generation of information for the routine operation of the system
Evolving of consumption coefficients


Macrometering (cont'd)
Amount of water produced and distributed
Loss of water in the production system
Determination of priorities in the process of installation of metering systems
Operational planning and optimization of operation practices


Leakage control
Notification of visible leaks
Users participation
Identification of critical areas
Effective and rapid repairing of leaks
Participation of the external staff in the notification of visible leaks
Organization of leakage control systems

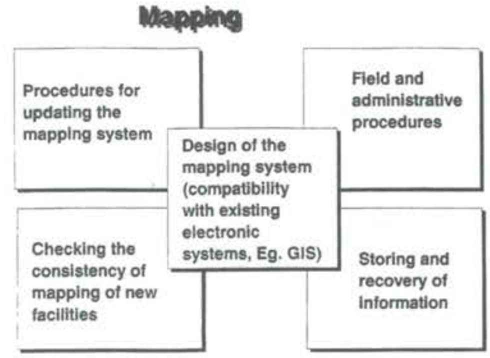

Leakage Control (cont'd)
Acquisition and maintenance of equipment
Procedures for the characterization of leaks
Processing and dissemination of information
Pressure management


PRESSURE CONTROL
Pressure Sectors
Pressure reducing valves

Leakage Control System

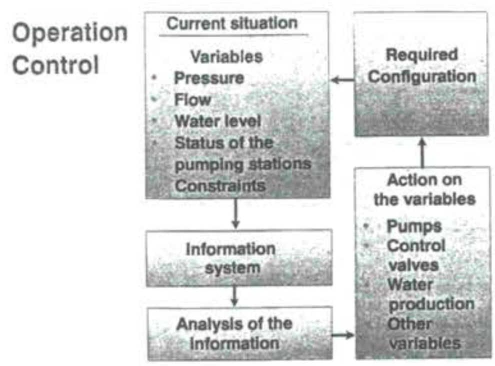
Three methods:

- Passive control
- Regular sounding
- Consumption monitoring



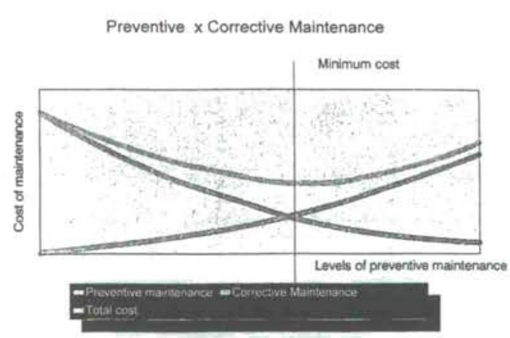
Improvement of House connections

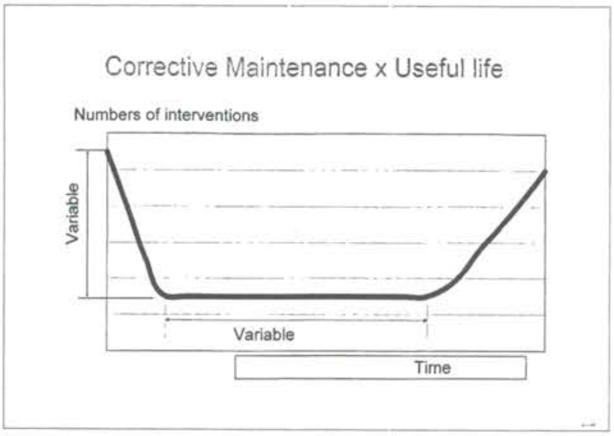
- Causes of leaks in house connections
- Determination of priority areas
- Reviewing of criteria for specification, acquisition, inspection, acceptance, storing and installation of house connections
- Training of plumbers
- Programmes of rehabilitation and replacement



Maintenance of Electromechanical systems

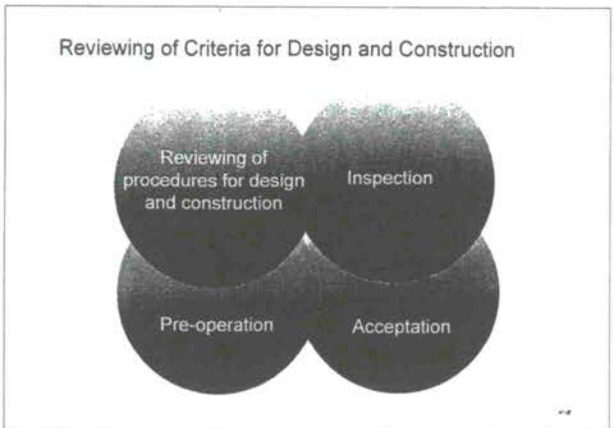
- Management of maintenance
- Establishment of procedures
- Preventive x corrective maintenance
- Preventive maintenance
- Rehabilitation
- Maintenance manuals

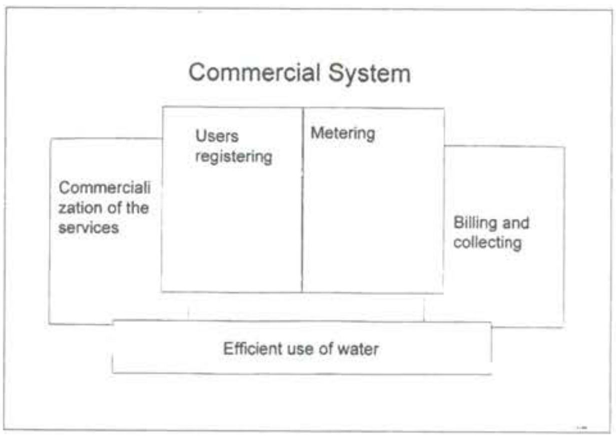




Maintenance of Pipe Distribution Systems

- Information systems and scheduling of maintenance tasks
- Formation of maintenance crews
- Procedures for interventions
- Specification and acquisition of equipment and tools
- Appropriate vehicles
- Performance control (indicators)





MONITORING AND MANAGING UNACCOUNTED FOR WATER

Richard G. Sykes, Andrew K. Enos and Ronald L. Bianchetti
East Bay Municipal Utility District, Oakland, California USA

INTRODUCTION

The East Bay Municipal Utility District (EBMUD) supplies water to approximately 1.3 million people in 35 cities and communities on the eastern side of San Francisco Bay in California. Over 90 percent of EBMUD's water supply comes from the Sierra Nevada Mountains via three 140-km (90-mile) long aqueducts. The remaining water supply is from watersheds and reservoirs in the local East Bay Hills.

Average water demand is approximately 760 million liters per day (ML/d) (200 million gallons per day or MGD). This water is produced by six water treatment plants. Two plants are operated year round, three plants are operated seasonally from 8 to 10 months per year, and the remaining plant is a standby facility. EBMUD's water distribution system includes approximately 6,400 km (4000 miles) of pipeline, 126 pumping plants and 165 treated water reservoirs.

EBMUD has conducted a program to monitor and manage unaccounted for water. This program is an integral part of the water system operation and maintenance and is critical to ensure efficient management of our limited water supply. Benefits of managing and minimizing unaccounted-for water include:

- Reduces demand on scarce water supplies and minimizes the need to develop additional supply
- Reduces water and revenue losses
- Reduces pumping and treatment costs
- Increased knowledge of the distribution system
- Reduction of property damage through improved maintenance

DEFINITION OF UNACCOUNTED FOR WATER

There is no universally applied or accepted definition of unaccounted-for water [1,2]. In general, unaccounted-for water is the difference between the water supplied to a distribution system and the water that leaves the system through its intended use. Some have defined unaccounted-for water as water supplied to a system less all metered water leaving the system. Other utilities use a broader definition whereby unaccounted for is all water that cannot be accounted for through measurement or estimation[3]. The value or percentage of unaccounted-for water is an excellent overall indicator of the operating efficiency of a water system.

EBMUD defines unaccounted-for water as total water plant production provided to the distribution system minus the sum of all metered flow from the system and all unmetered authorized uses. In this definition, unaccounted-for water includes water loss from all underground distribution system piping facilities, illegal connections or theft, and inaccurate metering.

Unaccounted-for water is very difficult to calculate if a water system is not metered. If the system is partially metered, then estimates can be made to account for water leaving the system that is legitimately being used in useful ways (e.g. fire fighting, hydrant and water main flushing, water quality, etc.). It is important that water utilities recognize and estimate these uses so that they can accurately determine the magnitude of losses such as leakage, illegal connections or theft, and inaccurate metering. EBMUD's system is metered for nearly all uses with the exception of fire hydrants. Most systems in the United States meter all residential, commercial and industrial uses.

Unaccounted-for Water Goal

A number of organizations have specified goals for utilities to use in managing unaccounted-for water. The California Urban Water Conservation Council, of which EBMUD is a member, identifies a 10 percent benchmark for unaccounted-for water [(4)]. If metered water sales plus other verifiable uses are less than 90 percent of water supplied to a distribution system, then steps should be taken by the utility to identify and reduce losses. In 1996, the AWWA Leak Detection and Accountability Committee recommended 10 percent as a benchmark for unaccounted-for water[(5)]. EBMUD water loss reduction programs aim to keep unaccounted-for water at 10 percent or less.

PROGRAMS FOR CONTROLLING WATER LOSS

EBMUD controls water loss using a variety of efforts. The first is to identify the magnitude and source of that loss. The second is to review accuracy of meters used to measure system inflow and outflow. The third is to develop an appropriate leak detection program. The fourth is to have a reasonable program to respond to identified leaks. The final step is to have a pipe replacement program that helps ensure a tight distribution system. Each of these efforts is described below in general terms that might be applicable to all water systems. Examples of EBMUD experiences are provided for each.

The First Step is Identifying Water Loss

Accounting for all water use is the first step in developing a program for water loss. Determing water loss quantity requires reliable estimates of water production and use. A checklist and method for determining unaccounted-for water is provided in "Water Conservation Plan Guidelines" published by the Unites States Environmental Protection Agency (USEPA) in August 1998. (This information is available on the World Wide Web at http://www.epa.gov/OWM/genwave.htm#guideline.)

The American Water Works Association Research Foundation (AWWARF) includes a water audit procedure somewhat similar to what EBMUD uses. The water audit is an accounting of all water into and out of a distribution system to determine the efficiency of the system and to identify the location and magnitude of water losses[1]. There are four basic steps for a water audit:

- Identify and quantify each source of water
- Identify, quantify and verify authorized metered water uses
- Identify and estimate unmetered water uses
- Identify and estimate water loss

The water audit information is the cornerstone of determining priorities for a program to control leakage and water loss.

EBMUD's process for estimating water loss involves measurement of all input into the distribution system and subtraction of the following items:

- All metered water use from revenue and non-revenue meters (non-revenue meters include fire services, some public facilities, and EBMUD facilities)
- All metered water use from portable hydrant meters supplied to contractors, cities and others for construction and municipal uses
- Estimates of water system flushing and cleaning
- Estimates of water loss from main breaks
- Estimates of water use from fire fighting and fire hydrant testing
- Estimates of leakage from distribution reservoirs

The remaining unaccounted-for water includes leakage from pipelines and underground appurtenances, meter inaccuracy, illegal connections and theft. From 1993 through 1997, EBMUD's annual rate for this water loss ranged from 8 to 10 percent. In 1998, the figure was 12 percent. For EBMUD, a 12 percent water loss rate equates to about 91 ML/d (24 MGD). Because of this recent increase, EBMUD initiated a review of its water accounting procedure. This review is underway and results are not yet available.

Meter Accuracy and Testing

Metered water sales are the base of revenue for EBMUD and most other water suppliers. Meter accuracy is therefore of great importance to ensure accurate billing. It is also important to water conservation efforts and necessary for accurately determining unaccounted-for water. AWWARF has indicated that meter accuracy declines over time, with under-registration being typical. The AWWARF also notes that the failure rate for small meters may be as high as 3 percent. Any water utility that wishes to measure and reduce unaccounted for water must ensure reasonable meter accuracy[1].

EBMUD's water system contains approximately 375,000 metered connections. Ninety percent of these are for residential customers. EBMUD maintains two programs to ensure meter accuracy. One program focuses on small meters. Small meters are defined as those with a diameter less than 76 mm (3 inches). These small meters represent about 80 percent of the revenue billed annually. Accuracy of these devices is determined by performing periodic calibration checks on a small subset of "worst case" units. For example, EBMUD just recently completed a check on 200 of its oldest small residential meters (16mm or 5/8 inch). This check indicated that 95 percent the units were reading within the specified accuracy of the device (typically registering 98 percent to 102 percent of actual flow). Based on these periodic checks, EBMUD assumes reasonable accuracy (within manufacturers limits) of its small meters. Currently, the replacement program for small meters is as-needed based on problems identified by meter readers or customers.

A more rigorous testing program is conducted for large meters which EBMUD defines as those with a diameter of 76 mm (3 inches) or greater. EBMUD has about 2,500 meters in this size range and they represent about 20 percent of revenue billed annually. Each of these devices is checked for accuracy at least once every 2 years. If accuracy is not within specified standards for the meter type and size, then the unit is repaired or replaced as appropriate.

All water meters are read monthly or bi-monthly by trained staff. Besides reading meters, these employees detect significant changes in metered water use and identify physical or accuracy problems. The meter readers issue repair orders for about 11 percent (about 41,000 units) of all meters annually. Thus, meter readers are an important part of ensuring meter accuracy, not to mention their role in identifying leaks in the vicinity of the meter.

Another step in ensuring meter accuracy is a review by staff who prepare customer water bills. At EBMUD, these employees are trained to identify unusual changes in water use patterns. As a result, they also issue meter repair orders based on possible accuracy problems. Repair/inspection orders of this type average about 6,000 annually.

Leak Detection Programs

Leak detection is an important tool in identifying and reducing water loss. Methods of leak detection range from very simple passive methods to complex systems using expensive electronic equipment and specially trained employees. Accurate distribution system maps will greatly aid a leak detection program.

Only about 30 percent of water leaks are evident at the ground surface [(1)]. Large, highly visible leaks are often reported by the public. Smaller, less visible leaks, such as at a meter or valve, may go unreported. Meter readers and other utility staff should report these leaks as an integral part of their work assignment. The remaining leaks, those which are not evident at the surface, should be part of an ongoing leak detection program.

For the non-visible leaks, listening devices are used for identification and location. These devices can be mechanical, such as a listening rod or geophones, or electronic, such as amplifiers, correlators, or amplitude attenuators. The mechanical methods are inexpensive and may be excellent for systems that cannot afford higher-priced electronic equipment, but are not as good at eliminating background noise and thus are less accurate. The electronic devices are more accurate but they are more costly. AWWARF provides an excellent description of various leak detection devices[1].

EBMUD has maintained a leak detection program since 1974, staffed by two employees. Each employee is equipped with the following items: a vehicle, electronic correlator, distribution system maps, pressure gauge, valve gate keys, hydrant spanner wrench, and traffic and safety equipment. About 320 km (200 miles) of pipeline are surveyed by the leak detection program each year. The program identifies about 150 leaks per year. This equates to about 0.5 leaks per km (0.8 leaks per mile) of pipe surveyed. Most of these leaks are on service laterals. Over the life of this program, EBMUD has found that fewer leaks are identified each year and the program is most efficient if the leak detectors focus on areas with poor soils and significant ground movement.

A utility that does not have a leak detection program may choose to retain the services of a qualified contractor to perform leak detection work until the cost-effectiveness of an ongoing in-house program is determined. Another alternative would be to provide existing maintenance crews with inexpensive listening devices which can be used on a limited-test basis. EBMUD provides selected maintenance crews with relatively inexpensive (approximately $2,000) electronic amplification devices to assist them in identifying leak locations prior to initiating repairs.

Leakage and Main Break Repair Practices

Identified leaks generally should be repaired in a timely, effective, and efficient manner. Utilities generally repair identified leaks when repair efforts are economically justified. In some cases, such as groundwater systems which provide no water treatment and where ample supply is available, it may not be cost-effective to repair small leaks.

Each water utility should establish standard criteria for determining which leaks are cost-effective to repair. Cost-effectiveness is based on the ratio of the cost saved by repairing the leak compared to the cost of the repair. Cost savings include reduced water leakage, energy savings due to reduced pumping, reductions in other O&M expenses related to the unit cost of water production (chemicals, labor, etc.), and deferred capital expenses. Some utilities, such as EBMUD, which operate in semi-arid areas, have a policy to repair any visible leaks and to conduct a cost/benefit analysis in those cases where leak repairs might be unusually difficult.

EBMUD's standard practice is to repair most visible or identified leaks regardless of size. If a leak is estimated at under 114 liters per minute (30 gallons per minute) (gpm), it is usually repaired as a low priority within 7 to 21 days of the work order identifying the leak. Leaks estimated at 114 liters per minute (30 gpm) or greater are repaired within one to seven days. These criteria do not apply to main breaks.

Main breaks represent a type of leak that is severe, usually highly visible, and has significant impacts to the utility and its customers (usually no water or low pressure). Typically, main breaks are repaired immediately as they represent loss or potential loss of service to utility customers.

Leaks can occur at fittings, joints and anywhere along the length of a piece of pipeline. Typical causes of leaks include corrosion, poor joint material, poor construction practices, insufficient thrust restraint, poor tapping practices, soil movement, and other reasons. Main breaks occur for the same reasons but may also result from improper pipe material specification, insufficient surge control, or breakage by equipment operating adjacent to the water main.

EBMUD typically repairs leaks and breaks along a water main by installing a full circle pipe clamp. This is the preferred method as it can be done with positive pressure in the water main, thus protecting water quality and minimizing the need to perform post repair flushing. Where this is not possible, the area to be repaired is taken out of service and the damaged pipe is cut out and replaced with a new piece of similar diameter pipe which is attached at both ends with couplings. The EBMUD water system contains numerous types of pipe material (cast iron, polyvinylchloride, steel, asbestos-cement), thus the repair system selected may vary. EBMUD makes approximately 850 main repairs per year for breaks and leaks.

For leaks in service laterals, EBMUD replaces a service by "pulling" a new line through the old line. This procedure includes the following steps:

- Excavation at the main and meter box
- A stainless steel cable is pushed through the existing service from the meter box.
- A cutting head is attached to the end of the cable at the meter box, and a copper pipe is attached to the back end of the cutting head.
- The cable is drawn through the old lateral, splitting it, and the copper pipe is drawn through the void to the main.
- The new copper lateral is connected at the meter box and main and the excavations are filled and paved.

About 2,800 service are identified annually. Of these, 1,800 are replaced by the "pulling" method. The remainder are repaired at the location of the problem and are fully excavated are replaced.

Pipeline Rehabilitation and Replacement Practices

EBMUD maintains a pipeline replacement program. That program has as its goal the replacement of each pipeline that has reached the end of its useful life. Useful life is primarily based on the cost-effectiveness of repairs versus the cost to replace. In order to make that determination, a data base of all main repairs is used to identify pipe segments with high repair costs. Where the present value of future repair costs exceed the life cycle cost for replacement, the pipeline becomes a candidate for replacement. Priority for replacement from this candidate list is based on cost, location, and customer impact.

In selecting pipe materials for replacement projects, EBMUD has a standard practice for material selection. Pipes between 200 mm (8 inches) and 500 mm (20 inches) are installed using mortar-lined and tape-coated steel pipe. For pipes 200 mm (8 inches) and under, PVC pipe is typically installed unless local soil conditions, load bearing conditions, or hydraulics dictate use of steel pipe. Pipes greater than 500 mm (20 inches) are specified either mortar-lined and coated steel or mortar-lined and tape-coated steel.

CONCLUSION

Continued evaluation of unaccounted-for water is important for water utility seeking to effectively manage its product and its distribution system. Once the magnitude and categories of unaccounted-for water are determined, a water loss management program can be developed and implemented. Key components of such a program include leak detection and meter accuracy and calibration. Pipe repair and replacement practices should also support water loss reduction goals.

Technology and expertise are available to support utilities in reducing water loss. A utility, at any level of economic development, could implement and maintain a water loss reduction program.

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LEAKAGE CONTROL AND UNACCOUNTED-FOR WATER ANALYSIS

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This paper gives an overview of the concepts and methodologies related to the practical implementation of leakage control and unaccounted-for water analysis. The paper delves into the various barriers and obstacles that a water utility will encounter, with particular reference to experience gained in the Maltese Islands. The following material is covered:

- **Overview of the Maltese Islands; the local scenario.**
- **Unaccounted-for water; concepts and terminologies.**
- **The first major hurdle, understanding unaccounted-for Water.**
- **Developing a water balance, implementation of a regional zoning scheme, obstacles to be overcome.**
- **Real losses; implementation of the ideal methodology, restructuring, resource allocation and outsourcing.**
- **Apparent losses; implementation of specialized projects, utilization of expertise from the private sector.**
- **Sustaining the system; maintenance and database management issues.**
- **Training and leading staff, cultural and educational issues.**

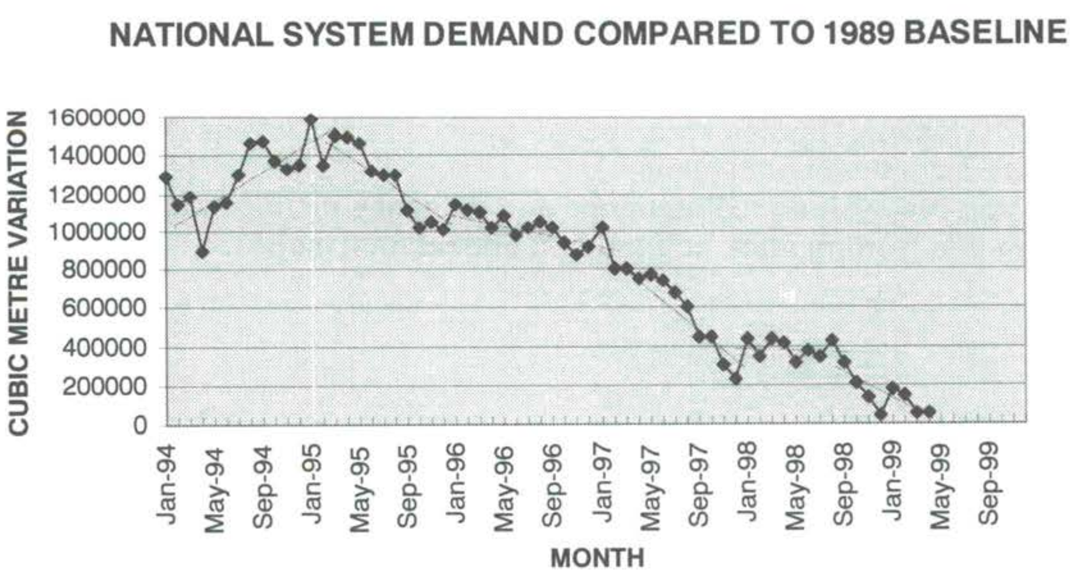
Overview of the Maltese Islands, the Local Scenario:

The Maltese Islands consist of three separate islands; Malta, which is approximately 95Km^2 and houses around 180,000 premises, Gozo, which is approximately 26Km^2 and houses around 20,000 premises and Comino, of negligible proportions. A total of nearly 370,000 habitants live on the islands, increasing to over 500,000 in the peak touristic season. The water distribution system is operated by one organization; the Government owned Water Services Corporation (WSC), employing around 1,200 full-time staff members.

Each and every premises on the Islands is metered and subsequently billed. The national water distribution network consists of around 3,400Km of assorted pipe network (mainly galvanized iron, cast iron, ductile iron and polyethylene), segmented into 8 Master Zones, 40 Cluster Zones and 300 zones. The WSC commenced studies and research into various schemes and techniques related to unaccounted-for water (UFW) way back in 1990. In 1994 a series of initiatives were implemented, to a large extent changing the methodologies and practices of the WSC in relation to UFW activities.

As a result of these initiatives, national system demand reached a peak in early 1995 before starting to drop. Notwithstanding a slight increase in billed consumption over the last 4 years, system demand has been reduced to 33% below its 1995 values, to an extent where the 1999 system demand now equals the 1989 system demand. Calculations indicate that national leakage has been halved, with leakage figures comparing favorably to international values. Optimum economic leakage targets have been set and, in some localities, already been achieved.

Chart 1

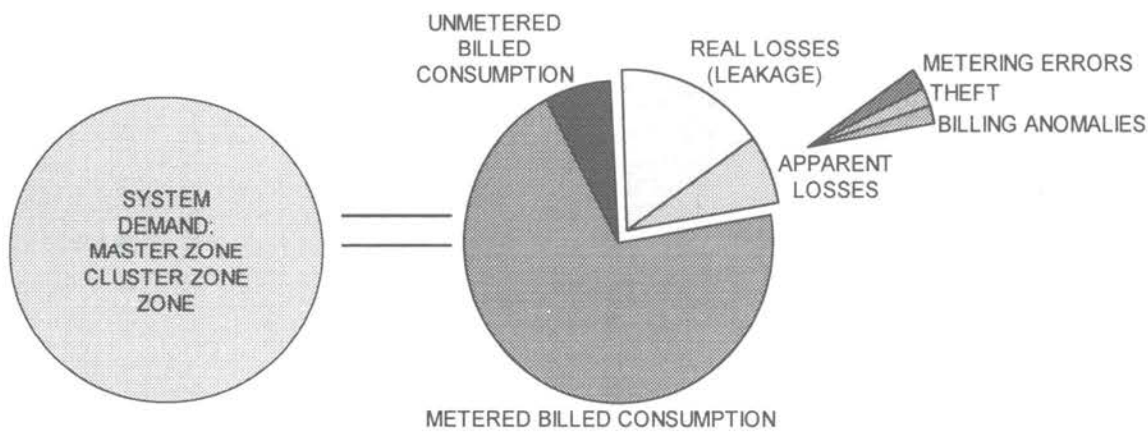


Unaccounted-for Water Concepts and Terminologies

The term Unaccounted-for Water (UFW) refers to an accumulated range of losses that will be experienced by a Water Utility when comparing the system demand of a hydraulic water network with the quantity of water that is acknowledged as consumed by the water consumers residing within the network. Throughout the paper, the following terminology is utilized:

- **System Demand:** This describes the quantity of water inputted into the water network, often also referred to as *System Input* or *Production less Reserves*. The system demand can be computed for any form of metered and hydraulically encapsulated water networks, such as Master Zones, Cluster Zones or Zones.
- **Hydraulically Encapsulated Area:** A part of the water distribution network that is separated from the remainder of the system by shut valves, capped mains and a minimum number of metered interaction points.
- **Master Zone:** A large hydraulically encapsulated segment of the Water Utility's distribution network, comprising numerous zones, reservoirs, production sources, trunk/transfer mains, etc.
- **Cluster Zone**: A smaller, more manageable part of a master zone that is also hydraulically encapsulated and usually comprises a limited number of zones, reservoirs and production sources.
- **Zone:** A segment of the network, hydraulically encapsulated, with preferably solely one metered (and data logged) supply inlet, zone size ideally below 3,000 premises.

Chart 2, Unaccounted-For Water Components:



- **Real Losses:** This first component of UFW consists of all forms of leakage within the network, such as service pipe leakage, leakage on fittings, reservoirs, trunk/transfer/street mains, etc. Any leakage downstream of a production source and upstream of the consumer revenue meter is termed a *real loss*.

- **Apparent Losses:** This term sums three principal sources of UFW that result in water that is actually consumed (or utilized) but not successfully billed. For this reason these three components are not a *'real loss'* (as is leakage) but an *'apparent loss'*.
- **Metering Errors:** This first component of the apparent loss range can be subdivided into two categories; A) revenue meter under-registration, resulting in a lower than actual computation of consumer water usage and B) production meter over-registration, resulting in a higher than actual computation of system demand.
- **Water Theft:** This second component of the apparent loss range consists of the illegal or unauthorized usage of water taken from the system.
- **Billing Anomalies:** This third component of the apparent loss range includes a multitude of factors that contribute to a distorted picture of legitimate consumer usage due to the ineffectiveness of the water utility's billing system.

<u>The first major hurdle; understanding unaccounted-for water.</u>

UFW is often unfortunately quantified in percentage terms, utilizing the following equation to depict the cyclic or annual UFW for a water utility:

$$\mathbf{UFW} = \frac{\textbf{System Demand - Billed Consumption}}{\textbf{System Demand}} * \mathbf{100\%}$$

This UFW ratio, whilst being simple to compute and easy to understand, often gives a warped picture of the true UFW content for a water utility since it depends upon the volume of billed consumption. Hence, for example, two utilities with identical real and apparent loss components will have entirely different UFW % values if the average per capita consumption of one utility is different from the other.

Any water utility that plans to advance substantially in the field of UFW analysis and control has to overcome this first major hurdle. Top corporate management, company stakeholders and shareholders, the consumer, all have to be educated to an extent whereby UFW can be properly quantified and understood in internationally recognized benchmarks. Failure to achieve this situation may result in the setting of UFW target levels which are either impossible to achieve or are not economically viable.

The following table 1 clarifies this issue. This table, issued by International Water Data Comparisons Ltd., in association with the International Water Services Association, depicts Gozo as reference number 3. The table compares various benchmarks used to gauge real losses with a calculation of real losses in percentage terms. In row 3, Gozo places 3rd of the set of 27 in terms of ILI and leakage computed in Lt/Prop/Day, but 16th in terms of % leakage due to the low per-capita consumption. This master zone with a 15.8% leakage content actually has a leakage level lower than the computed optimum economic leakage level !.

Table 1

World-wide International Leakage Indices Compared to Alternative Performance Indicators as at 23rd January 1999

Supply System Ref.	Average Pressure in metres	Density of Conns Conns/km	Ave length of pipe after edge of street (m)	International Leakage Index (ILI)	Real losses in litres/conn/day		Consump per conn per day l/conn/d	Real Losses as % of system input	
					l/conn/d	Rank		% of system input	Rank
1	35	55	3	0.45	19	1	539	3.5	3
2	50	53	3	0.53	32	2	525	6.1	6
3	45	103	0	0.97	42	3	266	15.8	16
4	40	38	10	1.21	74	5	7,824	0.9	1
5	57	47	30	1.31	146	12	496	29.4	23
6	106	28	0	1.32	202	14	1,023	19.7	19
7	35	39	6	1.55	76	6	1,734	4.4	4
8	46	72	14	1.62	104	7	533	19.5	18
9	60	55	0	1.66	114	8	1,199	9.5	8
10	46	71	23	1.72	130	9	543	23.9	21
11	39	86	0	1.77	70	4	1,280	5.5	5
12	57	45	0	1.94	132	10	1,142	11.6	12
13	54	48	20	2.91	263	16	511	51.5	25
14	30	35	10	2.94	138	11	5,633	2.4	2
15	70	31	5	3.25	342	18	4,230	8.1	7
16	30	65	5	4.99	180	13	567	31.7	24
17	46	37	0	5.42	320	17	2,208	14.5	14
18	50	58	5	5.94	367	19	2,552	14.4	13
19	36	29	15	6.21	401	21	719	55.8	26
20	39	26	10	6.44	436	22	3,004	14.5	15
21	35	29	20	7.06	477	23	2,652	18	17
22	31	79	0	8.02	256	15	2,481	10.3	9
23	48	114	0	8.04	370	20	1,742	21.2	20
24	71	21	0	8.15	956	27	1,669	57.3	27
25	45	24	10	9.39	759	25	6,921	11	10
26	37	27	10	9.48	600	24	5,214	11.5	11
27	45	24	10	10.25	832	26	3,230	25.8	22

This table contains data provided by Water Undertakings in Brazil, Denmark, France, Finland, Germany, Gibraltar, Greece, Iceland, Japan, Gozo, Netherlands, New Zealand, Singapore, Spain, Switzerland, Sweden, UK, USA and West Bank (Palestine) for various 12 month periods between 1995 and 1998. International Water Data Comparisons Ltd

Whilst this example depicts solely part of the UFW content, that of real losses, the same argument holds true for apparent UFW components. Benchmarks such as the simple m^3/Hour, Lt/Prop/Day or m^3/Km/Day should be utilized whenever and wherever possible to compute any of the three major components of apparent losses. Realistic target setting can now be put into play.

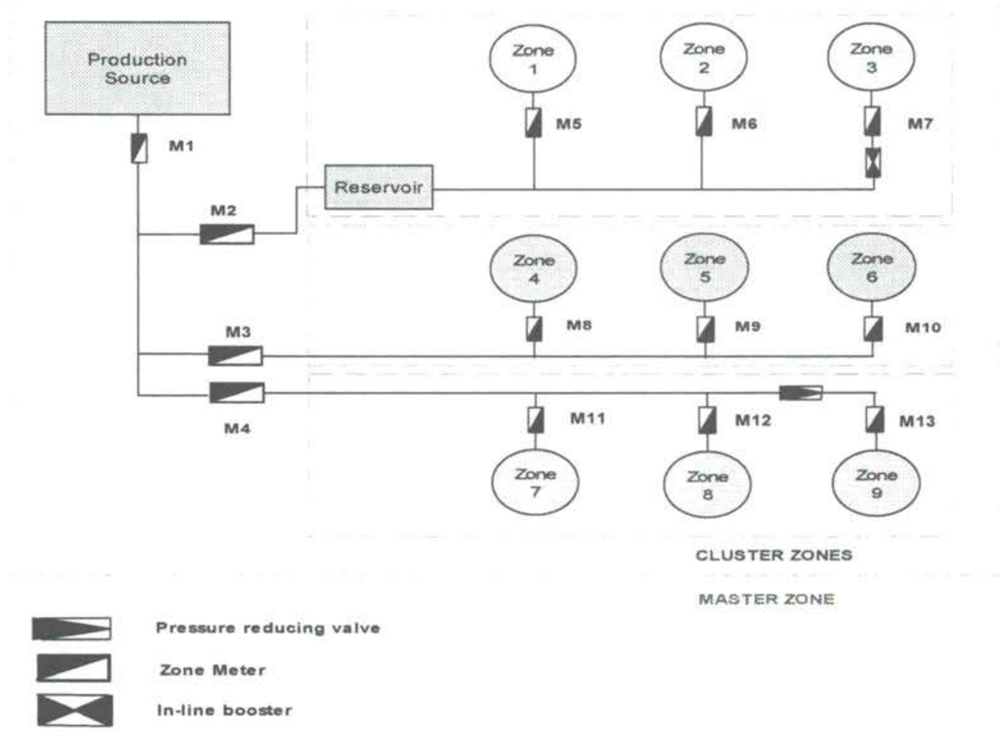
Developing a water balance, implementation of a regional zoning scheme, obstacles to be overcome.

The most critical task for any UFW management team is to develop a methodology whereby the quantification of the four UFW factors can be made. An appropriate English quote states that 'if you can measure it... you can manage it...'.

In this regard the primary objective of any water utility is to implement a zoning scheme whereby the complete water distribution network is broken down into manageable segments that can be easily metered, monitored and analyzed. The advent of telemetry or SCADA (supervision, control and data acquisition) systems may simplify the data acquisition and control processes but it must be appreciated that the advancement from more simplistic data logging to various level of automation only makes economic sense once the zoning scheme has been successfully and fully implemented.

The implementation of different zoning levels or hierarchies facilitates the development of a *'source to sink'* mode of comparison of flows within the network. It is this flow analysis, depicted in simplified form in schematic 1, that ultimately leads to the building of an effective water balance. The implementation and sustaining of a proper zoning scheme is hence the groundwork for all further operations related to UFW analysis and control.

Schematic 1



Practical Implications in the implementation of a National Zoning Scheme:

As was the case locally, many networks are developed gradually over time, with little consideration to zoning criteria. It usually takes a number of years for the successful implementation of a national zoning scheme as a prelude to the creation of a water balance. The following issues usually have to be resolved during the course of this development:

1. **Corporate commitment:** At this early stage of investment and development, corporate commitment is a top issue. The Corporation must understand the *vision* of what is going to be achieved and be ready to commit the necessary resources, without having the benefit of exact costings and targets.
2. **The issue of short-term vs. long term goals:** Even in the early stages of development, zone information can be utilized wisely to target high leakage areas for leakage control purposes. Hence, short-term savings can be achieved from the start, although the long-term target may take years to complete.
3. **Equipment and instrumentation:** Various new systems and techniques have to be tried, implemented and ultimately sustained, compatible with the local environment. In the Malta scenario, these included helical vane zone meters, flow/pressure data loggers, pressure controllers, acoustic and correlation detection equipment, ultrasonic clamp-on meters, digital pipe-locators, etc. All systems had to be chosen on par with the potential levels of expertise of local staff.
4. **Choice of methodologies**: Part of the necessary research and development also includes testing out different methodologies together with the choice of instrumentation. This, and further points below, are described in further depth when discussing real and apparent losses.
5. **Staffing and structuring:** Again, in conjunction with the above issues, restructuring is usually inevitable at some early stage in this development period. Specialized and dedicated ongoing training of the different levels of staff is an integral part of this staffing process.
6. **Data and data management:** This will include aspects such as simple leakage database creation to more advanced G.I.S. development.
7. **Corporate culture change:** The shift from the concept of simply supplying water at adequate pressure to creating and sustaining a low leakage level system demanded a slow but important cultural change in the mentality of existing staff.
8. **Consumer awareness & education:** Implementation of a national zoning scheme will unavoidably cause certain disruptions and shut-offs for the consumer. This is the best time to implement a PR campaign aiming at increasing consumer awareness and appreciation of what was trying to be achieved.
9. **Outsourcing of work:** Contracting out of excess workloads and certain specialized tasks may be an ideal way of balancing existing resources with the fluctuating quantities of work required.

The remainder of this paper can now focus more closely on the individual parameters formulating the UFW equation.

Real losses; implementation of the ideal methodology, restructuring, resource allocation and outsourcing.

A well balanced approach towards active leakage control demands the correct methodology and the implementation of related staffing and resource allocation. This was made clear to the WSC in the years leading to the 1995 peak system demands, where it became evident that the existing 30 man team haphazardly sounding the water network approximately 3 times yearly, was far from adequate.

The following diagram 1 indicates the four factors that constitute an ideal Leakage Control methodology. Failure of any one of these factors usually results in an inability to achieve significantly low leakage levels, or a failure to sustain these levels once achieved. On top of this, an understanding of the economics of leakage control and the computation of optimum economic leakage levels is also essential.

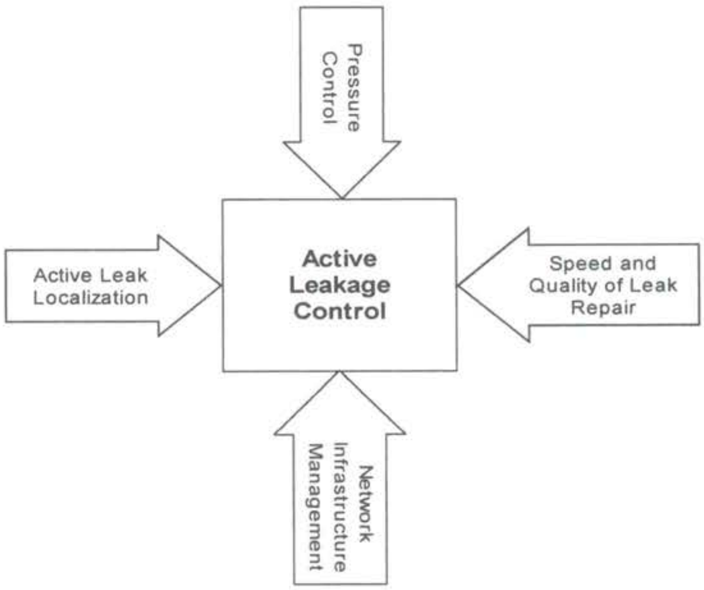


Diagram 1

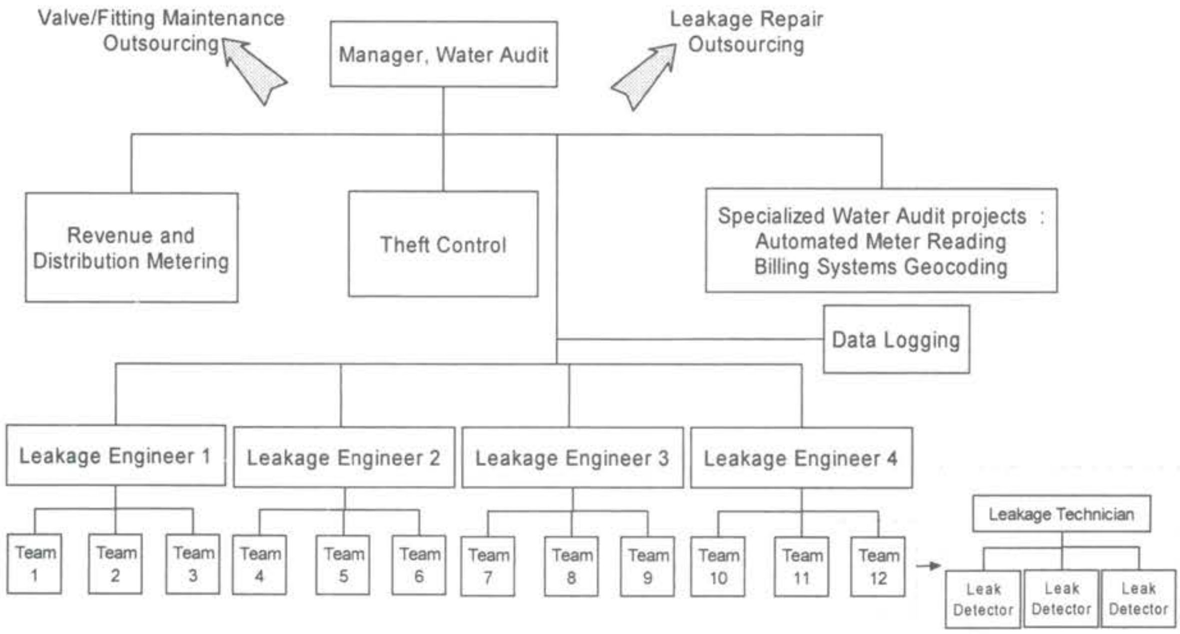
Throughout the development and implementation of the chosen leakage control methodology, a number of key issues usually need resolving. These are described in point form below:

⇒ **Research and development:** Various leakage detection techniques are usually attempted such as acoustic detection, correlation techniques, infra-red scanning and leak noise data logging. A range of pressure and flow data loggers and their interfacing with existing and available distribution water meters, should also be assessed.

⇒ **Particular environmental constraints:** The effect of soil and backfill conditions, network materials, ambient and background noise, existence of other utility's underground pipe, cable, gas systems, etc. all should be assessed and understood.

⇒ **Accountability of staff through proper structuring and target setting:** In a job as intangible as leakage control, the concept of setting accountability levels through an adequate, functional and decentralized structure is imperative. The structure depicted in diagram 2 was successfully implemented by the WSC, directly tackling all fields of the UFW range.

Diagram 2, new structural setup:



⇒ **Economic leakage level target setting:** Computations must be made to ensure that the economic leakage levels for each master zone are computed, understood and targeted.

⇒ **Contracting out of excess workload:** The outsourcing of certain tasks helps reduce the problems induced by the ever fluctuating workload related to leak control. As depicted in diagram 2, the WSC decided to contract out two major tasks, system maintenance and leakage excavation and repair. Coordination and communication between full-time staff and contracted staff is often a delicate issue.

⇒ **Union and institutional constraints:** No water authority functions in isolation. A powerful union, for example, can cause havoc to plans to implement what management may see to be the ideal leakage shift layout. The leakage manager often juggles a balancing act in his effort to push his concepts through.

⇒ **Day-Night shift operations:** The ideal working scheme for the chosen methodology must be implemented. This usually involves substantially night duty and a certain degree of flexibility to allow the leakage teams to function at both day and night according to need. In the case of the WSC, the concept of flexi-time was introduced here for the first time.

⇒ **Feedback and control:** Again, due to the intangible nature of leakage control, continuous and exhaustive evaluations of achievements and results is required.

Apparent losses; implementation of specialized projects, utilization of expertise from the private sector:

The complex issue of quantifying and reducing the various components of apparent losses often involves the implementation of dedicated projects upon completion of research into the particular field. The following examples are made:

Metering Schemes: A water authority must effect a conclusive study into the performance of different types and classes of revenue meters suitable for the domestic consumption trends. Various trials involving high frequency data logging of statistically chosen consumers and the testing of a range of meters on the achieved consumption trends, are imperative.

In the Malta scenario, site and laboratory research led to a conclusion on use of the Class D (Q_n=1.0 m^3/Hr) volumetric meter model. The task of replacing over 100,000 old class C meters with this model was subsequently contracted out to 6 chosen private companies.

Theft Control: This delicate issue involves institutional aspects such as a detailed study of legal and criminal codes of practice and the issue of relations between the water utility and other organizations. Furthermore, proficient water theft team/s have to be trained, launched and carefully supervised. Advanced pipe location equipment is often a necessary asset.

Studies into the Malta criminal code and repeated discussions with leading legal experts were the first steps taken locally. Minor amendments to the legal framework were made before the launching of theft control teams onto the consumer. Present steps are now being taken to contract out water theft control.

Billing Aspects: There exist a number of possible complications and discrepancies arising out of flaws or inefficiencies in the water authority's billing system. An example of this is the failure of an authority to access numerous consumer meters that may be installed inside the premises, this resulting in '*guessed*' estimations. Two vital projects can help quantify and subsequently reduce this type of *apparent* loss:

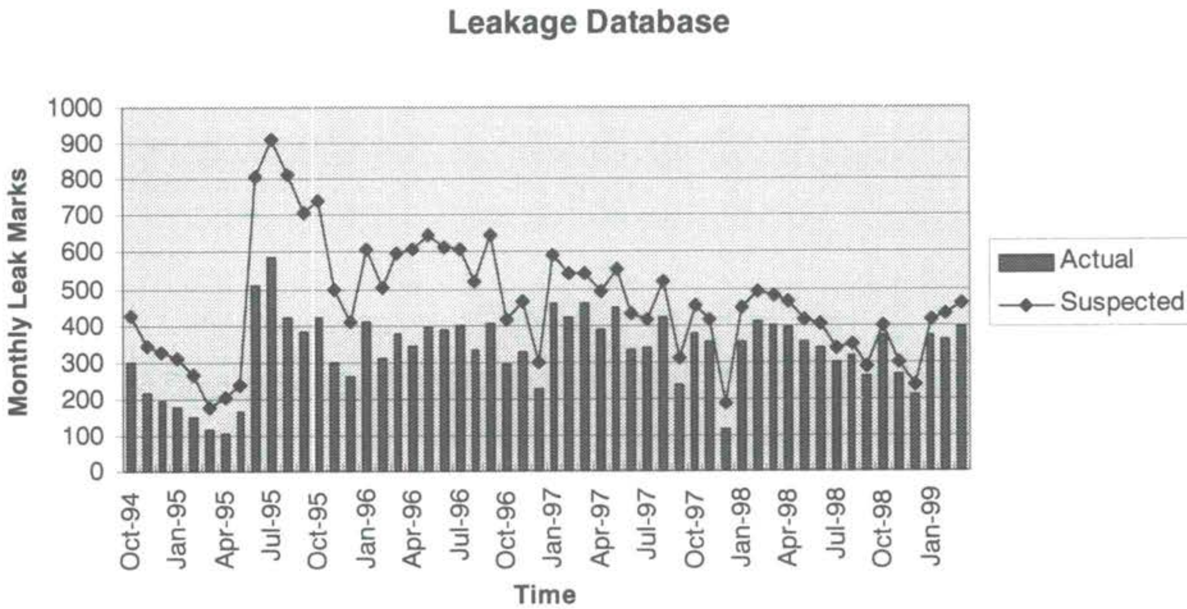
A) Geographical Information System (GIS): A GIS will allow the water authority to map out consumers onto '*points*' on a map layer. Dedicated software can then compute the summated billed consumption for each zone. Since the system demand and the leakage level of the zone are already known, the total apparent loss value can be computed.

B) Automated Meter Reading (AMR): Use of AMR can reduce substantially the apparent losses related to billing, thus allowing for the computation of apparent losses due to revenue meter under-registration. Expert help in this field can be found through organizations such as the Automated Meter Reading Association.

Sustaining the system; maintenance and database management issues.

Sustaining the methodologies that have been implemented is often no easy task. All resources have a finite life and must be regularly maintained, calibrated, replaced, etc. Problems may arise regarding standardization or purchasing issues. The more an organization diversifies in it's purchasing and maintenance schemes, the more it becomes open to long-term complications. Use of databases, such as the national leakage database depicted in chart 3, can help substantially in managing resources.

Chart 3



Training and leading staff, cultural and educational issues.

The management of UFW control involves a high degree of leadership and empowered teamwork. The leader must also be a team member and must involve himself in the daily difficulties and challenges faced by his workforce, if he wishes to hold their respect and esteem. The implementation of UFW methodologies often results in a culture clash where 'old' staff are required to change their mentality and attitude towards the dedication required for the job to succeed. Where, for example, an underground leakage may have previously been hidden and a problem to nobody, now the team has become empowered to quantify and locate it, and is being held accountable for it's elimination.

As was the case locally, water authorities may be faced with the sometimes daunting task of having to implement advanced techniques using staff that have only minimal educational levels. Ongoing training programs set up through a permanent training centre can target practically all educational requirement levels except the most advanced, for which outsourcing of the particular task is a solution.

Author: Alex Rizzo graduated in engineering at the University of Malta in 1989 and is presently concluding a masters in Business Administration. Mr.Rizzo was employed by the Malta WSC in 1989 and was immediately involved in R&D related to UFW for a period of four years before being placed in charge of the newly created water audit section in 1994. From 1994 to date, Mr.Rizzo has been in charge of all operations related to leakage and UFW control and manages an 80 man taskforce.

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LEAKAGE CONTROL & UNACCOUNTED-FOR WATER ANALYSIS

This paper gives an overview of the concepts and methodologies related to the practical implementation of leakage control & unaccounted-for water analysis. The paper delves into the various barriers and obstacles that a water utility will encounter, with particular reference to experience gained in the Maltese Islands.

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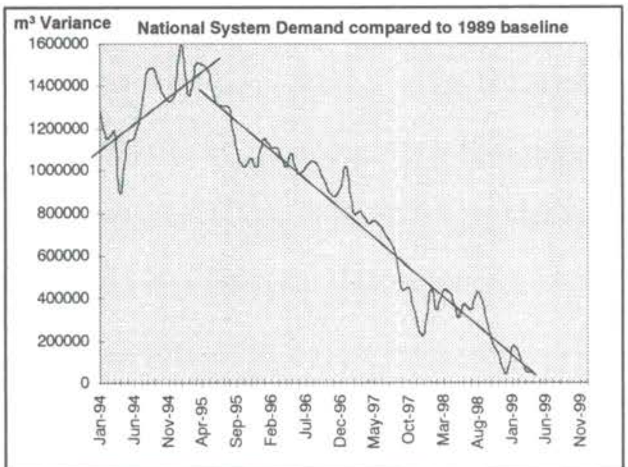
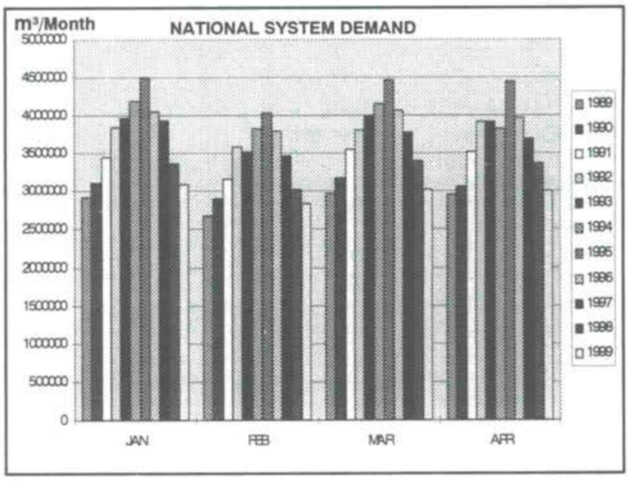
Overview of the Maltese Islands, the local scenario:

- Total of 200,000 metered premises, around 370,000 inhabitants
- Maltese Islands consist of 3 Islands; Malta, with a population of around 337,500, Gozo, with a population of around 32,500, and Comino, of negligible proportions.
- Unaccounted-for analysis started in the early 1990's, with a series of research and evaluation projects.
- Practical implementation of methodologies aiming at controlling **UFW** commenced in 1994.
- Successes obtained include a reduction of 33% in National System Demand, and a calculated halfing of leakage figures.
- Computed Gozo leakage at 1.75 Lt/P/Hr
- Computed Malta leakage at 6.7 Lt/P/Hr
- Pre-1994 leakage for Malta & Gozo at over 15 Lt/P/Hr

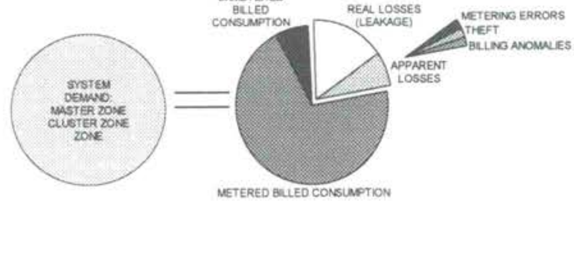




Unaccounted-for Water should be broken down & analyzed in it's individual components, for localized hydraulically encapsulated areas. Components are:

- **Real Losses:** This first component of UFW consists of all forms of leakage within the network, such as service pipe leakage, leakage on fittings, reservoirs, trunk/transfer/street mains, etc.
- **Apparent Losses:** This term sums three principal sources of UFW that result in water that is actually consumed (or utilized), but not successfully billed. These 3 components are:
- Metering Errors: A) Revenue meter under-registration, B) Production meter over-registration.
- Water Theft: The illegal or unauthorized use of water taken from the system.
- Billing Anomalies: A multitude of factors that contribute to a distorted picture of legitimate consumer usage due to the ineffectiveness of the water utility's billing system.

Unaccounted-for Water Components:



The first major hurdle; the computation and understanding of unaccounted-for water in internationally recognized benchmarks as opposed to simple % terms.

Percentages are misleading. They will be biased by the level of per capita consumption and will fluctuate unrealistically from season to season.

Commonly used % computation is as follows:

$$\text{UFW} = \frac{\text{System Demand - Billed Consumption}}{\text{System Demand}} \quad {}^*100\%$$

Internationally recognized benchmarks are:
Lt/P/Hr, m^3/Km/Day, ILI.

World-wide International Leakage Comparisons, 1999

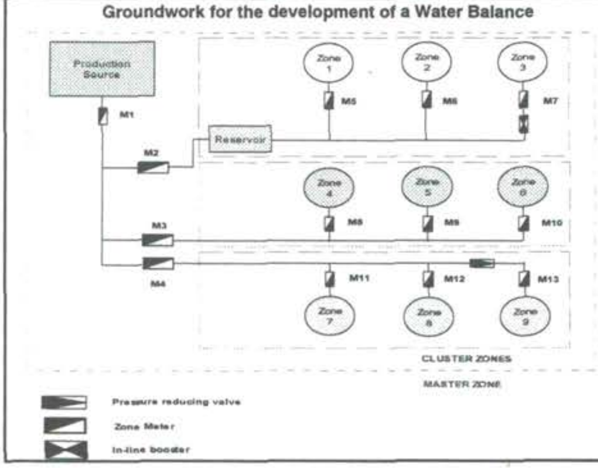
Supply System Ref.	Average Pressure in metres	Density of Conns Conns/km	Ave length of pipe after edge of street (m)	International Leakage Index (ILI)	Real losses in litres/conn/day		Consump per conn per day	Real Losses of system [illegible]
					l/conn/d	Rank	l/conn/d	% of system input
1	35	35	3	0.45	19	1	539	3.5
2	50	53	3	0.53	32	2	525	6.1
3	45	107	0	0.57	42	3	260	13.8
4	40	38	10	1.21	74	5	7,824	0.9
5	57	47	30	1.31	146	12	496	29.4
6	100	28	0	1.32	202	14	1,023	19.7
7	35	39	4	1.55	76	6	1,734	4.4
8	46	72	14	1.62	104	7	533	19.5
9	60	55	0	1.66	114	8	1,199	9.5
10	46	71	23	1.72	130	9	545	23.9
11	39	80	0	1.77	70	4	1,280	5.5
12	53	45	0	1.94	132	10	1,142	11.6
13	54	48	20	2.91	262	16	511	51.5
14	30	35	10	2.94	138	11	5,633	2.4
15	70	31	5	3.25	342	18	4,230	8.1
16	30	65	5	4.99	180	13	567	31.7
17	46	37	0	5.42	320	17	2,208	14.5
18	50	58	5	5.94	367	19	2,332	14.4
19	36	29	15	6.21	401	21	719	55.8
20	39	26	10	6.44	436	22	3,004	14.5
21	55	29	20	7.06	477	23	2,652	18
22	51	79	0	8.02	256	15	2,481	10.3
23	48	114	0	8.04	370	20	1,742	21.2
24	71	21	0	8.15	956	27	1,669	57.3
25	45	24	10	9.39	759	25	6,921	11
26	37	27	10	9.48	600	24	5,214	11.5
27	45	24	10	10.25	832	26	3,230	25.8

This table contains data provided by Water Undertakings in Brazil, Denmark, France, Finland, Germany, Gibra[illegible] Greece, Iceland, Japan, Gozo, Netherlands, New Zealand, Singapore, Spain, Switzerland, Sweden, UK, USA an[illegible] Bank (Palestine) for various 12 month periods between 1995 and 1998. International Water Data Comp[illegible] Ltd

The implementation and sustaining of an effective zoning scheme is the groundwork for all operations related to UFW and leakage control.

- The initial stages of introducing a zoning scheme can be the most difficult part of all. A proper scheme will take years to develop and numerous difficulties must be surpassed, such as:
- Corporate Commitment
- Long vs. short term goal setting
- Choice of adequate equipment and instrumentation
- Choice of methodologies
- Staffing & structure development
- Data & data management
- Corporate culture change
- Educating the consumer
- Outsourcing of excess labour

Groundwork for the development of a Water Balance



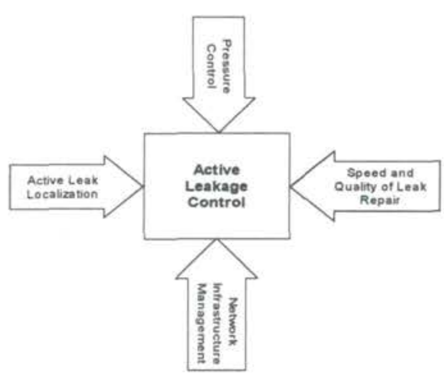
Real Losses: Active Leakage Control

A well balanced approach towards active leakage control demands the correct methodology and the implementation of related staff and resource allocation.

A standard and successful methodology involves four critical factors. Failure of any one of these factors usually results in an inability to achieve significantly low leakage levels, or a failure to sustain these levels once achieved.

On top of this, an understanding of the economics of leakage control is essential. Things must always be put into perspective. Economic leakage studies should be implemented only when at an adequately advanced stage of leakage control.

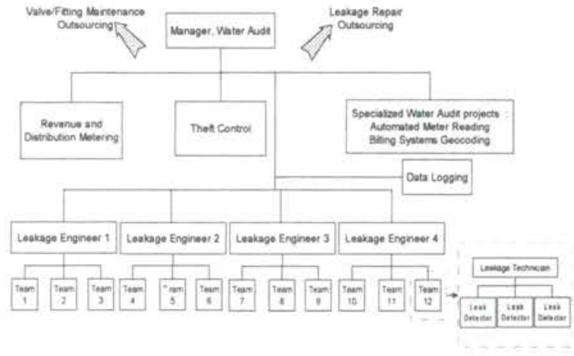
The ideal Leakage Control Methodology



Active Leakage Control, key issues that need to be resolved

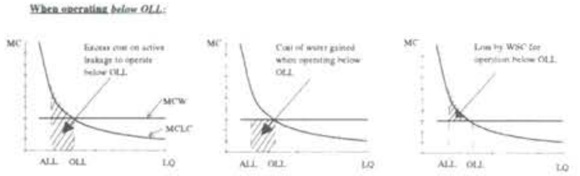
- Research and development
- Study of particular environmental constraints
- Accountability issues; proper structuring and setting of responsibilities
- Economic leakage level setting, where the marginal cost of leakage control equals the marginal cost of water being lost through leakage
- Contracting out, control and adverse reactions
- Part of the methodology, shift & work schemes
- Feedback and control; remember the intangible nature of the job

Structural outlay, accountability and outsourcing

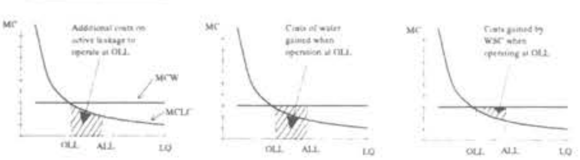


The optimum economic level of leakage control

When operating *below OLL*:



When operating *above OLL*:



Apparent Losses. Use of the regional zoning scheme and a variety of projects such as GIS & AMR allows for better quantification of the individual parameters, for a defined hydraulic area.

- GIS allows for the *mapping* of consumer data onto a hydraulic area, hence the top-down methodology can be implemented to compute UFW.
- AMR can be utilized to eliminate Billing Anomalies, and leakage figures can already be computed. Using the bottom-up methodology, what remains in the equation are meter under-registration & theft.
- Metering trials and lab simulation, combined with consumer trend analysis, allows for the computation of expected revenue meter under-registration. Further studies should be effected to evaluate what is the ideal meter size, class and nominal flow for a particular consumer category.
- Theft control, backed by proper procedures and legislation should reduce to minimal proportions the quantity of water theft in a hydraulic area.

Sustaining the system, maintenance and DB management issues

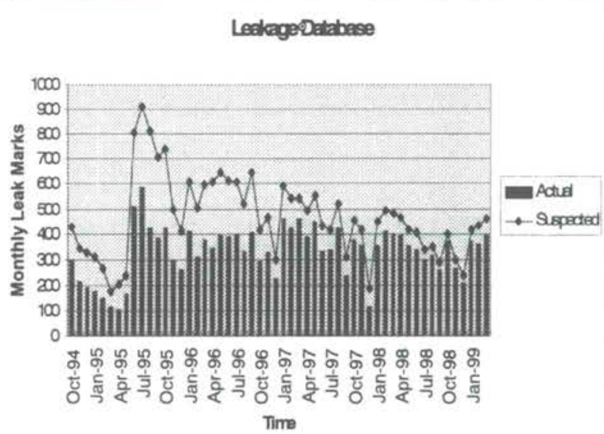
Sustaining the methodologies that have been implemented is often no easy task. All resources have a finite life and must be regularly maintained, calibrated, replaced, etc.

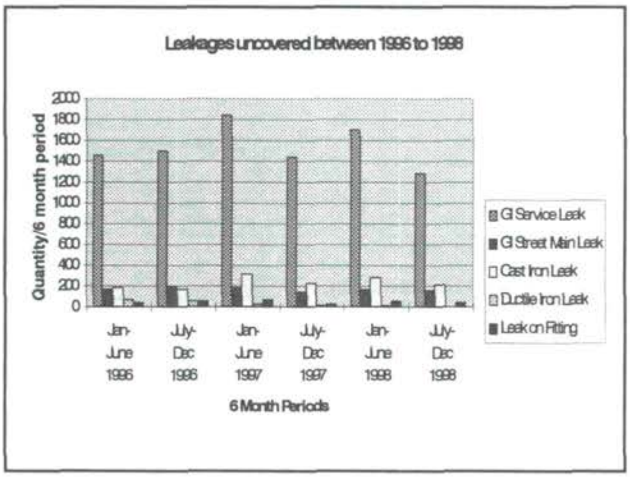
Problems may arise regarding standardization and purchasing issues. The more an organization diversifies in its purchasing and maintenance schemes, the more it becomes open to long-term complications.

Use of databases, as will be seen in the following example, may help substantially to track and manage rescurces.

Implementation of standards, such as the ISO 9002 Quality Procedures, has been found useful in the control it provides for the documenting and abiding to fixed procedures.

The WSC obtained ISO 9002 compliance certification in 1998





Training and leading staff, cultural and educational issues.

The management of UFW control involves a high degree of leadership and empowered teamwork. The leader must also be a team member and must involve himself in the daily difficulties and challenges faced by his workforce, if he wishes to hold their respect and esteem.

The implementation of UFW methodologies often results in a culture clash where 'old' labour are required to change their mentality and attitude towards the dedication required for the job to succeed. The team will have been empowered to tackle most jobs but will also now be held accountable for achieving the expected results.

As was the case locally, water utilities may be faced with the sometimes daunting task of having to implement advanced techniques using staff that may only have minimal educational levels. Ongoing training programs set up through a permanent training centre can target practically all educational requirements except the most advanced, for which outsourcing of the particular task is a solution.

The WSC set up the Institute of Water Technology Training Centre in 1993, in which all UFW employed personnel have regularly attended training schemes.

Session 6: Water Demand Management

Water Demand Management

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1. Acknowledgments:

Many colleagues from those who believe in water demand management - as a major planning and policy tool - have given me a hand in writing a booklet on the subject for UNCHS (HABITAT) as well as other papers, like the one here, dealing with the issue of water conservation and increasing efficiency of water use. They have gathered documents and data and had brought it to my attention, I am grateful to them all.

However, few of them went out of their way to enable me to use their material and those I have to mention (see also bibliography for special documents):

William Maddaus, a pioneer of water demand management in the USA and AWWA who had published important material on the subject for many years.

Sandra Poatel together with World Watch who has altered the world how critical water resources has become and how important it is to promote conservation strategies. The **water and sanitation collaborative council** who decided to promote the issue within its members from the developing countries and my colleagues there, **Dr. Lester Fordeb** of WASA / Trinidad and Tobago and **Donald Tate** from Environment, Canada. **David Brooks** of the IDRC in Canada, again a fighting spirit for the cause of conservation, who also reviewed my document, and **Ms. Rita Cessti** of the World Bank who is promoter of demand management in the World Bank, where supply management orientation is still the dominate sector thinking. **Ms. Ami Vickers** of Amherst, MASS. (USA), who has and is spending most of her professional capacity on water conservation programs. **Clive Harrions**, of Conservation Technologies (France and UK) a pioneer in the vision of including the private sector in the difficult task of reducing the unaccounted for water in the cities of the developing countries, and last but not least the **Asian Development Bank** who did a magnificent work on the Asian Utility Book, part of which I have used in order to influence other agencies to follow them.

I hope this publication will add another brick to a building which could accommodate the future generations the poor and the weak without a thirsty soul in its premises. Urban water conservation enables the reallocation of wasted water to the unserved. It fits the moto "**some for all versus all for some**".

Saul Arlosoroff,

Special consultant and adviser to UNCHS (HABITAT / RDD / BTIS, Nairobi, Kenya)

2. Preamble

Asia and Africa are experiencing the most rapid rate of urbanization in the world. The growing number of medium and large cities in the continent face a major challenge of providing their populations with adequate water supply, with large parts of the two continents facing sever water stress. African and Asian cities urgently need to put in place effective water demand management strategies that could promote the use of the limited water resources more efficiently, reducing wastage, and expanding the service coverage, particularly in the burgeoning low-income settlements.

A major environmental crisis is also looming large in the continents of Asia and Africa as cities continue to discharge ever increasing volumes of wastes into freshwater bodies, threatening water availability, quality and aquatic ecosystems. Several cities share one or more international river basins, which present a special challenge of managing water resources in these basins, avoiding future conflicts. A business-as-usual approach to urban water resources management threatens not only the sustainability of its cities precious water resources and supporting ecosystems, which are closely linked to the continents future, and the socio-economic environment of its populations.

3. Executive Summary

Water is more than just a commodity. It is an essential element to all life and is basic to most economic activities. Its role in human survival and health is well known, However, its economic value must be recognized and addressed in all policy and sector activities in order to initiate and promote the wise and efficient use of water resources in all sub-sectors, especially in the large urban centers. Using water in an efficient manner and managing competing demands in any city, country, or region are essential steps to ensure that water is no longer undervalued wasted and misused in our world.

This conference and others to be initiated within the international and the in-country discussions, as well as the support of the media, should be an integrated part of a global campaign to foster water conservation and to demonstrate to all governments of developing countries that substantial economic, social and environmental benefits will be generated by using water more efficiently, by implementing water demand management strategies, supplementing the supply management options.

In order to achieve demand management goals, we all should pursue the establishment of adequate policies, strategies and action planning for a step-by-step program to be adapted to the conditions of each site. Appropriate technological implementations, water metering, and pricing policies are indispensable elements in this global campaign as part of legislative, regulatory, and institutional reforms, to accommodate demand side management, on a wide-scale level in order to reach relatively large water savings and reduce the impact of water shortages, and delay the execution of expensive new water supply projects.

Appropriate water management should be seen as an integrated element in the developing countries' strategy toward sustainable development. It is directly linked to natural resource and environmental management – A major challenge confronting the developing countries. Let's examine a few of the major components of this global challenge:

In this decade alone, the world population will increase to 6 billion, with the growth mainly occurring in the developing countries. By the middle of the next century, only 50 years from now, there will be more than 10 billions – the increase will be mainly in the urban centers of the developing countries, while the growth of African and Asian urban centers may overshadow the ones in other continents.

Water use in developing countries is increasing at an accelerated pace, due not only to growing populations, but also as a result of the higher standards of living, increased per capita use, rapid industrialization, and the expansion of irrigation to supply the agricultural needs of the population growth. This forecasted growth has serious implications for environmental sustainability locally and globally. Neither economic development nor environmental management are expendable – both are essential. They must be integrated in a wise strategy that reconciles economic implications and environmental health.

Governments will have to follow innovative and clear strategies to accommodate this huge economic development without the further destruction of the environmental infrastructure. Water resources management and water conservation are essential components of a strategy aimed at achieving these goals of sustainable development.

National goals can only be achieved by the collective efforts of all water using sectors, the different levels of governments, and the public. Water conservation provides a unique opportunity for a collaborative national campaign:

- National and local governments should initiate creative approaches, courageous policies, regulations and their enforcement. They should test the use of incentives and sanctions, tax measures, support to Retrofitting (installation of water conservation technologies) and new technological modifications, initiate water abstraction charges, local 'water-markets' and tradable permits. The introduction of realistic full-cost pricing of water in a step-by-step action plan is essential for strategic implementation of Water Demand Management (WDM) in the urban and industrial sub-sectors, as well as in the agricultural sector.

- The industrial and institutional reform, in many developing countries, must include water conservation and pollution abatement components as an integrated activity. Re-use of waste-water within industries or within an industrial zone, re-use of treated municipal wastes for irrigation of fields and parks, and industrial cooling are just examples of key elements that reconcile pollution abatement with water demand management. Water efficient processes match energy conservation and reduction of total pollution in many of the rehabilitated industries in the western countries. They contribute to improved industrial management and its profitability and need not obstruct industrial economic viability. It is a common myth in many developing countries that industrial environmental management undermines the economic basis of the industry. USA, Japan, Germany, and Singapore, as an example, have the toughest environmental and water management standards, while these countries are of the top economic performers.

- The governments, the public, the multilateral and bilateral funding and donor agencies all have a role in the water conservation activity. We all have been wasteful users of water – pumping more than we need, polluting water and returning it to nature after inadequate treatment or no treatment at all. The time has come to move from constantly augmenting supply to managing demand. Reduction of water use delays new projects, sometimes indefinitely. It reduces pumping and treatment costs, decreases sewage flows and their disposal costs, increases utility's income through a reduction of leakages and improved water metering and thus provides the financial resources for well managed operations, terminating the vicious cycle of utilities mismanagement and inefficient distribution and wasteful water use.

- Many cities in the developing countries have often conflicting policies and rules – some of which actually foster increased water consumption. Low water prices are a known culprit within this contest. If municipal and industrial water users will pay realistic water prices, utilities will be able to maintain their systems, minimize losses, and maximize the quality and the level of service. When national and city governments stop subsidizing the expansion of water supply systems and have to take out loans and pay considerable interest for new projects, there may be a turning point in their attitude toward the implementation of demand management versus a supply augmentation strategy. The savings on delaying investments and savings on capital costs alone in one year could possibly finance a city wide Retro-fitting program leading to a 15 to 25% reduction in water use.

- High rates of unaccounted for water (UAF) are common in the cities of Asia. No utility can adequately function under such conditions for a long time. Cities in the developing countries are reaching extreme levels of unaccounted for water up to 40-60% of the water supplied. A universal and appropriate water metering system is a must whether for production, for block-metering (essential for leakage detection and flow management), or for billing for micro-metering at the household, office, park, restaurant or industrial site. Without metering system many of the proposed actions will not achieve their goals.

- Rate structures have been changed in many utilities from regressive to progressive block-rate-paying more per unit for the higher water consumption. Progressive block-rates encourage conservation and reduce waste. A proper well maintained water-metering system is a pre-requisite condition for that. The introduction of private sector assistance to local governments can prove to be a very important and effective tool, to reduce losses, install and read meters, retrofitting at the user end etc.

- Contractors dealing with the reduction of UAF and water wastage can be paid on the basis of the real water savings achieved. Contractors can also undertake the whole demand reduction program. They will move from house to house and execute a citywide Retro-fitting program, while the customers will pay for the installation through the water bills.

To sum up:

Water conservation and demand management is more than just a water consumption issue. Above all, it is a strategy promoting efficient and wise use of scarce resources.

Urban water demand management means securing the whole water cycle – using less, keeping the water clean and decrease of pollution downstream. Conservation is based on the recognition that water is a socio-economic commodity and a valuable production factor. It should be priced and allocated accordingly, while securing the basic needs of the poor and low-income groups.

For conservation strategies to succeed, all sectors of government and the economy - public and private - should collaborate. We must do a better job in disseminating information, informing countries and local government of successful case-studies and full-scale projects. The international organizations should promote the dissemination of successful case-studies between countries to avoid or minimize duplication, to avoid repetition of mistakes, and to enhance collaboration between user.

4. Introduction

Historically, the predominant approach to water resource development has focused on developing new supplies and structures to manipulate available supplies in order to meet perceived water needs. Hallmarks of this strategy include large dams, rivers, diversions, large water supply and waste treatment works, and many other such structures. All of these measures form necessary components of societal infrastructure, and have undoubtedly contributed to the advance of human civilizations. **However, because the water supply management approach considers water needs as requirements that must be met, and not as demands that are variable and changeable, this water supply management strategy may lead to overuse of the resource, overcapitalization, resource wastage, pollution problems, and many other problems of varying severity**. A most important fact, about these problems, is that the prevailing strategy in most cases does not suggest permanent, cost-effective solutions to them.

It is beginning to be understood, by governments of all levels, that these types of problems require a fundamental change in order to be solved efficiently and effectively. In this case, the new policy places water demands themselves, not structural supply solutions, at the center of concern and develops large, capital intensive new supply systems only after opportunities have been fully analyzed for lowering or mitigating the proposed demands in a more socially beneficial manner. **This new approach is referred to as water demand management (WDM)**. While not dismissing traditional aproaches, water demand management relies much more on socioeconomic techniques like economic analysis, establishment of incentives and disincentives, water conservation technologies, reduction of unaccounted for water, re-use of treated waste water, public education, water equity rights modification and other related instruments. These approaches have proven very cost effective in modifying water demand patterns, and in many cases, lowering the demands themselves, substantially. Structural components of demand management include: **comprehensive metering, leak detection and repair, installation of water savings techniques, water auditing, changes in water pricing concepts, clear institutional responsibility for the demand management aspects and last but not least, public awareness campaigns and constant education for water conservation**.

Experience in various regions like the state of California, the countries of Singapore and Israel, Canada and others show that if fully pursued and implemented, demand management could:

- Reduce water demands by 30-50% with no deterioration in life-style.
- Significantly reduce capital requirements for expansion of water supply and decrease distribution costs.
- Reduce the generation of pollutants, and therefore the requirements for new or expanded waste treatment systems.
- Enhance the development and adoption of new technologies with an impact on similar management of energy use.
- Promote financially sustainable water systems.
- Expand the coverage of available water development funds thus enabling cities in Africa, Asia and the developing countries in general to expand their water supply systems to the poor, low-income groups and unserved suburbs.
- Help meet the water needs of growing irrigation and industrial users located in or around urban centers and the needs of a growing world population

Water Demand Management – Some General Concepts:

Water demand management (WDM) places much more emphasis on the socioeconomic characteristics of water use. Demand management is much more aggressive in its use of economics to influence the origin of water demands to provide incentives for satisfying given "ends" in the cheapest possible manner. In other words, the various water uses are seen as consumers which can be influenced and governed by incentive structures, technology modifications, public education and other means. This is no more than applying public concerns and arrangements to currently unmarked natural resources. This is not to say that traditional supply management actions are no longer required – only that they need to be significantly re-evaluated and changed, delayed or decreased.

Applied to environmental issues, it follows that an effort is required to rethink basic approaches, which to date in most Western societies have been very focused in two areas – the erection of physical structures and the use of the law to provide answers to certain behaviors. The reality is, however, that most environmental problems, such as resource overuse and water pollution are allocational in nature. Legal and engineering approaches to these types of allocational problems are often very blunt and ineffective. UWDM will focus much more than on the present, on the use of economic instruments to influence water use, the fostering of new technologies, complemented by increased levels of public awareness and education about water uses.

5. <u>Development of Urban Water Demand Management Program</u>

Urban Water Demand Management (UWDM) is a strategy to delay costly new water resources development and connections to the cities and their consumers, as well as to re-distribute water to the unserved. It will improve inadequate supplies, reduce energy consumption, compensate for system inadequacies, reduce wastewater flows, and alleviate the demands of rapid population growth.

Defining Program Needs and Establishing Goals:

The first step in developing a long-term Urban Water Demand Management (UWDM) program is to define needs and establish goals. There are mainly three steps that aid in this effort:

Identifying Supply and Demand Problems

The nature and extent of supply-and-demand problems should be identified. In order to define the problems, the following questions need to be asked: (1) Is the problem systemwide or limited to one portion of the service area? (2) Is its major cause short-term (drought, supply contamination, or other emergency) or long term, as it is in almost all major developing countries cities. (3) If long term, is the problem caused by leakage, unaccounted for water, inadequate storage, pipeline delivery capacity, pressure, or inadequate source of supply? wastage by users? (4) Does the supply shortfall occur seasonally (during high demands), at specific peak-demand periods each day, or throughout the year? (5) Is reduction of use sought to meet peak demands or average use? (6) Is a low or high reduction needed to match supply with demand? (7) Is the need to meet government conditions or regulatory requirements a major factor in the reduction of demand? (8) Are budgetary and utility management capacity, main constraint to the efficient and effective supply and demand policy?

Evaluating Current Conservation Programs

If water conservation activities exist, they should be inventoried and evaluated for their effectiveness. Water conservation methods and ways to estimate water savings are described in the document.

The evaluation of existing water demand management activities should follow the same procedures as those used for evaluation additional supply measures. Expectations for further water savings should be tempered. When this assessment is completed, goals can be established to meet specific local needs.

Public Participation

As in many cases utility managers do not have the political support, will, courage and adequate incentives to embark on the urban water demand management program. Especially the problems associated with proper metering, pricing and retrofitting, as it calls, in most cases, an extensive public support.

A successful water conservation program depends a lot on user cooperation. The need for water conservation must be understood and supported by local leaders, otherwise, it will or may not function. Conditions or problems of concern should be communicated to key community leaders, who should be asked to assist in establishing the program goals.

The extent of public involvement will depend on the institutional characteristics of the utility and on the community setting. In a small city, ad hoc advisory committees and close communication with elected officials can provide adequate input and feedback to formulate the program. In larger cities, a formal advisory group may be needed to develop a program that can be presented to the general public. In either case, it is advisable to build into the planning process the time and techniques required to consult with community leaders and interest groups having major concerns about a water conservation effort. **These steps are especially critical if a retrofitting program is planned. It is essential, as well, when implementing a comprehensive water metering installation, reduction of unaccounted for water program and pricing charges**.

The following is a useful checklist of groups that may have a role in water conservation planning:

- Elected officials from all the jurisdictions immediately affected by the process; at the various government levels.
- Staff persons from water companies, key personnel from local government agencies.
- Representatives of major local economic interest groups – major industries, community groups leaders, contractors associations, farmers, tourism-boards, parks and gardens contractors and others.
- Representatives of major community forces – school boards, local unions, religious groups, block leaders, local press and media owners.
- Representatives of local environmental interest groups, if exist. (they could be a powerful support teams).
- Local professionals with credibility, such as economists, engineers etc.

Public participation should be part of a long- term public education program as well as an element of plan development. A plan that is responsive to public needs will receive continuing support. Workshops and seminars can be used to solicit input, and water conservation-equipment manufacturers can be invited to these sessions to exhibit their equipment. Public participation should continue throughout the planning and implementation of the program.

There is a tendency in many developing countries to deal with such programs as a top-down strategy and dis-regard the need and the forces in demand driven policies. Water conservation programs could become an effective instruments in creating and enlisting public participation and support groups, for the special program as well as other functions and actions to be initiated within the urban water srctor.

Establishing Program Goals

Goals should be tailored to local needs, and should be developed together with the public participation process. The following items are examples of a typical case:

- **Reduction of leakages and unaccounted for water** (decision making, budgeting, contracts, implementation).
- **Increase public awareness of methods to save water**, thereby encouraging customers to undertake water conservation measures on their own (importers, manufactures, outlets, contractor), buy and install, or contact, retrofitting contractors.

- **Reduce the water use of existing customers** by encouraging landscape improvements and by retrofitting existing dwellings, industry and business establishments. A special attention to large consumers, industry etc.
- **Reduce the water use of new consumers** by encouraging new dwellings and businesses to be as water efficient as possible in landscaping and inside use.
- **Reduce peak demand**, focusing on landscape irrigation, water intersive industries, offices; use, hotels, restaurants etc.
- **Initiate and complete the metering system** with possible expansion to individual homes, apartments etc.

Identifying Opportunities to reduce water demand

It is important that the selection and evaluation short, medium and long-term water conservation practices be based on a reliable estimate of current and projected water demands. Assumptions about water demand, including those based on projected population, urban and agricultural land uses, and per-capita use, should be clearly stated, since they will be the basis for decisions on water system sizing and related potential delay and savings in capital investments. Projections should be developed for each appropriate water-use category including residential, commercial, industrial (including process and cooling use), public (institutional), and unaccounted for water. **Moderate assumptions for reductions should be followed until it is proved that more rigid demand reductions can be used for planning basis**.

Assessing Legal and Institutional Factors

Some legal and institutional factors may serve as incentives for implementing programs of efficient use of water whereas other factors may impose constraints on the implementation of certain urban water demand management measures. In any event, the institutional, legal, and governmental conditions that affect water use will have an impact on the program and should be assessed in advance. The following factors should be considered:

- National government program and activities.
- State and local govt. statutes and administrative procedures for regulation of water supply and water use, including water-rights laws, administrative regulations and procedures, environmental permits, water and energy programs, and building and plumbing codes.
- Inter county impacts if any, court decrees, regional or local govt. water agreements.
- Local govt./municipal ordinances, agreements, and programs, including current efforts to reduce wastage of water, water-use ordinances and regulations, rate structures and policies, local building and plumbing codes and others.

This information can than be used to evaluate the practicality of each urban water conservation or demand management measures that are considered, using financial and socio-economic methods to set the priorities and schedule of the program.

Identifying Long-Term Conservation Practices

For each significant water-use category, appropriate long-term water conservation or demand management practices can be identified. Practices that have been successfully applied in other areas (of the country, cities elsewhere or in other similar conditions outside of the country) and have the greatest potential for reducing water use are good starting points. Other practices that seem particularly appropriate can also be evaluated. **Table1 lists typical long-term water conservation practices.**

Table 1: <u>Typical Long-Term Conservation Measures (Urban water demand management program)</u>

Area of Application	Conservation Measure
General	Public information In-school education Metering Pressure reduction Pricing Progressive rates structures Peak and off-peak rates (seasonal) Leak detection and repair System rehabilitation (mainly pipes and valves replacement)
Interior residential use (Retrofitting a/or new apts. And homes)	Low-flow shower heads Shower-flow restrictors Toilet-tank displacement (bottles/dams) Installing new low or Two volume flushing Tanks Faucet aerators Water-efficient appliances (Dish-Washers, washing/laundry machines)
Devices for new construction	Low flash toilets and ultra-low –flush toilets / Low flow showerheads. Pipe insulation.(mainly in colder countries) (Save water and energy). Faucet aerators.
Power generation (using fresh water)	Re-circulation of cooling water. Reuse of treated wastewater. In-system treatment and re-use.

Area of Application	Conservation Measure
Industrial use	Re-circulation of cooling water (when using fresh water) Reuse of cooling and process water Reuse of treated wastewater Efficient landscape irrigation Low-water-using fixtures. Process modification- cascading (Re-use of process wastewater between various processes).
Agricultural irrigation* (This is especially relevant for cities where a higher percentage of water used for gardens, parks and agriculture irrigation in the cities or around it using same water sources, A/or network).	Off-farm conveyance systems Canal lining, canal realignment, canal consolidation, On-farm distribution is and irrigation systems Ditch lining or piping Water-control structures Land leveling or contouring Sprinkler irrigation Drip irrigation Subsurface trickle/drip irrigation Tailwater recovery Irrigation scheduling/ inter season changes ./tensiometers pressure regulators
Landscape irrigation	Efficient landscape design Low-water-use plant material Scheduled irrigation Efficient irrigation systems/pressure Regulations, timers, drip irrigation.

*Agricultural irrigation coservation practices are not discussed in detail in this document. However they deserve special attention as in developing countries water is inefficiently used around the higher income homes and their gardens, municipal parks and irrigated landscapes and last but not least agricultural use within or around city limits, using the city water supply system or sharing the water resources with the cities.

6. Comprehensive Urban Water Demand Management (UWDM)

A comprehensive UWDM includes a variety of components and activities. It is implemented in stages according to the city and country conditions.

The program should deal with 5 sub-sectors of the city: **(A)** The Water Distribution Network (reduction of losses and unaccounted for water (UFW)); **(B)** The domestic sub-sector; **(C)** The commercial; **(D)** The industry; **(E)** Irrigation of parks and gardens, as well as agricultural irrigation within the city limits (or in the vicinity when using the same water source, for example).

The comprehensive program includes software and hardware components, the main ones are as following:

Software

1. Institutional ones - Specially establishing clear units with responsibility for water conservation and demand management.
2. Legal – Developing and implementing legal instruments in order to create the environment for reduction of water demand and wastage.
3. Economic – Initiating economic incentives and disincentives to promote conservation – Progressive Rate Blocks – water prices which rise with consumption based on water metering. Sanctions for over use, funds for installing water conservation fittings, systems, and replacement of leaking pipes and "retrofitting".
4. Public Education – Media and school campaigns, posters in the street, in public and commercial bathrooms, in schools, on radio and TV networks.
5. Removal of illegal use.

Hardware

1. Water Metering – Water metering is essential for any successful comprehensive UWDM as it is the basis for the link between consumption and price. It enables allocations, establishing norms for allocations, a Progressive Block Rate system, and control of wastage in all sub-sectors. It can be implemented in stages starting from the larger water consumers like the industry, commercial users, higher income domestic users and others. Meters to be installed on all users, including government offices, police, army, public taps.
2. Water Conservation Fittings – The replacement of older water wasting-fittings is defined as "retrofitting", changing toilets flushing tanks to low-flushing or double volume ones, replace faucets with new ones – non leaking – with flow regulators, replace shower-heads with regulated heads, or spring-activated ones in public / commercial bathrooms.
3. Replacement of old, leaking pipes – To be done following orderly registration of the precise sites of leaks and their frequency. It calls for precise mapping of the city distribution networks and defining the position of all valves, diameters of pipes, numbering it's sections – using a P.C. program for the monitoring.
4. The industry in many cities is a major water consumer. Use special water and wastewater prices, incentives and support by the UWDM unit will assist in implementing various actions to reduce wastage, promoting in-plant recycling

("cascading"), reduce freshwater cooling use, reuse of city treated wastewater and others.

5. Irrigation Methods – Replace old and wasteful irrigation methods in the city, parks, homes and commercial gardens or farmers within or around the city. Basic automation and drip-irrigation are few of the modern efficient methods.
6. Trading of water with treated wastewater effluents – Many cities, today, have already sewered their wastewater system and treat the discharges. As in many cities industry and farmers use freshwater, it is becoming a realistic option to trade freshwater for treated effluent – especially when groundwater aquifer is the source for the city supply as well as the industry and the irrigation. This action call for laying pipes and pumps to reach the users with the effluent coming-out of the sewage treatment facility.

7. Reduction of Unaccounted For Water (UFW):

This issue is possibly the most acute and first priority action within a WDM strategy. Levels of unaccounted for water could reach over 50% in large cities (see bibliography World-Bank, Tech-paper no' 72).
Efforts to reduce excessive unaccounted for water (UFW) in developing countries are hampered by several factors: lack of awareness of the practical possibilities and the potential financial and operating benefits by top management; lack of motivation at the operational level; and, particularly, lack of resources. This section is intended to clarify some of the issues, correct wrong impressions, and stimulate the interest of administrators and operators in making the resources available to improve reduction and control.

Recent national and international publications have identified the problem of unaccounted-for water, but little has been done to relate it to the conditions in developing countries. Nor have efforts been made to show how action can best be taken by management, in logical steps, to achieve effective control even when operational problems seem insurmountable.

The waterworks manager has many problems – perhaps more political and institutional then technical – but, first and foremost, the aim will be to provide enough water, at adequate pressure over the whole are served, to meet increasing demands. For this the manager must have the human, technical, and financial resources to meet both investment and operating costs. Demand management strategy, which includes reduction of UFW is an integral component of the utility goal.

Typically, the utility manager faces a situation in which the authority seeks to continue its traditional policy of improving the supply of water either by developing new resources or by expanding works. Data relating to the existing supply is likely to be inadequate for a realistic assessment of the supply situation; available figures on the quantity of water produced and consumed may be so inaccurate as to call for a good deal of interpretation by an experienced professional. The different divisions within the authority frequently lack confidence in the figures produced by the others, which perpetuates ignorance of true data and hampers opportunities for improved control. Excessive UFW is usually a clear indication of poor management and lack of maintenance. Excuses may be offered for delayed action, but it is necessary to begin

to accurately measure and assess the data to determine immediate and long-term strategy, which will necessarily include improved maintenance practices. Metering of production, maid supply to the city and consumption is essential to achieve the objectives of the utility, without it, the goals can not be achieved.
It is essential to demonstrate one way of proceeding, step-by-step, in producing more accurate data as a basis for the whole decision making process. A clear picture of the existing situation will facilitate the development of a strategy for whatever improvements are warranted and most economic to execute. They may be in the area of physical supply conditions or in the equitable collection of revenue necessary for the financing of improvements, the level of leakages, illegal use, inaccuracy of metering, etc.

If the production of accurate data demonstrates the existence of either an excessive loss of revenue from water consumed or an excessive loss of water from leakage – or indeed both types of loss – the action plan should go on to show how, by cost-benefit analysis, a strategy should be developed and implemented by stages to effect those improvements found to be economically justified. Such levels of water and revenue losses prevent most utilities from becoming manageable and efficient which reduces the suitability for private sector involvement, or private sector participation (PSP) considered today as a potential step toward achieving the utility objectives.

(World Bank, just as an example, has prepared a narrative slide presentation on reducing UFW, which can be obtained from the Economic Development Institute (EDI). An instructor's guide and participants manual with reading exercises and case studies are also available. Interested utility managers could always order these for their staff).

Case Study on Privatizing the Battle to Reduce Unaccounted For Water (Use of an external firm), [From conservation et al. See bibliography].

Unaccounted for water (UAW) is a problem everywhere, but most of all in developing countries. In many cases Consultants or specialist Contractors provide temporary advice, training and assistance to the existing utility in the hope that this will lead to better performance in the future. Poor metering, fraud, leakage, theft and overflows are institutional as well as technical problems, however. So long as responsibility for long-term success rests with the utility the chances are that the institutional aspects of the problem will prevail. Privatizing UFW control by devolving it to a financially separate and accountable body allows both these aspects of the problem to be addressed together.

The benefit of privatization this component of the utility responsibility is that UFW control will become a source of income and profit to local private-sector companies. These will have a much stronger incentive to keep it lower than the utility that employs them. The experience presents contrasting results from a privatized contract in France, which halved UFW in less than 2 years, and other projects in Korea and Malaysia which, while successful in the given context had a much smaller impact on UFW. It is essential to develop a set of criteria that privatization would need to satisfy to minimize the cost of UFW to the utility and community it serves.

Several methods of privatization are described leading to a formula that meets all the criteria. This takes the form of a company set up by the utility in joint venture with a Consultant (probably a local firm supported by an International consultant). The consultant manages the JV on behalf of the utility for a fixed term and this role is subject to competitive bidding. The utility and the Consultant share the profits of the JV.

This approach to privatization encourages:

- Speedy reduction in UAF
- Maximum use of local staff
- Optimum balancing of long-term control and reduction of UAF costs.

The longer effective action to reduce UAF is postponed, the more it costs. Privatization of this action yields the greatest benefit when the delay between identifying the need and doing the work is kept to a minimum. The need for improved UAF control and the value of the benefits this would bring can usually be established at the Master Planning stage of a project. The Master Plan should also be used to identify other measures to reduce demand and ease pressure on existing and future capital and operating costs.

Integrating water conservation (WDM) into the master planning process means that consistent sets of targets can be derived for different combinations of source development, UAF control and demand management. These options can be compared on the basis of economic and other criteria. The resource requirements of the preferred option can then be used to develop a coordinated program and budget for upgrading the system. The benefits of improved UAF control could be brought forward by as much as 2 or 3 years if the Terms of Reference for the Master Plan were broadened to include the preparation of Tender documents for the privatization of UFW control.

In many developing countries water shortages obstruct both the normal operation of the system and UAF control. Rationing by intermittent supply damages both the physical supply system and the credibility and esteem of the utility. Many of these problems can be traced back to inadequate revenue. Unrealistically low tariffs and poor revenue recovery lead to a progressive decline in the supply, abuse by consumers, the use of unsanitary shallow wells and the emergence of an informal, unregulated and inefficient system of water vendors, tanker supplies and private boreholes. In such cases the terms of reference for privatization could be extended to include all most of the major functions of the utility. The Consultant would then not only assist the utility to improve its financial and technical performance but also to match the supply to the latent demand and ability to pay for water in the community it serves. A method of providing incentives to the Consultant to provide the greatest supply at least cost can be developed.

National governments as well as local ones should consider the form of PSP-private sector participation as a step be step strategy for comprehensive privatization of water utilities.

8. Asian Water Utilities and Services:

The following graphs are based on an important piece of work, done by the Asian Development Bank through its Infrastructure Department, and titled water utilities data book (First edition 1993, Second 1997).
It gives an overview of utilities performance indicators of Asian cities.

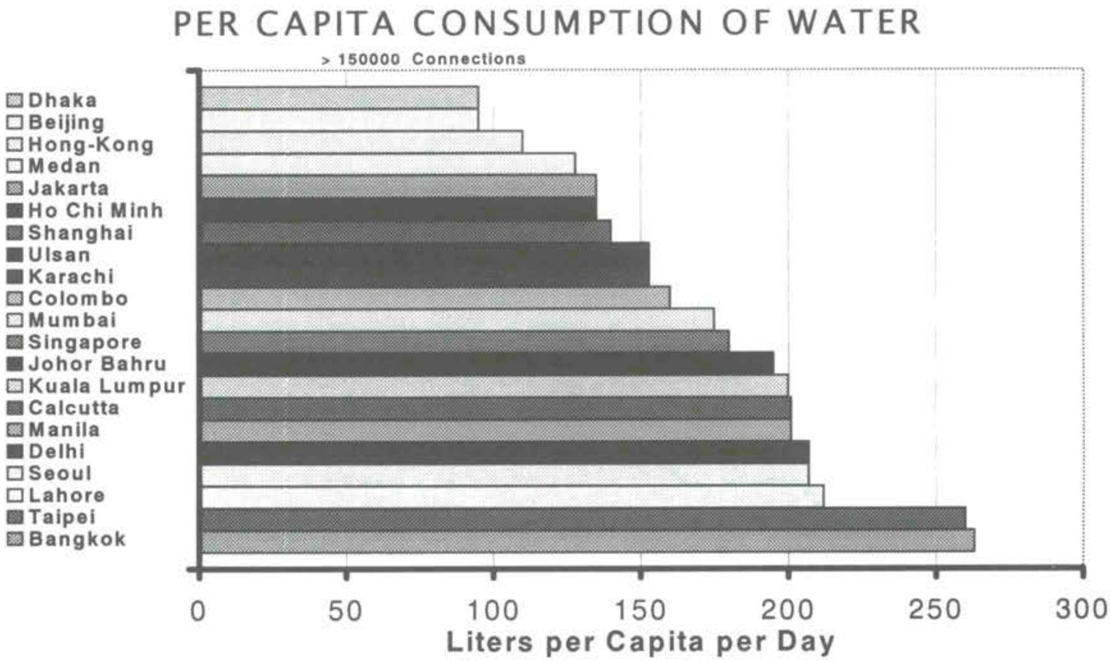
I have selected a sample of the graphs for this report – those which are more relevant to the urban water demand management and the efforts to reduce the unaccounted for water levels.

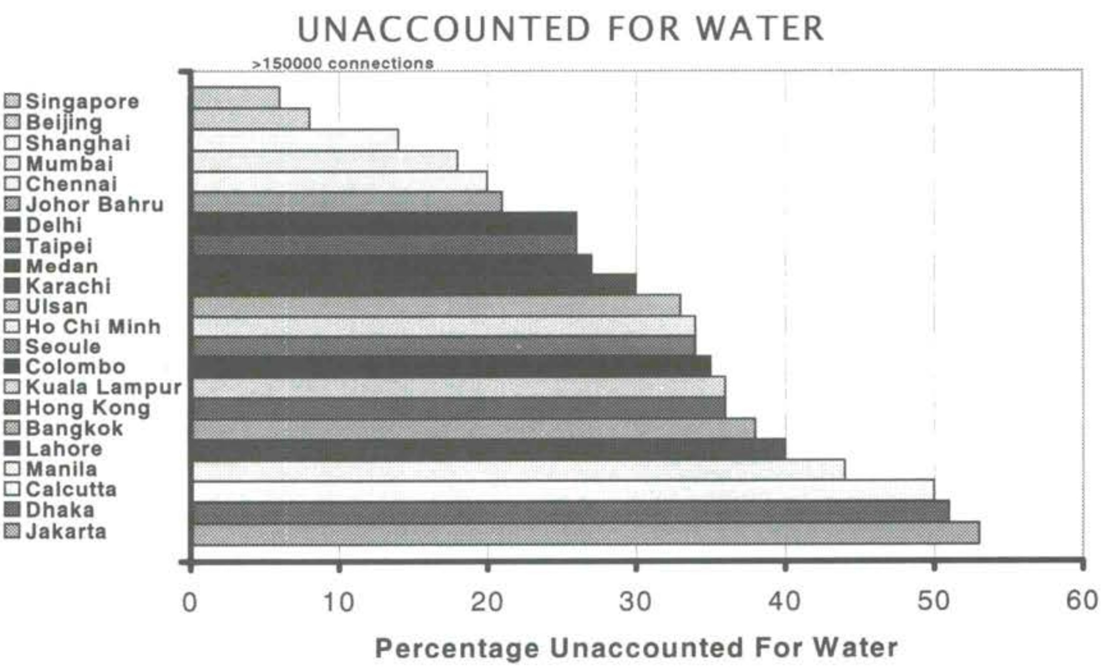
It is a very valuable contribution to the general sector work and to the understanding and potential solutions to urban water supplies.

I am grateful to ADB for allowing me to use their material.

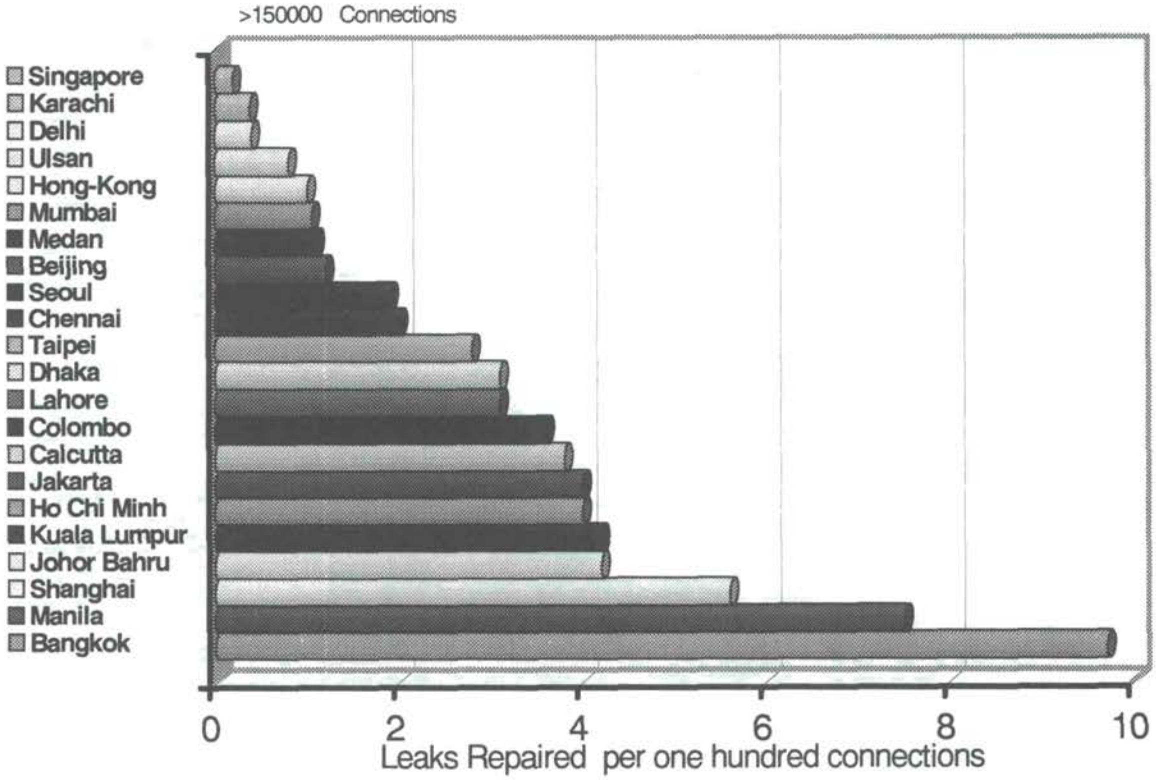
ASIAN (and pacific) CITY PARAMETERS AND ACTION TOWARD UWDM

(CITIES ABOVE 150,000 CONNECTIONS)

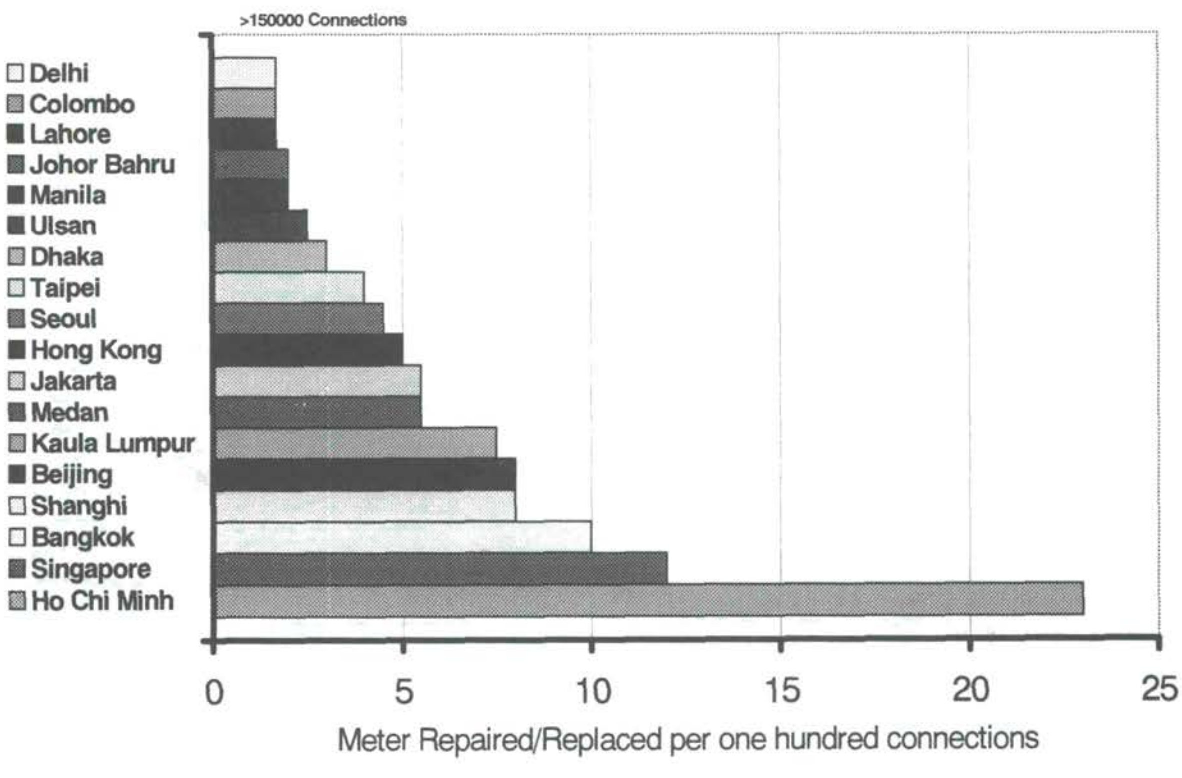


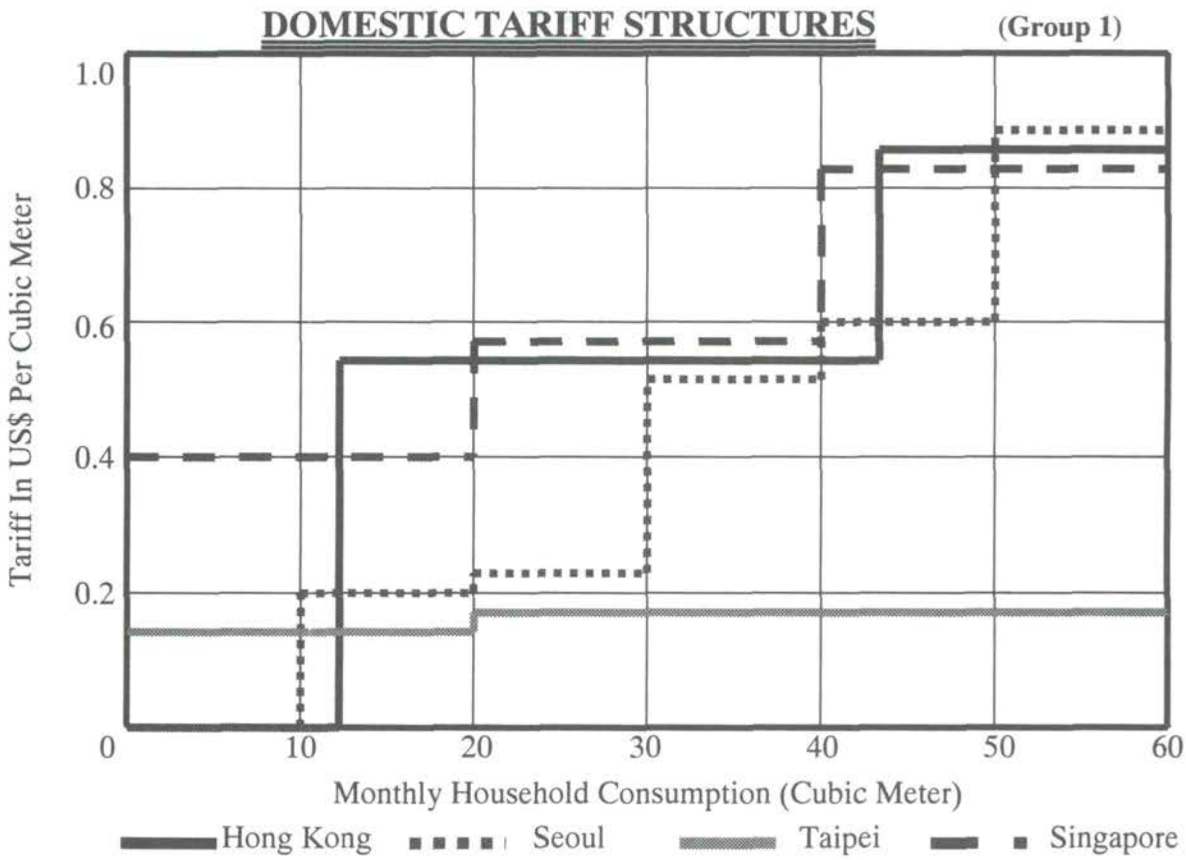


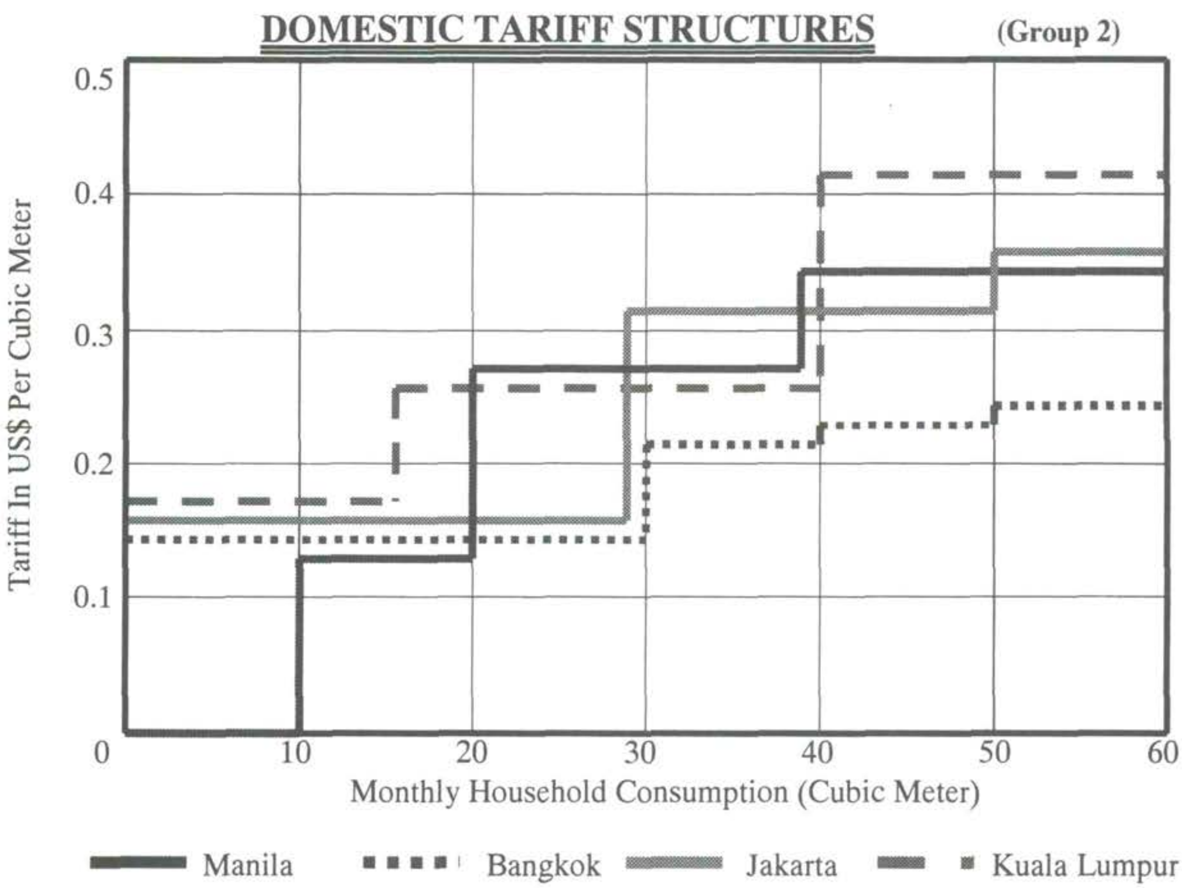
Leaks repaired annualy

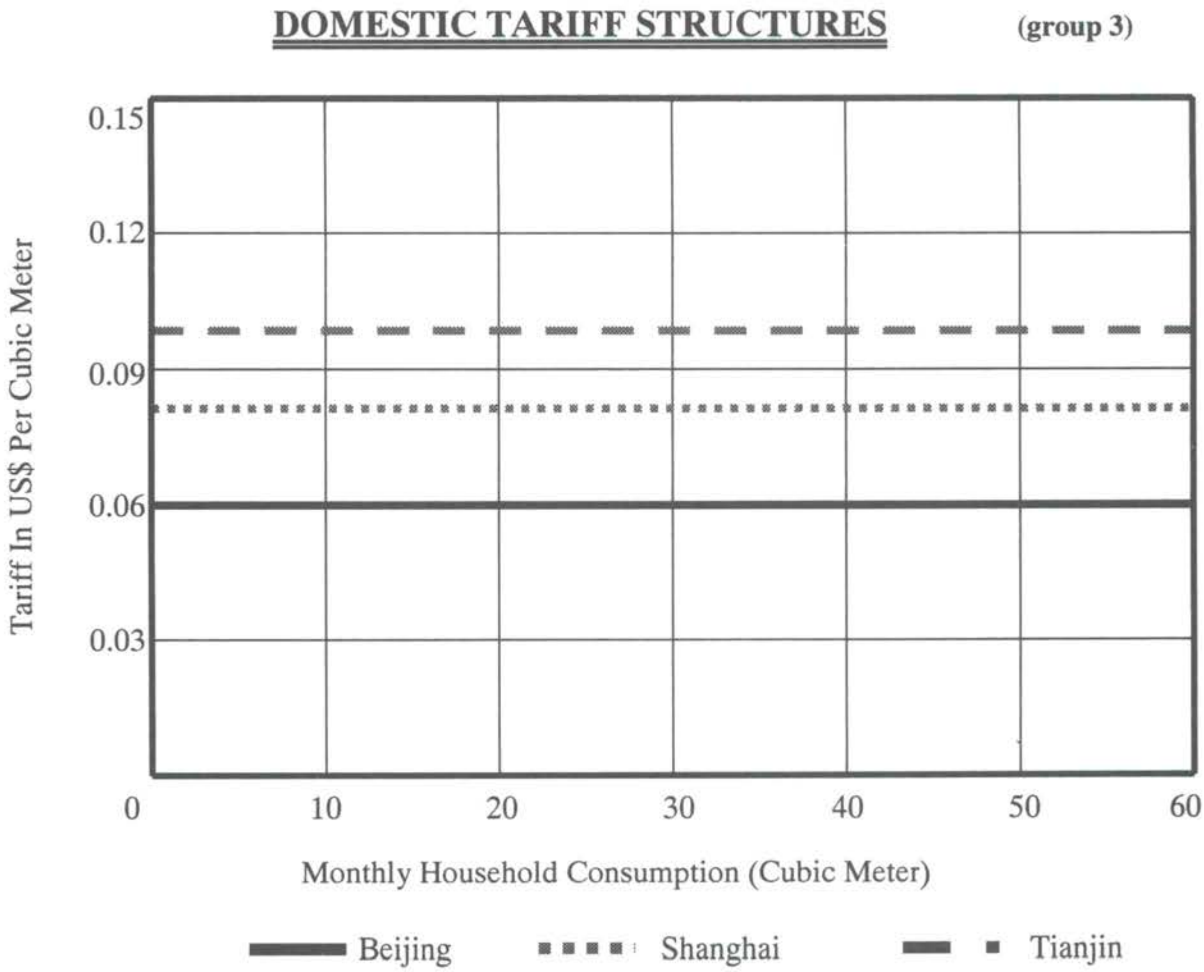


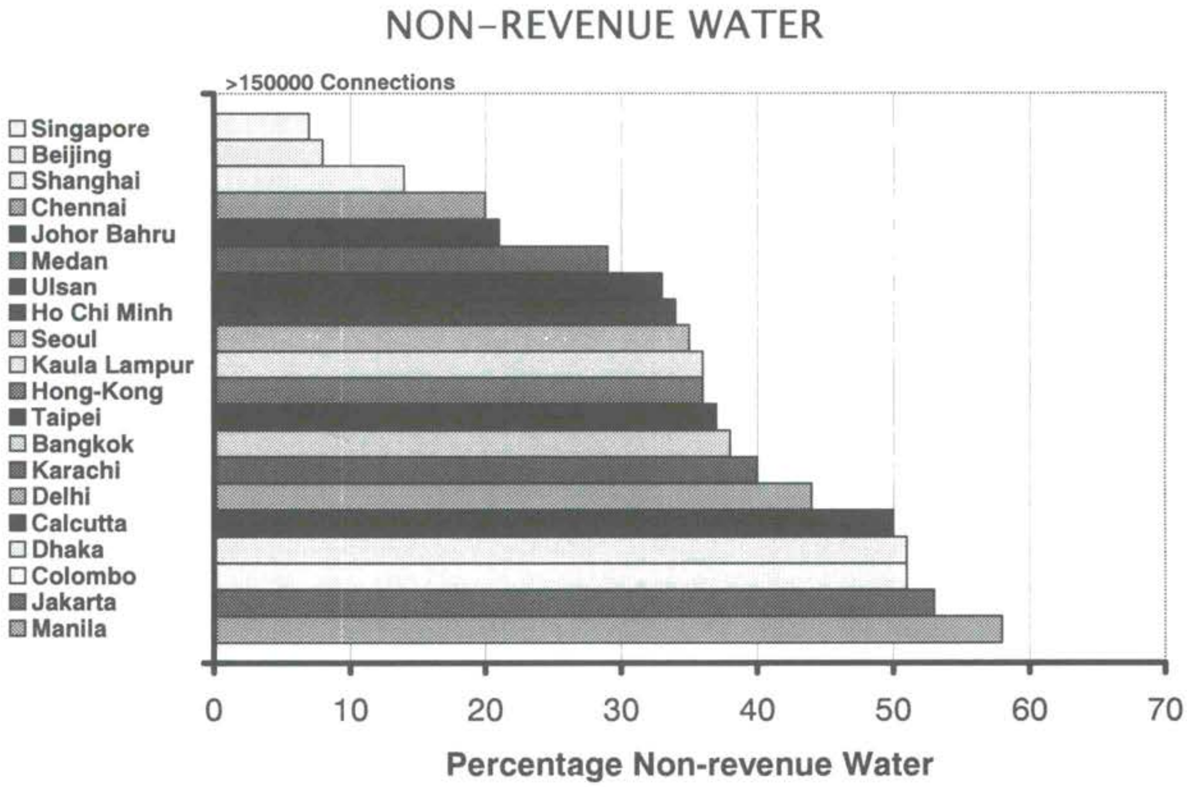
Meter repaired or replaced annualy

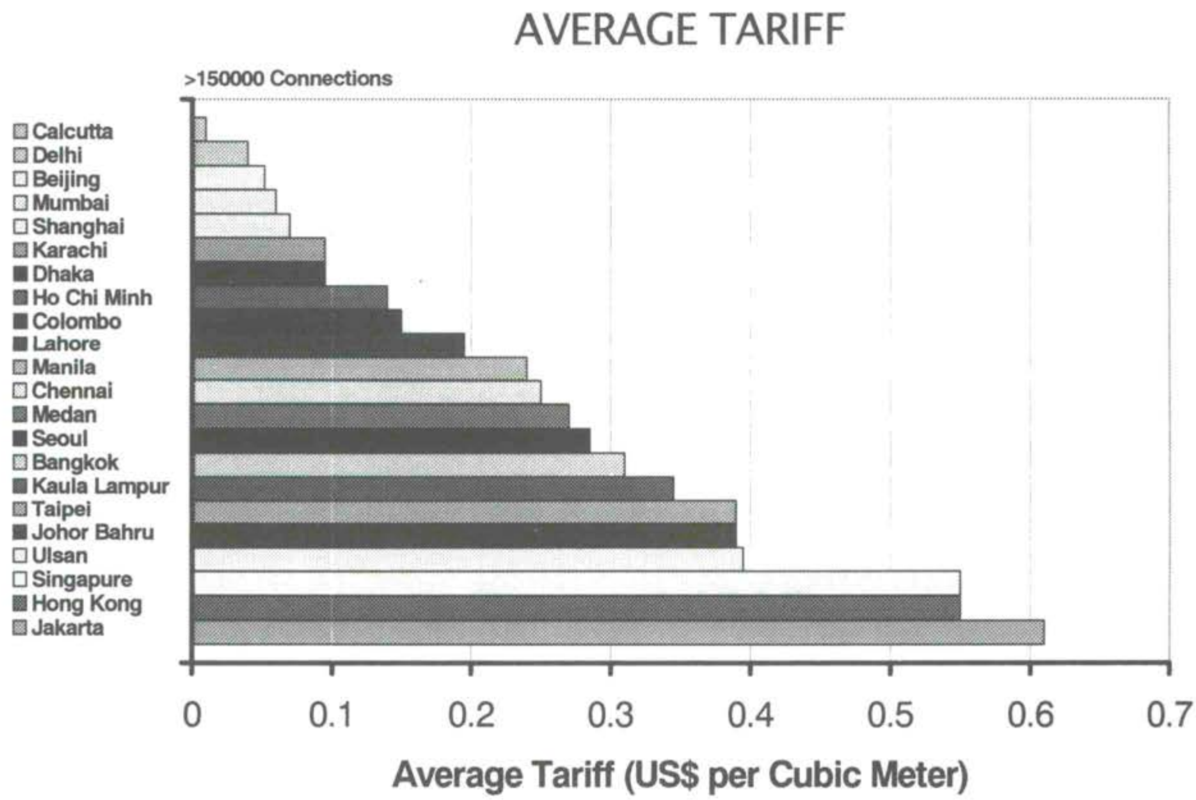



DOMESTIC TARIFF STRUCTURES
(Group 1)
Tariff In US$ Per Cubic Meter
1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
Monthly Household Consumption (Cubic Meter)
Hong Kong
Seoul
Taipei
Singapore


DOMESTIC TARIFF STRUCTURES
(Group 2)
Tariff In US$ Per Cubic Meter
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
Monthly Household Consumption (Cubic Meter)
Manila
Bangkok
Jakarta
Kuala Lumpur


DOMESTIC TARIFF STRUCTURES
(group 3)
Tariff In US$ Per Cubic Meter
0.15
0.12
0.09
0.06
0.03
0
10
20
30
40
50
60
Monthly Household Consumption (Cubic Meter)
Beijing
Shanghai
Tianjin


NON-REVENUE WATER
>150000 Connections
Singapore
Beijing
Shanghai
Chennai
Johor Bahru
Medan
Ulsan
Ho Chi Minh
Seoul
Kaula Lampur
Hong-Kong
Taipei
Bangkok
Karachi
Delhi
Calcutta
Dhaka
Colombo
Jakarta
Manila
0
10
20
30
40
50
60
70
Percentage Non-revenue Water


AVERAGE TARIFF
>150000 Connections
Calcutta
Delhi
Beijing
Mumbai
Shanghai
Karachi
Dhaka
Ho Chi Minh
Colombo
Lahore
Manila
Chennai
Medan
Seoul
Bangkok
Kaula Lampur
Taipei
Johor Bahru
Ulsan
Singapure
Hong Kong
Jakarta
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Average Tariff (US$ per Cubic Meter)

9. General Issues of WDM

Absence of a Policy Framework

Most developing countries have not developed instruments (either regulations or incentives) for internalizing the externalities which arise when one user affects the quantity and quality of water available to another. Industrial water tariffs are based on average cost pricing (rather than marginal cost pricing) and ignore the opportunity cost of water (i.e. benefit foregone in alternative use). Similarly, the effects of damages caused by pollution of surface and groundwater are ignored in determination of water tariffs. As a result, from an economic viewpoint excessive quantities of water are used, and excessive pollution produced, which causes loss of water resources and/or increased treatment costs. (treatment of water and sick persons).

Prices are important as these provide necessary signals

Contrary to the general beliefs, regulatory policies and economic incentives can and do bring about significant savings in household, commercial and industrial water use and reductions in withdrawals from resources a/or redistribution to the unserved. Various studies attempted to provide documentation of scattered but compelling evidence that improved policies can have major impacts. In a number of cases in developed and developing countries, it has been demonstrated that regulations combined with pricing and tariff policies have resulted in savings ranging between 20%-30% or more. The implications of these savings for meeting water supply needs of the urban poor without incurring additional investment costs have been presented in various studies.

Prices alone are not enough

However, an evaluation of water demand management experiences shows that it is important to use a judicious mix of regulatory mechanisms and economic incentives. Further, conservation should not be "pushed for the sake of conservation" since all demand management measures need not be financially viable and/or economically profitable. Those measures which are financially viable are those where the "cost of conserved water" (CCW) is less than the prevailing water tariff or less than the cost of the marginal or next resource to be developed, To insure both financial viability and economic profitability, water tariffs would have to be based on the cost of water supply to the utility plus (the opportunity cost of water" (i.e. benefit foregone in alternative use to incorporate economic externality).

The evidence reported in the case studies discussed in this paper shows that at least 20% to 30% and sometimes 50% of the current water used in households and industries can be saved by adopting the appropriate policy instruments (such as water tariffs, quantitative allocations, technology policies and fiscal incentives) in developing countries. Similar savings are also possible in irrigated agriculture by investments in canal living, advanced irrigation technologies encouraging less-water-intensive crops(through relative output prices) and raising irrigation rates. These steps could enhance the establishment of local water trading between farmers and neighbouring urban centers.

Water pollution control has both environmental and economic benefits

Further, encouraging industries and power plants to treat their effluents and sewerage water and recycle or reuse treated wastewater of the city in their own processes has twin benefits of environmental improvement and additional economic gain. It reduces the withdrawals of water for industrial use and its related costs since a part of its requirements are now met from recycled water. This reduction provides a net economic benefit if water at this withdrawal point has a higher economic value that if it is used down stream or pumped from the ground for other uses. It also provides an environmental benefit by improving the quality of water in the river/pond (where effluent/sewage was being dumped) for downstream users. In this sense, the environmental objective of improving water quality complements (rather than conflicts with) the economic efficiency objective of higher net benefits from water available for other uses. **This complementarily rather than conflicts in the environmental and economic objective** can be one of the key messages for policy makers in developing countries and bilateral and multilateral agencies financing investments in pollution control and demand management as an environmental protection instrument. One must remember that in many urban centers in the developing countries, the industry is a major water user and in many cases uses huge quantities and a source of pollution causing severe damages to water resources used for potable purposes or irrigation, in that city or down stream the disposal point.

Regulatory, fiscal and trade policies

This would require setting up of institutional arrangements to enforce legislation regarding treatments of effluent water, recycle and instal conservation technologies.
A sufficiently high level water tariff (reflecting economic cost) for industrial users and fiscal incentives such as tax concessions, low-interest loans and/or subsides or investments support towards meeting the initial cost of effluent/sewage treatments plants-will lead to the achieving of the two goals of environment and conservation Given the limitation of administrative machinery for pollution regulation, it is necessary to design a policy mix of regulatory mechanisms and economic incentives which will make it worthwhile for the enterprises to converse and recycle water for their own plants.
(See case studies in the document discussing such mixes of policies in various countries and cities – Chapter VI)

Societal Benefits from Water Conservation and Recycling

Demand management strategies leading to water conservation and recycling efforts could release enough water that significant proportion of the unserved urban poor can be given adequate and clean water supply without incurring additional costs on distribution and treatment of water. These additional supplies would also help in providing adequate and reliable water supply to new industries and commercial establishment leading to urban development and employment generation last but not least delay for years the construction of new dams, or pumping (and treating) river water having competing demands by down stream agriculture, industry or urban needs.

Economic Techniques

Economic techniques rely upon a range of monetary incentives (e g, rebates, supports for actions tax credits) and disincentives (e g higher water prices, charges on effluent discharge, etc.) to relay to users accurate information about the value of increasing supply, application of conservation and sustainability in the use of water resource. There are, however, two issues closely related to economic theory that should be addressed briefly, for they support strongly the case for water demand management. These are the issue of resource scarcity, and the concept of economic efficiency.

Scarcity, Resource Availability and Markets

The term scarcity is well understood to refer to current or potential shortage of a particular good or service, or a set of goods and services. In economics, the concept of scarcity is more tightly defined than in common usage, and carries with it a set of economic conditions and dynamics. Since economics itself has been defined as the science of scarcity, the economic framework is an appropriate one within which to frame this discussion.

The general findings of scarcity studies, is that resource scarcities seldom occur in the contest of marketed resources. This issue of market type, which reflect basic allocation arrangements, is of central importance to the scarcity issue. Most economic studies assume that the resources being considered are traded in reasonable competitive markets, under the influence of market forces, where the laws of supply and demand influence the production and use of resource commodities. In water related types of situations, resource scarcities on a society-wide basis seldom occur, because sub situations effects the needs to bring new or alternative resources on to the market. The contrasting class of natural resources is composed of so-called open-access resources, such as water for which conventional markets can hardly be found, despite that more and more examples are beginning to emerge where water markets water banks, or trading start to be integrated with the sector management.

Economic Efficiency

The basic reason why the market economic system works well in allocating marketed resources and in providing incentives for technological change is that it tends to produce efficient solutions to the production and consumption of resources. Suppliers have an incentive to maximize their profits by producing goods and services of acceptable quality at lowest cost. Consumers have incentives to satisfy their needs, again as cheaply as possible. When these two basic forces meet in the market, there is a tendency towards efficient resource allocations – that is, resource allocation at the lowest possible prices. The challenges that water managers face is to apply as many of the efficiency-generating properties of economics as possible, and as soon as possible. Failure to do so is currently causing enormous harm to water resources in many developing countries, and cause large populations, mainly low income urban groups as well as farmers, to suffer the consequences of water shortages leading to increased social and economic damages.

Full-cost water pricing: The term realistic water pricing refers to the concept that all water users should pay for water in proportion to their use of water services, and that the charges paid should cover the full cost of establishing and maintaining water services. In most parts of the world, the financing of water facilities is a complex combination of public subsidy, user charges, cross-subsidies among users and between user groups, and possibly other procedures. These practices have built up over decades of development, re-development and often, political expediency. The basic reason for this is that water systems, are by nature(1) a vital part of urban infrastructure, and(2) in cases so expensive as to be beyond the financial capabilities of many individuals, or the private sector.

However, the process of establishing, modifying, and making special arrangements for individual users or classes of users have resulted in an irrational practices.
Examples are very easy to identify. Flat rate charges for municipal water services are equivalent to giving away water free of charge. Giving industry free access to publicly-owned, openly available water resources is an automatic invitation to overuse and wastage of those resources. Massive public subsides for irrigation works have led to over-development of this resource, and have created a situation where food supplies may possibly be more expensive than they should be. While it is essential that food supplies be expanded world-wide, continuing public subsidies for this activity at their current levels is counter-productive in the long run, and a major cause for water shortages at many urban centers, soil and environmental damages.
Managing water demands focuses on water uses as demands, and, by using economic criteria rigorously, orients development only towards projects that satisfy efficiency criteria. Following these criteria will lead to the establishment of realistic water pricing and much more secure financing for water system developments. In the long run, this is most effective way of assuring that water resources are sustainably developed.
Effluent discharge fees: Effluent discharge fees constitute charges lived by some type of public agency on the discharge of unwanted materials. It is important to stress that such fees provide a good example of water demand management on the discharge side of the water use cycle. They provide firms with the incentive to minimize waste discharges. Probably more important, they are also given incentives to change their processes, products, and inputs toward decreasing the generation of pollution substance, and to re- capture valuable components in the waste stream.

Overusage and Overcapitalization

Excessive water use and overcapitalization are closely linked. In many cases around the world excessive water use is attributable largely to low water prices which prevented the development and wide scale installation of technologies which reduce water demand. Because water costs seldom enter into water use decisions, sectors tend to use water extensively, with no regard to conservation. Excessive use demands larger-than-necessary infrastructures, which lead to excessive capitalization. This heightens costs, in effect wasting billions of dollars of capital. To complete this vicious cycle of excessive demand, prices are kept low to maintain demand at design levels in order that revenue covers as many system as possible. But the situation is made more serious when ungoverned demands are projected to form design capacities for new or expanded water systems. This set of circumstances illustrates the interrelationship of excessive water use and on excessive capital outlays. In the absence of economic forces, this situation is virtually perpetual, and has a tremendous effect on water system capital demands.

Studies conducted during the last decades illustrates that not only can this vicious cycle be prevented, but that it is very cost efficient to do so. In a municipal setting, benefit: cost ratios for water demand management measures often exceed 10:1, which is very high in relation to most project experience in the water resource field. In industry, research is much less complete, but there seems little doubt that similar ratios would emerge.

Irrigated agriculture is a significant contributor to world food supplies. It is also the world's largest consumer of water. There is much evidence that many current irrigation practices are very inefficient in their use of water, and that, on average, over 50% of water used fails to serve its intended purpose. Water demand management principles suggest that irrigation water used needs to be carefully revised with a view to improving water use efficiencies and also to changes in irrigation technologies in most irrigating developing countries one should assume that urban water supply will not have shortages if irrigation efficiencies will be increased by only few percents.

The reality is that 10-20% increase can be achieved in most regions.

The issue of irrigation is mentioned in this context only because there is significant water use for irrigation inside the cities, or adjacant to them, competing for the same resources, or potentially trading the conserved water with the cities.

Building a Water – Aware Public Socio-Economic Issue

One can not deal with the pricing of water and its economic aspects, in general, without emphasizing the awareness issue. For any issue of public policy, the more aware the public is of the basic facts, the more likely it is to be able to make informed and difficult decisions. There may exist a thin line between public education procedures and manipulation, and the demand manager must make certain that their efforts fall into the former category. Public education is certainly one of the most important instruments for achieving a successful campaign for water demand management. In a very real sense, therefor, a well-informed public is true public good, which can promote public policy objectives like water demand management, adequate pricing policies and the necessary support to politicians having to take controversial economic decisions.

Public education is a fundamental method of influencing political opinion. A frequently expressed constraint to adopting water demand management approaches is that the political will to implement these approaches is lacking. This is particularly the case when proposals are made for increasing water prices. These are frequently opposed on the basis that they are politically unacceptable. Demand management solutions tend to be quite efficient economically, and accordingly, tend to save large amounts of money, sometimes over short period of time. Also they tend to stretch available resources over a larger number of projects. Once this basic fact is understood, the probability of public and political acceptance is increased.

The issue of wastewater reuse, a very important demand management tool, is another area where public education will prove beneficial. Objections to the more direct reuse of effluent, when it is known to be wastewater, arise frequently for aesthetic, religions or other reasons. Effective public education will be effective in countering these types of objections.

Market Based Instruments

The most important of the market-based instruments are: (1) water pricing; (2) pollution charges; (3) extraction fees for ground water exploitation, (4) establishment of water trading incentives and options (5) financial incentives for the adoption of water –saving technologies, and (6) incentives and rules to encourage utilities to become commercially viable.

The most important of the mandated or compulsory administrative instruments are: (1) user quotas and other rationing devices, (2) pollution control through effluent standards imposed at the municipal or firm level, (3) required installation of water saving technologies, and (4) mandatory reductions and reallocations among users in response to drought and other emergencies.

The boundary lines between these instruments are sometimes unclear. Users may be given quotas for water use; but be permitted to exceed the quota if they are willing to pay a higher price for the additional use. This is a mixed case. As in Israel the installation of some water- saving technology, or by ordering the installation of such technologies and enforcing the order. All of these instruments may be in-simultaneous use in a single country as they are, for example, in Mexico and in the U.S (in California), and others.

It is not possible to make the case that one set of these instruments is always better or worse than the other. Nor is it necessary to make an either /or choice between them. The choice of specific instruments should depend on their effectiveness and costs, which will tend to vary in different country, social conditions and local settings. Some general observations about them, however, can be made.

Only a few countries, such as in Israel or Singapore, for example, have made concerted national efforts to manage demand through conservation instruments of either type, in a more comprehensive way. Since 1983, China has made major efforts, primarily through mandatory instruments.

Market–based incentives as instruments for water demand management and conservation.

Water pricing policy lies at the heart of market-based incentives for improved water resource management and conservation. It is been argued by many, that empirical studies in a variety of country and local settings have confirmed that water consumers respond to price changes. Raising average price levels, therefore, is clearly a means of conserving water. What effects would this have on equity in the distribution of water resources and
efficiency of use ? is the concern about pricing policy primarily triggered by financial concerns about cost-recovery in the sector or does it have a broader significance? What criteria should be employed in setting prices?

It should first be observed that for prices to have the effects described above, the prices must be on a per unit basis, with payment tied to volumetric use. It enforces the installation, calibration, maintenance and reading of a comprehensive water metering system. [See Asian cities indicators (Chapter IV), as well as the case-studies (Chapter VI)].
A pricing system based solely on a flat rate regardless of volume used or a system based on property value would not have the effects predicted. Pricing based on use requires some means of measuring usage- normally through water meters. The reasoning for this is straightforward. Once the flat-rate is paid, the price for volumes used is essentially zero and, therefore, there is no incentive to conserve on use. The cost of meter installation, maintenance, and regular reading and billing are costs which need to be weighed against benefits in choosing pricing options to conserve water – such as progressive block-rates, which gradually become the prevailing method in metered urban water systems.

In some cases, volumetric pricing for low-income groups, small volume users - is not an economically attractive option. This is not the case, however, for most users and almost never the case for industrial and high volume domestic and commercial users.
So the basis for using economic instrument lies the proper installation and maintenance of the water meter.

What are the prevailing relationships which exist between the cost of providing services and the price?
As a factual matter, the prices charged to urban users of water and sanitation services are substantially below both the financial and economic costs in most developing country systems.
This, in turn, would imply that those who are being served, are enviable position of getting greater surplus value and using larger quantities of water at the expense of the utilities and the general public as well as those in the service area without access to system services.
Moreover, those who are served have less incentive to change their behavior, even if mandated to do so, than they would if they had to respond to the full financial or economic costs.

These adverse incentive effects impact on utilities, who respond to financial flows. If they are reasonably assured that their financial obligations will be met on a sustainable basis-if only through government –provided equity and subventions; they will have now substantial incentive to recover the surplus value and reduce the consumption of their current consumers. This is an important issue, when governments wish to enforce on the utilities a retrofitting strategy which causes in the short run, a reduction in revenue.

Moreover, since many of the largest users are likely to be locally and nationally powerful in a typical case, the utility may be understandably reluctant to enforce progressive rates and investments in conservation technologies.
So long as the price remains low, industry and other large users can argue successfully that it would not pay for them to install water-saving technology.

The utilities are more directly concerned with the financial costs than with the economic costs. The economic costs of water from society's perspective includes not only the direct cost of providing service, but also the cost that provision of water adds to dispose and treat the resulting waste water or enough to compensate for environmental damage created. In some circumstances, for example, when an aquifer is being mined to depletion becomes an additional cost to society. Since prices are generally not high enough to cover the incremental direct cost of service provision, it is dramatically clear that they fall far short of covering these additional costs. Consequently, the prevailing prices provide little incentive for users to adopt water-conserving technologies, thus justifying intervention by the authorities responsible for the general public good, protecting water resources from depletion, degradation, and social costs and environmental damages.

These provide the reasons and the democratic justifications, even in the context of water market economy to regulate sector performance and to make satisfactory and enforceable contracts with clear allocation of responsibilities and liabilities. To find the ways and means to lead utilities to integrate demand management instruments, tools and policies.

10. CASE STUDY - An Economic Approach to Scarce Water Management – Arid and Semi-Arid Conditions

(based on Harvard University and Middle-East groups projects)

As elsewhere in the world, governments in the water scarce regions tend to disregard the economic value of water or rts trade offs. Water problems are defined in terms of water quantities and the cost of providing them. This leads to an inefficient allocation of water resources within countries and contributions to impasses in disputes among sectors, counties, or countries.

These difficulties can be overcome by the systemic, rational treatment of water as a scarce resource and the application of the principles of economic analysis to its allocation. This can be done taking fully into account the fact that water can have social value beyond its private value and that it is the right of every government to set its own water policies.

The result is a method and a practical tool intended for water demand management, linking demand and supply issue into one integrated economic instrument, dealing with the issues of:

- allocation water among competing uses;
- the cost –benefit analysis of infrastructure projects;
- the analysis of domestic water policies
- Evaluation of proposed international agreements and arrangements.

By adopting the economic approach, governments can increase the total social benefits received by their constituents, and can reduce tensions among competing users by designing "win win" policies.

The following are some major propositions involved in the economic approach to analyzing water issues:

1. It is the scarcity of water, that gives water its value. Where water is very scarce, such scarcity is reflected in a private willingness to pay relatively large sums for small amounts of water. Where water is somewhat more abundant (albeit still scarce), the value of a unit of water is lower.

2. **Water can have a social value that goes beyond its private value.** For example, in a country where agriculture is socially desirable (but not necessarily privately profitable), the government may decide to subsidize water for agriculture. This subsidy reflects an excess of the social value of water over its private value. Even this policy does not necessarily contradict the concept of demand management as social values could be higher than the next resource to be developed.

3. The Value of water as a scarce resource, can be calculated using a system of prices (shadow prices) that takes into account both the private and the social values of water as well as its cost. Moreover, the value of a unit of water is different in different locations. For example, a given quantity of water delivered to a particular location can have a higher value than that of the same quantity of water in situ, party because of the costs of delivering the water to that location.

4. The necessity to allocate water among districts or among competing users naturally leads planners and policy makers to deal in terms of the **opportunity cost** of the water. The system of shadow prices produced by an economic model provides policymakers with the ability to do this explicitly.

5. **Water cannot be worth more than the cost of replacing it.** The possibility of desalinating unlimited quantities of seawater and its distribution costs puts an upper bound on the value of water in locations where desalination technology can be used and hence on the value of the associated fresh water supply in situ. This is indeed relevant to countries in the Persian gulf, the middle –east, various islands in central America or the Mediterranean Basin and others.

Allocating water as a scarce resource: markets or models?

In many countries, water is becoming a scarce resource. Especially in Arid and semi-Arid countries.
The allocation of scarce resources is the basic subject matter of microeconomic analysis. While the importance of water does not exclude it from the application of such analysis, water does present some special features that require special attention and (to some extent) special methods.

The economist's standard solution to the allocation of resources problem is to recommended a system of free, private markets. In fact, however, despite the widespread and powerful nature of that solution, it is not always applicable. In particular, a private market solution requires the following three things in order to generate efficient resource allocation:

1. There must be a large reasonable number of small competing sellers, buyers and feasible water conveyance system. river, piping net work, aquifer, etc.
2. The social and private costs associated with the production and use of the resource should coincide. In particular, the production or use of the resource must not impose additional costs on others that are taken into account by the producer or user.
3. Similarly, the social and private benefits from the use of the resource must coincide. Private markets fail to deliver efficient results where there are social values in addition to private ones.

In different regions, none of these conditions are met:

1. Water resources are usually not owned or sold by a large number of competing sellers. In many cases water is a public good allocated to users, administratively, linked to land'a/or mode of U.S.A
2. There are social costs to water extraction ("externalities") that are not reflected in private costs (environmental effects, effects of extraction in one location on costs in another, etc.). these are mostly known in the case of ground-water use, as externalities are not recognized , until problems arise.
3. There are often social or national values associated with the use of water for certain purposes or in certain locations that are not reflected in private benefits, i.e., in private willingness to pay for water. These values are reflected in national policies such as subsidies to agriculture, in central or in defined districts, crops, or industrial products.

Hence, private markets may not lead to efficient allocation and management of water resources and will serve demand management objectives, in a non opinion way.
Nevertheless, the economic approach to resource allocation car still be of great assistance, because it is possible today, with modern software and computers, to build a **model** of a water economy that takes account of the social- private tensions involved and generates the resulting efficient allocation of water.
In effect, such a procedure produces a **simulated market solution**, that overcomes the above-listed defects of actual markets. This is the approach of the middle east water project, coordinated by Harvard university and 4 other teams from Israel, Jordan, Palestine and the Netherlands.

The Middle East water project (HMEWP), constructs a model of a country's (or a region's) water economy. The area modeled is divided into districts. Within each district, demand curves are specified for three user types (households, industry, and agriculture). The costs of extracting water in each district are given, as are inter-district conveyance costs. Data are provided as to the infrastructure in place, including wells, inlet works, water treatment plants, desalination plants, and conveyance facilities.

All of these data can either reflect current, actual conditions or, more importantly can involve forecasts and "what-if" scenarios.

Given this information, the model proceeds to allocate the available water in an optimal manner. This optimization process takes into account both private values for water (as represented by the demand curves) and, very importantly, national or social policies towards water. In particular, the model user constraints on the solution, for example, by requiring that water be served for certain districts or uses by imposing various pricing policies.

The model solutions provide not only optimal water flows but also prices ("shadow prices") that serve to guide decisions and to value water. It is important, however, to distinguish these shadow prices from prices actually charged to consumers. Prices to the consumers are matters of policy, whereas shadow prices reflect the real value of water in different locations according to the policies and values imposed by the model user.

As in many countries agricultural water use is the major one, competing with the cities and industries for scarce water resources. Therefor, in this model, a special, detailed treatment is given to agriculture, so that the user can investigate the effect of different water conditions or policies on crop, choice, for example. However, the same can be used very effectively to evaluate optimal water allocations between industries, different water users in the urban centers, and the assessment of demand management policies as well as new supplies options.

The project's product: a decision-support tool

The model (or more properly, models) produced by the projects embodied on computer programs that run on modern laptop computers.**

The result is a powerful decision – support tool for water managers and policy makers. That tool can assist in the following areas:

- The tool can assist in the allocation of water among competing domestic uses and districts, by guiding policymakers to allocations that yield the greatest benefit to their society, according to the policymakers own assumptions and values.
- The tool can be used for the cost – benefit analysis of proposed in infrastructure projects. In this regard, it should be noted that the tool analysis the effects of infrastructure (or other) decisions taking – wide effects into account. It explicitly deals with the opportunity costs of water-allocations decisions.
- The tool can be use to analyze the costs and benefits of proposed water policies such as subsidies or taxes.
- The tool can be used to estimate the price that the using party should be willing to pay to import water.
- The tool can be used to evaluate the effects of proposed international water agreements on a particular party.

** It is worth noting that, about 10 years ago, the programs could only have run on the largest " main frames". 15-20 years ago, they could not have run at all.

It should be remember that the project's methods and tools do not themselves make water policy. They can only serve to guide it. Water demand policy will probably, always be guided in part by non-economic considerations.

The model does so by permitting the user to express what appear to be non-economic values and use them as inputs into the models.

A careful use of the tool provided by the project can thus prove considerable assistance in the making of decisions about water, especially when demand management strategies are part, or considered to be integrated in a city, county, or regional water resources management Schemes.

<u>The project's objectives:</u>

- **To promote the economic approach, as a way of thinking and analyzing water related issues, both domestically and regionally.**
- **To promote communications and cooperation on water related issues among all parties involve.**
- **To develop reliable, realistic and user friendly decision support tools for the efficient management of the water systems of water scarce countries or regions.**
- **To develop agriculture submodels for agricultural districts in each country.**
- **To examine the usefulness of these tools for policymakers and planners.**
- **To promote demand management strategies based on the economical values of water.**

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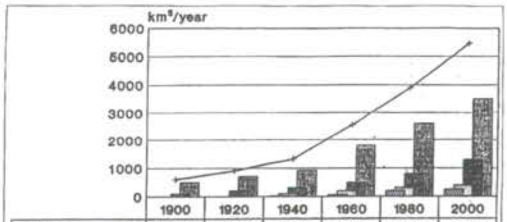


	1900	1920	1940	1960	1980	2000
Agriculture	500	700	900	1800	2600	3500
Industry	100	200	300	500	800	1300
Urban supply	0	0	100	200	300	400
Reservoirs	0	0	20	50	200	250
Total	600	900	1320	2550	3900	5450

Fig 1: Development of world water consumption

Concerns regarding water development

Social concerns
- Conflict over water and land use
- Reduced food security
- Water related diseases
- Reduced standards of living

Environmental concerns
- Degradation of ecosystems
- Irreversible degradation of aquifer systems
- Subsidence
- Reduction of soil fertility

Economic concerns
- Insufficient cost-recovery
- Inadequate supplies for future domestic and industrial uses
- Increasing cost of new schemes

Supply augmentation vs. demand management

Supply augmentation
- Short-term solution
- High cost
- Excacerbates the environmental degradation

Demand management
- Averts high infrastructural investments
- Reduces degradation of resources
- Reduces/prevents pollution, salination, waterlogging, and erosion
- Prevents conflict through inter-sectoral reallocation of water

Constraints to demand management

- Most countries provide subsidized or free water for irrigation
- Most countries subsidize water supply infrastructure
- Few countries accomplish significant cost-recovery
- Few countries have well defined demand management techniques

Technical tools

- Efficient irrigation
- Industrial recycling
- Conserving in cities
- Waste water reuse

Guidance and advocacy for water demand management

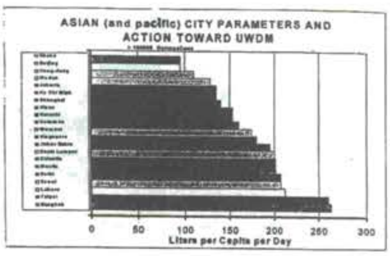
- Concerns regarding water development
- Supply augmentation vs. demand management
- Tools for demand management
- Constraints
- Institutional and Management Options
- Concluding remarks

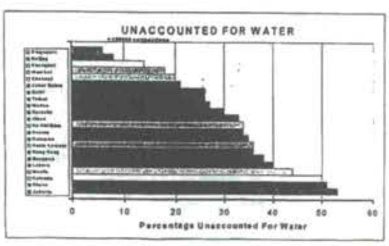
Concluding remarks

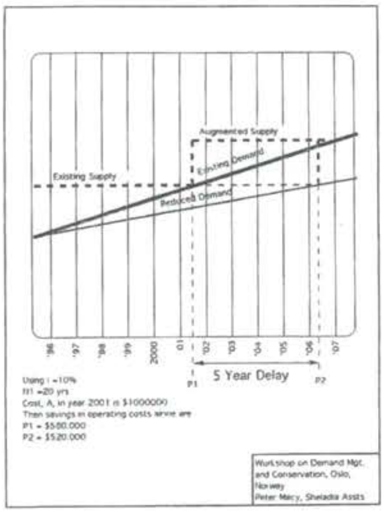
- ✓ Raising awareness and building commitment
- ✓ Efficient regulatory and legal framework
- ✓ Appropriate pricing practices
- ✓ Decentralization and small scale projects to enhance user participation

Typical Long-Term Conservation Measures (Urban water demand management programs)

Area of Application	Conservation Measure
General	Public information In-school education Metering Pressure reduction Pricing Progressive rates structures Peak and off-peak rates (seasonal) Leak detection and repair System rehabilitation (mainly pipes and valves replacement.)
Interior residential use (Retrofitting at/or new apts. And homes)	Low-flow shower heads Shower-flow restrictors Toilet-tank displacement (bottles/dams) Installing new low or Two volume flushing tanks Faucet aerators Water-efficient appliances (Dish-Washers, washing/laundry machines)
Devices for new construction	Low flush toilets and ultra-low – flush toilets / 2 volume flushing tanks Low flow shower heads Pipe insulation (mainly in colder countries) (Save water and energy). Faucet aerators Water-efficient appliances
Power generation (using fresh water)	Re-circulation of cooling water Reuse of treated wastewater In-system treatment and re-use
Industrial use	Re-circulation of cooling water (when using fresh water) Reuse of cooling and process water Reuse of treated wastewater Efficient landscape irrigation Low-water-using fixtures Process modification- cascading (Re-use of process wastewater between various processes).
Landscape irrigation	Efficient landscape design Low-water-use plant material Scheduled irrigation Efficient irrigation systems/pressure regulations, timers, drip irrigation
Agricultural irrigation (This is especially relevant for cities where a higher percentage of water is used for gardens, parks and agriculture irrigation in the cities or around it using same water sources. A/or network)	Off-farm conveyance systems Canal lining, canal realignment, canal consolidation, On-farm distribution and irrigation systems Ditch lining or piping Water-control structures Land leveling or contouring Sprinkler irrigation Drip irrigation Subsurface trickle/drip irrigation Tailwater recovery







February 25, 1994 — THE PHILIPPINE STAR

Most Asian lose a third of their water

More than one third of all piped water is lost in most Asian cities.

Unaccounted for water, mainly water lost through leaks or pilferage, is particularly high in Dhaka (62 per cent), Yangon (60 per cent), Manila (58 per cent), Jakarta (57 per cent), Hanoi (53 per cent) and Colombo (51 per cent). At the other end of the scale, the amount of unaccounted for water in Singapore in just eight per cent.

These are among the findings of the Asian Development Bank's *Water Utilities Data Book* — the first publication of its kind for the Asian and Pacific region. The publication presents data from 38 water utilities in 23 of the Bank's developing member countries.

"The most important finding is that regular maintenance, repair and replacement of meters for measuring all production and consumption of water is lacking in most of the cities we surveyed," says Arthur McIntosh, an ADB senior project engineer who coordinated the data book. "The time for demand management in water supply has arrived. But consumers won't take kindly to measures reducing their consumption when there are large losses in the system. And you cannot institute demand management if you cannot measure the consumer system."

At present, about two thirds of the utilities collect enough revenue from tariffs to cover operation and maintenance costs. The larger utilities which do not collect enough revenue include those located in the People's Republic of China, Pakistan and Bangladesh.

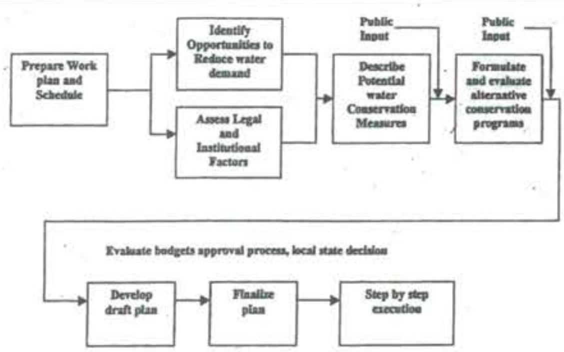


Figure 1: Proposed scenario for Planning steps for a water conversation program

Approaches for water demand management

Water saving devices and appliances

Peter Thomas
HATI – Company for craft technology and innovation, Berlin

As a plumber, my understanding of water demand management is focused on the usage of water inside buildings and on outside rainwater treatment. Since in Berlin more than 90% of the inhabitants live in residential homes with more than 20 persons, I have specialised in the water household of these buildings.

When I started with my work in the mid-seventies, most of the old residential homes in Berlin had only one tap inside the flat. Several families had to share the toilet on the main floor. In these old homes the water consumption was 50 to 70 litre per person a day.
In the same period, the water consumption in modernised homes and new flats was three times higher as in the old residential homes. Publications of the waterworks show that per person, 170 to 210 litre were consumed every day.

Core element of this integrated urban waterproject in Berlin is an aprroximately 800 m² large graywater purification plant. The plant is situated like an island within an approx. 1.000 m² large rainwater pond.

Without a vision of efficiency watermanagement, town modernisation leads to a three times higher water usage and sewage. To be able to deal with the higher water consumption, new water catchment areas and also tract of land should be applied to purify the three times more sewage.

In the former situation of West-Berlin, which was surrounded by the wall, there were neither additional restricted areas for water catchment nor were there areas for sewage plants. This situation is similar to that of most big cities in the world. In the beginning of the 80-ies, other waterworks in Germany like Hamburg, Munich and the agglomerate Frankfurt, had big problems to retrieve enough water from the water catchment areas because of dehydration.

Therefore, watermanagement needs to be an integrated part of the local governments modernisation and town-renewal strategies.

The political discussion on the field of energy (resistance against nuclear energy) late 70-ies / early 80-ies mobilised some societal groups to surge for practical solutions.

Graywater heat recovery system

Graywater has a very high heat source. In several appartement-houses the heat of the graywater is used for the domestic hot water supply system.

The average temperature in a highly efficient thermal insulated graywater storage tank is more than 26 °C.

20 to 25 percent of the energy for the domestic hot water supply system can be recovered directly (without a heat pump system).

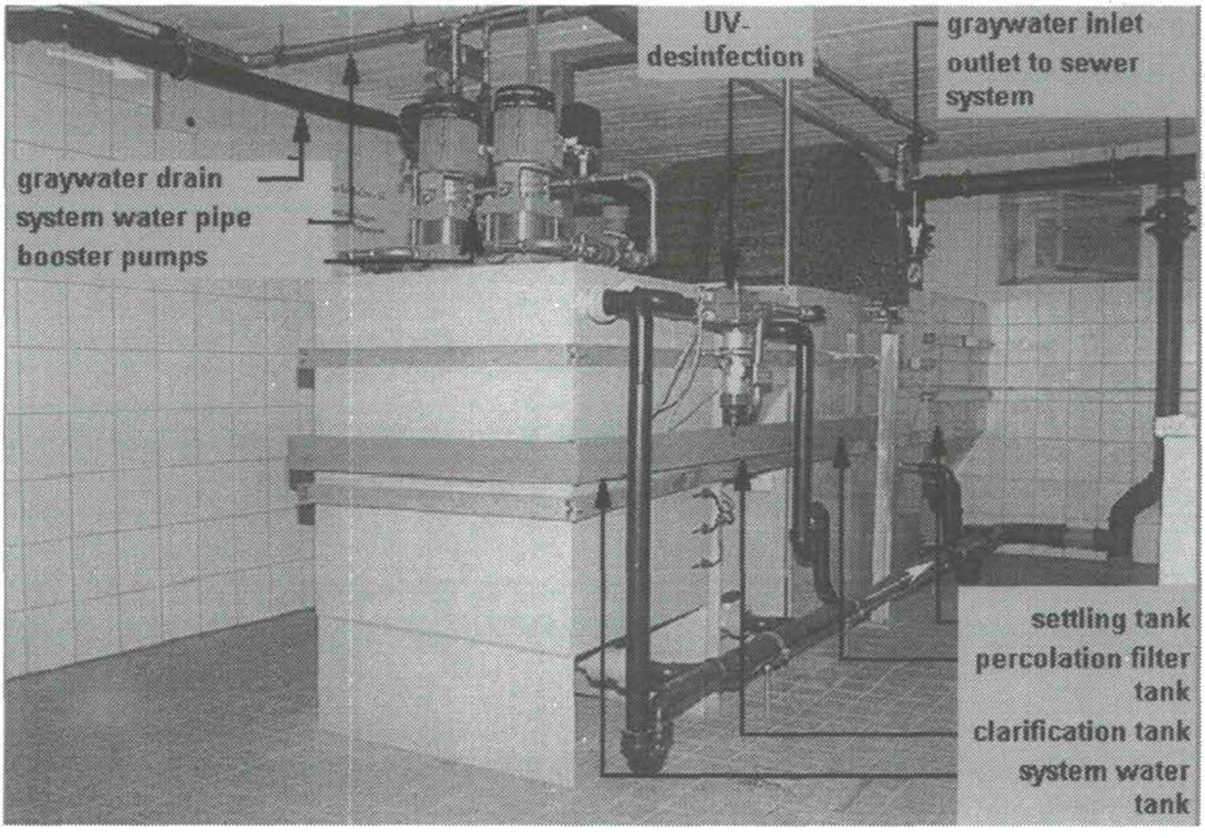
One of the consequences of the energy crisis was, that in the beginning of the 1980-ies one started to separate graywater, just to subtract the thermal energy from the graywater. The additional costs for the separate pipes, the integration of a reservoir and a heat exchanger was only financed with the saved energy costs.

Missing were the elements purification and re-use of the graywater. Building on the principle Japanese experience (chemical purification of graywater cannot be realised in Germany) we developed multiple different methods for biological graywater purification. Finding the right combination between centralised and decentralised systems was the main target in Berlin. Furthermore, we wanted to achieve the bilateral and integral optimisation of the system components.

How much water flows out of a shower head, how much flows into the sink while washing, what is the water consumption of domestic washing machines? These are all important factors for sizing the graywater settling tank and also the purification plant has to fit these individual water usage.

No other element has the ability to integrate particles as water does. High water consumption means high investment costs for water-conditioning and high costs for wastewater treatment, independent from the fact if this process is centralised or not.

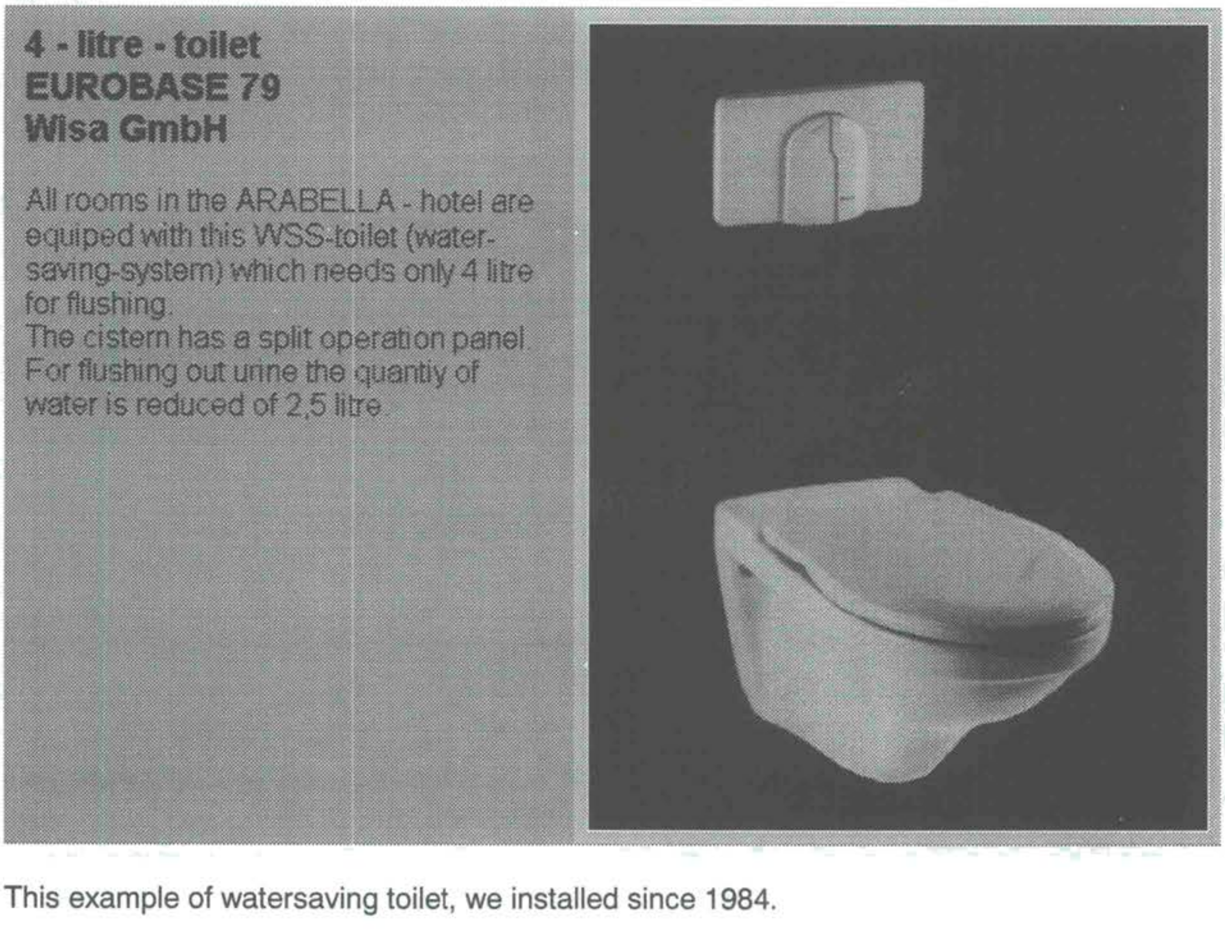
As a plumber I have learned, that purification is most efficient, when the wastewater is more concentrated. Dependent on the quality, specific methods can be used. More and more experts do agree, that it makes no sense to collect wastewater of different qualities and substances of a whole city and lead it to a central point to efficiently extract the different elements. It is much more efficient to purify the water at the point of producing. One of the advantages of local wastewater purification lies in the fact that, depending to the individual water quality, the best specific purification method can be chosen and installed.



General view: Graywater purification plant in an appartement house in Hannover

Another important side aspect for an industrial country like Germany is following: we need new and intelligent products, which current jobs can be secured and new ones are created. This can be done by offering customised, local know how and solutions. In the sideline, in the field of energy, hardware components have to be customised to fit national and regional requirements. On the other side, the technical hardware for water saving equipment is world-wide the same.

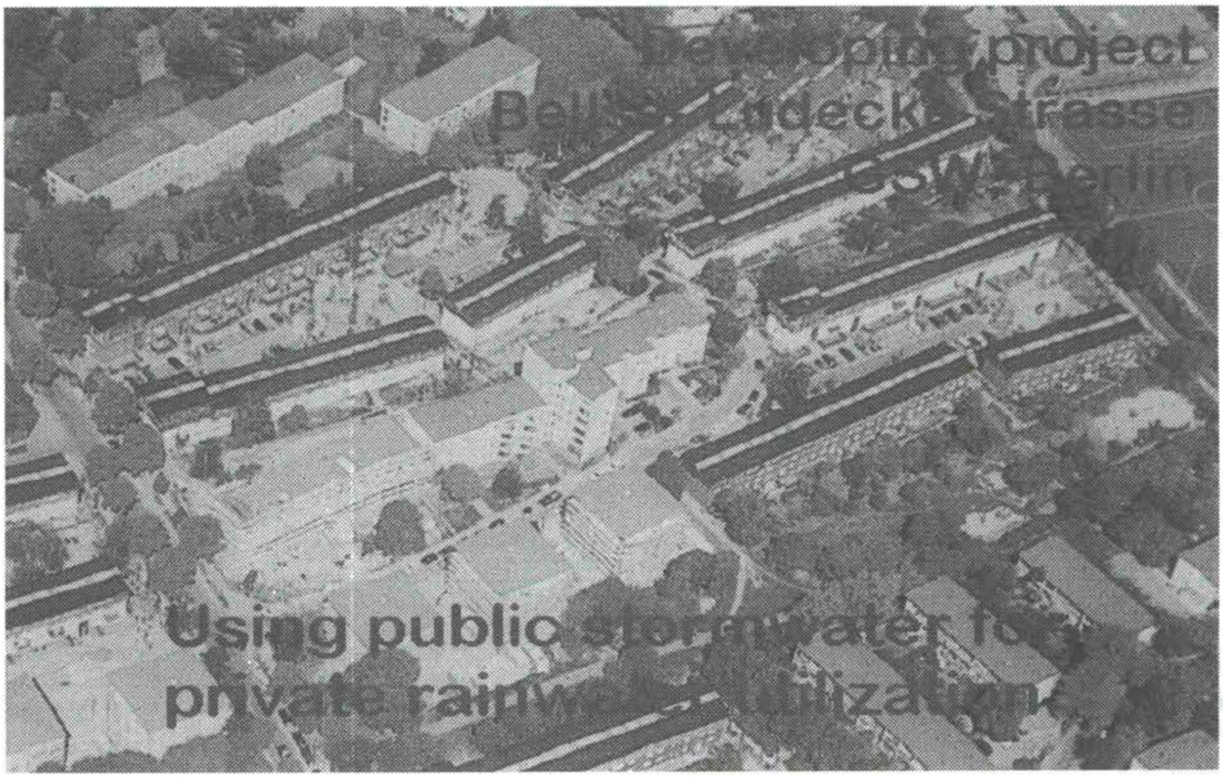
But also another experience from the energy sector is important to me as a sanitary engineer. The usage of the system water also has a big influence on the installed watersupply system. American toilets usually need 5 gallons water, British toilets however use only 2 gallons. The discussion about limitation the flushing volume for urine up to 4 litre has lead to the usage of the first 6 liter toilet in Germany in 1979. In earlier projects, we used imported toilets from Sweden, which used about 1 gallon water. In Germany one is intensively working on the development of a 3 litre ceramic toilet using only 3 litres flushing water. This is achieved by a water saving siphon with a diameter of 55 mm. The first prototypes in steel function perfectly without any problems. Problem with ceramic is however, that during the production procedure, the size of the toilet reduces at about 10 % and could lead to irregularities in the siphon. This could lead to a more difficult disposure of faeces.



This example of watersaving toilet, we installed since 1984.

If at the place of consumption watersaving toilets are installed with 3 or 4 litres for the flush and perhaps Urinals with 2 litres, the size of the service water tank can also be sized much smaler than for a 2-gallon WC.

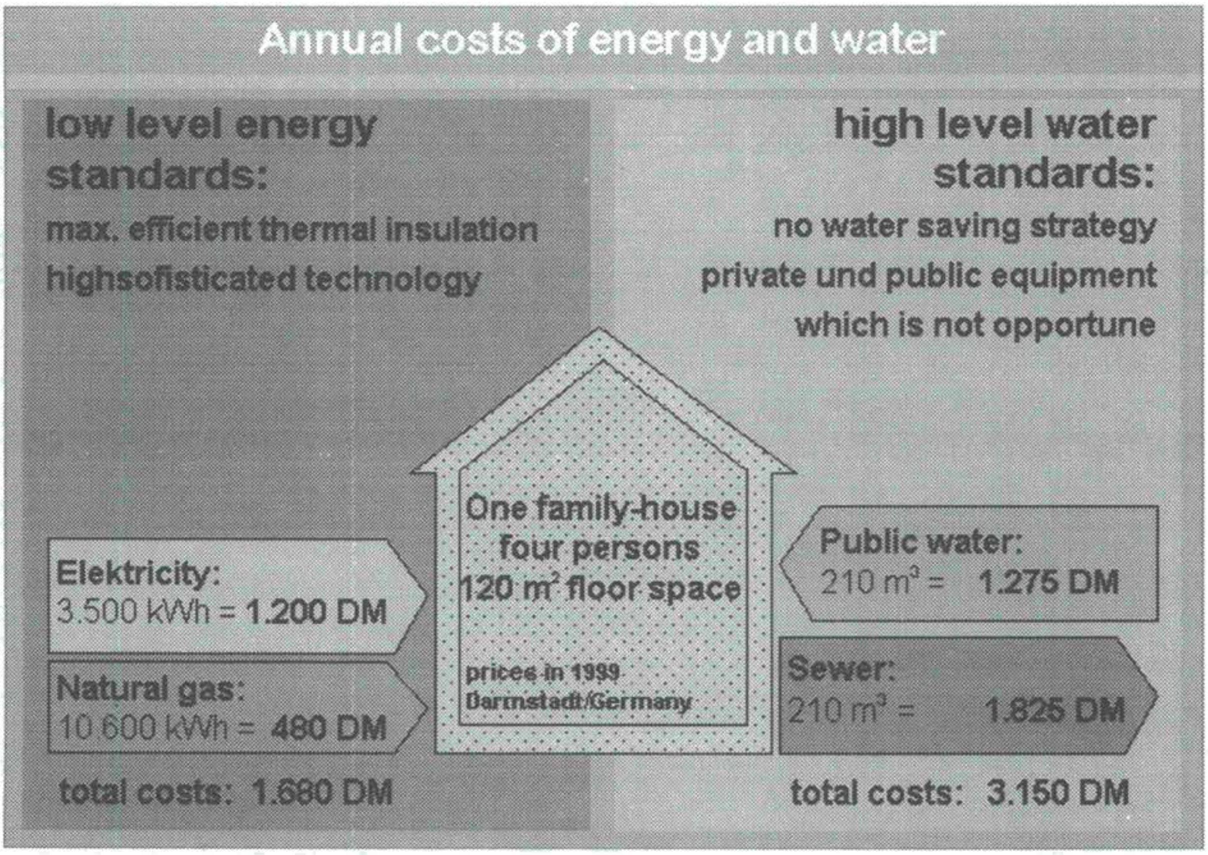
The same consideration are valid in the field of rainwater utilization. Sadly I found, that the size of the rainwater storage tanks is mostly to large. The volume (and the investment costs) could be much smaller, when architects, engineers and plumbers know much better the supplying techniques and the characteristic of using service water.



In this project, public stormwater is stored in a private settling tank (160 m^3) purified in a two-stage hydroponic system and utilized for toilet flushing in about 80 flats and irrigation.

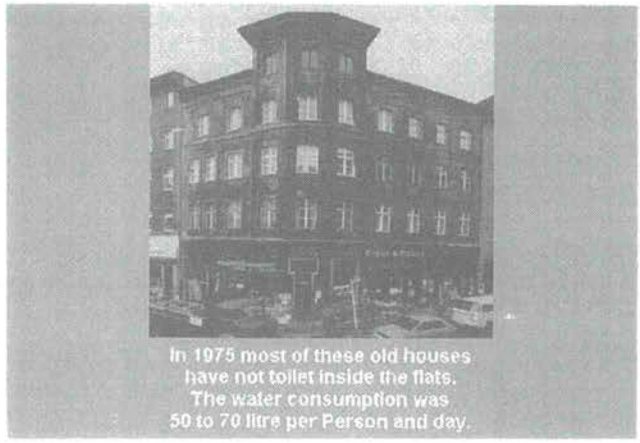
The knowledge about watersaving strategies, substitution of portable water and reduction of discharche capacity is not only important for scientists and the staff of water works. The empirical results of such projects should be broken down to the level of practical men. Electronical medias makes it much easier to get the appreciation of the necessary product- und technical-information which supports the working process. In opposite of print medias that's often the case, that electronical information are ten times cheaper to copy and distribut the information. More important than the availability of information is, that electronical documents can be indivualized and modified to the needs of each one.

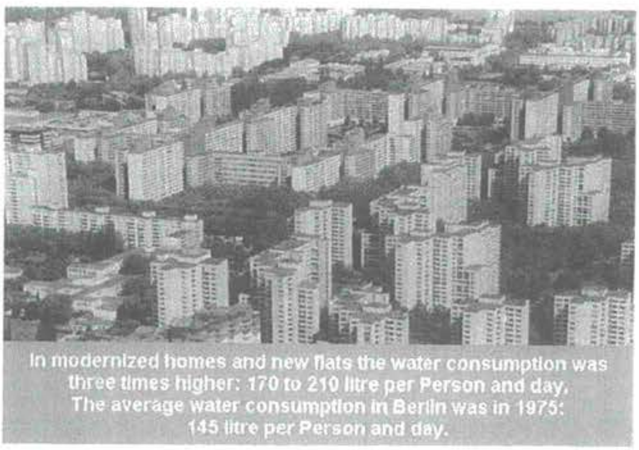
To transform the strategy 'each reader of electronical books is his own author', we need multimedia tools which are easy to handle, on condition that user should not change the programme. HyperTool is such a tool. Practical man can document within a view hours their knowledge and of one's experience in electronical form. Specially skilled workers needs the great variety of multimedia forms (like text, pictures, drawings, video- or audio-sequences) for documentation and change their experience among colleagues round the world.



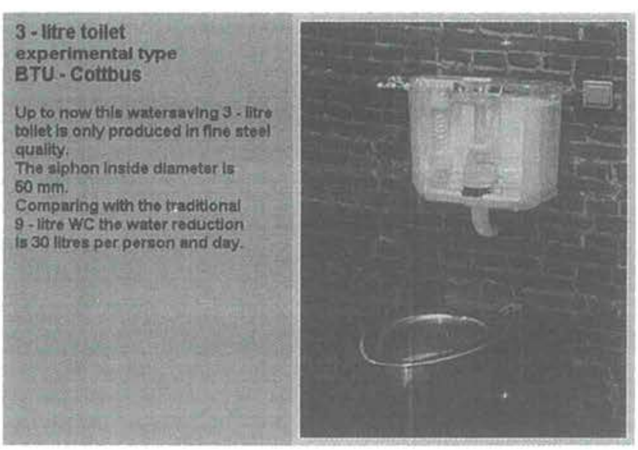
To protected the water resources, we have to develop low water level standard houses/ blocks which allows a high hygienic comfort. It will contains watersaving components as well as a supplying system with different qualities of water. I am sure, the installation is a high sofisticated technology, which combines the specific advantages of centralized and decentralized system.

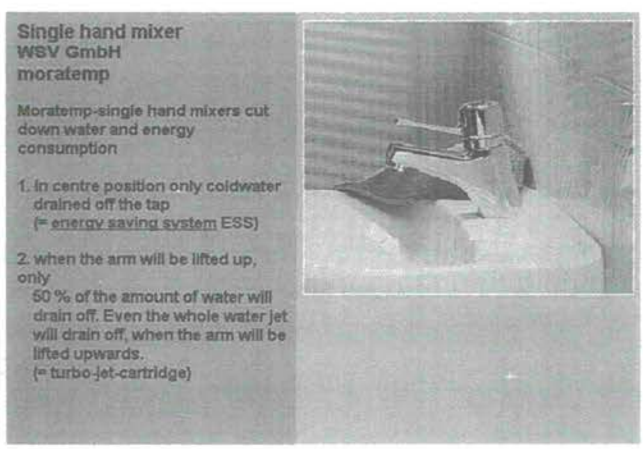

Approaches for water demand management
Water saving devices and appliances
Peter Thomas, HATI - Berlin


In 1975 most of these old houses
have not toilet inside the flats.
The water consumption was
50 to 70 litre per Person and day.


In modernized homes and new flats the water consumption was
three times higher: 170 to 210 litre per Person and day.
The average water consumption in Berlin was in 1975:
145 litre per Person and day.


4 - litre - toilet
EUROBASE 79
Wisa GmbH
Traditional toilets need 6 or 9 litre water for flushing.
This WSS-toilet (water-saving-system) from Sweden needs only 4 litre to flush out excrements.
The cistern has a split operation panel. For flushing out urine the quantiy of water is reduced of 2,5 litre.
If the WSS - system is installed in traditional drainage systems with large diameters of the floor channel, a flow amplifier has been installed in the basement to achieve an ever sufficient flow.

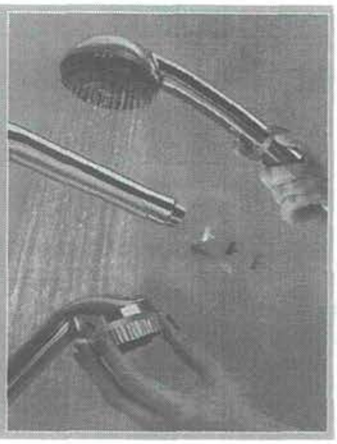

3 - litre toilet
experimental type
BTU - Cottbus
Up to now this watersaving 3 - litre toilet is only produced in fine steel quality.
The siphon inside diameter is 60 mm.
Comparing with the traditional 9 - litre WC the water reduction is 30 litres per person and day.


Single hand mixer
WSV GmbH
moratemp
Moratemp-single hand mixers cut down water and energy consumption
1. In centre position only coldwater drained off the tap
(= energy saving system ESS)
2. when the arm will be lifted up, only
50 % of the amount of water will drain off. Even the whole water jet will drain off, when the arm will be lifted upwards.
(= turbo-jet-cartridge)

Saving water with showers Hansgrohe GmbH

Sanitary Industrie offers a lot of facilities which allows a high shower-comfort and at the same time save water and energy.

In all personal showers we installed flow-limiters, which fixes the outflow to maximum 9 litre per minute, that's more than 50 percent.



Definition of graywater

Graywater is "low polluted" waste water from bathtub or shower, sink, wash basin and washing machine. Graywater has a high heat source.

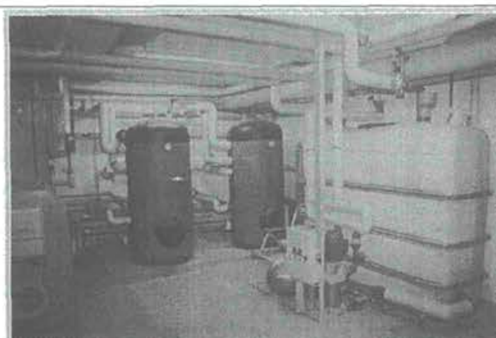
Only in few projects, the graywater from dishing and dishing machine is treated in the graywater purification unit.

Graywater heat recovery system

Graywater has a very high heat source. In several apartement-houses the heat of the graywater is used for the domestic hot water supply system.

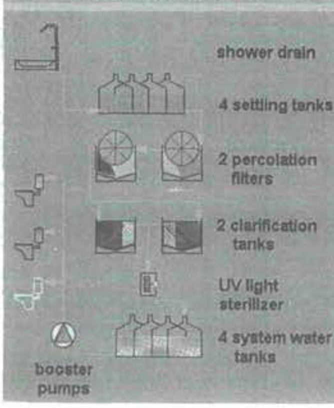
The average temperature in a highly efficient thermal insulated graywater storage tank is more than 26 °C.

20 to 25 percent of the energy for the domestic hot water supply system can be recovered directly (without a heat pump system).



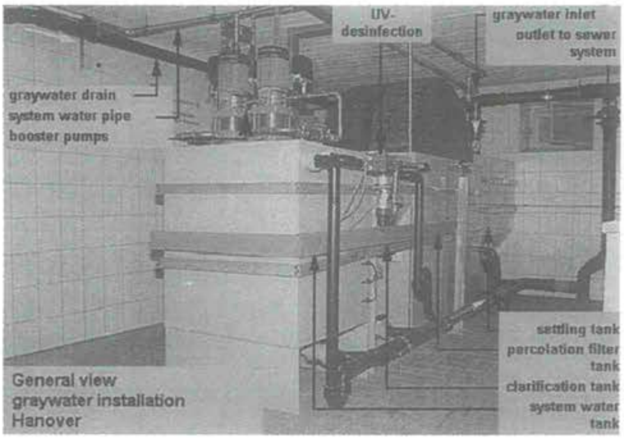
On the left hand side there is the heat-pump installed to recover the energy from graywater from more than 100 flats for the domestic hot water supply system in the back.

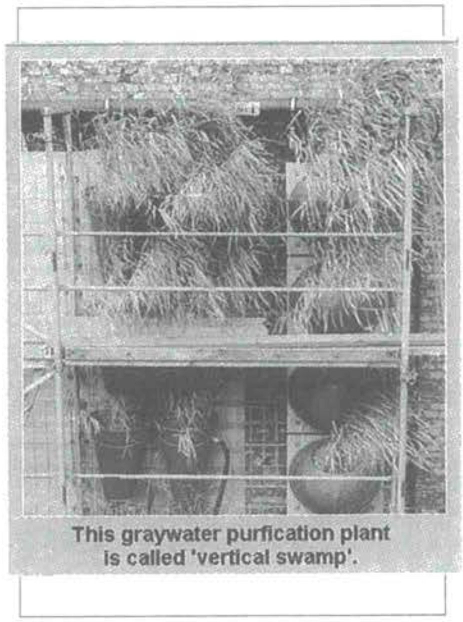
Graywater purification plant: Arabella-Hotel

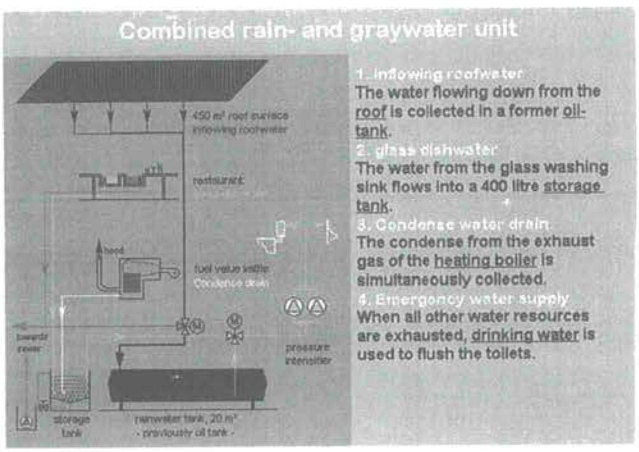


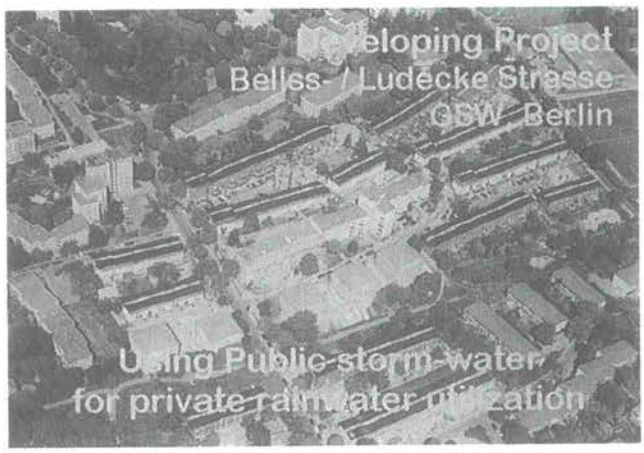
Graywater is collected in four settling tanks where hair and small particals should settle. Aerobic bacteria grow on the surface of the percolation filters producing biolocical cleaning. In the two clarification tanks, the biomass is settled by inclined filters.

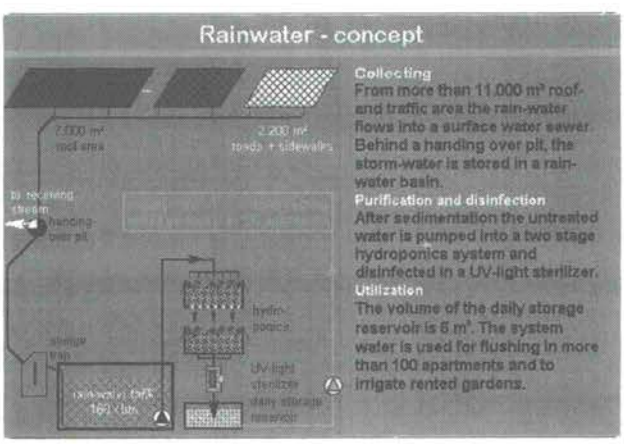
Slideshow

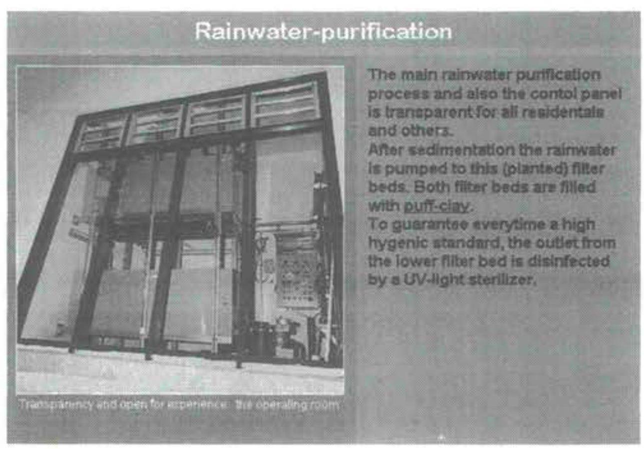

UV-
desinfection
graywater inlet
outlet to sewer
system
graywater drain
system water pipe
booster pumps
settling tank
percolation filter
tank
clarification tank
system water
tank
General view
graywater installation
Hanover

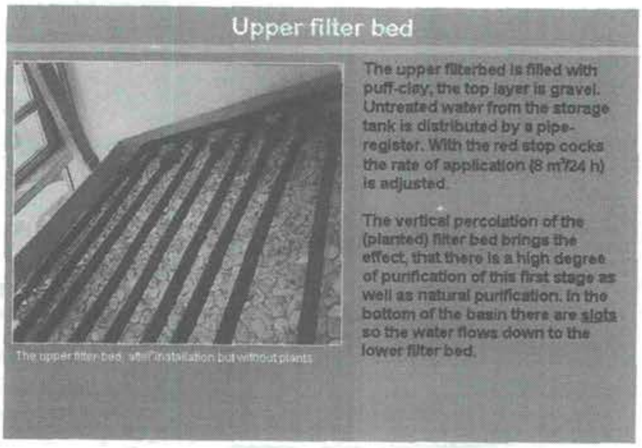

This graywater purfication plant
is called 'vertical swamp'.

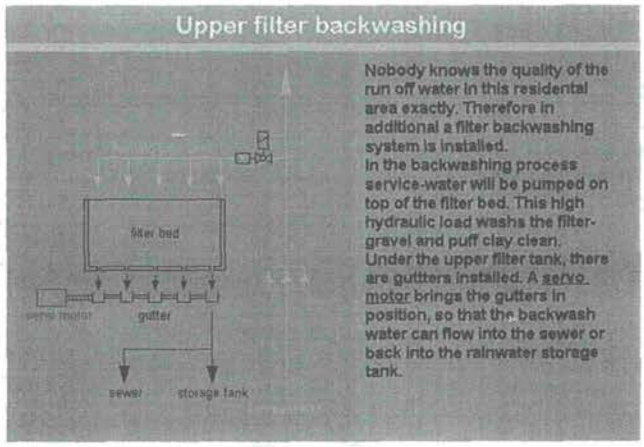

Combined rain- and graywater unit
450 m² roof surface
inflowing roofwater
restaurant
hood
fuel value kettle
Condense drain
pressure
intensifier
storage
tank
rainwater tank, 20 m³
- previously oil tank -
1. inflowing roofwater
The water flowing down from the roof is collected in a former oil-tank.
2. glass dishwater
The water from the glass washing sink flows into a 400 litre storage tank.
3. Condense water drain
The condense from the exhaust gas of the heating boiler is simultaneously collected.
4. Emergency water supply
When all other water resources are exhausted, drinking water is used to flush the toilets.

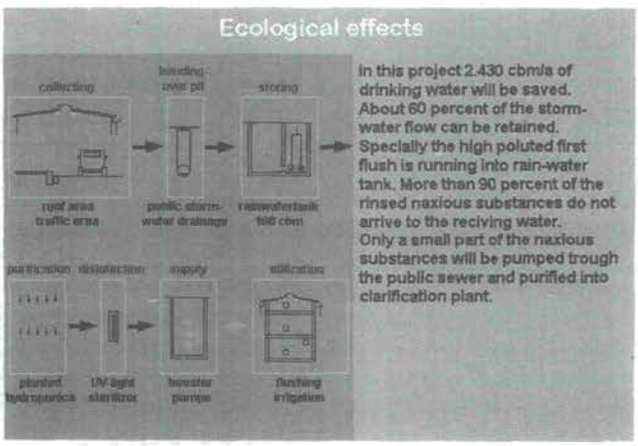

Developing Project
Beliss- / Ludecke Strasse-
GSW Berlin
Using Public-storm-water
for private rainwater utilization

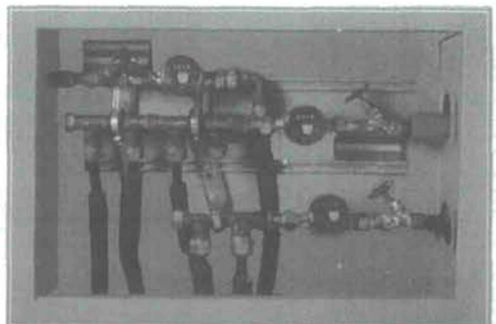

Rainwater - concept
7.000 m²
roof area
2.200 m²
roads + sidewalks
hydro-
ponics
UV-light
sterilizer
daily storage
reservoir
Collecting
From more than 11.000 m² roof- and traffic area the rain-water flows into a surface water sewer. Behind a handing over pit, the storm-water is stored in a rain-water basin.
Purification and disinfection
After sedimentation the untreated water is pumped into a two stage hydroponics system and disinfected in a UV-light sterilizer.
Utilization
The volume of the daily storage reservoir is 6 m³. The system water is used for flushing in more than 100 apartments and to irrigate rented gardens.


Rainwater-purification
The main rainwater purification process and also the contol panel is transparent for all residentals and others.
After sedimentation the rainwater is pumped to this (planted) filter beds. Both filter beds are filled with puff-clay.
To guarantee everytime a high hygenic standard, the outlet from the lower filter bed is disinfected by a UV-light sterilizer.

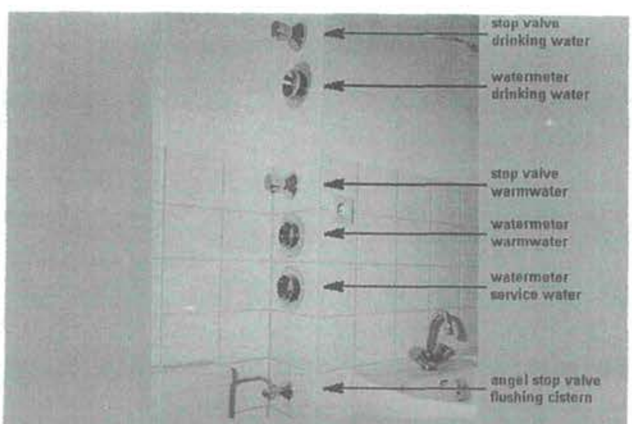




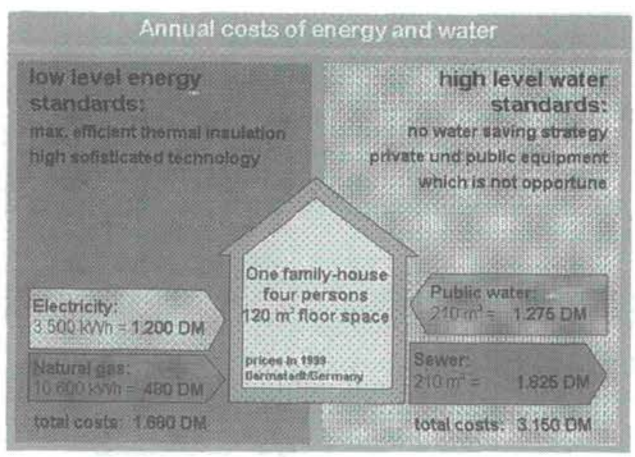




In every flat three water meters are installed for user-specific payment



typical bathroom installation



RESIDENTIAL END USES OF WATER
AND
DEMAND MANAGEMENT OPPORTUNITIES

by
John Olaf Nelson, General Manager, Valley of the Moon Water District
President: John Olaf Nelson Water Resources Management, JONOlaf@home.com

"We have met the enemy and he is us."
(Walt Kelly, creator/author of Pogo and recalled on his death on Oct 18,1973)

"Every man is his own chief enemy."
(Anacharis, 6th Century BC Scholar)

RESIDENTIAL END USES OF WATER

Introduction:

In 1996 the American Water Works Association (AWWA) Research Foundation embarked on a research project entitled "The North American Residential End Uses of Water Study" (REUWS). Cosponsoring the study were a number of regional agencies, states and fourteen cities. Twelve study sites were targeted across North America: the cities of Boulder and Denver in Colorado; Eugene, Oregon; Seattle, Washington; the City of Lompoc and San Diego in California and special water districts serving Walnut Valley and Las Virgenes, California; the City of Tampa, Florida; City of Phoenix, Arizona; the neighboring cities of Scottsdale and Tempe, Arizona which were treated as one study site; and the neighboring Canadian cities of Waterloo and Cambridge, Ontario which were also treated as one study site. Site characteristics are shown in Table 1.

The research team was lead by Aquacraft, Inc., Colorado, 80302, www.Aquacraft.com (William DeOreo, Peter Mayer), the principle contractor who collected water use data and performed data logging and analysis; Planning and Management Consultants Ltd., Carbondale, Illinois, www.PMCL.com (Eva Opitz, Benedykt Dziegielewski, Jack Kiefer and William Davis) handled sampling, survey design, model analysis and statistics; and John Olaf Nelson Water Resources Management was responsible for customer surveys and project quality assurance and quality control. The final report has been submitted for publication by AWWARF and will be available later this year. The report and comprehensive database will be available on CD ROM from AWWARF, 6666 Quincy, Denver, CO. The database, a rich resource of residential water use information, is prepared in Microsoft ACCESS and includes 28,000 daily use records, 38,700 daily weather records, 1.96 million end use event records, 6,000 survey response records, and 39 weather station identity records. Tables are cross linked with a Keycode to protect individual customer privacy.

Purpose of Research:

The purpose of this project was to identify typical end uses of water in single family detached homes for the participating water utilities. This need had been identified as the highest urban water conservation research priority at a special workshop held by the Water Conservation Division of AWWA in 1993. While not intended to be utilized to represent a typical picture of residential water use for all of North America, the surprisingly stable indoor water use portion does lend itself to being combined for comparative purposes.

Research Strategy:

The research strategy was to identify a representative sample of single family detached homes in each of the 12 study sites, survey a representative sample of these to determine information from the customer, and select a representative sample for data logging in winter and summer months. The initial sample of representative homes in each study site numbered 1,000 dwellings. A comprehensive survey form containing 41 questions was mailed to this sample. The response rate ranged from 38% to 66% with a mean of 48%. From survey respondents, 100 homes were selected for data logging. Water use of the parent population, the 1,000 representative sample, and the 100 data log sample was calculated and statistical checks made at each step to assure the validity of each sample.

Data logging involved installing a relatively small battery operated data-logger manufactured by F.S. Brainard and Company, Burlington, New Jersey in the meter box and strapping a transducer to the magnetic type meter head. For two weeks in the summer and two weeks in the winter, the average flow rate passing through the meter was recorded every 10 seconds. Software developed by Aquacraft called Trace Wizard© was then used to identify individual end use events, i.e. a gravity toilet refill cycle, clothes washer cycle, shower event, bath event, irrigation system cycle, faucet event, leakage, etc. Each type of event is unique and can be graphically represented by a trace (see Figures 1 through 4 for examples of different traces).

Trace types also varied from home to home (different clothes washing machines, shower habits, etc. Once characteristic traces were determined for a given home, the software then automatically searched the entire logging record collected for that home and identified and segregated end uses of water. The software was capable of segregating 99% of all events successfully. The event categories were: bath, clothes washer, dish washer, faucet, irrigation system, toilet, evaporative cooler, hot tub, humidifier, treatment system (generally a water softener), swimming pool, leak and unknown.

Heretofore physical measurement of residential end uses has been limited to a few very expensive (and intrusive) micro-metering studies involving very small samples. Over 1.9 million event records were measured for the 1,188 logged homes in the REUWS.

Other data was also collected: metered water consumption from utility billing records, weather data, water and sewer rates and data on water conservation programs and efforts.

Results:

Survey data revealed the statistics shown in Table 2.

A total of 28,015 days of 10 second interval data was collected from the 1,188 homes. Average daily water use was 1,548 Liters per day (Lpd) [409 gallons per day (gpd)] with a standard deviation of 1,840 Lpd (486 gpd). The indoor fraction was 655 Lpd (173 gpd) and had a standard deviation of 356 Lpd (94gpd). Indoor use was much less variable than outdoor use. Ninety percent of indoor use was less than 1,136 Lpd (300 gpd) on average.

Total per capita use for the 12 study sites averaged 650.3 Liters per capita per day (Lcd) (171.8 gcd) with 381.5 Lcd (100.8 gcd) or 58.7% coming from outside use, 6.4 Lcd (1.7 gcd) or 1% unknown and 262.3 Lcd (69.3 gcd) or 40.3% from indoor use. Standard deviation for indoor use was 161.3 Lcd (42.6 gcd). Median indoor use was 227.5 Lcd (60.1gcd). Mean indoor use varied by 99.9 Lcd (26.4 gcd). Median indoor use varied by 48.8 Lcd (12.9 gcd), about half as much.

Typical distribution of indoor household water use is shown in Figure 5. Frequency of fixture utilization is shown in Table 3.

The leakage amount includes outside leaks since these could not readily be separated from indoor leaks. The Trace Wizard analysts opined, however, that the lions share of leakage could be attributed to leaking toilets - principally flapper valves. Regards the surprisingly high average leak rate of 36.0 Lcd (9.5 gcd), analysis revealed that nearly 60% of leakage volume was explained by only 10% of the logged homes.

Costs:

The total budget for the project was $881,000 with $530,000 in cash from AWWARF and the government agencies and utilities plus $288,000 of in-kind contributions (mainly in the form of labor) from the utilities. The average cost per home based on the 1,188 logged homes was therefore $742. Each home was logged a total of four weeks. Since this was a pioneering research effort, considerable time was donated to the project by the consultant team over and above the budget amount. This is estimated at $200,000. The true cost to conduct the study is therefore estimated at $910 per logged home. Estimated cost of future logging efforts, including initial analysis, sample size determination, survey work, field logging and analysis and report is shown in Table 4.

The technology employed in REUWS can readily be employed in any metered community around the world to determine end uses of water. The technique is equally successful in determining end uses for most small commercial sites as well provided coincident occurrences of the same type of event are infrequent. Characterization of end use of water is essential to sound formulation and conduct of an effective water conservation program.

DEMAND MANAGEMENT OPPORTUNITIES

Research of the literature and application of the findings of the REUWS has been performed by the author (go www.waterwiser.org/wtruse98/main.html) and reveals opportunities for demand management. This is not new information, but the level of accuracy is certainly enhanced over prior literature on the subject.

As shown in Figure 5, we now have very accurate data on the distribution of residential indoor end uses. From the data collected in the REUWS, an improved estimate of unit water savings for household water using fixtures was made - see Table 5 for details and Table 6 for recap. Improved estimates on typical penetration of ultra low-flush toilets and low-flow shower heads is also possible (Table 7). Application of these values indicates that the amount of existing indoor savings achieved to date by long term water conservation efforts, based on the sample analyzed in the REUWS, is 12.2 Lcd (3.2 gcd) which means typical indoor use had likely achieved a level of 274.5 Lcd (72.5 gcd) prior to the conservation efforts of the late 1970's, 80's and 90's. Calculation of indoor end uses of water both for the "without" and "with" case based on conservation technology now commonly available is shown in Table 8. Figure 6 shows the comparison graphically.

The result is that for the typical single family home in North America, indoor water use (without any conservation fixtures) of on the order of 274.5 Lcd (72 .5 gcd) can be expected to drop by 32% to 187.8 Lcd (49.6 gcd) given technologies now in hand. The differential is 86.7 Lcd (22.9 gcd). Of this amount, it appears that 12.2 Lcd (3.2 gcd) of savings or 14% has already been accomplished. This leaves plenty of room for improvement. Principal indoor opportunity targets are toilets, clothes washers, shower heads, faucet aerators and leak repair. Whether retrofit strategies are justified for a given water utility depends on the avoidable costs and other factors unique to that utility.

To the extent that fixtures commonly used in North America are used in Asia, development of baseline information on end uses of water as described in the first section of this paper and implementation of regulations and cost-effective strategies targeting the opportunities outlined in the second section of this paper, makes good sense.

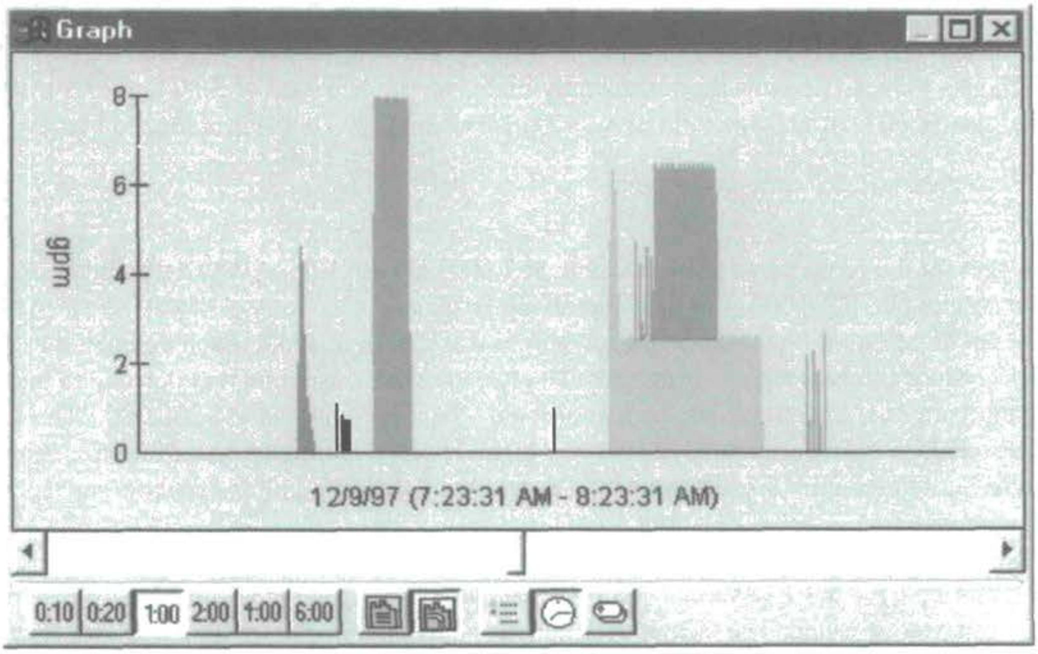


Figure 1 - The green event is the refill cycle following a toilet flush. The yellow events are faucet openings. The series of blue volumes are the sequential cycles of a clothes washer event (initial fill, extraction cycles, rinse fill, final extraction cycles). Extraction and rinse cycles are plainly visible on top of the red event which is a shower event - in this case taken in a bath tub. The trace shows water coming form the tub spout for about 30 seconds while hot water is waited for and temperature adjusted. The tub diverter valve is then flipped and water starts to flow through the shower head – in this case a low flow head which restricts the rate to 9.5 Lpm (2.5 gpm). The shower continues for about 10 minutes. The final set of the clothes washer extraction cycles occur shortly after the shower ended.

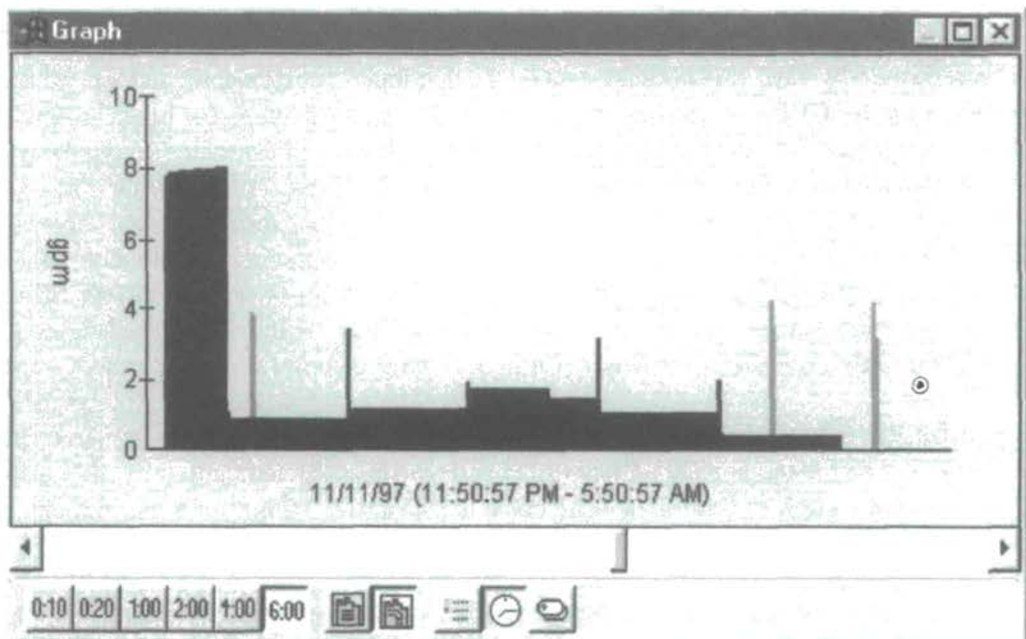


Figure 2 - Shows outside irrigation taken from a home in Phoenix, AZ. Here in a six hour view, two toilet flushes can be observed occurring simultaneously with the operation of an irrigation cycle controlled by a timer. Seven irrigation zones are clearly delineated by the small but consistent differences in flow rate over the 4.5 hour irrigation session. The first zone with an 30 Lpm (8 gpm) flow rate is a turf area and the remaining six zones cover different drip irrigation areas. Another toilet flush follows the irrigation event.

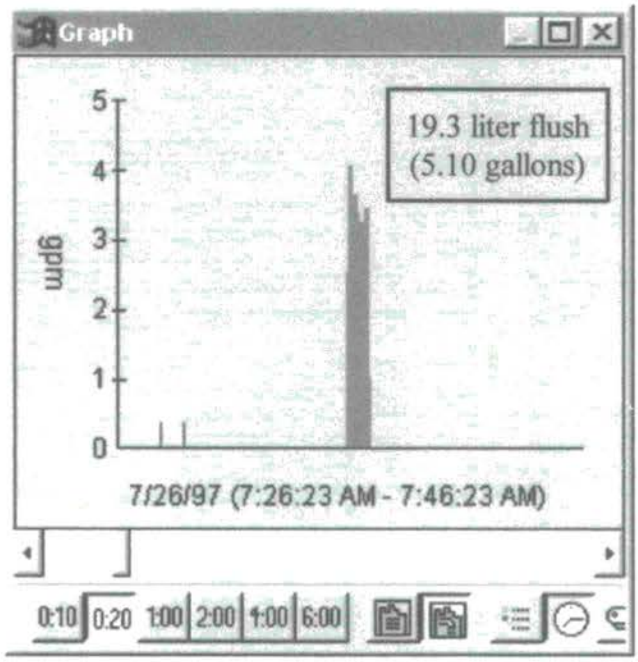


Figure 3 - Trace of Refill Cycle for Non-ULFT (gravity flush toilet)

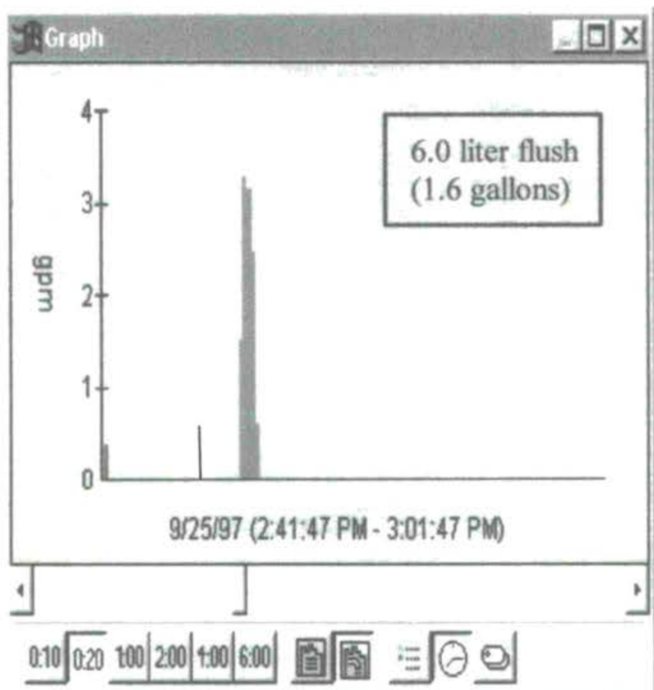


Figure 4 - Trace of Refill Cycle for Ultra Low Flush Toilet (pressure assisted flush toilet in this case)

Figure 5 - Distribution of End Uses

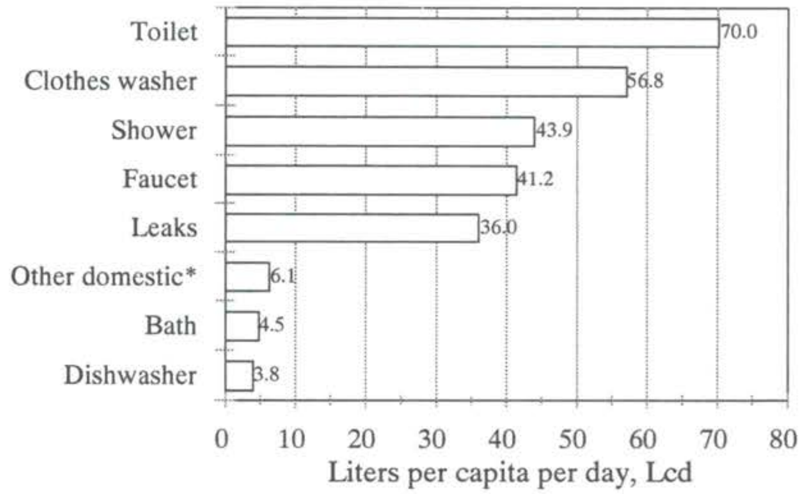


Figure 6 - Comparison of End Uses "Without" and "With" Conservation

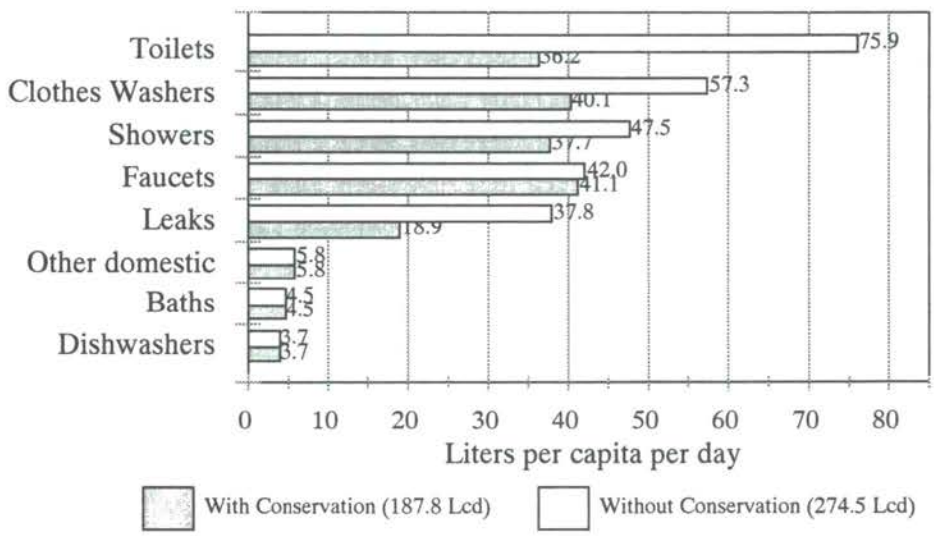


Table 1 - Characteristics of 12 Study Sites

Region	Name	SF Accounts (1)	Annual Rainfall Centimeters	Average Annual Temp., °C	Net ET (2) Centimeters	Maximum Use Month
Northwest	Seattle, WA	303,000	94	13.0	67	July
Northwest	Eugene, OR	27,523	119	12.0	71	July
West Coast	Lompoc, CA	5,740	46	15.6	87	July
West Coast	Las Virgenes, CA	12,740	44	18.3	122	August
West Coast	Walnut Valley, CA	18,307	57	19.4	170	August
West Coast	San Diego, CA	171,952	43	17.8	105	August
Southwest	Phoenix, AZ	254,781	10	22.6	186	June
Southwest	Scottsdale, AZ (3)	42,811	10	22.3	186	June
Southwest	Tempe, AZ (3)	29,700	10	22.8	186	June
Mountain	Boulder, CO	16,904	43	10.9	77	July
Mountain	Denver, CO	174,688	27	11.1	85	July
Southeast	Tampa, FL	60,830	138	22.8	79	July
Midwest/Canada	Waterloo, ONT (4)	14,972	104	6.9	40	August
Midwest/Canada	Cambridge, ONT (4)	23,614	104	6.9	40	August

Notes:

1. SF = single family detached homes.
2. Net ET = annual reference evapotranspiration less effective rainfall, i.e. rainfall that contributes to crop growth.
3. Sister cities. Treated as one site.
4. Sister cities. Treated as one site.

Table 2 - Survey Responses
(from 5,928 homes)

	Amount	Percent
Fixtures/Equipment per home:		
Toilets (average)	2.27	
Showers only	0.74	
Bathtub/shower combinations	1.21	
Bathtubs only	0.22	
Clothes washers, homes with		98.0%
Dishwashers, homes with		75.0%
Portion having front loaders		2.3%
Evaporative cooler present		9.1%
Water treatment (softener) present		25.1%
Demographics:		
Household population (average)	2.71	
Adults (>18)	2.08	
Teenagers (13 - 17)	0.20	
Children (<13)	0.43	
Education Achieved:		
Completed some college		77.0%
Advanced degree (Masters/PhD)		20.0%
Annual Household Income:		
Median	$55,000	
<$50,000		45.1%
$50,000 - $150,000		48.8%
>$150,000		6.1%
Residency Status		
Home owner		92.0%
Rent		8.0%
When Home was built		
Before 1980 (old style toilets)		71.0%
1980 to 1992 (13.2 Lpf (3.5 gpf) toilets)		24.6%
After 1992 (6.0 Lpf (1.6 gpf) toilets)		4.4%
Attitudes:		
Scale Value >		Greater than 4
Water conservation is important (1)		90.0%
Quality of their landscape (1)		51.0%

Notes:

1. On scale of 1 to 5 with 5 being best.

Table 3 - Home Fixture Utilization

Measurement	Mean Utilization per capita per day
Toilet flushes	5.05
Showers taken (1)	0.75
average shower duration	8.2 minutes
Clothes washer loads	0.37
Dishwasher loads	0.10
Faucet utilization	8.1 minutes

Notes:

1. Taken in shower stalls and bathtubs with shower fixture.

Table 4 - Estimated Cost to Sample, Survey and Log 100 Homes
(One 2-week Logging period)

Item	Cost (1)
Prepare plan	$1,500
Sample selection, survey work (2)	3,700
Site visit (3), install data loggers (4), (5)	13,000
Analysis (5) and Report (includes creation of database)	18,000
Contingency, 10%	3,600
Total	$39,800
Per Home	$398

Notes:

1. Assumes utility provides in-kind help to identify and download consumption data print and post survey, communicate with customers, and provides field technician (meter reader generally) to aid in setting data loggers and collecting same for return to Consultant.
2. Assumes Survey sample of 1,000 homes and Logging sample of 100 homes.
3. Includes air travel of $500.
4. Assumes data loggers are provided by contractor on a rental basis, not purchased. Assumes water utility employs standard magnetic head type meters and that meters are in an enclosure (meter box or house where data logger is reasonably secure.
5. Based on two-weeks of data logging per home

Table 5 - Unit Savings Measured by REUWS and Reported in the Literature

Item	Source	Lcd	% savings	Penetration	Remarks	References
1	Toilet Savings:					
	A&N Studies for MWD	43.2		73%	large sample, statistical model	1,2,3
	AWWARF REUWS	39.7	52%	15%	large sample (comparison of 289,000 toilet flushes)	6
	Tampa-micro metering	23.1	46%	100%	small sample	5
	EBMUD-micro metering	20.1	41%	100%	small sample	4
	Heatherwood	9.8	17%	50%	small sample	7
	Avg	27.2				
	Use	39.7			high confidence in AWWARF REUWS	
2	Clothes Washing Machines (horizontal axis):					
	Heatherwood	41.3	61%	100%	very small sample	7
	Thelma		20%		lab tests, avg of 6 models	9
	Seattle Demonstration		58%		per load	8
	Manufacturer's literature		40%		Maytag's "Neptune", Frigidaire's "Gallery"	12
	Bern Clothes Washer Trial	27.3	38%	100%	20,000 wash loads, 103 clothes washers	15
	Avg	34.3	43%			
	Use		30%		prefer to remain conservative	
3	Shower Savings:					
	HUD	27.3			small sample	10
	Tampa-micro metering	13.6	34%	100%	small sample	5
	EBMUD-micro metering	6.4	28%	100%	small sample	4
	AWWARF REUWS	17.0	34%	35%	large sample (48,700 shower events)*	6
	Seattle Study	15.9			statistical model	11
	Avg	16.0	32%			
	Use	9.8			avg. of Tampa and EBMUD studies	
	* 70% of events were at a rate less than 9.5 Lpm (2.5 gpm). Consumer throttling suspected of accounting for more than half of the indicated "savings".					
4	Faucet Savings:					
	Heatherwood	9.8		82%	small sample	7
	AWWA	1.9			apriori judgement	13
	Nelson	0.9			apriori judgement	14
	Avg	4.2				
	Use	0.9				
5	Leak Repair:					
	Heatherwood	20.8	77%		small sample	7
	Nelson		50%		apriori judgement	14
	Avg	20.8	64%			
	Use		50%			
All	Fully Retrofitted Home (all of the above measures installed)					
	Heatherwood	84.0	33%		small sample	7

Table References

1 A&N Technical Services, Inc., The Conserving Effect of Ultra Low Flush Toilet Rebate Programs, Metropolitan Water Dist. of Southern CA, June 1992

2 A&N Technical Services, Inc., Continuous-Time Error Components Models of Residential Water Demand, MWD of Southern CA, June 1992

3 A&N Technical Services, Inc., Ultra Low Flush Toilet Programs: Evaluation of Program Outcomes and Water Savings, MWD of Southern CA, Nov 1994

4 Stevens Institute of Technology, East Bay Municipal Utility District Water Conservation Study, Oct 1991

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9 Hill, Pope, Winch; Thelma: Assessing the Market Transformation Potential for Efficient Clothes Washers in the Residential Sector, Conserv96

10 Brown and Caldwell, Residential Water Conservation Projects, Summary Report, U.S. Dept of Housing & Urban Development, Water Resources Bull., June 1994

11 Whitcomb, John, Water Use Reduction from Retrofitting Indoor Water Fixtures, Dec 1990

12 Specifications and literature obtained from Maytag and Frigidaire, June 1997

13 Maddaus, AWWA Water Conservation Report, 1987

14 Nelson, John Olaf, AWWA WaterWiser Web Project, 1998 Residential Water Use Summary, www.waterwiser.org/wtruse98/main.html (soon to be updated to wtrus

15 Tomlinson, J.J. and D.T. Rizy, Bern Clothes Washer Study, March 1998, Prepared by Energy Div. of Oak Ridge National Laboratory for the U.S. Dept. of Energy

Table 6 - Recap of Unit Savings Rates

Fixture Measure	Use Rate	Savings, Lcd (gcd)
Low flush toilets	6.0 Lpf (1.6 gpf) (1)	39.7 (10.5)
Horizontal axis clothes washers (2)	(varies)	17.2 (4.5)
Low flow showerheads	9.5 Lpm (2.5gpm) (2)	9.8 (2.6)
Faucet aerators (4)	8.3 Lpm (2.2 gpm)	0.9 (0.3)
Leak repair (5)	(varies)	18.9 (5.0)
Total (if all measures installed)		86.6 (22.9)

Notes:

1. Lpf = liters per flush, gpf = gallons per flush
2. Based on indoor use of 274.5 Lcd
3. Lpm = liters per minute, gpm = gallons per minute
4. Installed on kitchen sink and bathroom faucets
5. The leakage rate shown is an average for a large population of homes. Leaks are concentrated in less than 10% of the homes.

Table 7 - Household (Indoor) End Uses of Water "Without" and "With" Conservation

End Use	Without Conservation		With Conservation (1)		Savings	
	%	Lcd (2)	%	Lcd	%	Lcd
Toilets	27.7%	75.9	19.3%	36.2	52.4%	39.7
Clothes Washers	20.9%	57.3	21.4%	40.1	30.0%	17.2
Showers	17.3%	47.5	20.1%	37.7	20.7%	9.8
Faucets	15.3%	42.0	21.9%	41.1	2.3%	0.9
Leaks (3)	13.8%	37.8	10.1%	18.9	50.0%	18.9
Other domestic (4)	2.1%	5.8	3.1%	5.8	0.0%	0.0
Baths	1.6%	4.5	2.4%	4.5	0.0%	0.0
Dishwashers	1.3%	3.7	2.0%	3.7	0.0%	0.0
Inside Total	100.0%	274.5	100.0%	187.8	31.6%	86.6

Notes:

1. Application of the water conservation fixtures/measures shown in Table 6.
2. The sum of this column is based on the average "inside" uses measured in 1,188 homes on 12 North American study sites adjusted upwards by a factor of 1.046 to account for estimated "in-place" savings savings (about 5%) due to preexisting conservation achievements.
3. The leakage rate shown is an average for a large population of homes. Leaks, in actuality, are concentrated in less than 10% of the homes.
4. Includes pools, hot-tubs, evaporative coolers, humidifiers, home treatment devices (mainly) softeners), et

The North American Residential End Uses of Water Study

REUWS

- American Water Works Association Research Foundation
- 22 Districts, Cities and Regional Agencies

- Study Team
  - Aquacraft, Inc.
    Bill DeOreo
    Peter Mayer
  - Planning, Management Consultants, LTD.
    Eva Opitz
    Ben Dziegielewski
    Jack Kiefer
    Bill Davis
  - John Olaf Nelson Water Resources Management

- 12 Study Sites

	SF Accounts
Northwest:	
Seattle	303,000
Eugene	27,500
West Coast:	
Lompoc	5,700
Las Virgenes	12,700
Walnut Valley	18,300
San Diego	171,900
Southwest:	
Phoenix	254,700
Scottsdale/Tempe	72,500
Mountain:	
Boulder	16,900
Denver	174,700
Southeast:	
Tampa	69,800
Midwest/Canada:	
Waterloo/Cambridge	38,600

- Some Statistics
  - 1.2 million homes
  - 2.4 - 3.1 persons/home
  - 2.8 persons/home (avg)
  - 3.4 million people
  - Rainfall: 10 - 138 cm
  - Temperature: 7 - 23 °C
  - Max. Use Month: June/July/August

- Site Sampling Process
  1. Select 1,000 homes
  2. Mail Survey
     - 41 questions
     - response: 38% - 66% 48% (avg)
  3. Select 100 homes
     - log 2 weeks in summer
     - and 2 weeks in winter
  4. Analyze with Trace Wizard® to determine end use events

- Data Loggers
  - Meter-Master Data Loggers
  - F.S. Brainard & Co. Burlington, NJ
  - reliable
  - durable
  - battery operated
  - easy to install
  - sufficient memory
    - 21,000 records
    - 10 second readings
    - 2 week period

- Event Categories
  - Bath
  - Shower
  - Clothes washer
  - Dishwasher
  - Faucet
  - Toilet
  - Cooler (evaporative)
  - Hot tub
  - Humidifier
  - Treatment (softener)
  - Swimming pool
  - Leak
  - Unknown (1%)

- Data Logging
  - 1,188 homes (99%)
  - 28,000 days of 10 second readings

- Access Database (linked by keycode)
  - Billing data - 12,000 homes
  - Survey Data - 5,900 homes
  - End Use Events - 1.96 million
  - 39 Weather Sites

Cost to Sample, Survey and Log 100 Homes
(One 2-week Logging period)

Item	Cost, $
Prepare plan	1,500
Sample selection, survey work	3,700
Site visit, install data loggers	13,000
Analysis and Report	18,000
Contingency, 10%	3,600
Total	39,800
Per Home	398
Per Week	199

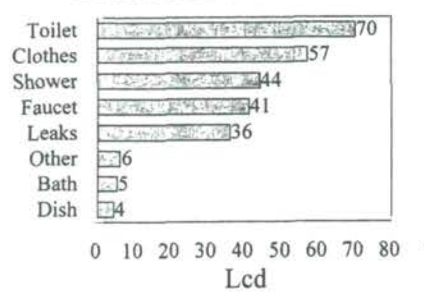
- Survey Responses

• Toilets/home	2.27	
• Shower stalls	0.74	
• Bathtub/shower	1.21	
• Clothes washers		98%
• Dishwashers		75%
– High efficiency		2%
• Water softeners		25%
• Own home		92%
• Rent		8%

- Average Daily Water Use / home
  - 1,550 Lpd (SD 1,840)
  - Indoor: 660 Lpd (42%) (SD 360)
  - 90% of Indoor use > 1,140 Lpd

- Per capita Use
  - 650 Lcd
  - Indoor: 260 Lcd

Distribution of End Uses



Fixture Utilization

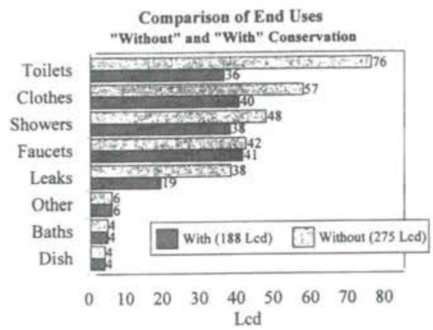
Measurement	Utilization pcd
Toilet flushes	5.05
Showers	0.75
Average shower duration	8.2 minutes
Clothes washer loads	0.37
Dishwasher loads	0.10
Faucet utilization	8.1 minutes

Unit Savings Rates

Fixture / Measure	Use Rate	Savings, Lcd
Low flush toilets	6.0 Lpf	39.7
Horizontal axis clothes washers	(varies)	17.2
Low flow showerhead	9.5 Lpm	9.8
Faucet aerators	8.3 Lpm	0.9
Leak repair	(varies)	18.9
Total (all measures)		86.6

Household End Uses of Water "Without" and "With" Conservation

End Use	Without		With		Savings	
	%	Lcd	%	Lcd	%	Lcd
Toilets	28%	76	19%	36	52%	40
Clothes Washers	21%	57	21%	40	30%	17
Showers	17%	48	20%	38	21%	10
Faucets	15%	42	22%	41	2%	1
Leaks	14%	38	10%	19	50%	19
Other domestic	2%	6	3%	6	0%	0
Baths	2%	4	2%	4	0%	0
Dishwashers	1%	4	2%	4	0%	0
Inside Total	100%	274	100%	188	32%	87



- Opportunity for Reduction:

	Lcd	gcd
• w/o Conservation	275	73
• w. Conservation	188	50
• Reduction potential	87	23
	32%	
• Already achieved	12	3
	14%	
• Yet to achieve	75	20
	86%	

- Where to get CD ROM

  AWWARF
  6666 Quincy
  Denver, CO 80235
  303 347-6103

- E-mail addresses of Study Team

  www.Aquacraft.com
  www.PMCL.com
  jonolaf@home.com

WATER DEMAND MANAGEMENT AND THE URBAN POOR

Madeleen Wegelin-Schuringa
IRC International Water and Sanitation Centre

1. Introduction

The provision of adequate water supply and sanitation to the rapidly growing urban populations is increasingly becoming a problem for governments throughout the world. The continuing expansion of the numbers of people in cities who need water and sanitation services and who cannot readily get these services by self provision, form a continuous pressure to either invest in additional production capacity or to stretch the available supplies to serve more people. At the same time, industrial activity also demands the expansion of urban water supply services. The water resources are threatened not only by this rapidly increasing demand but also through diminishing quality caused by pollution and saline intrusion as well as reducing quantity caused by overexploitation and denuding of water catchment areas. Finally, water demand for agricultural use in most places is also growing and competing with water availability for urban use.

The predominant approach towards meeting these increasing water demands has been towards supply augmentation schemes. But, the cost of developing new sources or expanding existing sources is getting higher and higher as the most accessible water resources have already been tapped. The real cost of water per cubic meter in second and third generation projects in some cities have doubled between a first and the second project and then doubled again between the second and third (Bhatia and Falkenmark, 1993). At the same time, governments are becoming reluctant to pay the rising investment costs as long as utilities are unable to meet these cost from user charges.

It has been demonstrated in many countries that saving water rather than the development of new sources is often the best 'next' source of water, both from an economic and from an environmental point of view. Water demand management therefore is seen as the preferred alternative to meet increasing water demand and can be defined as a strategy to improve efficiency and sustainable use of water resources taking into account economic, social and environmental considerations.

The main objective of water demand management is to contribute to more efficient and equitable provision of water and sanitation services and to reach this objective a number of instruments have been developed. These instruments are interdependent and mutually reinforcing and the most optimal way they are applied will depend on the prevailing local conditions and are the topic of a number of presentations in this symposium.

With regard to the domestic consumer, water demand management measures can be divided in:

1. Water conservation measures:
   - Leakage detection
   - Reduction of illegal connections
   - In-house retrofitting
   - Out-of-house water saving measures
2. Water pricing measures:
   - Water metering

- Tariff structures

3. Information and educational measures:
- Awareness raising
- Public involvement
- In-school education

4. Legal measures
- Rules and regulations that form the basis of WDM policy
- Regulations on resale of water

In all cities, a distinction can be made between different income groups (high, middle and low), between the different types of urban areas they live in and hence between the different water demand management measures which are applicable. The authorities responsible for water supply mainly provide subsidized services to high and middle income areas and the inequality of access to basic services is most severely felt in low-income urban areas, where up to 60% of the urban populations are living. The focus of this paper is especially on the applicability of WDM strategies for the urban poor and on approaches to ensure that the WDM savings are indeed also used for a more equitable provision of the water supply. The water quality aspects of WDM, including monitoring of quality, are outside the scope of this paper.

2. Current provision patterns in cities in developing countries

Urban water supply coverage has actually decreased between 1990 and 1994 in parts of the developing world, an indication of urban growth but also of deterioration of existing systems.

Table 1: Urban water supply coverage in 1990 and 1994

AREA	1990	1994
Latin America	90%	88%
Asia and the Pacific	83%	84%
West Asia	87%	98%
Africa	67%	64%

Source: Water Supply and Sanitation Sector Monitoring Report, WHO, WSSCC and Unicef, 1996

This coverage includes house connections and access to public standpost, managed by the water utility. The overview below gives some more insight in the division between the two types of supply. The people who are not covered by the public network, are dependent on private wells or boreholes, rivers or springs, vendors or neighbours.

Table 2: Percentage of urban population connected to city network or dependent on communal water points

City	Houseconnection	Public tap
Jakarta (1991)	30%	30%
Delhi (1992)	53%	37%
Phnom Penh (1992)	70%	-
Casablanca (1997)	80%	17%
Ouagadougou (1994)	38%	17%
Conakry (1989)	20%	5%
Buenos Aires (1993)	80%	-

Source: Lyonnaise des Eaux, 1998

These percentages do not reflect the intra urban differences and do not show the desperate water situation existing in many low-income urban areas. For Jakarta, for instance, the Northern sector, which is the most disadvantaged district in terms of water supplies, the coverage was only 13% with private connection and 27% with public standpost, the remainder being dependent on water vendors and neighbourhood resale. This neighbourhood resale can address a very large percentage of water demand, for instance in Conakry, 35% of the residents obtain water from such source. Actual access to safe drinking water is likely to be lower than is reflected by the above percentages due to intermittent supply. Many residents augment the water provided by the utility with water from other sources. In general, access to utility provided water supply is dependent on location and income and different for different segments of society:

High income consumers are able to meet their water requirements at individual household level by being connected to the municipal water supply system or by installing their own facilities such as wells, boreholes or rainwater harvesting systems. The service level is usually in-house multiple taps. Water demand management options applicable for this group are in-house retrofitting and out-of-house water saving measures (garden, swimming pool). Water pricing measures may only be effective in combination with extensive awareness raising campaigns as rich people tend not to save water because of cost.

Middle income groups are the majority of the customers of municipal infrastructure services and hence the recipients of the usually heavy subsidies with which water supply systems are operating. Generally they are connected to the municipal water supply system with individual house or yard connections. In case they live in estates, these estates may have an autonomous piped system, either connected to the municipal system or having a separate source (well, borehole, rainwater collection) for the estate. The category middle income is very diverse with the conditions at the upper end of the category being very near to those of the high income category and the lower end near to conditions in low-income areas. Where water supply systems are deteriorating and becoming insufficient as a consequence of the growth of the urban population, it is specifically this category which experiences a deterioration of service levels and who would benefit directly from an improved and more efficient supply system. The most effective water demand management options for this group are water pricing measures, especially increasing block tariff rates and an effective awareness raising strategy. Depending on the level of organisation within the communities, public involvement in the design of community level water saving measures and leakage control may also be feasible.

Residents of low-income urban areas are rarely consumers at individual household level. The type of water supply system depends on the type of settlement with regard to legal status and security of tenure, and the location within or outside the city limits (suitability of land, but also distances to existing urban infrastructure services). A description of the different types of settlements is given in table 3. Apart from the type of low-income areas within urban areas, a distinction has to be made between different sizes of cities and overall coverage of water supply infrastructure in these cities.

Table 3 also shows that Water Demand Management options in low-income areas depend on the type of system in the area. With household connections, metering and block tariffs are applicable, although this may have adverse effects on access for the poorest (see

3.2). Public taps can be metered and also from hand pumps water can be sold by the bucket. Vending systems are in itself an extremely effective form of WDM as the price per unit will ensure water conservation. Whether or not this vending can be done legally and controlled, depends on the rules and regulations in place.

Table 3: Low income urban areas and water supply systems

Location	**Legally occupied areas**	**Semi-legally or illegally occupied areas**
Central city	Inner city slum. **Connected to city network, but service low due to poor maintenance and repair, and overcrowding.**	Small squatter areas on redevelopment sites and public land. Very low security of tenure. **Public taps or vendors**
Within official boundaries of urban area	Low-income housing areas of different types. **House-or yard connections service low due to poor maintenance and repair ; vendors**	Old squatter areas unsuitably located. **Public taps or handpumps, vendors**
Outside official boundaries, occupied or in process of urbanisation	Low-income housing areas of different types. **Autonomous system (borehole, tankers, wells, springs)**	Squatter areas and passively urbanised villages. **Wells, river, springs**

Adapted from Wegelin (1996)

Having services at community level does not necessarily mean that there is 'a community' in the sense of organization. The extent of 'community' depends on the way the settlement has originated, on the homogeneity of the population in terms of ethnic background, on the length of stay of most residents, and on the presence and acceptance of traditional forms of leadership. De facto security of tenure and the extent of owner occupancy versus tenant occupancy further influence community cohesion. Residents of low-income urban areas often only obtain infrastructure services if they have the ability to form community based organizations (CBO) of local residents. Only as a CBO can they negotiate with local authorities.

3. Issues affecting Water Demand Management activities in low-income areas

One of the assumed results of Water Demand Management is that the increased availability of water will lead to a more equitable distribution of this water, and thus enhance access of the poor to water supply services. Experience in water supply services to the urban poor, shows that some of the measures taken to facilitate access in fact makes the water more expensive for the poor and that a more equitable distribution needs an active, community focused strategy. Aspects that play a role in the development of such a strategy are legal conditions, water conservation measures, tariff setting, public information and demand responsiveness.

3.1 Regulations regarding retail sale of water

In some places resale of water is restricted by law or by the utility. Reasons for the restriction vary from the impossibility to serve customers in an illegal area and free distribution at public standpost to the argument that profit made by formal or informal vendors should rather be made by the utility itself. Profits in the vending systems, especially where the access to the vending market is restricted, can be enormous.

> *In Nigeria, for instance, the vast majority of residents obtains its water from an elaborate and well organized water vending system, selling 2.96 million gallons per day for which they pay about US$28,000. At the same time, the public water utility was supplying about 1.5 million gallon per day for which they collected US$ 1,100. Thus the water vending system was providing double the supply and collecting 24 times as much revenue as the water utility (Whittington e.a., 1988).*

The vending systems may be controlled by people working in the utilities itself. Therefore deregulation of water sales and easing of supply constraints that could substantially lower both hauling costs and the price of water, may be very difficult to realize as this would threaten the interest of powerful groups (Lovei and Whittington, 1991). On the other hand, vending systems are a source of income generation for many otherwise unemployed people, and profits for these 'small' vendors tend to be not very large. Their prices are a reflection of the price per unit at source, time spent on the hauling of water and the waiting times at the water point.

With or without restrictions, vending systems are serving millions of customers in cities in developing countries. The differentials in the cost of water (ratio of price charged by water vendors to prices charged by the public utility) vary from city to city and are dependent on various factors such as access to alternative sources and control and competition of the resale market.

Table 4: Differentials in the cost of water in selected cities

City	Price ration
Abidjan	5:1
Dhaka	12:1 to 25:1
Kampala	4:1 to 9:1
Karachi	28:1 to 83:1
Lagos	4:1 to 10:1
Lima	17:1
Nairobi	7:1 to 11:1
Port-au-Prince	17:1 to 100:1
Surabaya	20:1 to 60:1
Tegucicalpa	16:1 to 34:1

Source: World Bank, World Development Report 1988

Since the higher and middle-income residents are more likely to be connected to the water network, it is the low-income groups who are most dependent on vendors. This invalidates the often used argument by public utilities and formal sector water providers that they cannot provide water in low-income areas because residents in low income areas cannot pay sufficient for their water to operate and maintain the system and also to get a return on the capital investment. To the contrary, the prices paid by consumers show willingness-to-pay and economic demand and provide a good basis for water investment decisions and for the design of tariffs.

➡ ***Households served by vendors pay considerably higher unit prices for water than those connected to the water supply system. An open market and no restriction with respect to resale of water will lower the price per unit and will give residents a chance to generate some income. In addition, it gives communities the option to organize and manage their own water supply.***

3.2 Water pricing measures

One of the measures taken to promote water conservation and at the same time increase access and equity in water supply provision, is the establishment of different forms of tariff setting. In a progressive block tariff system (also called increasing block tariff system), the first 5 to 10 m3 have a low, subsidised tariff and the following blocks have an increasingly higher tariff. The rationale for the system is to promote water saving practices with all households and to ensure that low-income households can afford to use an amount of water that is necessary to keep themselves and their environment healthy, typically 20-25 litres/cap/day. The effects of this system, however, can be adverse for the poor in specific circumstances that are quite common throughout cities in the developing world. The first of these is that many low-income families do not have their own connection and buy water per bucket at a neighbours house. With the resale, the neighbour will end up in a higher tariff bracket and will adapt the price per bucket. A second is that many low-income families do not have an individual water connection, but live in compounds with more families or in apartment buildings where individual families have one or more rooms. These people often all share one water meter and the communal water bill ends up in the highest tariff block because of the high number of users. The sharing of one water meter may be the result of utility policy to install one meter per building or may be the result of an attempt to save on the connection cost or meter rent as is illustrated below:

> *In Rada, Yemen, the system of block pricing was not sufficiently explained to the customers, who had to pay a connection fee to get a house connection. Since in many houses, several households are living together, these households thought to economise on the connection costs by sharing a connection. When their first bills came, they were outraged by the water fees as the block tariff was such that the fees rose steeply after the first 10 cubic metre and then again after the second 10 cubic metre. Many of the houses with several families had consumed over 40 or 50 cubic metre falling in the highest tariff and ending up with an unaffordable water bill. (Wegelin and de Wildt, 6th monitoring report Rada, Yemen, 1996).*

➡ ***Although the progressive block tariff system is a very good instrument for water demand management, the system can have negative effects if the aim is to subsidise minimum water requirements for the poor, especially when the consumers have not been effectively informed about the structure of the tariff system.***

3.3 Water conservation measures

High rates of unaccounted for water are common in many cities in developing countries, reaching extreme levels of 40%-60% of the water produced, representing critical water and financial losses. Of the total UFW, an estimated 50% is caused by leakage, usually the result of either lack of maintenance or failure to replace aging systems. Where utilities are focussing on the reduction of leakages, they usually concentrate on the technical aspects of leakage control. However, reporting of above ground leakages by the public, would assist in leak detection and thus reduction of losses. Yet, for people to inform a utility on leaks, requires not only awareness of the need to report, but also information on where to report and motivation to do this reporting. The contrary is usual: a leak is welcomed as a source of free water and is likely to go unreported as long as possible.

> *When a community group in Kibera, a low-income settlement in Nairobi, were digging the trenches for the piped connection to their community water kiosk, one of the women struck a small diameter pipe which was already located under the trench. The water burst outside forming a small fountain. Within five minutes, the first people arrived to collect the water in all kinds of receptacles. In the next ten minutes a line was formed with people waiting for free water and within half an hour, a man who owned the shop in front of which the leak occurred, started to ask money for the water. It was only days later when the owner of the pipe realized that the lack of water was not caused by one of the usual 'irregularities in supply in the main', that the leak was fixed. (author experience)*

Similarly, illegal connections can be expected to go unreported if residents do not feel responsibility for the system or a sense of being disadvantaged by these connections. For a utility, it is extremely difficult to get an overview of the incidence and number of illegal connections in a densely populated low-income area, where houses are not numbered and a maze of small footpaths form the roads. They will always be dependent on information from within the area. Also with regard to sources of resale of water as it is highly likely that many of these are also illegally established or operating from a non-metered household connection, forming a large part of Unaccounted For Water.

A final water conservation measure that applies to low-income areas, is metering of public supplies. The Water Utilities Data Book of the Asian Development Bank gives an overview of methods of payment for water for these supplies:

Table 5: Methods of payment for water through public taps and standpipes

Method of payment	Number of cities
Metered use	12
Flat rate	9
Property tax	2
Combination	3
No payment	7

The total number of cities reviewed in the Data Book is 50, but only 33 out of these have public supplies. Of course, these statistics concern only major cities in Asia and do not reflect the situation in smaller cities and the different continents. But on the whole, there is a tendency to move away from free or utility managed standpipes and this is very much justified. Free, non-managed public taps have an extremely short life span and are a source of much wastage. They also do not reflect the principle of water as an economic good.

➨ ***The agency needs the co-operation and involvement of the residents for leak detection or reduction of illegal connections. They will only do this when they have a sense of ownership for the system. Where they get water through vendors, kiosks or public taps, this may only be present if the service is based on demand existing in that community and is managed and operated with community involvement***

3.4 Public information and demand responsive approaches

It has for long been assumed that communities do not know their infrastructure needs - especially low-income communities. Thus decisions have been made on assumptions by engineers and planners and not on actual information and understanding of household water demand. It is increasingly being recognized that this top-down approach has been the reason for the failure of many initiatives and that communities have to be involved in the decision making process on the water supply system based on their demands. Approaches to project design which incorporate such features are also known as Demand Responsive Approaches (DRA), which is based on four principles:

- Water has to be managed as an economic as well as a social good
- Management has to focus on the lowest appropriate level
- A holistic approach to the use of water resources has to be adopted
- Women have to play a key role in the management of water

Key features in such approaches are:

1. Community members make informed choices on:
- Whether to participate in the project
- Technology and service level options based on willingness to pay – based on the principle that more expensive systems cost more
- When and how their services are delivered
- How funds are managed and accounted for
- How their services are operated and maintained
2. An adequate flow of information is provided to the community and procedures are adopted to facilitate collective action decisions within the community and between the community and other actors.
3. Governments play a facilitative role, set clear national policies and strategies, encourage broad stakeholder consultation and facilitate capacity building and learning
4. An enabling environment is created for the participation of a wide range of providers of goods, services and technical assistance to communities, including the private sector and NGOs

(Sara, Garn and Katz, 1998)

Although the term demand responsive approach is relatively new, there are already many experiences and examples of urban communities that have been involved in their own water supply provision. These show that effective information is crucial. Initially, this information is necessary for people to decide whether or not to get involved and to decide the level of service they want and are willing and able to pay for. Once the system is in operation, customers need to be informed on any changes in the ongoing supply such as changes in fees, changes in collection systems or changes in operating hours. Utilities are so used to their (assumed) monopoly that they often completely disregard this aspect of their service, leading to unwillingness to pay for the service with the customers. It is because the usually adequate information and operating service that people prefer vendors and community based systems. But where utilities decide to establish a special section to deal with communication with low-income communities, the results are very promising:

> *SANAA (the water agency in Tegucicalpa, Honudras) helps the communities in low-income urban areas to set up their own water service associations. These associations install independent water supply systems which residents pay for and operate and maintain and which in the long run cost less than continued buying from unregulated water vendors. Different water source options are promoted such as: direct sale of water from the main network through a master meter; construction of community wells provided with electric pumps, leading the water to a communal tank for further distribution; and water trucks from the SANAA distribution centres which fill up communal tanks from which the community distributes further and pays for the bulk delivery. An evaluation in six communities showed an average service coverage of 85% of the households. Because of problems of water and electricity distribution in the city wide network, water is distributed to different parts of the city at different hours. But the information is communicated effectively, so kiosks are open at different, but fixed times, and women can adjust their domestic management to these hours. (Espejo et al. (1993)*

Community based systems vary in degree of community ownership, degree of responsibility for operation and maintenance and in degree of community organization needed as a basis for the service. Examples of systems, progressing in levels of autonomy, are:

Group taps are closest to private connections. Under this system households jointly take one private connection and share the bill. Essential social conditions for the success of this system are that the users form their own group and decide in whose name the connection is registered, where the tap is located and how costs are shared.

A communal water point consists of several taps with a bucket stand, a drain, a soakpit and a valve box which contains also the water meter and can be locked. The user group chooses a small (usually three persons) tap committee, which unlocks and locks the valve box, oversees proper water use, receives and divides the water bill between the user households, collects the money and pays the public authority.

In **community-managed vending kiosks** water is sold per bucket at public vending points or kiosks. The committee manages the overall fund and takes care of maintenance and repairs of the water supply, up to replacement of pumping equipment.

An **autonomous local distribution net** is operated by a community organisation that buys water in bulk from the urban utility. The utility either installs a metered master connection to the city net, or fills a community reservoir. From there the local community distributes the water on to the members of the local water user association through private connections or shared taps. The community pays the water charges to the utility and operates, maintains and manages the local system.

Small **autonomous water supply systems** can be operated by a community. User households are members of a local water users association with an elected water management committee. The water utility gives technical advice and helps arrange for the investment loans, which are partly paid by the community through the water tariff. Sometimes water utilities establish a special unit for experiments with alternative water supply systems.
(adapted from Van Wijk, 1997)

It is not justified to assume that all communities are interested or capable to manage their own systems, many prefer not to be bothered and to pay for a regular service based on a service level they want. But, similar systems or service provision could also be provided effectively by utilities or private water vending enterprises as long as the community has been involved in the process of decision making on the service, according to DRA principles. In this process, transparency with the utility and the private enterprises is a key issue.

➡ ***Effective information and transparency are main factors that influence community interest and ability to become involved in their own water supply provision. An important advantage of community managed systems is the sense of ownership, leading to higher rates of payment and less abuse of the system. An additional advantage is that profits made in the system can be used for other developmental purposes within the community, rather than flowing back to the utility or private sector.***

4. Conclusions

Because in many countries a majority of urban residents lives in low-income areas, it is important to extend Water Demand Management instruments also to these areas. A number of these instruments may not be applicable, such as retrofitting or out-of-house water saving measures, some may have unintended side effects such as the increasing block tariff systems and others are quite applicable, such as metering. But some important instruments that apply to these areas, such as leakage detection, reduction of illegal connections and awareness, require an attitude within these communities that can only be expected if they feel co-ownership over that water.

Demand responsive approaches and community management of water supply systems can bring about this attitude. Effective information and communication are the most prominent requirements on which demand responsive approaches are based and essentially, this feature is also the most important basis for water demand management. Technologies can never change people's attitude and will only be applied effectively if people are motivated to do so. The participatory methodologies that are applied in the DRA approaches and that give communities the power to assess their own priorities and make their own decisions, can also be applied to motivate people to adopt Water Demand Management instruments.

Governments and utilities that want to promote Water Demand Management, therefore should embark on a process of community involvement and consultation and apply demand responsive approaches to water supply in low-income urban areas. For this to happen, it may be necessary to carry out legislative and institutional reforms, facilitating community ownership and management.

The agency will need to change from provider to facilitator, coordinator and supporter of the communities in the management of their water supply. It means that the staff will need to adjust their attitudes and have to become transparent in their decision making. Instead of making all decisions themselves and giving instructions to the community, they will need to listen to people's views and ideas. They will need to answer questions communities ask on technical options, costs, reliability, service levels, requirements for operation and maintenance and on water demand management instruments. This may require the establishment of a new section responsible for information, education, mobilisation and participation of communities and extensive capacity building with the staff to carry out this new role.

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With regard to the domestic consumer, water demand management measures can be divided in:

1. Water conservation measures:
   - Leakage detection
   - Reduction of illegal connections
   - In-house retrofitting
   - Out-of-house water saving measures

2. Water pricing measures:
   - Water metering
   - Tariff structures

3. Information and educational measures:
   - Awareness raising
   - Public involvement
   - In-school education

4. Legal measures
   - Rules and regulations that form the basis of WDM policy
   - Regulations on resale of water

Percentage of urban population connected to city network or dependent on communal water points

City	Houseconnection	Public tap
Jakarta (1991)	30%	30%
Delhi (1992)	53%	37%
Phnom Penh (1992)	70%	-
Casablanca (1997)	80%	17%
Ouagadougou (1994)	38%	17%
Conakry (1989)	20%	5%
Buenos Aires (1993)	80%	-

DIFFERENT CLASSES OF CONSUMERS

- High income consumers are able to meet their water requirements at individual household level by being connected to the municipal water supply system or by installing their own facilities such as wells, boreholes or rainwater harvesting systems.

- Middle income groups are the majority of the customers of municipal infrastructure services and hence the recipients of the usually heavy subsidies with which water supply systems are operating. Generally they are connected to the municipal water supply system with individual house or yard connections.

- Residents of low-income urban areas are rarely consumers at individual household level. The type of water supply system depends on the type of settlement with regard to legal status and security of tenure, and the location within or outside the city limits

Low income urban areas and water supply systems

Location	Legally occupied areas	Semi-legally or illegally occupied areas
Central city	Inner city slum. **Connected to city network, but service low due to poor maintenance and repair, and overcrowding.**	Small squatter areas on redevelopment sites and public land. Very low security of tenure. **Public taps or vendors**
Within official boundaries of urban area	Low-income housing areas of different types. **House-or yard connections service low due to poor maintenance and repair; vendors**	Old squatter areas unsuitably located. **Public taps or handpumps, vendors**
Outside official boundaries, occupied or in process of urbanisation	Low-income housing areas of different types. **Autonomous system (borehole, tankers, wells, springs)**	Squatter areas and passively urbanised villages. **Wells, river, springs**

Issues affecting Water Demand Management activities in low-income areas

- Regulations regarding retail sale of water
- Water pricing measures
- Water conservation measures
- Public information and demand responsive approaches

Regulations regarding retail sale of water

Households served by vendors pay considerably higher unit prices for water than those connected to the water supply system. An open market and no restriction with respect to resale of water will lower the price per unit and will give residents a chance to generate some income. In addition, it gives communities the option to organize and manage their own water supply.

Differentials in the cost of water in selected cities

City	Price ration
Abidjan	5:1
Dhaka	12:1 to 25:1
Kampala	4:1 to 9:1
Karachi	28:1 to 83:1
Lagos	4:1 to 10:1
Lima	17:1
Nairobi	7:1 to 11:1
Port-au-Prince	17:1 to 100:1
Surabaya	20:1 to 60:1
Tegucicalpa	16:1 to 34:1

Water pricing measures

Although the progressive block tariff system is a very good instrument for water demand management, the system can have negative effects if the aim is to subsidise minimum water requirements for the poor, especially when the consumers have not been effectively informed about the structure of the tariff system.

Water conservation measures

The agency needs the co-operation and involvement of the residents for leak detection or reduction of illegal connections. They will only do this when they have a sense of ownership for the system. Where they get water through vendors, kiosks or public taps, this may only be present if the service is based on demand existing in that community and is managed and operated with community involvement

Public information and demand responsive approaches

Effective information and transparency are main factors that influence community interest and ability to become involved in their own water supply provision. An important advantage of community managed systems is the sense of ownership, leading to higher rates of payment and less abuse of the system. An additional advantage is that profits made in the system can be used for other developmental purposes within the community, rather than flowing back to the utility or private sector.

TYPES OF COMMUNITY BASED SYSTEMS

Group taps are closest to private connections. Under this system households jointly take one private connection and share the bill. Essential social conditions for the success of this system are that the users form their own group and decide in whose name the connection is registered, where the tap is located and how costs are shared.

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International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
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Special Session

Special Speech
&
Introduction to IETC's "maESTro"

Changing the Concept of Sewage Works for Sustainable Society

-Separation of urine and feces for recovery of useful materials and stopping contamination of water bodies.

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Introduction

Lakes and reservoirs are most vulnerable water bodies on the earth, where all contaminants converge on resulted in difficult harmonization among many users in terms of water quality. Among contaminants, the most common elements are nitrogen and phosphorus that are basic elements of food production. After the world war II, food shortage was serious any place of the world except US and a few countries. It was introduced so called Green Revolution in the agricultural sector, which was very successful to support necessary food supply for the most of population avoiding starvation. The factors involved in the success included the use of large amount of fertilizers, namely nitrogen and phosphorus, and application of synthetic agrochemicals, etc. Over use of fertilizers brought eutrophication problems in water bodies of lakes and reservoirs, and even closed seas. Eutrophication problem of freshwater becomes serious for drinking water supply as well as drinking water for cattle, sheep, etc. Even aquaculture faces difficulty with maintaining of the production of marketable species.

EU has introduced regulations on the use of fertilizers for control of eutrophication and ground water contamination from nitrate. Less number of countries have similar regulations. Over use of nitrogen brought another serious threat on the water environment, namely ground water contamination, which is also a problem for drinking water supply in many countries regardless developed and developing countries.

Nitrogen is a basic element in the global cycle between water and air that is the largest pool. After the world war II, nitrogen fixation from air into ammonia became large production. Comparing to the large amount of nitrogen fixation, it occurred less amount of denitrification, which upset the nitrogen cycle, resulted in the accumulation in nitrogen with surface water as well as ground water.

Phosphorus is another important element for agriculture, but very effective for eutrophication of water bodies. Although it seems that the supply of this fertilizer is not limited so far, the mineral storage of phosphorus is not reassuring in the future, because that the origin of mineral phosphorus was the past birds feces.

It is necessary to find a solution of stopping water contamination due to over use of nitrogen and phosphorus. This paper tries to bring a new concept of sewage works that can provide a solution.

What are the differences between urine and feces in terms of nitrogen and phosphorus contents

It is very interesting to know the differences between urine and feces in terms of nitrogen and phosphorus contents. Table 1 shows that urine is rich with nitrogen (88%), phosphorus (67%), and potassium (71%), which may be different from the common sense of the people. Urine is free from pathogens that can be found only in feces.

Table 1 Nutrient distribution between urine and feces (After SEPA, 1995)

Parameter	Urine		Feces		Total discharge	
	g/person/day	%	g/person/day	%	g/person/day	%
Wet weight	900-1200	90	70-140	10	1000-1400	100
Dry weight	60*	63	35	37	95	100
Nitrogen	11.0	88	1.5	12	12.5	100
Phosphorus	1.0	67	0.5	33	1.5	100
Potassium	2.5	71	1.0	29	3.5	100

*A large proportion of this dry substance is rapidly biodegradable. Much of it already degrades in the sewage pipes.

Table 2 provides the information of pollution loads of a person to the water environment. When it combines the data of Table 1 and 2, the following estimation can be drawn that urine contains 66% of nitrogen and 50.3% of phosphorus discharged by a person in the form of sewage.

Table 2 Pollution loads of waste water generated by a person (After Sewage Works Guideline, Ministry of Construction, Japan, 1996)

Item	Average g/person/day	Std. deviation	No. of Data	Urine + Feces %	Gray water %
BOD5	58	18	99	32	68
CODmn	26	9	96	36	64
SS	44	16	99	47	53
T-Nitrogen	11	3	9	75	25
T-Phosphorus	1.2	0.2	8	75	25

If we collect urine separated from feces, and treat in some way for the recovery of nutrients to provide to agricultural sector, we can reduce nitrogen and phosphorus loads on water bodies by replacing synthetic fertilizers. This is a practice of nutrients recycling from urban areas to agricultural areas, which is a key factor for building a sustainable society. This practice is also a promising solution for controlling eutrophication in lakes and reservoirs, and ground water contamination of nitrogen.

Four different types of toilets

There are four different types of toilets available in concept. The first is a water toilet without separation of urine-feces. This practice has a long history starting from Indus Civilization. The Roman Empire period to the modern sewage works initiated in London, 19 century. The second is a water toilet with separation of urine-feces, which a Swedish community started an experiment in Stockholm. The third is a dry toilet without separation, which is still in use in Japan, Korea, Taiwan and China. The fourth is a dry toilet with urine-feces separation, which was in use in Old Japan, Vietnam, etc, and is promoted by the Ecological Sanitation Group of SIDA from 1997. The advantage and disadvantage are compared in the Table 3 that describes four different types of toilets. It should be pointed out here that many developing countries may not be able to install sewage works for their urban areas simply because of water shortage, where a dry toilet system with urine-feces separation is a better solution for sanitation problem. This issue is not discussed in this paper.

Table 3 that describes four different types of toilets

Type	Advantage	disadvantage
I. Water toilet without separation of urine-feces		
	Applicable congested urban areas	
	Pipe installation easy	
	Sanitation kept well	
		Water consumption is large
	"Western Concept"	Not applicable water scarcity urban
		N, P poor removal
		Estrogen, etc. poor removal
II. Water toilet with separation of urine-feces		
	Recovery of N, P, K, & hormones for agriculture & medicine	
	Easy treatment of N, P, hormones.	
	Control for eutrophication & ground water contamination	
	Sanitation kept well	
	Water save by urine collection	
	"New Concept" by Swedish	Difficult for congested urban
		Not applicable water scarcity urban
		Urine collection by trucks
		Recovery and treatment plant necessary
III. Dry toilet without separation		
	Recovery of N, P, & K for agriculture	
	Water save	
	" Japanese Practice"	Collection by vacuum trucks
		Night soil treatment plant
		Poor sanitation
IV. Dry toilet with urine-feces separation		
	Recovery of N, P, & K for agriculture	
	Water save	
	"Ecological Sanitation"	Collection by vacuum trucks
		Better sanitation

Water toilet with separation of urine-feces

If we can design a toilet that can accept urine and feces in separate way, we can change the one collection pipe system into the two pipe system in which the urine pipe collect a very small amount of urine with additional washing water by the urine pipe. Feces are collected by the same as the current sewage pipe with gray water of households. Comparing to the current standard sewage pipe system, the difference is that only urine pipe system is necessary for addition. Fig-1 showed such a new concept.

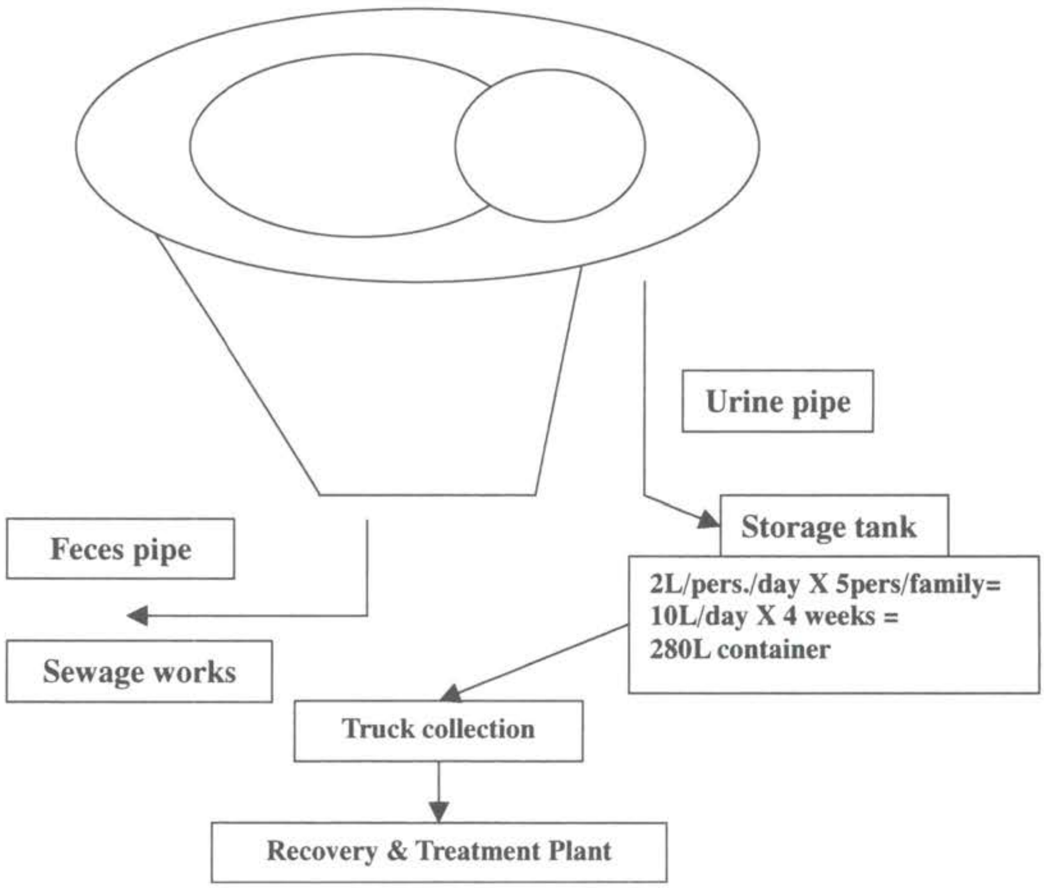

Fig-1 Urine and Feces Separated Toilet

Nitrogen and Phosphorus Loading to Lake Biwa

Eutrophication of Lake Biwa has been one of the major water issues in the Osaka, Kobe, Kyoto urban areas. The water quality of the lake controls the drinking water quality of those major cities, because that they take water from the Yodo River that flows from the lake. The efforts of Shiga Prefecture Government have been put on reducing loads of N & P from point sources including municipal waste water and industrial waste water 8 (Fig 2). The population coverage by public sewer works in the catchment area of Lake Biwa is about 50% as of 1997. Major treatment plants for collected sewage around Lake Biwa conduct biological denitrification and chemical phosphorus removal. Small size community treatment plants that cover very small portion of the population, do not treat nitrogen either phosphorus. The remaining 50% population shall be covered by either major treatment plants or small size community plants. Under the estimation of 90% population coverage by sewage works in the future, it is not enough to reduce nitrogen and phosphorus loads to reach the stream standards set for prevention of eutrophication of the lake. All efforts are necessary for preventing from further eutrophication. However, nutrient loads from non-point sources are not in the list of measures against eutrophication. It is very necessary to reduce the nutrients run-off from the agricultural sector.

Nitrogen and Phosphorus removal by waste water treatment plants

The current waste water technology can provide biological and chemical processes for removing nitrogen and phosphorus. However, the available processes have fatal inconsistency with the aim of sustainability of our society and the environment.

Nitrogen is removed by denitrifying bacteria when it is oxidized by nitrifying bacteria into nitrite and nitrate in the aeration tanks of waste water treatment plants. The efficiency of denitrification is about 70 to 80 % which is not enough to improve nitrogen levels in most of lakes and reservoirs from preventing eutrophication. How to improve the efficiency is the big challenge for engineers. A simple solution is to provide more organic carbon source to sewage, which mean discharging more food waste to sewer!! It is contradicting the direction of sustainable society. Unless a waste water treatment plant accepts good organic pollutants of nitrogen free as the form of industrial waste water, it is impossible to adjust the more efficient balance of BOD:N in sewage.

Another concerning aspect of incomplete denitrification is production of $N2O$ in stead of $N2$ during the biological process. $N2O$gas is a strong global warming factor that should be controlled by any human activity.

Phosphorus removal can be done by the biological process that requires a strong reduced condition prior to the denitrification process, which mean more carbon sources than denitrification. Japanese sewage quality is, in general, less carbon source to nitrogen and phosphorus, mainly because that dietary conditions are different from western countries. It is necessary for Japanese municipal waste water treatment plants to conduct chemical process rather than the biological process in order to discharge good quality of phosphorus in effluents even under storm water conditions. The occurrence and intensity of rain-fall is much larger in Japan, which often create difficult conditions to the biological phosphorus removal process. Biological phosphorus removal process requires a reduced condition for phosphorus release from bacteria, which can be controlled by the supply of

enough carbon sources in sewage. Storm water dilutes such conditions often and upset the biological process. The precipitated phosphorus is not recycled to agriculture because that the chemical form is not available for plant uptake as fertilizer. This practice is not a sustainable way.
If we can eliminate urine from sewage, the proportion of BOD:N:P of sewage is greatly improved to be 100:8.2:1.0 from the current 100:19:2.0 according to the data of Table 1 and 2. This improved proportion can give us much better efficiency of the performance of municipal waste water treatment plants.

Endcrine disruption issues and municipal waste water treatment efficiency for estrogens

Endcrine issues put us a difficult situation with sewage works. Sewage system accepts large number of synthetic as well as natural chemicals as its structure and function. The sources of endcrine disruptors may be quite wide ranging from households, hospitals, laboratories, and industries. Storm water may contain endcrine disruptors. Among endcrine disruptors, estrogen mimics are very much concerned with sewage works. Human urine contains natural estrogens discharged by males as well as females in significant amount such as 18ug/male/day, 20-40ug/female/day, and 28mg/pregnant/day. Besides natural estrogens, estrogen mimics are also discharged in sewage. Our laboratory found the estrogen fate in municipal waste water treatment plants in Japan, which showed the removal efficiency of natural estrogens is very poor, specially with 17ß estradiol that is the most powerful estrogen and potential for disrupting male fish reproductivity in receiving waters. The effluents from investigated municipal waste treatment plants contain several to10ng/L of 17ß estradiol. The urine recovery from sewage improves this situation. Urine may contain other types of hormones, such as growth hormone, etc.
Urine may contain urokinase that is an enzyme to prevent from blood clogging. Urine may contain harmful substances such as conjugated drugs used for medical treatment, which put a new problem to sewage works.

Conclusion

Nitrogen and phosphorus are basic elements of lives on the earth. We do not have any global plan in which we could adjust local and global cycles of them. We are facing eutrophication and ground contamination due to over discharge of the elements into the environment. Human waste is the important form of the elements in global and local cycles. If we separate urine and feces from human waste for the recovery of those elements, and other chemicals including estrogens, etc, we may be able to develop a new type of sewage works that could be more efficient for water use and the protection of the water environment.

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4. Shiga Prefecture Government Report on the Environment, 1995

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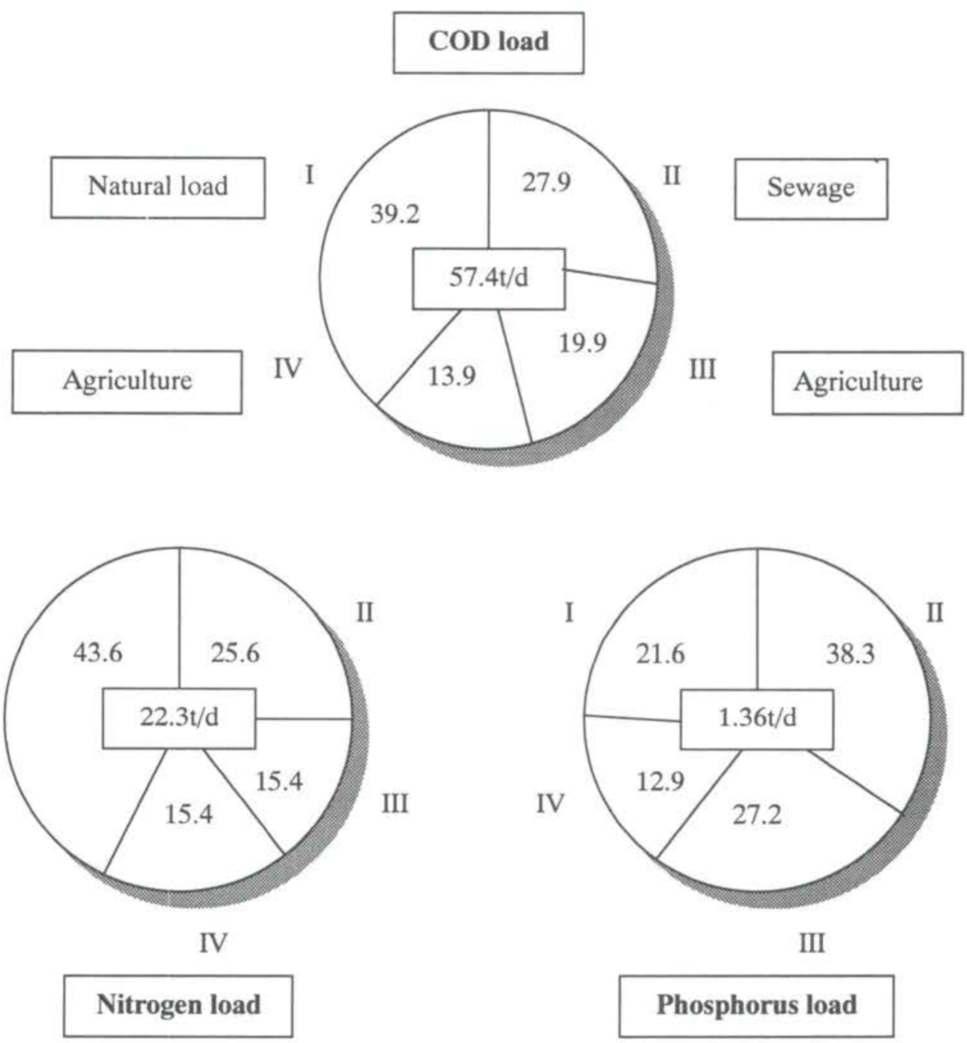


Fig 2 COD, T-N and T-P Loads on Lake Biwa by Different Sources (1995)

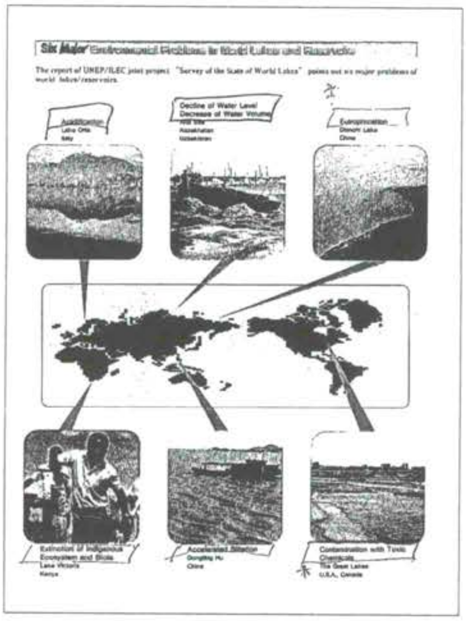


Table 1 Nutrient distribution between urine and feces (After SEPA, 1995)

Parameter	Urine g/person/day	%	Feces g/person/day	%	Total discharge g/person/day	%
Wet weight	900-1200	90	70-140	10	1000-1400	100
Dry weight	60*	63	35	37	95	100
Nitrogen N	11.0	88	1.5	12	12.5	100
Phosphorus P	1.0	67	0.5	33	1.5	100
Potassium K	2.5	71	1.0	29	3.5	100

*A large proportion of this dry substance is rapidly biodegradable. Much of it already degrades in the sewage pipes.

Table 2 Pollution loads of waste water generated by a person(After Sewage Works Guideline Ministry of Construction Japan,1996)

Item	Average g/person/day	Std. deviation	No. of Data	Urine +Feces %	Gray water %
BOD5	58	18	99	32	68
CODmn	26	9	96	36	64
S S	44	16	99	47	53
T-Nitrogen	11	3	9	75	25
T-Phosphorus	1.2	0.2	8	75	25

4 types of sanitation

Type	advantage	disadvantage
Sewage work (I) Water toilet without separation of urine-feces	Applicable congested urban areas Pipe installation easy Sanitation kept well	
"Western Concept"		Water consumption is large Not applicable water scarcity urban N, P poor removal Estrogen, etc poor removal
(II) Water toilet with separation of urine-feces	Recovery of N, P, K, & hormones for agriculture & medicine Easy treatment of N,P, hormones Control for eutrophication & ground water contamination Sanitation kept well Water save by urine collection	
"New Concept" by Swedish		Difficult for congested urban Not applicable water scarcity urban Urine collection by trucks Recovery and treatment plant necessary
no sewage work (III) Dry toilet without separation	Recovery of N, P, & K for agriculture Water save	
"Japanese Practice"		Collection by vacuum trucks Night soil treatment plant Poor sanitation
(IV) Dry toilet with urine-feces separation		

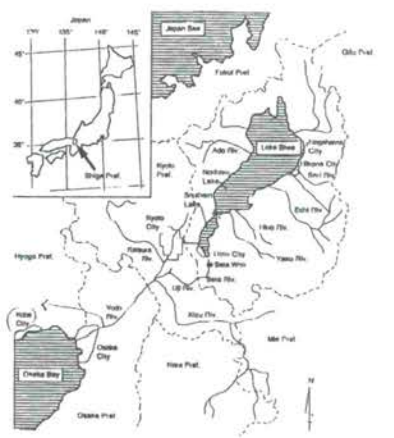


Figure 1. Lake Biwa and the Yodo River Region.
Source: "Lake Biwa", Shiga Prefectural Government, 1991

14 million people take water from Lake Biwa & Yodo River System

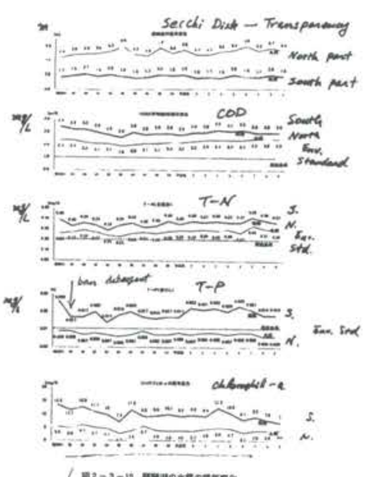


図2-3-18 琵琶湖の水質の経年変化

National Project
Lake Biwa Comprehensive Development /15 years
15 billion US $

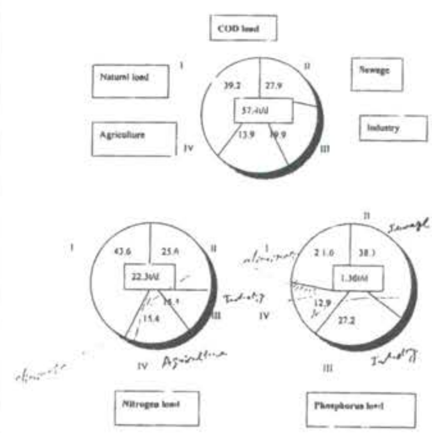
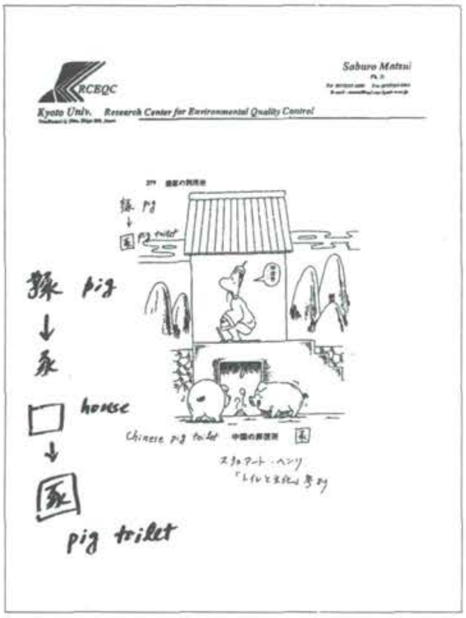
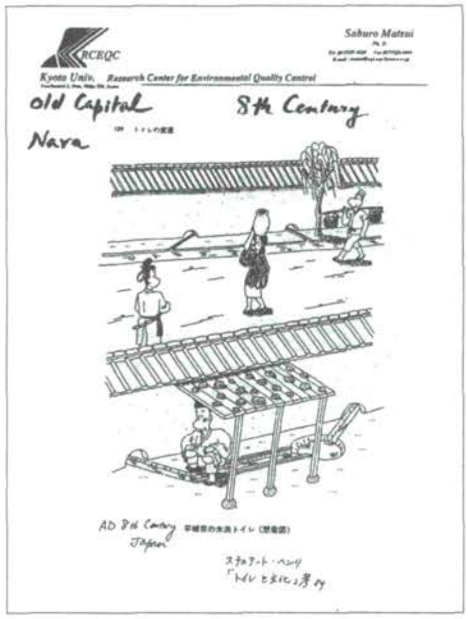


Fig 2 COD, T-N and T-P Loads on Lake Biwa by Different Sources(1995)

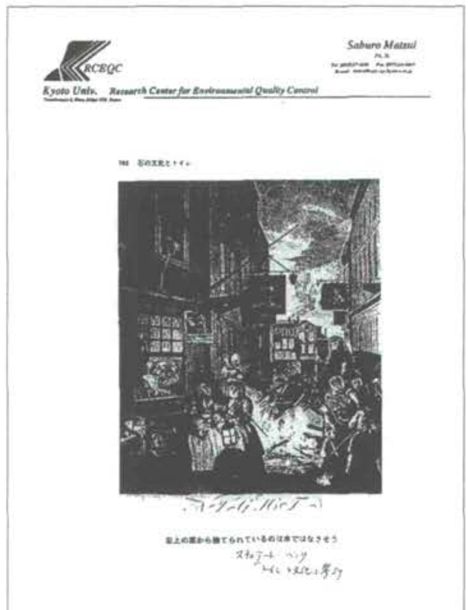


RCEQC
Saburo Matsui
Kyoto Univ. Research Center for Environmental Quality Control
豚 pig
家
house
圂
pig toilet
Chinese pig toilet 中国の豚便所



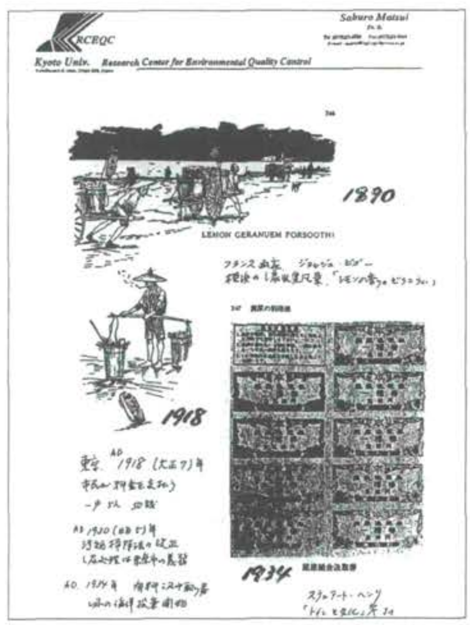
RCEQC
Saburo Matsui
Kyoto Univ. Research Center for Environmental Quality Control
Old Capital
8th Century
Nara
AD 8th Century
Japan

RCEQC
Saburo Matsui
Kyoto Univ. Research Center for Environmental Quality Control



RCEQC
Saburo Matsui
Kyoto Univ. Research Center for Environmental Quality Control

RCEQC
Saburo Matsui
Kyoto Univ. Research Center for Environmental Quality Control
17th ~ 19th C.



RCEQC
Saburo Matsui
Kyoto Univ. Research Center for Environmental Quality Control
1890
LEMON GERANIUM FORSOOTH!
1918
1934

RCEQC

Saburo Matsui
Ph. D.

Kyoto Univ. Research Center for Environmental Quality Control

1950

Sanitation of Japan

public Sewage Works	50%
Night soil collection	20%
Tandon Jokaso	28%
Gappei Jokaso	0.1%
others	1.0%

Dedicated treatment plant
1,800 public corporation

Water sources for Japanese

Surface water	70%
ground water	30%

Life span expectancy
Female 83 years Male 77 years

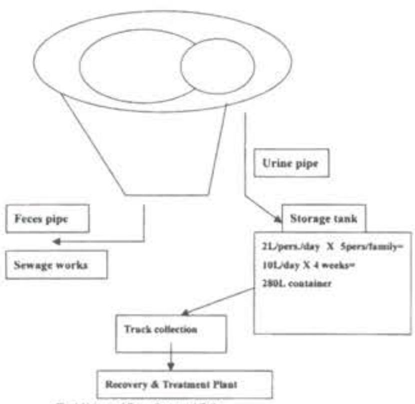


Fig-1 Urine and Feces Separated Toilet

Introduction to maESTro

Directory of Environmentally Sound Technologies (ESTs)

Robert Rodriguez, Information Network Officer, UNEP-IETC

UNEP IETC Shiga Office, 1091 Oroshimo-cho, Kusatsu City, Shiga 525-0001, Japan
Tel: +81-77-568-4580, Fax: +81-77-568-4587, URL <http://www.unep.or.jp> e-mail maestro@unep.or.jp

I. Introduction

1. UNEP International Environmental Technology Centre (IETC)

IETC's main role is to promote the adoption and use of Environmentally Sound Technologies (ESTs) to address urban environmental problems, such as sewage, air pollution, solid waste and noise, and the management of freshwater basins in developing countries and countries with economies in transition.

2. Definition of ESTs

Environmentally Sound Technologies (ESTs) encompass technologies that have the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, these technologies protect the environment, are less polluting, use resources in a sustainable manner, recycle more of their wastes and products, and handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes.

Furthermore, as argued in Chapter 34 of Agenda 21, ESTs are not just "individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organisational and managerial procedures". Consequently, when considering technology promotion, IETC's approach incorporates both the human resource development (including gender relevant issues) and local capacity building aspects of technology choices. ESTs should also be compatible with nationally determined socio-economic, cultural and environmental priorities and development goals.

Information on ESTs, however, is often hard to obtain in a standardized, user-friendly format. To help solving this problem, IETC created a searchable electronic EST-directory, called maESTro.

II. maESTro

1. What is maESTro?

maESTro is an information tool which contains information on a full range of environmentally sound technologies, institutions and information sources related to water pollution, environmental management, human settlements, hazardous substances, solid waste, wastewater, water augmentation and more. The information is regularly updated by IETC as well as by EST contributors, individual users, organisations and institutions.

maESTro was first developed as a database to disseminate free of charge information on Environmentally Sound Technologies (ESTs) on floppy diskettes, CD-ROMs and report (hard-copy format). In March 1998, in response to maESTro users' request, IETC decided to further develop maESTro on the worldwide web so that people can access those information through the Internet. The newly developed web-maESTro can be found at the "Searchable EST Directory" on IETC's homepage (http://www.unep.or.jp/).

2. EST Contributors

Since 1996, maESTro has been honored to collaborate with numerous government ministries, including the Ministry of Environment in New Zealand, the Ministry of Nature & Environment in Mongolia, the Ministry of Environmental Protection in Lithuania, the Ministry of Environment & Forests in India, the Ministry of Housing, Municipality & Environment in Bahrain, the Ministry of Environment in Lebanon, the Ministry of Energy & Mines in Eritrea, and the Ministry of Environment of the Republic of Korea.

Efforts have been focused on negotiating with potential environmental information contributors to develop the exchange of EST-related information. The contributors to maESTro include: UNIDO in Austria, GEC (Global Environment Centre Foundation) in Japan, Environment Canada and others (see Table 1).

Regarding entries of information in the "Technology" database, IETC initially focuses on technologies owned by public institutions or results from publicly funded research and development institutions. However, under the conditions of special agreements, and based on in-kind or financial support to IETC's activities, also private sector technologies might be added to the Directory.

Table 1. EST Contributors

A	Argentina	- Instituto de Limnologia Dr. Raul Ringuelet
	Austria	- UNIDO
C	Canada	- Corporations Supporting Recycling (CSR) - Dalhousie University - Environment Canada - Ontario Centre for Environmental Technology Advancement (OCETA)
	Chile	- INTEC
	Colombia	- Universidad Industrial de Santander
	Czech	- AGSS Ltd
E	Ecuardo	- Corporcion Okios
	Egypt	- University of South Valley
G	Germany	- International Transfer Centre for Env*tal Technology (ITUT)
	Greece	- Aristotle University
H	Hungary	- Bay Zoltan Foundation for Applied Research Institute of Logistics and Production Systems
I	India	- Centre for Resource Education (CRE) - Ministry of Environment and Forests - APCTT
J	Japan	- Ministry of Construction - Global Environmental Centre Foundation - International Environmental Technology Centre - ILEC (International Lake Environment Committee) - International Centre for Environmnetal Technology Transfer (ICETT)
	Jordan	- Royal Scientific Society
K	Kenya	- Environment Liaison Centre International (ELCI)
	Kiribati	- Work & Energy
	Korea	- Korea Institute of Industry & Technology Information - Korea Envrionmental Technology Research Institute (KETRI)
L	Lybia	- International Energy Foundation
M	Malaysia	- Centre for Environmental Technologies (CETEC)
P	People's Republic of China	- National Environmental Protection Agency (NEPA) - China Association of Environmental Protection Industry - Tsinghua University
	Philippines	- Centre for Advanced Philippine Studies
	Poland	- Institute for Ecology of Industrial Areas
S	Switzerland	- World Health Organization - EMPA, Swiss Federal Laboratories for Materials Testing and Research - UNCTAD
T	Thailand	- Asian Institute of Technology (AIT)
U	Ukraine	- Ukrainian State University of Food Technologies
	United States of America	- Global Environment & Technology Foundation - Massachusetts Institute of Technology (MIT) - Work & Environment Institute - United States Environmental Protection Agency (USEPA)
	United Kingdom	- WRc
	Uruguay	- Environmental Management Secretariat (EMS)

Data as of January 1999

3. maESTro Categories

The data in maESTro are categorized into three fields: "Technology", "Institution", and "Information System" (Figure 1).

1) Institution: compilation of currently about 460 institutions worldwide dealing with ESTs
2) Information System: Information tools (i.e. data bank, directory) that supply information on ESTs
3) Technology: "Hard[1]" and "Soft[2]" technologies in the world.

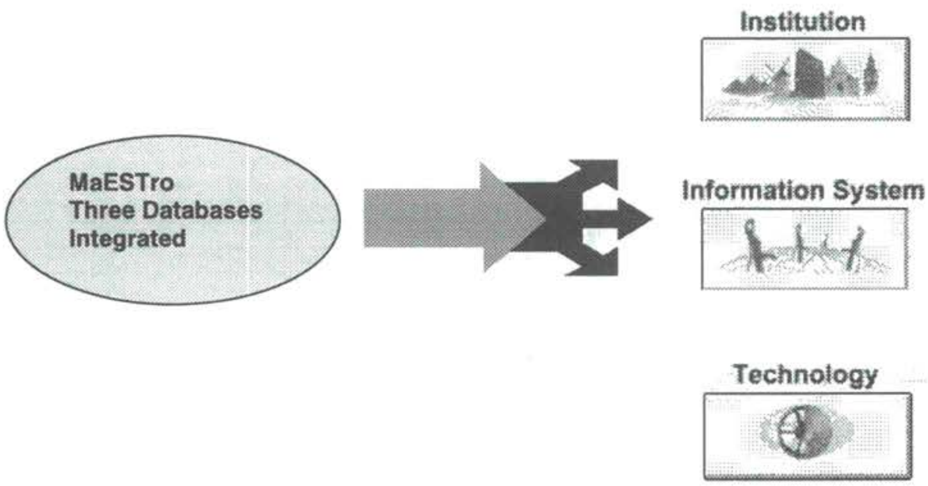


Figure 1: maESTro Categories

Users can browse the information through three query parameters: keywords (waste water, treatment, etc.), geographical location and INFOTERRA themes[3].

[1] Hard technologies include infrastructure, pollution control, sewage and waste treatment facilities, water treatment and supply technologies, remediation technologies and pollution monitoring equipment.

[2] Soft technologies refer to management techniques (such as environmental technology assessment, risk assessment and auditing) that provide the contextual framework through which "hard" technologies should be applied.

[3] INFOTERRA theme is a rudimentary environmental thesaurus for the specific purpose of providing a basic reference tool to describe the information holdings of institutional sources of information at national level. The themes listed are drawn from relatively high level in the environmental terminology hierarchy, and are published in six different languages- Arabic, Chinese, English, French, Russian, and Spanish. For more information on INFOTERRA themes, please contact: UNEP Thesaurus Team, Division of Environmental Assessment and Early Warning, UNEP, P.O. Box 30552, Nairobi, Kenya. E-mail: infotinf@unep.org, Web-site: http://www.unep.org/

III. Benefits for maESTro users

1. Free of Charge

Users can access the maESTro database free of charge. maESTro is growing rapidly through increased number of IETC's networking partners as well as individual Internet users in the world. As the use of maESTro becomes more widespread, information exchange will become more feasible.

2. Global Networking

maESTro is an interactive database: all maESTro users (individuals, organisations and companies) can browse, insert and modify their own data through web, e-mail, and/or mail (diskettes for those without Internet access).

3. Various Formats to Disseminate Information

maESTro is available on-line on the Internet. For those who do not have Internet access, IETC provides maESTro in the form of CD-ROM (called PC maESTro), floppy diskettes and/or report (hard-copy) for free of charge.

a) Report (Hard-Copy) Format

Report (hard-copy) format of maESTro is provided free of charge to users upon their requests (Figure 2). PC maESTro users can also utilize this function by clicking on REPORT button in the PC maESTro software. The hard-copy maESTro includes: Preface, Table of Contents, EST Directories on the request, and Index by INFOTERRA themes and Location.

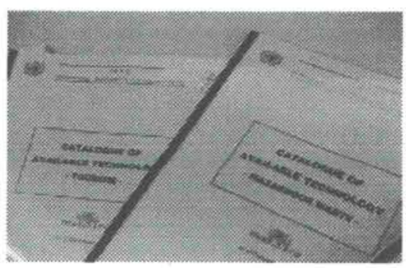


Figure 2: Outlook of Hard-Copy Format maESTro

b) CD-ROMs and Floppy Diskettes (PC maESTro)

maESTro is also available in CD-ROMs and/or floppy diskettes (Figure 3). Users can browse, modify, insert, import and export data with their PCs. The system is user-friendly, and with just a click on the mouse, the information appears in a standardized format called Directory Interchange Format (DIF). Through DIF, maESTro is fully compatible with major international databases such as UNEP's Global Resources Information Database (GRID) and the database of the National Aeronautics and Space Administration (NASA).

Information in CD-ROMs and floppy diskettes is updated by IETC, and the latest version of CD-ROMs and floppy diskettes are regularly provided to registered users for free.

Figure 3: Outlook of CD-ROM maESTro

c) Internet (web-maESTro)

The web-maESTro enables all Internet browsers to log in for free anytime in search of environmental information and to browse the latest data in a timely and direct fashion (http://www.unep.or.jp/maestro/). The data is updated on a daily basis by IETC. Furthermore for better understanding, images are attached to some information.

Although registration is not mandatory, IETC recommends users to register with web-maESTro for their convenience. Registration in web-maESTro is free and needs no approval from IETC. Following is the advantages entitled to the registered users.

- Personalized information
  On the welcoming page of maESTro, you will see the number of new and updated information has been entered since your last visit.

- Notification by e-mail
  For your convenience, whenever there is a major change in the maESTro system, you will be notified by e-mail.

- Insert and modify data
  Users can insert and modify their own information into the maESTro database. Users who have inserted new data can keep, preview, modify and delete their data in the Personal Database until the data is completed satisfactorily and is ready to be sent to IETC for verification.

- Working group facility
  Furthermore, maESTro offers a working group facility that enables users and their partners to work together using network system. This means that users can share, view, and modify information from different members in the same working space/group.

IV. Disclaimer

1. Liability

All information collected and disseminated through maESTro remains under the full responsibility of the original source of information. No guarantee is given, nor responsibility taken by IETC for errors or omissions in the Directory, and IETC **does not accept liability** for any information or advice given in relation to or as a consequence of data contained in our information system.

2. Endorsement

IETC's mandate is to provide users information on technologies. IETC **does not endorse** particular technologies disseminated through maESTro as environmentally sound.

3. Copyright

V. Contact Us

All information in maESTro is continuously amended and updated. For this purpose, technology owners and other interested institutions are welcome to add their information on ESTs to this EST Directory. Assisted by maESTro, each institution can manage its internal information collection and management with other institutions. All entries made will be accessible through a global network of maESTro contributors and users, and also linked to the UNEP/IETC Homepage for Internet browsers.

Please address your queries and requests regarding maESTro to:

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1091 Oroshimo-cho, Kusatsu City,
Shiga, 525-0001, Japan
Tel: +81-77-568 4580
Fax: +81-77-568 4587
e-mail: maestro@unep.or.jp
URL: http://www.unep.or.jp/maestro/

Requests form of maESTro package

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Floppy Diskettes CD-ROM

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Tel. #: ______________________ Fax #: ______________________

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Please fax this form to IETC, Shiga office <+81-77-568-4587>, or mail to UNEP IETC, 1091 Oroshimo-cho, Kusatsu City, Shiga 525-0001, Japan, attn: Ms. Annie Chan Wee.

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International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
Kobe, Japan, 8-10 June 1999

Session 7: Integrated Approaches for Efficient Water Use

– Learning from Case Studies

AN INTEGRATED APPROACH FOR EFFICIENT WATER USE IN SINGAPORE

George Madhavan, Senior Engineer
Water Department, Public Utilities Board, Singapore

A Introduction

The Republic of Singapore comprises a main island and some 60 smaller islands with a total land area of 648 km^2. Being a small island nation, Singapore has limited natural resources. In Singapore, 100 per cent of the population is supplied with potable water, which can be consumed straight from the tap.

The Public Utilities Board (PUB) is the national water authority. It was established in 1963 as a statutory authority to take over the functions of production and supply of electricity, water and piped gas from the then City Council. On 1 October 95, PUB's former electricity and piped gas undertakings were corporatized. PUB remains the water authority and regulator for electricity and piped gas industries. The Water Department of the restructured PUB remains responsible for the provision of an efficient and reliable potable water supply in Singapore at the most economical cost.

B Growing Demand for Water

About half of Singapore's land area is used for water catchment and all available major surface water resources have been developed. Surface run-off is collected in 14 impounding reservoirs, treated at six treatment plants and thereafter distributed through a network of 14 service reservoirs and more than 4,850 km of pipelines to serve the entire population. PUB serves some 1,013,000 water accounts. To augment Singapore's own water resources, about 50 per cent of the water required is imported from the neighbouring State of Johor in West Malaysia.

The rapid industrial, economic and social development of Singapore has resulted in a sharp increase in water demand. In 1950, when the population was a little over 1 million, the demand for potable water was 142,000 m^3/day. By 1998, the population had quadrupled but potable water demand had increased ninefold to 1,280,000 m^3/day. From 1991 to 1998, water demand grew at about 3.3 per cent per annum.

The per capita consumption of domestic customers grew by an average of 0.4% over the last decade from 161.1 litres/person/day in 1990 to 166.2 litres/person/day in 1998. The non-domestic consumption increased from 399,000m^3/day in 1990 to 562,000m^3/day in 1998 with an average growth rate of 4.5% over the last decade.

The Singapore Government is actively exploring new and alternative sources of raw water to augment existing sources, including desalination of sea water, but recognizes that water derived from any new source will cost many times more than that from current sources.

C An Integrated Approach

Whilst new and alternative sources can be developed, it makes better economic sense to ensure that the existing water supplies available are used in the most efficient ways. This will reduce water demand and allow current limited resources to be stretched to the fullest extent. To make every drop count, Singapore has adopted an integrated approach for efficient water use. This approach encompasses not only ensuring that PUB's Network Infrastructure is efficiently operated but also water demand is well managed through measures like water conservation, public education, tariffs and legislation to encourage customers to use water efficiently within their premises. The approaches can be broadly categorised as follows:

- Design of Water Reticulation
- Metering
- Mains Replacement and Rehabilitation
- Intensive Leak Detection Programme
- Quick Response to Reports of Leaks
- Demand Management

I) Design of Water Reticulation

In order to ensure that all customers have a reliable and continuous wholesome water supply, only qualified persons are permitted to carry out the design and installation of water reticulation systems. All applications for water service work must be made through licensed plumbers. Where the work involves the design of a pumping system or storage tank, a professional engineer must also be engaged to make the submission for PUB's approval before the licensed plumber can proceed with the work. The professional engineers and licensed plumber shall comply with the Singapore Standard – Code of Practice for Water Services and the Public Utilities (Water Supply) Regulations in their submission and water service installation works. Completed water reticulation systems are inspected and certified by PUB officers prior to turning on of water supply.

Plumbers are licensed by PUB to ensure that good standards of plumbing work are maintained in customers' premises. There are currently some 800 licensed plumbers whom customers can select to carry out water service work in their premises.

All water pipes and fittings are required to be approved by PUB before they are allowed to be installed and used in customers' reticulation system. This is to ensure that materials that are put in use are of acceptable standards in design, performance and construction so as to prevent wastage and contamination of water supply.

II) Metering

In order to know that water is used efficiently, the water supplied from the waterworks and all water consumed by customers must first be accurately accounted for. Singapore adopts a full and accurate metering policy. All the 1,013,000 accounts are metered. Even supplies to temporary worksites are fully metered.

(a) Water meters used

The accuracy of waterworks' output meters is of utmost importance, as any error in registering the production output would significantly affect the water balance account. This is especially so in the case of Singapore where unaccounted-for water is low.

Since 1985, PUB has replaced the waterworks' output meters with electromagnetic flow meters. These meters are highly reliable and accurate to within $\pm$ 0.5 per cent for velocities above 1.0 m/s. To ensure reliable and accurate flow measurement, PUB has checked waterworks' output meters monthly based on volumetric calculation of the drawdown from the clear water storage tanks at the waterworks.

PUB uses customer meters ranging from 15 mm to 200 mm in diameter and ensures that all meters in service are accurate to within $\pm$ 3 per cent. About 970,000 meters of 15 mm diameter meters are used mainly for domestic consumption accounting. These meters comply with ISO 4064/1 Class C standard and are semi-positive displacement type, which register accurately even at low flow rates. About 40,000 large meters of various types and sizes (25 mm to 200 mm diameter) are in use for registering consumption accurately at different types of customer installations. To ensure accurate metering, PUB has, since 1985, purchased compound type 50 mm, 100 mm and 150 mm diameters meters. Compound meters have main meters to register high flows and by-pass meters to register low flows and, as a result, have better flow-capturing characteristics.

(b) Billing

A computerized billing system that incorporates a check programme is used to verify meter readings. Any abnormally high or low consumption is automatically detected by the computer during the billing process and singled out for further investigation. Customers' are alerted to check for leaks on their premises if there is unexplained high consumption. This enables leaks and defective meters in a customer's reticulation system to be identified promptly.

Customers' are also encouraged to read their own meters. To facilitate this, customers are given specially designed forms for them to record their monthly water meter readings. This will allow customers to track their own water consumption and to manage their own usage. As customers will be charged for the water used, they can be expected to be more judicious in using water if they track the amount of water they use.

III) Mains Replacement and Rehabilitation

The need to minimise leakages in the Network Infrastructure cannot be over emphasised. PUB places much importance to this and the various measures adopted by PUB to minimise losses due to water leakage in the Transmission and Distribution Network has yielded impressive results.

Since 1980, PUB prohibited the use of unlined galvanised iron pipes and only corrosion resistant, more durable pipes made of copper, stainless steel, and galvanised iron pipes which are internally lined with materials such as UPVC or high density polyethylene, are allowed to be used. This has effectively reduced main leaks and poor water quality problems.

In 1983, an island-wide survey was conducted to identify all old unlined galvanised iron connecting pipes and unlined cast iron watermains. Based on the results of the survey, a comprehensive programme for replacement of old unlined galvanised iron connecting pipes with copper or stainless steel pipes and old unlined cast iron mains with cement lined ductile iron mains was initiated.

Under the programme which was completed in 1993, a total of 68,400 unlined galvanised iron connections and 181 km of unlined cast iron watermains were replaced. The total cost of the programme was S$56 million.

As a result of the replacement programme, the number of leaks detected on watermains and connections islandwide fell sharply from 18,000 in 1985 to 4278 in 1998. There was also a significant decrease in number of complaints of discoloured water and poor pressure. Complaints of discoloured water decreased from 1157 cases in 1985 to only 65 in 1998 while poor pressure cases dropped from 3,564 to 309 over the same period.

IV) Intensive Leak Detection Programme

The PUB has over the years implemented a comprehensive and intensive leak detection programme. The leak detection programme covers the entire Network Infrastructure which comprises some 4,840 km of watermains ranging from 100 mm to 2,200 mm diameter. The programme involves visual inspection for leaks along all Transmission and Distribution pipeline routes and conducting leak detection night tests for distribution mains of 500 mm diameter and below. Since 1990, the programme has been intensified to ensure that the entire Network Infrastructure is surveyed at lease twice a year and night tests implemented at lease once a year. Zones with older mains and those prone to leakages are checked even more frequently. Detected leaks are repaired immediately.

V) Quick Response to Reports of Leaks

The quantum of loss from a leaking main depends on the length of time between the occurrence of the leak and isolation of the main. In this respect, public cooperation in reporting leaks is essential. To facilitate public reporting of leaks, PUB operates a 24-hour Water Service and Operations Centre that receives and promptly investigates such reports. The Centre operates three shifts round the clock and is equipped with facilities such as a Complaints and Fault Monitoring System, Computerized mapping and retrieval station and key-phone system. A VHF network is used for communication between the Centre's control room and its fleet of six service vans which cover the entire island. On average, the Centre receives 18 leak reports on watermains from the public per week.

To facilitate quicker response, maps showing all mains and valves are maintained and updated regularly through a computerized system Automated Information and Mapping System. The System stores records of all water mains and appurtenances in digital form to facilitate easy and quick retrieval and updating. Distribution network maps of areas affected by a leak can be readily obtained from any one of six retrieval stations installed at various bases, including one at the Centre.

VI) Demand Management

The Government's approach to demand management can be summarized under four broad headings:

- implementation of water conservation measures;
- tariff re-structuring;
- legislative measures;
- educating the public

(a) Implementation of Water Conservation Measures

A water conservation plan was formulated in 1981 to ensure that water is used efficiently. The measures implemented are as follows:

i) Mandating The Installation Of Water Saving Devices

Water saving devices include self-closing delayed action taps, constant flow regulators, pressure reducing valves, dual-flush cisterns (4.5/9 litres), low capacity flushing cisterns (introduced in 1992) and spring loaded nozzles. Since November 1983, the installation of water saving devices has been mandatory for all non-domestic premises and all private high-rise residential apartments and condominiums.

Since 1992, low capacity flushing cisterns that use only 3.5 to 4.5 litres of water per flush have been installed in all government-owned apartments. These cisterns are an improvement over dual flush cisterns that use 4.5 or 9 litres of water per flush. With effect from April 1997, it became mandatory for all new and ongoing building projects to use only low capacity flushing cisterns.

ii) Encouraging the reuse or recycling of process water

All applications for non-domestic water supply must be submitted to the PUB Water Department for pre-planning consultation, evaluation and approval. Special emphasis is placed on evaluating applications with anticipated water requirement exceeding 500 m^3/mth. Evaluation is based on a set of norms for water usage. Applicants whose water demand exceeds these norms are advised to adopt water conservation measures such as reuse or recycling of process water, and substitution of potable water with non-potable water, wherever possible, to reduce their potable water requirement. A procedure has also been established with other government authorities to discourage the setting up of water intensive industries in Singapore.

iii) Encouraging substitution of potable water with non-potable water

Non-potable water includes industrial water, rainwater, sea water and pond water.

Industrial water, which is treated sewage effluent, is piped separately to industries in the Jurong Industrial Estates, located in the western part of Singapore, to supplement their potable water requirement. It is used mainly for cooling, washing of premises and process applications. Currently, about 980,000 m^3/mth of industrial water is used by the industries in this area, thus reducing potable water usage.

iv) Offering Incentives for Water Conservation Projects

In line with the national effort to conserve water, the Economic Development Board (EDB) grants investment allowance incentives to companies that have invested in plant and equipment which conserves potable water. EDB also administers the Resource Productivity Feasibility Study Scheme and Resource Productivity Scheme.

(b) Tariff Re-Structuring

Pricing is an important and effective mechanism in persuading customers to conserve water. It is the Government's policy to price water not only to recover the full cost of its production and supply, but also to reflect the scarcity of this precious resource and the high incremental cost of expanding supply. A water conservation tax is levied as a surcharge to the tariff to reinforce this message.

Prior to July 1997, the tariff structure, including the water conservation tax, had multiple tiers corresponding to increasing consumption levels. Households were charged substantially less than businesses although households consumed more than half the water supply in Singapore. The tariff structure (Table 1) was revised on 1 July 1997 with the implicit message that water conservation must start from the first drop of water used. Adjustments will be phased over four annual increments up to the year 2000 and the Government's long-term objective is to restructure the tariff into uniform flat rates.

Table 1 Comparison of Singapore's Old and New Water Tariffs

Tariff	Consumption	1997 Rates Prior to Revision			w.e.f. 1 July 1997			w.e.f. 1 July 2000		
Category	Block	Tariff	WCT	WBF	Tariff	WCT	WBF	Tariff	WCT	WBF
	(m^3/mth)	(S\$/m^3)	%	(S\$/m^3)	(S\$/m^3)	%	(S\$/m^3)	(S\$/m^3)	%	(S\$/m^3)
Domestic	1 to 20	0.56	0	0.10	0.73	10	0.15	1.17	30	0.30
	20 to 40	0.80	15	0.10	0.90	20	0.15	1.17	30	0.30
	Above 40	1.17	15	0.10	1.21	25	0.15	1.40	45	0.30
Non-domestic	All units	1.17	20	0.22	1.17	25	0.32	1.17	30	0.60
Shipping	All units	2.07	20	0	1.99	25	0	1.92	30	0

WCT - Water conservation tax

WBF - Waterborne fee, a sewerage charge passed onto the Ministry of the Environment, which is responsible for sewerage and sewage treatment.

(c) Legislative Measures

The Public Utilities (Water Supply) Regulations, and the Singapore Standard CP48: Code of Practice for Water Services, also stipulate water conservation measures with which customers must comply.

(d) Educating the public

i) Conducting Water Audits and Giving Advice to Customers

Each year, PUB officers inspect water service installations at some 3,500 premises comprising industries, commercial buildings, hotels, condominiums, restaurants, construction sites and public places. Inspections are made to storage tanks, pipes and fittings to ensure that they are in good working order and are being properly maintained, and to detect leaks and wastage of water. Such water audits are conducted primarily for the industrial and non-domestic sectors although general advice is also given to the domestic sector.

In 1991, a market-oriented programme was introduced whereby large customers consuming more than 5,000 m^3/mth are visited by PUB officers every six months to find out if the water supply meets their requirements. During such visits, the message of water conservation is emphasized, water audits are conducted and checks are made to ensure that specified water conservation measures are in place.

ii) Implementing Public Education and Publicity Programmes

There is an ongoing public education and publicity programme to educate the public and raise its awareness of the need to conserve water. The programme includes:

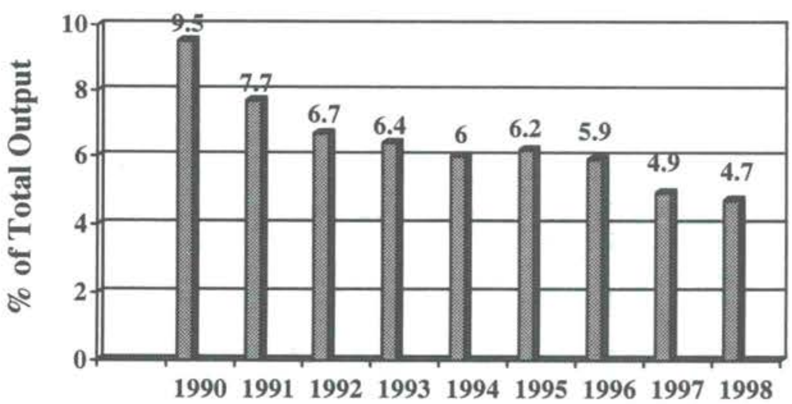
- distributing publicity materials to customers;
- encouraging visits to waterworks for schools and the public;
- delivering talks to schools and to public and private organizations;
- including water conservation topics in schools' curricula;
- mounting save water campaigns.

The public is reminded regularly of ways to conserve water. Part of this programme is the delivery of talks on water conservation to schools and to private and public organisations. Water conservation topics are included in school textbooks used in Singapore. Publicity materials on water conservation, such as posters, pamphlets, comic books and stickers, are also distributed to customers to create and sustain awareness of the need to use water wisely and make water conservation a way of life.

D Unaccounted-for Water

Unaccounted-for water provides a good measure of the efficiency of a water supply system. In Singapore, reducing and controlling unaccounted-for water has been given high priority and, through the implementation of various programmes, the PUB has reduced unaccounted-for water from 9.5 per cent of water supplied in 1990 to 4.7 per cent in 1998. See Chart 1.

Chart 1. Singapore's unaccounted-for water, 1990 - 1998



E Conclusion

Given Singapore's limited water resources and increasing water demand, adopting an integrated approach to use water efficiently is an integral part of the water supply management policy. The present unaccounted-for water figure of 4.7% and a low per capita consumption is testimony to the effectiveness of the measures adopted. The PUB will continue to strive and look into new ways to ensure that water is used wisely and efficiently. This is to ensure that the island of Singapore will continue to have an adequate supply of water to meet its future needs.

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The author would like to thank the Public Utilities Board for this nomination and the United Nations Environment Programme/International Environmental Technology Centre for the invitation to present this paper on 'An Integrated Approach for Efficient Use of Water' at the International Symposium on 'Efficient Water Use in Urban Areas' at Kobe in June '99.

AN INTEGRATED APPROACH FOR EFFICIENT WATER USE IN SINGAPORE

PUBLIC UTILITIES BOARD
SINGAPORE

SCOPE

- **INTRODUCTION**
- **GROWING WATER DEMAND**
- **AN INTEGRATED APPROACH**
  - i) Design of Water Recticulation
  - ii) Metering
  - iii) Mains Replacement and Renewal
  - iv) Intensive Leak Detection Programme
  - v) Quick Response to Leaks
  - vi) Demand Management
- **UNACCOUNTED-FOR WATER**
- **CONCLUSION**

SINGAPORE

- Area 648 Sq Km
- Population 3.9 million
- Public Utilities Board (Water Authority)
- 14 Impounding Reservoirs
- 6 Treatment Plants
- 14 Service Reservoirs
- 1,013,000 Customer Accounts

GROWING DEMAND FOR WATER

- 1950 - 142,000 cu m/day
- 1998 - 1,280,000 cu m/day
- Rate of Growth from 1991 to 1998 - 3.3% Per Year
- Per Capita Growth from 1991 to 1998 - 0.4%
- 1998 Per Capita Con - 166.2 l/per/day

AN INTEGRATED APPROACH

- Design of Water Reticulation
- Metering
- Mains Replacement and Renewal
- Intensive Leak Detection Programme
- Quick Response to Leaks
- Demand Management

DESIGN OF WATER RETICULATION

- Designed by Qualified Person
- Comply With Code of Practice
- Approved Materials Used
- Inspected by PUB

METERING

- Full Metering Policy
- 1,013,000 Accounts
- Electromagnetic Flowmeters for Waterworks
- Single Meters for 25 and 15mm dia meters
- Compound Meters for 50mm to 200mm dia meters
- Accuracy ± 3%

BILLING

- Check Programme to Detect High/Low Consumption
- Customers Record Their Own Meter Readings

MAINS REPLACEMENT AND RENEWAL

- Replacement of Galvanised Iron Connections and Unlined Cast Iron Mains
- Leaks Reduced from 18,000 in 1985 to 4,278 in 1998
- Discoloured Water Reduced from 1,157 cases to 65
- Poor Pressure Reduced from 3,564 to 309

INTENSIVE LEAK DETECTION PROGRAMME

- Covers 4,840 Km of mains from 100mm to 2,200mm dia
- Visual Inspection for bigger mains
- Leak detection night tests for mains 500mm dia and below
- Areas prone to leakages checked more frequently

QUICK RESPONSE TO LEAKS

- 24-Hr Water Service & Operations Centre
- Good communications system
- 24-hr stand-by repair teams
- Automated Information & Mapping System

DEMAND MANAGEMENT

- Water Conservation Measures
- Tariff Re-structuring
- Legislative Measures
- Educating the Public

WATER CONSERVATION MEASURES

- Mandating Use of Water Saving Devices
- Encourage Reuse or Recycling of Process Water
- Encourage use of Non-Potable Water
- Incentives for Water Conservation Projects

Table 1 Comparison of Singapore's Old and New Water Tariffs

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	20-40	0.80	15	0.10	0.90	20	0.15	1.17	30	0.30
	above 40	1.17	15	0.10	1.12	25	0.15	1.40	45	0.30
Non - Domestic	All Unit	1.17	20	0.22	1.17	25	0.32	1.17	30	0.60
Shipping	All Unit	2.07	20	0	1.99	25	0	1.92	30	0

WCT - Water conservation tax.
WBF - Waterborne fee, a sewerage charge passed onto the Ministry of Environment, which is responsible for sewerage and sewage treatment.

LEGISLATIVE MEASURES

- The Public Utilities (Water Supply) Regulations , and the Singapore Standard CP48 : Code of Practice for Water Services Stipulate Water Conservation Measures which Customers Must Comply

PUBLIC EDUCATION

- Conducting Water Audits
- Distributing Publicity Materials
- Visits to Waterworks
- Delivering Talks on Water Conservation
- Water Conservation Topics in School Curricula
- Mounting Save Water Campaigns

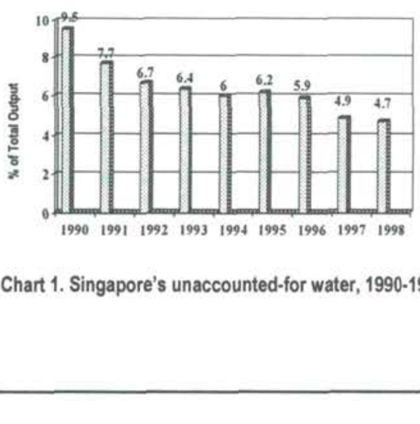

Chart 1. Singapore's unaccounted-for water, 1990-1998

CONCLUSION

- Unaccounted - for water at 4.7%
- Per capita consumption at 166.2 l/p/d

Potential of water harvesting in India: some case studies

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Abstract: India today is in the throes of a water crises in urban and rural areas. The irony is that in many parts of the country there is scarcity amidst plenty. The tradition that the Indian people had to manage their water demands by harvesting water and catching every drop of rainwater has eroded thanks to the takeover by the State. Public community participation has almost disappeared. However, a new paradigm is emerging where communities in both urban and rural areas have now again taken water into their own hands to meet their demands. In some places the state government is also exploring the potential of water harvesting and has passed appropriate regulations. This paper discusses the past, its relevance to the present and future and the technological solutions that have been put into operation in a few parts of the country.

PART I: The past and the present

Introduction: India today is in a huge water crises. As clean water sources are being vicously attacked by pollution and overexploitation, hardly any river or groundwater aquifer near a city today escapes the perils of pollution. The situation in rural areas is hardly any different. While agricultural lands go thirsty many thousands of villages find it difficult to get clean drinking water. And the women have to walk miles to get a pitcher of water.

India is witnessing two major discontinuities that emerge in the management of water since the 19th century. One, the State has emerged as the main provider of water, replacing communities and households as the primary agents for provision of water. Two, there has been growing reliance on the use of surface and groundwater. The earlier reliance on rainwater and floodwater has declined, even though rainwater and floodwaters are available in much greater abundance than river water or groundwater.

Water balance of India: According to one water balance study of India, the country receives 400 million hectare- metres (mham) of rain and snowfall. Another 20 mham flow in as surface water, coming from outside the country.

These 420 mham provide the country with river flows of 180 mham- of which as much as 75 % takes place during the rainy season- and another 67 mham is available as ground water. Thus, total river flows and groundwater add up to 247 mham, of which a substantial amount (150 mham) must flow out to neighbouring countries and to the sea.

Potential of water harvesting: India has an enormous amount of water- theoretically as much as 173 mham- lost as evaporation or becomes soil moisture- that can be captured directly as rainwater or as run-off from small catchments in and near villages or towns. Capturing the flood waters of major rivers can further increase water availability.

If even 20-30 mham can be captured through rainwater harvesting, tremendous pressure can be taken off the country's groundwater and surface water resources, and the availability of clean water would be greatly extended.

Theoretically, the potential of water harvesting meeting household needs is enormous. In reality, there is no village in India, which cannot meet its drinking water needs through rainwater harvesting. Why is Cherrapunji, in Northeast India short of drinking water when it gets more than 15 metres of rainfall every year? Simply because it does not capture the rain that falls. As Aizawl, a neighbouring city does.

Theoretically, if rain was captured on the area of the union territory of Delhi, the capital of India, there would be enough clean water to met the drinking water needs of every individual in India.

Problems with the current strategy: India's projected use of water is 105 mham in 2025 AD, up from 38 mham in 1974. While the demand for irrigation water is expected to increase from 35 mham to 77 mham, the demand for domestic and industrial uses, which are highly polluting uses, is expected to shoot up from 3 mham in 1974 to 28 mham in 2025 AD.

Of the 105 mham use projected for 2025, some 70 mham is expected to come from surfacewater and about 35 mham from groundwater. This exclusive reliance on riverwaters and groundwater is already leading to a number of problems.

a) Heavy extraction of water from rivers:
Already, there are numerous rivers that are so heavily exploited that they have no river flow left during the summer season. The ministry of environment and forest is talking of the need to legislate 'minimum river flows', but none of the agencies involved with water resources development are listening.

b) Construction of large dams versus small water harvesting structures:
This strategy has led to serious problems of forced human displacement, forest submergence, waterlogging and emergence of diseases like malaria and a change in biodiversity and ecology of the region. With the population growing rapidly in India, if large dams are going to be the only option that the government exercises, these problems are only going to increase. Added to this, land availability for resettlement of the displaced will also go down continuously.

c) Heavy extraction of groundwater:
The groundwater table is falling rapidly in many parts of the country.

State endangered problems:

*There are also financial problems and human problems with state sponsored water supply.

* The state subsidises water. People squander it.

* The state soon runs out of money- for new projects to meet the bloated and burgeoning demand and for maintaining the projects already built.

* The state becomes responsible for water supply. The people just sit and watch and demand. They do not lift a finger.

Aggravating factors will become even more aggravating in the future:

* The water demand will grow in the future with population growth and increased urbanisation, industrialisation and agricultural modernisation, the three key elements of modern economic development.

* An acute crises can already be seen in smaller river basins like those of the Yamuna, Sabarmati, Noyyal and Bhavani. The pollution is further reducing the availability of clean water which means that greater stress on the remaining sources of ground water and surfacewaters.

Water harvesting:

What has water harvesting traditionally meant?

* It has essentially meant valuing the raindrop.

* It has meant capturing the rain where it falls or capturing the run off in your own village or in your town.

* Additionally, it has meant taking measures to keep that water clean which, in turn, has meant not allowing polluting activities to take place in the catchment.

The synergy between land, rain and humans:

The most beautiful about water harvesting is that there is a human -rain-land synergy as the following table shows:

Region	Annual levels rainfall	Rain-yield potential from one hectare of land (*)	Human population density	Land availability for water harvesting	Surface quality for water collection efficiency	No. of people whose water needs can be met at 100 litres per person from one hectare of land
Rural-arid	100 mm	1 million litres	Low	High		27

Rural-humid	2000mm	20 million litres	High	Low	More roof tops available	27
Urban	-	-	Very high	Very low	More roof tops and built up surfaces available with high runoff	

(*): Assuming rainwater collection efficiency of 100 per cent

What this table shows clearly is that rainwater harvesting is possible in all possible human-land-rain scenarios.

An integrated approach: make water everybody's business:

What does water harvesting as a strategy for meeting human needs mean in management terms?

* It means making water everyone's business. It means a role for everybody with respect for water. Every household and community has to become involved both in the provision of water and in the protection of water sources.

* It means re-establishing the relationship between people and their environment. Turning water into a sacred element of nature.

* It means the empowerment of our urban and rural communities to manage their own affairs with the state playing a critical supportive role and civil society playing a critical role in encouraging equity and sustainability in the use of water.

A millennial tradition:

Rainwater harvesting was an old tradition in may parts of the world, particularly in India. India receives most of its rains in just 100 hours a year. For the remaining 8,660 hours, there is nothing. Indians knew that if they did not catch the water where it fell, they would have nothing later on. So they developed a civilisation built on raindrops. Some examples:

* *kundi*- this is an artificial water harvesting system. Anywhere in the desert, slope the land towards the centre, put cement or limestone on the artificial catchment to increase the runoff and make a well in the centre. Cover the well with a dome and put a lock to the precious water. Even with only 100 mm of rainfall, as in Jaisalmer district right in the heart of the desert in Rajasthan, 1 million litres of water are available through the year.

* Ladakh is a high altitude desert. It hardly gets any rainfall. But it has glaciers, which feed the streams. There is no water available in the morning. But as the glaciers melt during the day, there is water and the streams are full. The people here have learnt to capture the evening and night run off in a tank. This they use for irrigation the next morning.

* The famous fort of Chittor was built high on a hill with no groundwater or streams. Who needed them anyway? The fort's builders built enough tanks to capture water. A population of about 50,000 could live here for years without any problem. In 1987, the town of Chittor ran out of water. But not the fort.

The relevance of yesterday, today:
Given the current crises in India, as well as the world over, water harvesting is relevant even today. Water harvesting is needed in urban and rural areas, by the rich and the poor, and by industrialised as well as developing countries.

This is perhaps why Frankfurt, Copenhagen, Tokyo and Aizwal and Chennai in India are all becoming votaries of water harvesting.

In India, 'water rich' states like Kerala and Meghalaya and 'water-poor' states like Rajasthan and parts of Gujarat are all finding it useful.

This paper brings a message of hope and action. It asks for redefinition of the role of the state, of households and of communities.

Part II. Case studies

A. Coastal areas
Chennai, Tamil Nadu
1. ***General information***:
* Capital of Tamil Nadu
* Annual rainfall 1100 mm
* Urbanisation, last 150 years, rapid in the last 30 years.

2. ***The coastal suburbs***:
* Residential area has developed within 1 km from the coastline
* Rapid development
* Ground water, initially very good, is now deteriorating

3. ***Availability of fresh water***:
* Ground water
* 'Metro' water supplied by the state through pipes from surface water (rivers)

4. ***Problems and consequences***:
* Rapid depletion of ground water
* Saline water intrusion into the groundwater aquifer
* Indiscriminate paving has resulting in flooding of the rain water and no recharging of the ground water, all the rain water goes into the sea
* Commercial water tankers supply water (at a cost) even on days it is raining heavily.
* There is water all around a well, but none inside
* Water is brought from far off places while large quantities of rainwater is let off into the sea.

5. ***Necessity driven changes:***

There have been some efforts by the municipal corporation civil society, individuals and builders. These efforts have been directed to keep the ingress of salt water at bay, to provide water and to recharge groundwater aquifers.

*The state regulations now require that every new building that is built must have some sort of rain water structure in place before they are granted a water connection or a sewage connection from the corporation.

* The builders have been asked to conserve rain water in all their projects. It is now mandatory to make a pebble bed of 1 metre width and 1,5 metre depth all around the building.

Builders in Chennai are also undertaking artificial recharge for augmenting the underground water table by artificial infiltration of rainwater and surface run off.
This will

* stem decline of groundwater levels
* supplement existing supplies
* remove suspended solids by filtration through soils
* store cyclic water surpluses for dry periods
* prevent sea water intrusion that threatens to ruin the freshwater in coastal areas

6. *Design elements*:

Some methods that have been adopted for rainwater harvesting include:

i) *Percolation pits:*

Square pits 4' x 4' x 4' in size, filled with small pebbles or brick jelly and river sand, covered with perforated concrete slabs wherever necessary.

ii) *Percolation pits with bore*:

Where the depth of clay is more, recharge through percolation pits with bore is suggested. The bore is at the centre of a square pit and the pit is filled with pebbles or brick jelly and the top is filled with river sand and covered with a perforated concrete slab.

iii) *Roof top water collection and recharge*:

Rooftops of houses provide an excellent and economical form of collection centre for rainwater. If properly diverted and used for artificial recharge, it will augment ground water to a great extent. The roof is connected to the well after filtering through a PVC pipe. A valve system can be incorporated to allow the initial part of the rainwater to be flushed out to get rid of impurities on the roof.

iv) Bathing water:

Bathing water collected in the bathroom can be directed to a percolation pit. However, the connecting pipe should have a 'U' bend which will act like a water seal and not allow bad odour or insects into the bathroom.

v) *Preservation of run off inside the compound*:
The ground level near the gate should be raised to retain water as much as possible inside the compound. Alternatively, a sloping gutter across the gate can be constructed and the rushing water directed towards a percolation pit.

Run off can also be diverted into suitably designed recharge structures in public parks, playgrounds, airports, railway stations, temple tanks, artificial ponds and huge dug wells for recharge. For high rise buildings, the water can be directed into a recharge well.

vi) *Storm water drains*:
The storm water drains inside the premises should have a 6'' boundary wall to ensure that the rain water, instead of rushing into the drains and going waste, stagnates over the ground for some time and seeps into the soil. Where there is a slope, a retaining wall should be built for underground water seepage.

Storm water drains along the road should be so designed that they have a perforated covering slab and percolation pits at regular intervals of depth of 20' to 50', depending on the soil condition.

vii) *Recharging through defunct open wells, bore wells and hand pumps*:
Dry wells can be recharged. Roof water and run off water can be diverted into these wells after filling of the wells with pebbles and river sand. The wells will however need prior desilting.

B. Hilly areas:

Aizawl, Mizoram:

1. *General information of the state:*

* Mizoram is a state located in the extreme northeastern part of India.
* The entire state is mountainous, covered with green vegetation.
* The state has an average rainfall of 250 cms. And a shortage of water to use and drink.
* The entire population resides along the hill slopes, with agriculture as their main livelihood. Industry has yet to show its face.
* The atmosphere is clean, the air pure and the rain water clean and ideal for domestic uses.

2. *Geology:*

* The rocks are sedimentary, consisting mostly of hard shales. The run off is rapid.
* Traditional means of water supply is rain water collection during the rainy season and using this stored water during dry days.
* Water is also tapped from springs, which however give surplus water during the rains and dry up when the rains stop.

3. *The town of Aizawl*:
* Population: 3,00,000
* Piped water supply- pumped from a perennial river, through a static head of 1040 metres using a 8 kilometre long 305 mm diameter pipeline.
* This water supply has been designed for a population of 80,000 with 135 litres per capita per day (lcpd) rate. .
* Supply is grossly insufficient.
* Roof tops fortunately continue to be the main source of water to households and institutions.

3. *Water harvesting structures*:
* Roof top water harvesting structures in Aizawl as in the rest of Mizoram are elegant in their simplicity.
* To suit the climate and topography, the houses are constructed with sloping roofs using galvanised iron sheets. At the end of the roof is a gutter made of GI (galvansied iron) sheets which simply directs all the water that falls on the roof into a storage tank.

4. *Design parameters*:
Rain water catchment depends on two things:
i) Rain fall (ii) the area on which the rain falls.
To arrive at the quantity of rainfall available the following formula can be applied:

Catchment Area x Run-off factor x Rainfall= Quantity of water

Example: If a roof is 10m long, 5 m wide and the rainfall is 250 cm, rainwater available in a year is:
10 x 5 x (250/ 100) x 1000 = 1,25,000 litres

For a family of 8 persons this can give water daily:
125000/ (8x365) = 42 lpcd

The bare minimum domestic water consumption by an average Mizo family having a water reservoir with rain water, without internal pipe connections is assumed as 10 lpcd. The longest period of dry days without rain or very little rainfall is assumed as 120 days. Thus, the quantity of rain water required by an average Mizo family of 8 to last the dry season is:

8 x 10 x 120 = 9600 litres, approximately 10,000 litres (to round off)

Thus one tank of 10,000 litres capacity rain water tank is enough.

Most of the tanks are cylindrical, constructed with GI sheets. To catch water from the roof, GI semi circular rain gutters are normally used. The first few showers are let off before the water is collected and stored.

A study conducted on this water stored for its quality has indicated that if stored for long periods of time, this water runs the risk of being contaminated by bacteria, however, a monthly dose of chlorine or bleaching powder is enough.

C. Island town:
Andaman and Nicobar islands (Will be presented at the symposium)

D. In the Plains:
The President's Estate (Will be presented at the symposium)

Conclusion:
A number of options, fairly simple are available do deal with the current water crises. For a country like India, it means valuing the raindrop and catching water where it falls as has been indicated by the above case studies. We have the tradition and the wisdom, which is dying. This needs to be revived and improved upon with the modern technologies that are now being developed and the requirements that exist. What is required is water harvesting in a new age. A number of states like Tamil Nadu, Andhra Pradesh, Himachal Pradesh and Madhya Pradesh have already made some moves in this direction.

The state has reached its limits and community participation has now become essential.

Integrated Approach for Efficient Water Use
Case Studies

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1. GENERAL

This paper follows the paper on Water Demand Management (WDM) – which has been submitted separately. It deals only with case studies in the Middle East, East Asia, USA and Africa.

The case studies show clearly that water demand management can produce significant results, reducing demand and water wastage at levels of 20-40%, thus creating a new large source of water within the cities with relatively low investment per unit of water. Lately experts look at WDM not as a task to reduce demand only, but as an augmentation strategy to supply the unserved, stop intermittent supply and delay expensive capital investments in new water projects.

2. CASE STUDIES

2.1 GENERAL COMMENTS:

Selected case studies were chosen for this paper. The writer decided to start with Israel, a western Asian nation which has embarked on a comprehensive water demand management strategic plan from its early days as a developing country. It allows the experts as well as decision makers to have a significant retrospective view of the results 50 years later.

Other case studies selected deal with large urban centers in Asia concerning the objective of the conference. They are mainly from Singapore, China, Korea, Malaysia as well as short sections on the USA.

Case studies were selected to present different socio-economic conditions and diversified issues of water demand management. More comprehensive ones are presented from Israel and Singapore while the others present cases of national policies and selected cities, only.

2.2 CASE STUDY - ISRAEL*

SUMMARY:

This section focuses on Israel as a case study of water resources management with an emphasis on Water Demand Management (WDM).

Development and water experts, who have an interest in the Middle East and in the economic development process of semi-arid countries, often pose the following question: how does Israel, a semi-arid country, prosper with less than 300 cubic meters of water (per capita per year) for all its uses, while international organizations define arid countries with less than 1000 c.m./cap. /year as highly stress countries, where water becomes a severe constraint to socio-economic growth.

This section will try to clarify some of the policies, legislative basis and selected economic issues that enabled Israel to reach a GDP of $16000 per capita per year, supply much of its agricultural needs (except grains), export agricultural products, supply its population and industry and maintain a high standard of living, all with very limited fresh water resources.

The basis of the past strategy as well as the future one lies with a balanced combination of measures: legislative, institutional, economic, and technological focusing on water demand management, increased efficiency of water use in agriculture and the industry, re-use of most of its treated sewage effluents as well as the economic and integrated use of its total surface and ground water resources.
Potential future water markets (internal and possibly regional), continuous updating of its water pricing policies and future large scale sea and brackish water desalination will enable the country and its immediate neighbors (as part of the peace process) to continue their social and economic growth despite the water scarce conditions that all entities of the middle-east are facing.

INTRODUCTION:

The policy of Israel to meet the growing demand for water focuses on combined supply and demand activities and investments, while the long range solution lies with the total re-use of its wastewater as well as brackish and sea-water desalination. Present activities are aimed at delaying the high investments and the associated costs involved with the integration of large-scale sea-water desalination, an expensive unlimited source of water, which will be a major supplementary source of fresh water as of 2015 and on.

The 4 main instruments are:

1. **Pricing and economic policies**

Progressive block rates coupled with total metering system (for every farmer, house, apartment and industry), prices are updated automatically with a cost of living formula, removal of subsidies, water abstraction fees.

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* This section is based on a research work done by the writer (S. Arlosoroff) as a researcher of The Harry S. Truman Institute, Hebrew University, Jerusalem.

2. **Re-use of sewage effluents.**

Recent regulations have increased the quality levels of sewage treatment of effluents in order to maximize its re-use potential and minimize the health and environmental risks as well as enhancing the trading instruments for the exchange of fresh water allocations, with treated effluents mainly for irrigation purposes. The policy concentrates on reduction of fresh water allocations to the farming community and replacing it with treated wastewater effluents. (Total sewerage costs borne by the city).

3. **Water conservation/improved efficiency of water use.**

Continued policies concentrate on mixed tools including: (a) allocations, norms and progressive block rates for each sector, and (b) research, development and implementation of agronomic techniques as well as wide scale implementation of technological means to improve water use efficiency and reduce water consumption in the domestic sector, commercial, industrial and the irrigation of agriculture products as well as irrigation of urban parks and gardens.

4. **Sectoral water allocations – based on norms representing optimal use.**

Recently major changes in the approach toward the water sector have been initiated, including elimination of urban allocations, imposing sanctions for unaccounted for water (if rises above approved levels), and the possible introduction of "water markets," trading with administrative allocations on an economic basis between members of a sector, between sectors, and hopefully in the future between Israel and its neighbors.

THE REGION:

Many of the Middle East and North Africa countries face an environmental crisis, much of it as a result of water scarcity and the existing and potential pollution of their water resources. It is estimated that the investment needed to deal with and solve the problem could reach US $70-80,000 million in the period of 1995-2005 (World Bank).

The hydro-geological conditions are in constant deterioration. As extraction from ground and surface water resources increases, so do the problems associated with low water levels and decreased quality. Inadequate human and industrial waste discharges as well as inappropriate waste water re-use programs lead to higher concentrations of chemicals and organic contaminants.

The concentrations of heavy metals and toxic compounds have already reached alarming levels in various sites in the region and the projected future cleaning costs could reach prohibitive levels unless urgent and strict measures are introduced.

The expected population growth in the region is likely to exacerbate the problems. World Bank forecasts indicate growth of approx. 40 per cent in population (from 250 million in 1990) to 350 million by the end of the century. Some regional governments may be unable to generate the financial and human resources needed to provide adequate water and sanitation facilities to meet the future demand.

Already, almost 20 per cent of the total population in the region lack an adequate potable water supply and almost 35 per cent lack appropriate sanitation. Less than 20 per cent of the urban water supplied in 1990 has been properly treated; in the industrial world this figure is above 70 per cent.

Most of the countries in the Middle East therefore face serious water scarcity and pollution problems already, while water shortages are reaching acute levels. During the last 20 years the average water availability per capita has dropped from 3500 m/3/capita and will fall to approximately 1500 m/3 per capita by the year 2020 for the whole region. Israel, the kingdom of Jordan and the Palestinian Autonomy are in the most acute level. All fall below 300 m/3/capita. (Cubic meter per capita or c.m/c

ISRAEL – GENERAL BACKGROUND:

The present population of Israel is approximately 6.0 million and is increasing at an approximate rate of 2.2-2.5 per cent per year. Best estimates for the year 2020 indicate a potential population of 10-13 million Israeli citizens. (The variation is mainly due to unpredictable future immigration levels).

Present average of urban water consumption (domestic, commercial, and industrial) is approximately 110 m/3 per capita per year. It would have been today approximately 150 m3/c if not for past efforts that have resulted in over 30 per cent savings. Present industrial forecasts coupled with projections for urban water consumption per capita converge at an estimate of 110-120 m/3 per capita per year by the year 2020. These figures assume a much higher standard of living coupled with the continued of rigid and wide-scale implementation of demand management policies. When multiplied by the projected population, the level of urban and industrial water demand will amount to approximately 1000-1300 mcm (million cubic meters) of fresh water per year out of approximately 1700 mcm/year total available fresh resources.

Inelastic agricultural demand for water to supply basic fresh food (dairy products, eggs, and vegetables) are estimated at 25-30 m/3 per capita; this adds an additional 220-330 mcm/y.

Re-use of treated effluents in Israel will reach 70-75 per cent of the total DCI (domestic, commercial, industrial) use which amounts to almost 100 per cent of the total sewered flows (the entire population will be sewered by 2010). The estimated treated effluent flow by 2020 will be approximately 700-1000 mcm/y.

DEMAND MANAGEMENT IN THE AGRICULTURE AND INDUSTRIAL SUB SECTORS:

This endeavor includes continued efforts, both technological as well as economic, and agronomic to further reduce water demand and improve the efficiency of water use, for the production sectors, Incremental costs of water saved in these two range from US $0.05 – 0.40 (per cm). The figures for irrigation assume increased production per unit of water in real terms; they do reflect changes in the basic production cycle that is adapting to more economical cropping patterns like genetic engineering as well as modifying industrial processes.

The levels of "indirect" additional water production through savings and improved efficiency of water use are very important as they represent permanent reduction in demand. Israel has already gone a long way in its efforts in these two sectors. The

term 'effort' is much more complicated than it sounds. It means the large-scale application of appropriate irrigation technology (drip, sprinkler, automation), changes in industrial water use and water processes (like 'cascading' water uses and cooling methods).
Training, public education, and effective extension services has been and must accompany the promotion and implementation instruments. Finally, the efficiency of pricing mechanism and the application of a market or trading system can play a dominant role in the whole operation.

The significant achievements of Israel's agricultural sector have lead to 300% real term increase which clearly identify the significant results over 45 years in economic as well as physical terms. A comparison of prevailing prices for irrigation water between most irrigating countries and Israel illustrates and partially explains the gap in the countries agricultural yield/c.m, and the potential for reducing agricultural water demand. Presently Israeli farmers pay an average of 0.20 $/c.m (3 blocks, the upper over 0.3 $/c.m), one of the highest in the world.

URBAN WATER CONSERVATION:

"Unaccounted for water" (UFW) causes significant water and financial losses to urban utilities and municipalities. Unaccounted for water has been substantially reduced in Israel (down to 10% on average from 25% 15 years ago), but remains a serious problem in other Middle Eastern countries, where for example, UFW rates in some cities are over 50 per cent and represent critical water and financial losses. Leakage, estimated to account for about 50 per cent of the total UFW, could reach 30 c.m per capita/year. A utility's annual economic losses could equal approximately US $15 million per one million urban residents in Israel.
There is no doubt, given experiences in Israel, Singapore and other countries, that these losses can be reduced to more reasonable levels. Large sums of money can be saved and reinvested in the utility for further conservation and maintenance efforts, as well as development of new resources.

Studies done in Israel and California show that the costs of water saved through leakage control vary significantly, from US $0.15 – 0.35/m/3. UFW reduction activities are usually an integral part of improving utility management; in many cases utilities cannot reach financial viability without lowering UFW to less than 20%. Comprehensive urban demand management addresses demand reduction at the commercial, household, and utility levels and, if applied on a large scale, should reduce the cost of water and demand for water in the Middle East region as a whole. Demand management efforts in Israel, Singapore, California, and other regions have produced convincing results using water conservation kits (Retrofitting). The strategy and the kits (including toilet flush reduction, two-volume flushing, regulated shower heads, flow regulators in the kitchen and bathroom sink taps, leakage control and technologies to improve garden and park irrigation) achieved demand reductions of 10-25 per cent (sometimes 20-40 per cent). Retrofitting should be done in first priority in commercial buildings, where no economic incentive influences the water demand however the potential saving at the domestic consumers is usually greater.

RE USE OF HUMAN AND INDUSTRIAL WASTE WATER EFFLUENTS:

As stated before, water effluents become an integrated water resource and are traded for fresh water. Israel has completed most of its efforts at establishing and adopting water demand management for existing industries while new industries are currently installing efficient cooling systems and pre-designed_internal 'cascading' facilities. The price mechanism as well as effluent charges are gradually being enforced and are contributing their share to industrial water demand management. Many of the industries are located in the urban sector and are subject to the additional utility prices. The industrial sub-sector has observed an increase of 250% of industrial production per unit of water (in real terms) following 20 years of demand management campaign.

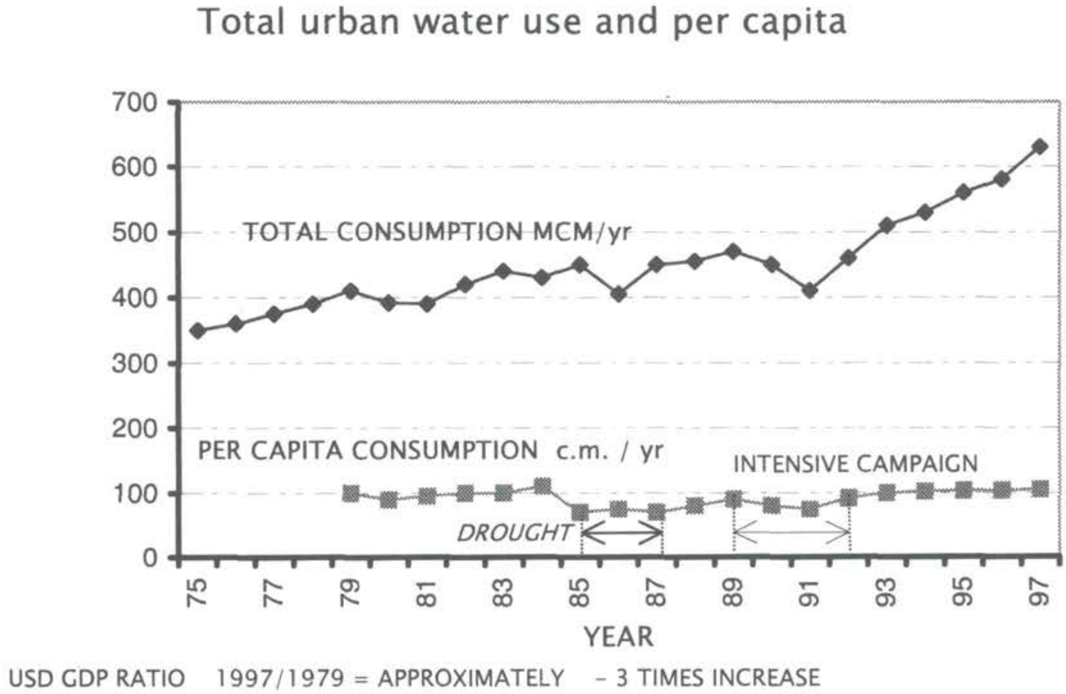
Re-use of urban sewage effluent should be analyzed in the context of industrial and urban conservation. When effluent charges are enforced and subsidies are removed, market forces may typically produce the optimum results. However it is reasonable to assume that local re-use for irrigation purposes will be the most cost-effective solution, mainly in areas where aquifer pollution is not expected. This option dictates the use of economic tools to define the upper level of investments in urban water conservation (retrofitting and reduction of UAF) as most of the wasted water will be later used as effluent for
irrigation purposes.

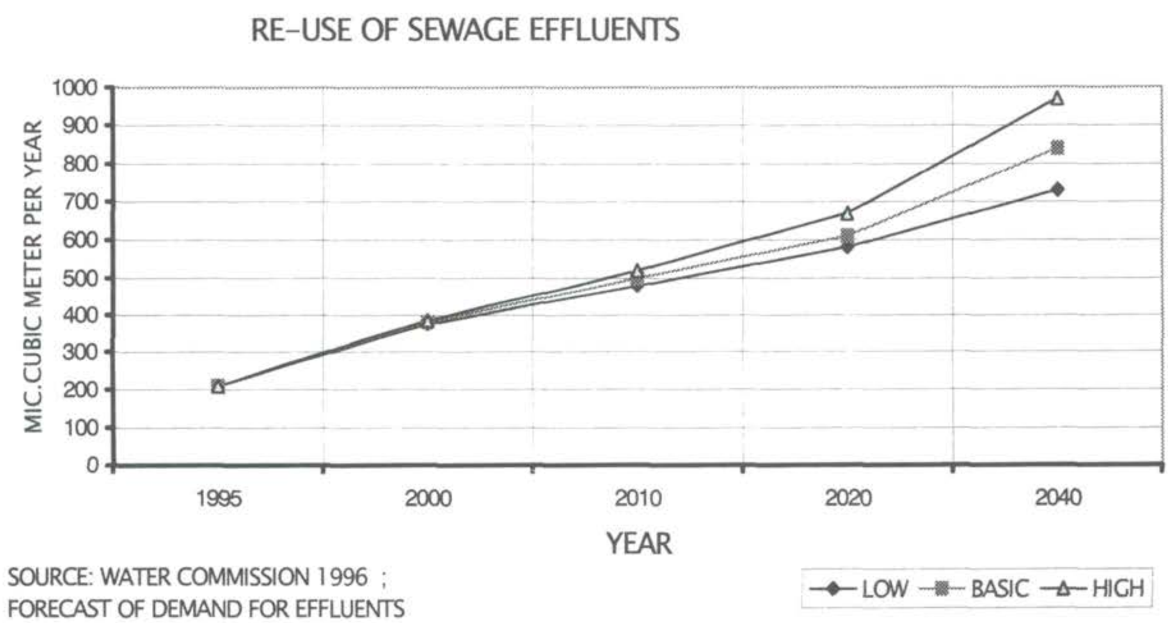
Re-use of effluents in Israel in restricted to industrial field crops (cotton, maise etc) and to horticulture using mainly underground drip irrigation.

WATER MARKET – A TEMPORARY OR PERMAMENT SOLUTION ?

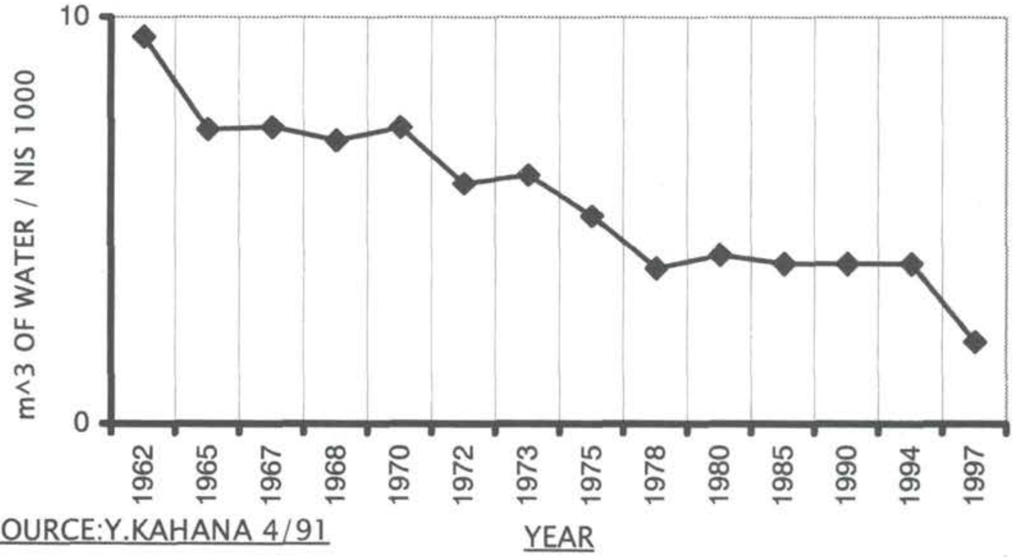
Water in Israel is used within a system of allocations (annual or multi-annual) while in most countries it is user rights that determine the demand. In many regions, a person who owns land (or cultivates it) has the right to the water flowing beside or under the plot. In other regions various quota systems allocate the amounts of water on an annual, monthly, weekly, daily, or even hourly basis. Veteran users usually have the rights to continue to use the resource, when shortages prevail.

In Israel it has been shown that the efficiency of water resource allocation and use can be substantially improved through the increased use of price and trading mechanisms. Trading water on the margin or using a system in which urban/industrial demand is met by supply from farmers selling quotas reduces inefficiency of administrative allocations. Irrigation water in Israel was, and is today, partially subsidized when supplied by the National Water Company, and administrative allocation system which create a 'rent seeking' operation for the development of new resources and higher demand both lead to certain inefficiency which could be improved if the law will be changed to allow trading between consumers using the national water system, as conduit and or using the aquifers as common – pools allowing one to pump more and others less to be compensated by the farmer.

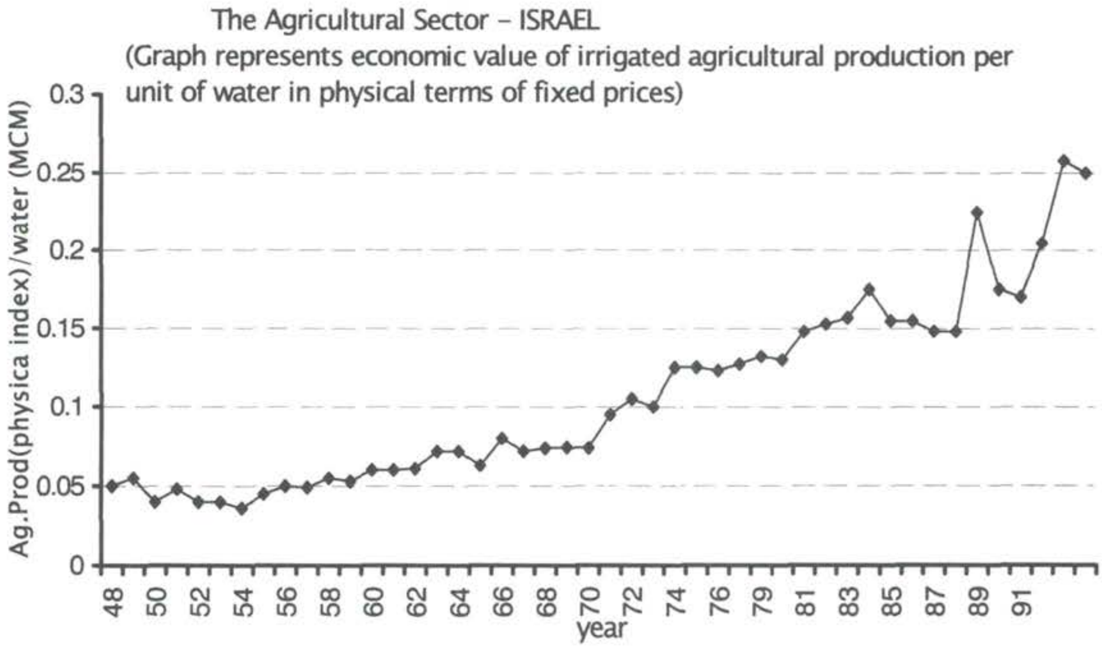

Total urban water use and per capita
700
600
500
400
300
200
100
0
TOTAL CONSUMPTION MCM/yr
PER CAPITA CONSUMPTION c.m. / yr
INTENSIVE CAMPAIGN
DROUGHT
75
77
79
81
83
85
87
89
91
93
95
97
YEAR
USD GDP RATIO 1997/1979 = APPROXIMATELY - 3 TIMES INCREASE


RE-USE OF SEWAGE EFFLUENTS
MIC.CUBIC METER PER YEAR
1000
900
800
700
600
500
400
300
200
100
0
1995
2000
2010
2020
2040
YEAR
SOURCE: WATER COMMISSION 1996 ;
FORECAST OF DEMAND FOR EFFLUENTS
LOW
BASIC
HIGH

AVERAGE INDUSTRIA WATER CONSUMPTION m^3 PER NIS 1000 OF PRODUCTION (AT PIXED PRICES)



SOURCE:Y.KAHANA 4/91



source:isarel statistical abstract ,central bureau of statistical israel.

2.3 CASE STUDY - SINGAPORE EXPERIENCE IN WDM

(See bibliography Singapore Public Utility Board)

In 1950, the population of Singapore was a little over a million and the demand for potable water was 142,000 cubic meters a day. By the middle of the 90's, the population has increased by 3 times but the water demand has increased by more than 7 times as result of industrialization, the commercial sector growth and high standard of living. Daily consumption averages over 1.05 million cubic meters. Over the past 10 years, the growth rate in Singapore's water demand averaged 3.0% per annum. Such a rate of growth has not only presented a great strain on Singapore's limited water resources, but has also demanded a strong emphasis on Water Conservation as well as on the management of the Water Distribution System. Singapore is trading water with Malasia, however the capacity is limited.

TOTAL APPROACH IN WATER CONSERVATION:

A total approach in water conservation is adopted. It can be broadly summarized as follows:

- Keep Unaccounted-For Water Low
- Conservation in customers' premises
- Tariffs and use of economic incentives and disincentives.

Keep Unaccounted-For Water Low

Unaccounted-For Water (UFW) is the difference between the total amount of water supplied to a transmission and distribution system and the consumption of water accounted for (which includes water sold to customers and other functions). UFW is taken as a measure of the efficiency of the water supply system. The question of how much that percentage should be depends on the economics of reducing the water loss – whether it will be more profitable to take action to reduce water loss further as compared to the postponing of a new development, and the relative costs.

In Singapore, the UFW for the early nineties has been reduced from 11% in 1988 to 6.7%. UFW can be traced to:

- Meter inaccuracies
- Losses through leakages
- Illegal connections and others

Meter inaccuracies occur because of:

- deterioration of meter accuracy caused by age, use and the effects of the quality of water.
- Inherent under-registration of even new meters caused by their being subjected to flows below their threshold of accurate registration.

In Singapore, the entire water supply system from waterworks to customers' taps is fully metered. Electro-magnetic flow meters are used to meter the production at each waterworks. The accuracy of these works output meters is of particular importance as an error would grossly affect the water balance account. For this reason, calibration tests are carried out monthly for these meters using the draw-down of clear water storage tanks in the waterworks.

LOSSES THROUGH LEAKEAGES:

Early Detection and Repair of Leaks

Leaks are unavoidable in a water distribution system. The leakages (especially underground leakages) which go undetected, constitute real loss in the water distribution system. On the other hand, leakage and other losses which have been detected and attended to can still contribute to UFW losses if they are not reported in a timely fashion and repaired.
The extent of loss from a leaking watermain depends on the length of time between the occurrence of the leak and the isolation of the main. Here, public cooperation in reporting leaks is essential. This cooperation can be achieved through continual public education on water conservation starting with the young in schools. To facilitate public reporting of such leaks and quick repair, a 24-hour Water Service & Operations Center receives and promptly investigates such reports. Prompt response to such reports encourages future public cooperation' and support to the whole conservation campaign.

To minimize the time required for identification, location, and isolation of water-mains, drawings showing all mains and valves are maintained and updated regularly through a Computerized Mapping and Information System which stores records of all water-mains and appurtenances in digital form to facilitate easy updating and retrieval. Exact nature and sites of leakage are registered on the computerized maps for early detection of sections to be replaced.

Leakage detection night tests are carried out for the entire distribution network during 11 months of the year, leaving one month to re-test the leak-prone regions. The test procedure involves:

- Isolating the sub-region by shutting off all the strategic boundary valves and individual services valves to customers.
- Setting up a waste detecting water meter with flow recording chart at the waste detecting meter connection position.
- If the meter continues to register after all the boundary and service valves have been shut, it would mean that there is a leak in the sub-region. The team then carries out step tests by isolating section by section of the distribution system until the leaking section is identified. If calls for high level of valves maintenance and their quality as well.
- Further investigations are then carried out using mechanical, electronic and computerized acoustic instruments to locate the leaks for repair.

Four types of leak detecting equipment are currently being used:

- Stethoscope
- Geophone
- Electronic Leak Detector
- Leak Noise Corrolator

The intensive leak detection program has contributed significantly to keeping underground leakage to a very low level and has reduced by at least 50% the amount of water that would have been lost.

Mains Replacement and Rehabilitation

Conscious of the need to use more durable and corrosion-resistant piping materials to reduce the incidence of main leaks, the PUB and its water department has since 1980, prohibited the use of unlined galvanized iron pipes. Since then, only corrosion-resistant pipes made of copper, stainless steel and galvanized iron pipes which are internally lined with materials such as uPVC or high density polyethylene are allowed for use, between the main system and the taps.

An island-wide survey was conducted in 1983 to identify all unlined galvanized iron connecting pipes and unlined cast iron watermains in the distribution system. Based on the survey and customers' reports on discolored water, poor water pressure and leakages, a comprehensive replacement program to replace old unlined cast iron mains with cement-lined ductile iron pipes and unlined galvanized iron connecting pipes with stainless steel or copper pipes was carried out.

The various measures and replacement programs implemented to renew and rehabilitate the transmission and distribution system have proven to be effective. The number of leaks has decreased by more then 70%.

Illegal Connections

There are few cases of illegal or unauthorized draw offs. In 1992 for instance, there were only 2 documented cases. As a deterrent, anyone found responsible for carrying out an illegal draw off is prosecuted in court and fined up to a maximum of S$50,000 under the Public Utilities Act.

WATER CONSERVATION IN CUSTOMERS' PREMISES:

Since 1981, the PUB has continued to pursue its long-term water conservation plan to ensure that water is being efficiently used.

Water Conservation Measures

The following measures have been implemented by the PUB to conserve water:

- Specify the installation of water saving devices (such as spring-loaded nozzles, constant flow regulators, self-closing delayed-action taps, thimbles, etc) at all non-domestic premises and high-rise residential apartments.
- Encourage industries to reuse or recycle their process water whenever possible, or economic to do so.
- Encourage the substitution of potable water with non-potable water (such as treated sewage effluent, so called industrial water, rain water, sea water, etc) for non-potable use in industrial and commercial premises.
- Establish liaison with government authorities to discourage the setting up of water intensive industries and to grant investment allowance incentives to companies which have invested in plant and equipment to conserve a substantial amount of potable water.
- Water audit and advice to customers

- Continue to educate the public on the importance of water conservation through talks and exhibitions to schools and both private and public organizations. Water conservation is also included in school textbooks used in Singapore.

Tax Incentive for Water Conservation Project

In line with Singapore's national effort to conserve water, the Economic Development Board (EDB) grants investment allowance incentive to companies which have invested in plant and equipment to conserve substantial amount of potable water. Taxable income of an amount equal to a specified percentage (up to 50%) of the cost of the plant and equipment are exempted from tax.

Tariffs:

Water tariffs are recognized to be one of the ways of curbing demand growth and encouraging the efficient use of water. As such, they are reviewed periodically. To encourage customers to conserve water, block tariffs are used for domestic consumption. In addition to the water tariffs, a water conservation tax of 5% on all consumption above 20 cu m/mth for domestic consumption and 10% on all non-domestic consumption was introduced in April 1991. With effect from April 1992, this tax has been revised to 10% and 15% for domestic and non-domestic customers respectively. The revenue generated by the tax is future promoting the conservation efforts of the country city and country as a whole.

LEGISLATIVE MEASURES:

The Water Supply Regulations and Singapore Standard CP48:1989, Code of Practice for Water Services also stipulate measures which customers must comply with. (see following).

Only approved pipes and fittings are allowed to be used in the potable water reticulation system to prevent wastage and contamination of the water supply. They are constantly reviewed to ensure conformity with current standards and requirements.

In addition, only licensed water service workers are allowed to perform any water service work. This is to ensure that a high standard of plumbing work is maintained.

SINGAPORE STANDARD CP48:1989 - CODE OF PRACTICE FOR WATER SERVICES - Section Seven: Water Conservation

General:
It is important that every customer must help to conserve water and curb water wastage. Water conservation measures must be adopted in domestic and non-domestic premises.

Water Conservation Measures:
It is mandatory to adopt water conservation measures in the following areas:
Toilets/washrooms in all non-domestic premises (including the common amenities of condominium).

- Install self-closing delayed-action taps at all wash basins.
- Install self-closing delayed-action shower taps at all shower points.
- Install constant flow regulators at all wash basin mixers, shower mixers and bib taps.

(a) Kitchens/stall/cooking areas in all non-domestic premises
- Install constant flow regulators at all sink taps.

(b) Canteens (excluding cooking areas).
- Install self-closing delayed-action taps at all wash basins and wash troughs.

(c) Laboratories.
- Install constant flow regulators at all wash basins and sink taps except for safety reasons.

(d) Vehicle Washing Areas.
- Construct earth removal platforms and water recovery systems for washing of vehicles at construction sites.
- Construct water recovery systems at vehicle washing point for other premises where washing of vehicles are required.

(e) Condominium/Residential apartment units/Hotel rooms/Massage rooms/Hospital Wards.
- Install constant flow regulators at all wash basins, wash basin mixers, showers, shower mixers, bib taps and sink taps.

(f) Other areas.
- Set up water recycling system to reuse water for cooling purposes.
- Construct a rain water collecting system, wherever possible, to collect rain water for non-potable usages such as gardening, washing, etc.
- Set up water pre-treatment plant for boiler usage to reduce boiler blow-down.
- Set up water recovery system for boilers, wherever possible, to recover condensate as make-up water.

Note:
Constant flow regulators are not required where water pressure at the fitting is less than 1 bar. As a guide, these regulators need to be installed only where the static water pressure at the fitting exceeds 1.5 bar.

2.4 CASE STUDY - WATER CONSERVATION IN CHINA

(See Bibliography)

By the middle of the 1990's, there were 515 cities in China, of which the urban population amounted to approx.15% of the total population. Their gross industrial product was 70% of the whole nation's economy. Urban water supply has been recognized as the fundamental facility for adequate urban management , economic development, and improvement in living standards.

PRACTICE AND PROGRESS ON UWC (URBAN WATER CONSERVATION) IN CHINA:

Much attention has constantly been paid to urban water conservation (UWC) in China with the development of the urban economy. The policy of laying equal stress on both water resource development and water conservation started in the 1980's in order to balance supply with the increased demand.

The Water Act of the People's Republic of China issued by the People's Congress in 1988 decided that planned water consumption must be formulated and the water saving practiced strictly, viz. the water saving is put into national law. The Supervision and Management Measure for the Application of Building Toilet Utensils as well as some other standards were issued by the government identifying urban water conservation as an issue for legislative management.

Since the mid 80's cumulative total water saving of the cities all over the country has reached more than 10,000 million m3. The industrial water reuse rate has increased to over 50% from 20% in 1983 and the water consumption per 10,000 Yuan (RMB) industrial product has been reduced by more than 40% in real terms. Significant economic, social, and environmental benefits have been achieved.

ACTIONS TAKEN:

1) Saving water resources, alleviating the conflict between supply and demand. According to the statistics of cities all over the country, the average water saved annually is about 1,100-1,200 million C.M.
2) Reducing the discharged wastes in order to protect the water resources and urban environment. The amount of annual water saving is equivalent to at least 900 million m2 of wastewater being re-used by all sectors.
3) Effectively controlling the urban soil subsidence.
4) Decreasing industrial water consumption, saving energy and reducing production costs and pollution.
5) A) Enhancing public awareness. The acute situation of water supply and the practical and strategic significance of water saving are spread by all means including the media, schools, etc.

   2nd) Water conservation offices were established all over the country at provincial, county, city, and town levels.

Implementing management of water demand. Industrial water consumption accounts for more than 70% of the urban water use, and consequently the strengthened management of industrial water consumption can seriously benefit the total urban water conservation efforts. Local uwc managerial sections have been carrying out the various management measures to reduce industrial water consumption.

Accelerating water saving technology development. Industrial water saving depends on the technology development concerned, which results in extensive research and application of water saving technology as well as the construction of water-saving demonstrative projects in order to assist and influence the industry in China. The petroleum, metallurgical, papermaking, printing and dyeing industries have developed unique water saving technologies, methods, changes of processes, use on non fresh water for cooling etc, etc.

Future policies in water saving will be enforced all over China in order to promote the economic development despite its water shortages.

POLICY GOALS:

By the year 2000-2010 half of the increased water demand by the industry will have to be met by means of water saving. Implementation of urban water saving instruments must be reinforced, regulations be formulated and enforced, investments increased, and technical innovations developed.

R&D on water conservation technology. Difficulties faced by the water users concerning water conservation will be dealt with by research and development by all sectors.

Economic Measures Low water prices are the main reason for water wastage. A rational and national water pricing system will be established step by step in accordance with the national regulatory policy on prices. The principles of overcharging for overuse and charging for sewerage costs will be enforced.

Re-use of treated human wastes. Urban wastewater re-use is an important source to meet industrial demand and reduce the use of fresh water resources. The total sewage discharged in the early 90's amounted to over 35 billion m3/y most of which is untreated. Policy will lead to large investments in treatment and re-use.

Sea water desalination and use. In order to meet the water demand by industry along the coastal cities, sea water desalinating will be exploited and utilized. The utilization of sea water could significantly assist the economic development of coastal cities. Economic and technical problems will be analyzed and addressed.

To conclude: China will not have any other choice but to promote and enforce urban and industrial water conservation in all towns and cities, especially the coastal and the mega-cities.

WATER CONSERVATION IN BEIJING:

Beijing is the capital of the People's Republic of China. Its urban population consists of about 8 millions. There are 10 waterworks and approximately 2500 wells. The volume of annually sold water is estimated at 300 million cubic meters in the city.

With the development of the city economy and population, the water demand increases at a rate of 3-3.2% per year.

In view of the importance of water resource in urban development and management, the municipal government is accelerating construction of new water facilities, and has allocated the highest priority to water conservation measures.

Since the early 80's, water conservation has become the most important policies and investments in order to support the city growth despite its limited water resources. The guidance of the municipal government with commitment to a series of laws and regulations aimed at demand mgmt. are the main tools to achieve the city goals.

More than ten years of practice has proven than advocating water conservation energetically, spreading advanced technology and developing facilities for water conservation could be a very successful strategy in parallel to development of new water plants. It has reduced substantially the rate of demand growth for water. As most of the available new water resources are being utilized, the rapid development of the city enforces water demand management. A solid foundation has been laid for further reforms and strategies to promote the city economy and optimize its performance as a modern city.

Over the past 15 years, the total volume of conserved water was over 1500 million cubic meters. Specific efforts to address the goals of water conservation in the industry has enabled a substantial increase in production per unit of water.

Over the past 15 years, the municipal government has made an investment of over 15 billion Yuen to build more than 2000 industrial water conservation facilities. The city and government policy is to prove the feasibility and enforce rigid water conservation policies to change the historical concept of supply management.

Water serves as an indispensable and precious resource for a city like Beijing. Wasted water can not be replaced. Water conservation is the most important undertaking for the benefit of the future generations.

- Approx. average of 5 Yuan (RMB) per USD during the period.

WATER CONSERVATION IN DALIAN CITY (LIAONING, PROVINCE) DALIAN'S CURRENT WATER SUPPLY:

The population within the Dalian municipality responsibility is approximately 6 million, of which over 2.5 million is urban. Dalian City itself has a population of approximately 2 million.

Principal economic activities in Dalian are harbor transport and transshipment, tourism, fisheries and industries, including machinery, metallurgy, textiles, food processing, electronics and building materials.

Prior to 1980, Dalian had effectively exhausted locally available sources of fresh water, both from surface flows and from under ground. In 1983 the first stage of Biliu Reservoir Project was inaugurated. This project involved the supply of water from sources to the northeast of Dalian through a system of reservoirs, pumping stations and pipelines from a distance of up to 150 kilometers. The first two stages of the project are now completed and have the capacity to increase the water supply to Dalian by 380,00 m3/day. The third stage will add another 620,000 m3/day to the available supply, for a total of 1.0 million m3/day from this source. Costs per unit of water are at least 4-5 times than the costs of the previous resources.

DEMAND MANAGEMENT OPTIONS:

The City of Dalian has been in the forefront in the area of water demand management and conservation in China. It has an established Water Conservancy Office, which oversees the implementation of water demand quotas, the coordination of conservation activities and public education at the local level. In conjunction with the Water Supply Company, the office has access to water metering data which covers approximately 95% of all consumers, and has instituted programs to locate and repair leaks and other losses in the water distribution system.

PRICING POLICY:

Prior to 1991, typical prices charged to water consumers were 0.15 yuan/m3 for domestic users and 0.21 yuan/m3 for industrial users. The first water demand management option being implemented by Dalian is the raising of prices charged to all consumers to better reflect actual production costs and produce incentives for consumers to reduce demand. This policy means that between 1991 and 1994 prices will increase by over 400%, to range between 0.9 yuan/m3 for domestic consumers and 1.2 yuan/m3 for institutional and commercial consumers. Further increases have been implemented since 1994. This new pricing policy will likely be an effective method to decrease demand for water, and will place the onus more directly on individual consumers to conserve, rather than on a centralized authority.

WATER REUSE:

When industrial consumers pay for actual water costs, the incentive to reuse water is much higher. Industries within Dalian are leaders in the reuse of water, with statistics showing that approximately 80% of industrial water is presently reused.

In the commercial sector, pilot projects are being designed for the study of grey water reuse in large commercial and institutional facilities such as hotels. The feasibility of installing grew water treatment facilities and recirculation systems in new buildings has been examined, as well as retrofitting existing buildings with the required equipment as part of a World Bank supported project.

REDUCTION OF WASTED WATER:

In the domestic and institutional sectors, Dalian has conducted a demonstration project in the Dalian University of Technology students' dormitories on the use of low consumption fittings such as toilets and taps. They hope to expand this demonstration project and test the viability of these fixtures throughout other parts of Dalian.

The other area where potential exists to reduce wasted water is in the distribution system. Many pipes were installed during the early part of this centry in Dalian, and leaks are believed to be significant. An ongoing repair program exists on an "as required" basis.

REPLACEMENT OF FRESH WATER:

Within the industrial sector, the use of sea water for "non-contact" processes such as cooling water is practiced extensively, as well as some "contact" uses in industrial processes. The large majority of this sea water use occurred in the chemical industry, a thermal power plant and a petrochemical plant.

The replacement of fresh water with sea water in some domestic or institutional uses such as toilet flushing is being considered. Incremental costs are compared with costs of other resources and measures.

Any initiatives taken to replace fresh water with sea water in "contact" processes must take into account the bylaws which govern waste discharges and policies to recycle water. Because of the corrosive nature of sea water, treatment facilities are expensive to build, and so in order to meet dilution requirements of discharged wastewater. Industries may increase the use of sea water rather than decreasing or recycling it, and discharging the wastes into the ocean.

LEGISLATIVE CONTROLS, SOCIAL CAMPAIGNS AND EDUCATION:

Dalian has instituted public education programs, local committees and media campaigns to promote water conservation. Contests and awards have been part of the activities promoted to increase awareness of responsible and rational water usage.

Through the Water Conservancy Office, enforceable quotas on water use were established for industries, commercial business, institutions and farms. The Office set fees for water use and stiff fines for consumers exceeding their quotas. This quota system is a variation of pricing structures used in other countries where prices for water increase with the amount consumed. The penalties for high consumption are built into the price structure.

By giving the Water Conservancy Office the authority to grant licenses and establish quotas, a mechanism exists for legislating industries and commercial enterprises to implement water conservation measures as a condition of their license. There are draw-backs to the system.

SPECIFIC PROJECTS PROPOSED BY THE WATER CONSERVANCE STUDY:

1) Reduction of UFW (unaccounted – For – Water):
This project ranks as priority one in terms of internal rate of return for the Water Supply Company, and has the potential to save the greatest amount of water. The project will involve historical and physical analysis of water line breaks and leaks in Dalian, sector by sector metering, and development of a systematic program for replacement or repair of the problem areas of Dalian's existing distribution network.

2) Water Conserving Retrofitting:
The Dalian University of Technology is estimating a 40% reduction in fresh water consumption by a full scale retrofitting of plumbing fixtures to low consumption fixtures. Over a ten year prior, the savings in costs over the required capital cost payback are estimate to produce approximately a 30% internal rate of return when completed and if results will meet the expectations the project will become a demonstration one for the city and the province.

3) Large Scale Conservation Projects are being implemented in hotels, breweries, steel plants, power plants, dye industries, and others.

2.5 CASE STUDY - KOREA

(See Bibliography)

INTRODUCTION:

Overview of Korea:

The republic of Korea (Korea) is located at the eastern end of the Asian Continent and adjacent to the Yellow Sea. The total land area is 99,450 km2: farmland constitutes 21,379 km2 (22%); forests cover 63,762 km2 (64%); and only 4% of the total land is used for housing, public and industrial sites.

At the end of 1995, the population of Korea reached more than 44 million representing a population density of 450 persons/km2, one of the highest in the world.

Characteristics of Water Resources:

The annual average precipitation is about 1,274 mm, roughly 1.3 times the global average. However, the average annual rainfall per capita is about 3,000 m3 which is only 10% of the global average.

Two thirds of the annual precipitation occur in between June and August, which is largely discharged to the sea accompanying heavy floods.

Korea has an economic potential of about 127 billion m3 per year of water resources. However, 45% is lost through evaporation and infiltration.

WATER CONSERVATION POLICY:

Backgrounds:

Heavy seasonal fluctuations in precipitation in Korea necessitate a large volume of reservoirs to mitigate such unbalances. However, the Country lacks proper sites for construction of dams and the costs for land acquisition are skyrocketing. In some municipalities, the available source of water falls far behind the water demand particularly during dry season and, therefore, water shortage arises regularly. Deterioration of raw water quality and the need for higher water quality standards result in the ever-increased capital and operational costs.

Rapid increase in water consumption, shortages of water resources, the high costs for developing and maintaining of the new water sources, and the limited capital source have made it imperative to manage water demand and water resources more efficiently.

Furthermore, the fact that water charge is comparatively inexpensive in Korea leads to excessive and unreasonable water demand. Water pricing needs to appreciate and reflect its economic value, if the authorities wish to continue and enhance its economic growth.

The responsible authorities have launched a water conservation program since 1990 in an attempt to harness the ever-increasing water demand. Reuse of typically non-potable sources of water have been conceived as viable alternatives to new water supplies. The efficient distribution of the produced water resources and the adoption of water saving devices have been encouraged.
The Government is constantly reviewing water rates in appreciation of the needs of pricing water at its real value. The importance of establishing water saving ethics through education and communication is receiving attention. Industries, which suffer from shortage of water, have embraced the following measures to reduce demand:

- Recycling cooling water through cooling towers
- Changing production processes
- Reuse of water washing operations
- Reuse of wastewater
- Installation of water saving devices

Introduction to Wastewater Reusing System:

Major water savings can be obtained by re-use of municipal and industrial wastewater. Reclamation involves the treatment of wastewater to permit an environmentally safe use of the treated water for applications such as in toilet flushing, street cleaning, landscape, agricultural and industrial use. This measure reserves the fresh water supply for drinking , food production and other high-quality uses.

Reduction of Non-revenue Water (Unaccounted for Water – UFW):

Non-revenue water (UFW) is the difference between water produced and water paid for. NRW includes meter underrun water, water used in flushing water mains, fire fighting water, water taken illegally from the distribution system, loss through leaks, water exempted from charge due to bad taste or odor, and unaccounted-for water due to defective meters.

An analysis carried out in 1991 indicated that UFW in Korea reached approx. 35%, of which system leakage was approx. 20% and unclassified other use was approx. 15%.

The major problems caused by the high UFW with regard to managing water supply systems as follows:

- It is a loss of water produced and, if properly controlled, would delay the need for expanding facilities. Reduction of leakage is the most economical way to increase supply capacity, beside domestic and commercial retrofitting.
- It reduces the capacity to obtain revenue and so is a financial loss, resulting in an inability to properly manage the utility, causing financial problems to maintenance, replacement of work pipes etc, which in turn increases losses.
- Water rates have to be increased unjustifiably to cover the financial loss.
- It allows, in case of low pressure, infiltration of non-potable groundwater into the distribution pipes through holes and broken joints resulting in water pollution causing health hazards.
- Leaks destabilize ground conditions causing road and pavement damage and also increase wastewater flows.

In consideration of the above, the responsible Ministry (M0C) set out a 10-year program starting in August 1991 to reduce UFW. The program includes leakage reduction, meter management and measures to counter illegal connections to reduce UFW down to 20% by the year 2001. The leakage water will be decreased down from approx. 20.1% to 12%, and other UFW from approx.15% to 8% respectively.

Meters will be installed inside and outside private premises.

- If the metered water consumption is not compatible with standard water consumption of similar scale businesses, then the service pipeline and meter will be checked carefully.
- A penalty will be imposed on any illegal use equal to five (5) times the legal rate for the period of illegal use.
- Part of the penalty imposed will be awarded to the person who provided the information on illegal use.

Pricing Policy:

In Korea, water utilities adopt similar water tariff structure with progressive rate blocks. A minimum quantity is provided to domestic consumers at a specially low rate. Domestic use consumes about 70% of the supply.

Sewerage charge are calculated based on water consumed but the operations are maintained separately from that of water supply.

Water tariffs do not reflect the real cost of water and have been set more on social and political considerations. It is intended to price water closer to its real value. Additionally a consolidated policy for water and sewerage rates will have to be established.

Water Conservation Arrangements:

Enforced instruments have not yet been initiated to govern arrangements for conserving water including the domestic and commercial retrofitting with water conservation means. However, the City of Seoul has its own regulations to impose the provision of water saving toilets, one-touch faucets and low-flow showerheads in houses and apartments constructed by the City itself. The Korea Housing Corporation has introduced water saving toilets, as the first step toward a broader program.

A regulatory framework on water conservation retrofitting installation is currently under preparation by the authorities.

Retrofitting toilets, showers and washing machines in households in order to reduce water demand is an attractive and effective way to achieve immediate decrease of water wastage. Such devices, when installed, automatically lead to conservation without any efforts demanded from the consumers and will lead to direct monetary savings. Demonstrating projects, assisted by the World Bank or self funded, are being executed.

Conclusions and recommendations:

If demand increase is uncontrolled, the reserve stock capacity is expected to reduce from about 10% in 1991 to 6% in 2000, and to less than 2% by the year 2010 even with further development of reservoirs. Demand management and water conservation are therefor the only alternatives available to Korea. The Government indeed launched a water conservation program in 1990 under the direction of MOC (Minister of Construction).

The high and still growing water consumption (per capita) and pollution of resources have not only exacerbated the water scarcity situation but also increased water treatment costs. This clearly demonstrates again the imperative need for demand management and water conservation including pollution control.

Korea is in its initial stage "the of water conservation era", as other developing countries are in similar situations. Major programs presently under implementation are as follows:

- Reuse of properly treated wastewater effluent for non-potable water supply (industrial, irrigation and possible double – systems).
- Piping network and household leakage reduction as well as unaccounted-for water reduction
- Introduction of water saving fittings by the non-governmental bodies as a demonstration projects.

Further consideration will be given to the following measures:

- Evaluation of water reuse potential for non-potable uses.
- Encouraging industrial water conservation efforts.
- Transformation of pricing policy to conservation-oriented rates
- Establishing programs for water saving retrofitting.
- Introduction of camping for public information and education
- Development of a standard benefit-cost evaluation methods including both qualitative and quantitative factors to be used on the potential and planning measures.

2.6 CASE STUDY - MALAYSIA

(See bibliography, C. Harrison, Conservation)

The Johor Bahru Project(South Malaysia):

Johor Bahru and its hinterland occupy the southern tip of South West Malaysia and have a population of about 800,000 people. A causeway links the town to Singapore. Historically, the island of Singapore was supplied from the mainland and the Singapore Public Utilities Board still operates a number of sources and treatment works in the State of Johore. Johor Bahru gets about half its treated water on the trunk mains feeding Singapore. The rest of the supply comes from a dam and treatment works belonging to Johor Bahru but operated under contract by a private company. Water losses in Johor Bahru were difficult to estimate precisely but were of the order of 35%. Singapore and Malaysia both enjoy high rates of economic growth and Johor Bahru, at the junction between the two, is an economic HUB with a rapidly growing population and industrial base. Demand for water in the region is rising rapidly.

The project started as a consultancy assignment on fairly standard World Bank terms, won in competition with other consulting firms. The contract was in two phases, a Study phase of 12 months followed by an Implementation phase of 18 months. There were difficulties in mobilizing the resources necessary to carry out repairs to the system and install meters, as new pressure valves and other items needed for the project. The delays that resulted from these problems gave rise to an extension of time but it was clear to both the client and the consultant that further help with setting up the leakage control system would be needed.

The consultant proposed a solution based on the rates agreed in the consultancy proposal but in which he would act as a contractor. This takes the form of a fixed price contract to finish the setting up of 147 leakage control districts, with leakage in each reduced to less than 20% of the supply. The contractor is paid a portion of his lump sum pro rata for each district meeting the target (i.e. set up with losses less than 20%). In addition the contractor finances and manages sub-contracts for the minor works and repairs needed for the project, reimbursed by the client at cost plus a fee to cover finance and management costs. The project continues until losses in all 147 districts are below 20%.

The results so far are very encouraging. Supply from the sources has leveled off despite rapid growth in consumption. Losses in many districts are down to 13% or less.

Lessons from the Toulon (France) and Johor Bahru Contracts:

The conclusion must be that although the contractor is pointed in the right direction, neither contract aims him precisely at defined target. The beneficial elements of the Toulon and Johor Bahru contracts that it is nevertheless important to retain are:

- clearly defined budget
- incentive to reduce existing losses quickly
- incentive to be efficient
- freedom of action for the contractor
- simple administration

- contractor responsibility for minor works
- shared benefit giving client and contractor a common interest in success

Elements that it might be advantageous to add are:
- contracts open to competitive tender as well as direct negotiation
- incentive payments linked to long term total cost of water losses and control, including:
  1) capital cost of setting up the control system
  2) long-term operating cost of the control system
  3) marginal cost of supplying water losses from existing sources
  4) capital cost of developing new sources to supply water losses

- simplicity of project preparation
- targets defined without the need for precise determination or explicit statement of existing losses
- ability to include other services in terms of reference that it would be sensible to carry out alongside water loss control (e.g. mapping, modelling, condition surveys, rehabilitation studies).

There are other demand Mgmt. Activities in Malaysia, however in order to diversify the case studies mentioned in the paper, this innovative project was selected.

The benefits of both the examples (speedy reduction in losses, economical uses of resources, clear budget) can be obtained with price competition and incentives to minimize long-term costs by the use of a <u>Target Cost Reimbursable contract that includes the cost of water losses in the target cost.</u>

2.7 <u>CASE STUDY - U.S.A</u>

(Establishment an Effective water loss reduction program)

<u>Overview:</u>

The management of water distribution systems is more critical today than ever before. With the added requirements brought on by the growing urban population in the developing countries and as a result of the growing need for water conservation.
Water demand management is receiving greater attention throughout the world. As a result of:

1. Increased population pressures, mainly in the urban sector.
2. Shortage of potable water supplies, and uneven distribution of water when the low- income groups lack the proper services.
3. Infra-strūcture problems in distribution systems.
4. Ground and surface water depletion and contamination.
5. Development of new resources are getting scarcer remote and costly.

With more regulatory agencies getting involved in water conservation and water quality issues, it is important to clearly establish what water utilities can realistically achieve in terms of water accountability. Most regulatory agencies in the United States are recommending that water utilities strive for a metered ratio of somewhere between 85 to 95 percent.

Because water utilities pay for operating costs with revenues collected, they are forced to look for some form of return on their expenditures for replacing water lines a/or water meters. If a return is not in the forecast, most utilities understandably will resist making those system improvements.

Major areas where utilities water loss can occur:

Production meters and records
Large meters in blocks
Domestic meters
Non-revenue usage
Unauthorized usage
System controls
Underground leakage

Inaccurate production meters and records create a serious problem. If these records are not correct, the metered ration is not accurate and the utility has no way to determine its real water loss and the associated revenue loss. Field testing of production meters even under ideal field test conditions may yield accuracies in the range of 100% plus or minus 2%, while field testing under normal field conditions are accurate commonly to a deviation of plus or minus 3% to 5%, while in developing countries the range is far beyond 5%.

Allowable leakage is another area of concern. It is common to find as much as 2% to 4% of total production in a given system may be lost to unavoidable background leakage. Allowable leakage is synonymous with the term unavoidable leakage, which is the quantity of water that is inevitably lost from a well-maintained water system.
These problems escalate when considering developing countries. Methodologies often used to control unaccounted – for – water do not work in developing countries for several seasons. One consideration is that a continuous 24-hour water supply, with adequate pressure, and accurate metering must exist.

Developing of water loss program:

A successful water loss reduction program should include the following:
1. Water conservation program.
2. Water rate review.
3. Meter management program.
4. Leakage control.

Water Conservation:

For many utilities worldwide, water conservation is inevitable and will have a profound financial impact. In most systems sales will decline when water conservation programs are implemented. Revenues also will decline accordingly unless revisions are made to the water rate structure. The above graph shows a large drop in production and sales in a water systems where conservation measures were implemented. In this system, water rates were increased in order to compensate for the decline in water sales volume and revenue. However, in developing countries conditions differ and re-allocation to unserved consumers or unmet demand will compensate for the potential loss.

In the United States, it is difficult to implement a successful water conservation program where the system is not totally fitted with accurate meters, or where the rate structure is regressive.

Effective metering accuracy is not just a result of accurate metering devices, but also a proper type and size, properly applied and installed.

When utilities adopt a water conservation program, they need to examine carefully its overall impact on operations. In particular, the cost-effectiveness of meter replacement and maintenance. Not all meter replacement and meter maintenance measures prove cost-effective. Further, depending on the design of the rate structure, these measures may not encourage conservation.
With reduced monthly consumption, the return on meter expenditure was reduced almost in half.

Water rate Review:

Utility managers need to review carefully the impact that water rates have on water distribution operations. Water operations and customer behavior must be considered when water rates are under review.

Meter management:

The most expensive water loss in a distribution system in terms of direct cost is that which is associated with meter mismeasurement, sometimes referred to as inaccurate metering. Mismeasurement may result from poor meter quality, poor water quality, use beyond useful life, improper sizing, mis-application, and improper installation.
Metering may be the single most important component in the water system. Meters usually are responsible for most of a water utility's revenues, which pay for the salaries, supplies and equipment needed to operate the system.

Nevertheless many, utilities purchase meters on a low- bid basis, and in many cases end up with meters that do not perform as well as others.

The cost difference is far less significant than any of the other possible differences between the meters. Meter life expectancy and their sustained accuracy is an area that utilities must examine in detail as an essential part of the purchase process.
Water quality has a profound influence on the useful life of a water meter. Too frequently water utilities replace meters using meter age as a benchmark. Water quality and total consumption throughput are the most important factors to consider in designing a meter replacement program.

Many utilities should implement a large meter maintenance or replacement program. It is common for 2% to 3% of customers in a system, to generate more than 50 percent of the revenue. Also, meter sizing is a major problem, and can cost utilities hundreds of thousands of dollars in unnecessary meter purchases, labor and lost revenue.

Underground leaks:

The one area that has an immediate impact on water conservation is that of underground leak detection programs. However, not all leak surveys are cost effective or successful. Not all leaks will be located, regardless of experience of consultant or employee or equipment in use.
Dedicated agreements between contractors dealing with leakage detection and utilities may reduce the cost effectiveness of leakage investigations.
The incentive for leak detection is greatly reduced.

Benefits of the Water Audit

- Maximize earned revenues.
- Reduce operating costs
- Minimize system wear
- Identify hidden problems
- Provide data for management decisions

In terms of *direct costs,* the monetary impact that leakage has on a water system includes:

1. Cost of water purchased.
2. Energy costs to pump water.
3. Costs to treat water, mainly chemicals.

California

Southern California, with its imposing mountain ranges, white-sand beaches and ever-growing population, is a desert region depending largely on imported water for its economic survival. With its population increasing by approximately 280,000 persons per year, and its water supply diminishing, the area faces serious problems unless actions are taken.

About two thirds of the water used within the coastal plains and inland valleys of Southern California comes from three sources: Northern California through the State Water Project's 444-mile, California Aqueduct, the Colorado River through the 242-mile Colorado River Aqueduct, and the Eastern Sierra Nevada via the 338-mile Los Angeles Aqueduct. The remaining third is pumped from groundwater basins underlying many of the communities that make up the region.

Due to legal, political, institutional, and environmental barriers restricting the development of new sources of water, plus the potential for droughts, innovative water management strategies must be developed.

- Los Angeles has reduced the amount of water it diverts from the Eastern Sierra Nevada by approximately 70,000 acre-feet per year due to court rulings. More of their share of Colorado River water, which in turn could have the portion of river water diverted to Southern California via the Colorado River Aqueduct.
- Environmental measures designed to provide more water for fish and wildlife have cut the amount of water delivered to Southern California from northern regions of the state.
- Ground water levels in the region have fallen because of increased pumping. Some groundwater sources have grown salty due to seawater intrusion and chemical pollution.
- One of the most dependable, abundant, and under-utilized supplies of water is reclaimed water. Southern California homes and businesses use more than 2 million acre-feet of water each year (An acre-foot is enough water to meet the needs of a 4 persons in California household for 1 year). Subsequently after the water is used it must then be treated at local wastewater treatment plants and finally discharged into streams, rivers, and the ocean. In order to better manage our water resources we need to further treat wastewater providing us the opportunity to recycle our water for reuse.

  The principle of water recycling is as old as life itself. Nature has been using, cleaning, and reusing water countless times. Water from oceans, lakes and rivers evaporates, then falls as rain or snow. Precipitation falling on the earth percolates through the soil to ground water basins. In the process impurities are removed. In lakes and rivers heavy solids settle to the bottom, natural bacteria decompose organic material, and tiny particles are filtered out through the soil.

In water recycling, we use proven technologies to reproduce nature's way of doing things. Water reclamation plants remove solids in settling tanks, use active bacteria to digest organic material, filter out the small particles through layers of natural materials or sophisticated filters and disinfect the final product.

About 265,000 acre-feet of water are currently being reused in 150 Southern California recycling projects and an additional 70 projects are either in the planning or construction stage. Literally hundreds of parks, golf courses, schoolyards, cemeteries, nurseries, roadway median and industries throughout the state use recycled water.

Recycled water is also used for supplementing groundwater supplies. More than 35 agencies either already have or are planning the construction of a ground water recycling facility.

3. UNCHS (HABITAT)/UNEP–MANAGING WATER FOR AFRICAN CITIES

3.1 PROPOSED COUNTRY ACTIVITIES

General

UNCHS, UNEP and UNFIP have embarked on a programme which includes WDM components in approximately 8-10 cities in Africa. A summary of these activities is included here in order to promote similar program in Asia.

The general project objective is to promote the improvement of efficiency of water use in the urban areas of Africa through joint activities in a number of selected and agreed cities, to introduce WDM measures and instruments at the city level.

The role and TOR of UNCHS (HABITAT) is of a technical assistance nature, promoting and assisting in the implementation of actions to broaden city and nation wide understanding and support to the importance and potential costs / benefits of WDM policies and strategies of execution.

The project length and budgetary capacity is limited, it was therefor decided, following consultations with African decision makers and sector professionals, **to focus our joint actions on actions which can bear fruits in a relatively short period with a minimum capital investment** and to avoid those which demand lengthy decisions making process, and high capital investments.

Therefor the project will focus on promoting WDM plans, policies and strategies, demonstrating water conservation technologies (retrofitting) at the end user and **public awareness avoiding the expensive and lengthy operations like**: Unaccounted for water reduction, replacement of worn pipes, installing or completing comprehensive water metering systems and introduction of significant changes in the water pricing policies. These activities are important and form integrated components of an effective urban water demand management, however fall out of the capacity and the scope of this project.

3.2 *WDM in Johannesburg (South Africa)*

It was proposed to undertake jointly with the authorities and counterparts in Johannesburg the following activities:

a. **Developing water conservation and demand management strategy for Greater Johannesburg Municipal Council.**
b. **Monitoring and evaluating retrofitting under various UAW (reduction of unaccounted-for-water) activities**
   A number of interesting activities involved in UAW reduction, are proposed issues of importance to be potentially replicated in other cities, as well as in other African countries. We shall be evaluating the results of these programs, each by itself, as important parameters for UNCHS global efforts:
   - Evaluation of (UAW) leakages reduction and partial retrofitting in Soweto – completed and on going by Randwater.

- Evaluation of leakage reduction and partial retrofitting project done in Tembissa – East (Randwater).
- Evaluation of Inner Johannesburg project to deal with deteriorating high risers blocks of apartments, densely populated, where bulk metering for a block will be transferred into an individual apartment metering.
- Evaluate the results of an interesting exercise, being negotiated at the present by GJMC and 3 international firms for an UAW reduction, when payment is linked to actual savings of water.

c. Reviewing existing MIS in GJHBG and pilot testing a selected model in a demonstration area.

The component will deal with evaluation of models to be tested in a demo site. Our role will be to assist in the selection of one for testing and the potential integration of an adequate MIS-GIS - subsystem to be a tool for distribution network control and management.

3.3 *WDM in Lusaka (Zambia)*

Structure of WDM Components in the Joint Project:

It was agreed to include in the joint project 3 separated actions, however linked to one objective and program, in order to promote the basic planning, responsibility and the demonstration of savings and cost / benefit by the installation of water conservation technology (a retrofitting exercise), As following:

- **Developing water conservation and demand management strategy for Lusaka.**
- **Demonstration of Water Demand Management Techniques** (Retrofitting). The focus of this activity is on reduction of water wastages, to achieve socioeconomic objectives by producing indirect additional water quantities **through the use of water conserving fittings mainly in public buildings and sites to demonstrate the financial savings and the potential for reallocation of the saved water to the unserved low income groups and compounds**.
- **Establishment of water demand management unit** (WDMU). Having responsibility for the overall objective of reducing demand and water wastage in the city and promote a nationwide awareness and similar actions.

3.4 *WDM in Accra (Ghana)*

Current levels of unaccounted for water in Accra are around 57%. The water sector is currently under reform and UFW will have to substantially reduced before privatization takes place. A utility mapping project has been initiated and there are many opportunities for reducing demand and adapting current tools to improve management of water distribution. The industrial sector is a large user of water and practical demonstration linking cost savings to water use reductions are attractive to industrialists. Activities will focus on:

- Assessment of efficiency of water use in industry.
- Development of a monitoring framework for WDM.
- Development and implementation of selected pilot-scale demonstration site (domestic and institutional) for retrofitting etc.
- Development and implementation of selected pilot-scale demonstration (industrial)..

3.5 *WDM in Dakar (Senegal)*

The project TOR is within the World Bank / IDA-funded Senegal long term water project to demonstrate water demand management measures, implemented by UNCHS (HABITAT).

It is proposed to implement a pilot project in Dakar in public buildings and/or the university. Retrofitting of faucets, showerheads and toilet flushing will be tested using modern high-quality fittings which can be imported and later manufactured locally. These fittings will be installed in public/ office / university buildings where there is no financial incentive to conserve water. Apartment blocks could be included where one bulk meter is installed for all residents and individual apartments usually pay for water at a flat rate.

A possible site to demonstrate treated human wastes re-use, is also being considered. An awareness campaign will be developed and implemented, directed to all users in the pilot area before retrofitting and throughout the project duration.

3.6 *WDM in Addis-Ababa (Ethiopia)*

A water demand management and conservation strategy will be developed for the city of Addis Ababa. The city has developed a Water Mater Plan and a Wastewater Master Plan. The plans highlight the following issues: So far there has been no distinctive water demand and conservation strategy for the city of Addis Ababa. Most of the projects conducted by AAWSA are of a supply driven nature. In view of the severe water shortage there is an urgent need for comprehensive water demand management strategy for Addis Ababa.

Addis Ababa's water conservation and demand management strategy (WCDMS) will be developed. Water demand management capacity building in AAWSA will focus on the following areas:

- Institutional capacity building, establishing a WDM unit in AAWSA.
- Capacity building in GIS for mapping the line system.
- Capacity building in reducing unaccounted for water (leak detection).
- Promotion of WDM in existing and planned water projects.
- Establishment of a WDM unit.

The prevailing water loss in the city water supply network is high to the extent of affecting the authority's efficiency. This is not only due to system losses but on the consumers' side as well. A unit under the water services department exists looks at pin pointing visible leaks only. Its functions will have to be broaden to include wider WDM actions.

3.7 <u>WDM in Abidjan (Cotedivoire)</u>

The component will promote water demand management demonstrations for industrial and domestic installations and improving service coverage for the urban poor.

Although water resources are not currently limited in the city, demand will gradually reach levels where groundwater resources may be insufficient. There is a need to develop a demand management strategy now to ensure that all actors use water efficiently and delay capital intensive future supply expansion needs. The amount of water currently used by industry is not well known. However, rough estimates show that this amount is excessive.

This component seeks to undertake a demonstration in selected areas of the city, where consumption can be reduced with relatively little capital investment in retrofitting technologies or the use of appropriate economic instruments:

- Selection of suitable industrial and domestic sites for demonstration.
- Development of WDM strategy for selected establishments.
- Assessments of existing situation, implementation of WDM strategy and evaluation of effectiveness of strategy.
- Public awareness campaign on reduction of water consumption and protection of water resources from pollution.
- Develop a public awareness campaign on conservation of water resources, targeted at women and children, including development of educational media for schools, video films and high-level government commitments.
- Development of information tools for industrialists and agriculturists on water conservation and control of pollution.

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    C) Water, Peace and the Middle-East (J.A. Allan, Tauris Academic Studies, London 1996).

Table 2.2: Local Water Resources: Development Potential (until 2040) *
(*REF. 3193, REGIONAL PROJECT, GTZ, GERMANY)

Core Party Area	Local Option	Incremental Development (MCM/a)	Investment Cost (MUS$)	Unit Water Cost (US$/m³)
Israel	Conventional Water Resources	25	n.a.	0.30-0.70
	Loss Reduction	(25)	n.a.	n.a.
	Treated Wastewater Reuse	841	n.a.	0.05-0.30
	Brackish Water Desalination	(30)	n.a.	0.30-0.57
	Fresh Water Supplies	25	n.a.	
	Treated Wastewater Supplies	841	n.a.	
Jordan	Conventional Water Resources	306	1494	0.23-0.27
	Demand Management	(287)+20	352	0.21-0.28
	Treated Wastewater Reuse	470	2221	0.57
	Brackish Water Desalination	74	450	1.00
	Fresh Water Supplies	400	2298	
	Treated Wastewater Supplies	470	2221	
West Bank	Conventional Water Resources	80	315	0.35-0.72
	Demand Management	(72)	76	0.01-0.38
	Treated Wastewater Reuse	84	266	0.38
	Brackish Water Desalination	(50)	(148)	0.32-1.23
	Fresh Water Supplies**	80	391	
	Treated Wastewater Supplies	84	266	
Gaza Strip	Conventional Water Resources	1	8	0.54
	Demand Management	(40)	42	0.06-0.12
	Treated Wastewater Reuse	65	205	0.41
	Brackish Water Desalination	(20)	112	0.39-0.41
	Fresh Water Supplies**	(30)+1	162	
	Treated Wastewater Supplies	65	205	
Region	Conventional Water Resources	462		
	Demand Management	(384)+20		
	Treated Wastewater Reuse	1460		
	Brackish Water Desalination	(60)+74		
	Fresh Water Supplies**	556		
	Treated Wastewater Supplies	1460		

Notes: [illegible]

a. Making available all relevant data.

b. Determining the appropriate occasions for drilling of wells.

10. In order to enable the implementation of paragraph 7 above, both sides shall negotiate and finalize as soon as possible a Protocol concerning the above projects, in accordance with paragraphs 18 - 19 below.

The Joint Water Committee

11. In order to implement their undertakings under this Article, the two sides will establish, upon the signing of this Agreement, a permanent Joint Water Committee (JWC) for the interim period, under the auspices of the CAC.

12. The function of the JWC shall be to deal with all water and sewage related issues in the West Bank including, *inter alia*:

a. Coordinated management of water resources.

b. Coordinated management of water and sewage systems.

c. Protection of water resources and water and sewage systems.

d. Exchange of information relating to water and sewage laws and regulation

e. Overseeing the operation of the joint supervision and enforcement mechanism.

f. Resolution of water and sewage related disputes.

g. Cooperation in the field of water and sewage, as detailed in this Article.

h. Arrangements for water supply from one side to the other.

i. Monitoring systems. The existing regulations concerning measurement and monitoring shall remain in force until the JWC decides otherwise.

j. Other issues of mutual interest in the sphere of water and sewage.

13. The JWC shall be comprised of an equal number of representatives from each side.

Costs and cost reduction

The last decade has seen massive reductions in costs in all three main cost areas: capital, power, operation and maintenance. This is due mainly to:

- Technological development
- Increasing size of plants
- Lower interest rate and energy cost
- Changes in project management
- Aggressive competition worldwide by equipment suppliers

Thus, for example, the cost of one cu. meter of desalinated seawater dropped from one dollar in the early 90s [3,4] to 70 to 80 cents over seven years.

The cost of a typical plant of 20,000 cu.m./day output, erected at the beginning of the decade in the Canary Isles was about $20 million in capital outlay. The desalinated water cost was about one dollar, apportioned as follows:

■ Capital charges at 8% for 20 years	30 cent/cu.m
■ Power costs 5.5 kWh/cu.m. @ 8 cents	44 cent /cu.m
■ Operation and maintenance	24 cent /cu.m
■ Total	98 cent /cu.m

By comparison, the capital cost of a plant of equal capacity in Eilat [5], Israel, which commenced operations in 1997, and will produce 20,000 cu. meters per day by 2000, is also $20 million, but the cost of water is 25% less, as shown below:

■ Capital charges at 6.5% for 20 years	27 cent /cu.m
■ Power costs 4 kWh/cu.m. @ 6 cents	24 cent /cu.m
■ Operation and maintenance	21 cent /cu.m
■ Total	72 cent /cu.m

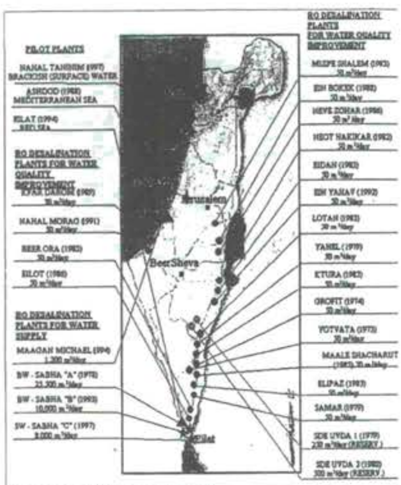


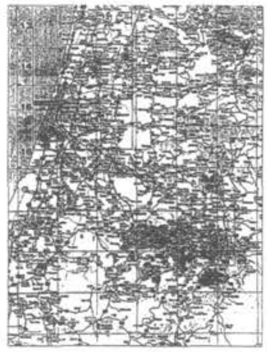
Fig. 2: Distribution of MEKOROT'S Desalination Systems (1998)

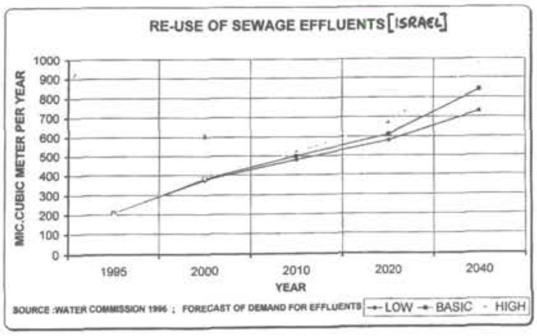
Table 1. Main parameters of biological treatment, annual averages 1997 (Soffer et al., 1997)

Parameter	Raw Sewage	Polishing Pond effluent	Removal (%)	Activated sludge effluent	Removal (%)
Suspended Solids (105o), mg/l	380	32	91.6	8	97.9
BOD, mg/l	422	19	95.5	6	98.6
COD, mg/l	1,020	105	89.7	53	94.8
COD(filtered), mg/l	339	60	82.3	42	87.6
Ammonia(filtered) - N, mg/l	39.9	9.4	76.4	7.3	81.7
Total N, mg/l	63.3	16.5	73.9	10.8	82.9
Phosphorus, mg/l	14.4	5.6	61.1	2.7	81.2
Total Bacteria, log conc.	7.17	5.80	19.1	5.46	1.7
Coliforms, log. Conc.	8.22	5.45	33.7	5.34	2.9
Faecal Coliforms, log conc.	7.27	5.12	29.6	4.29	3.0
Chloride, µg/l	297	318	--	289	--
Boron, mg/l	0.62	0.60	--	0.55	11.3

Wastewater Treatment and Groundwater Recharge

Dan Region Reclamation Project





Fertigation technology

- Drip Fertigation - superior fertigation method.
- The additional advantages of Drip technology in wastewater reuse:
  - Higher growth potential - faster nutrients expor
  - Highly controlled, growth, environment.
  - Health risks- a safer application, odors free.

vvastewater reuse in tree production

- Irrigated forestry is in its infancy
- Waste water irrigation in forestry has an advantage over agriculture
  - -Health factors
  - -Economic values
  - -Social and Aesthetic concerns

Productive purposes

- Wastewater is enriched with minerals nutrients.
- Crops irrigated with WW can produce yields as high and sometimes even higher than those with clean water.
- Reuse saves the cost of fertilizers and the cost of treating the wastewater to reduce the nutrients content.

Conservation of water

- A key issue in arid and semi arid area.
- Substitution of clean water by wastewater:
  -Avoid overexploitation and sallinization of groundwater.
  -Recharge groundwater for later use.
  -Release clean water for domestic use.

Introduction

- Reuse of wastewater for irrigation is:
  - safe
  - environmentally sound
  - cost efficient way to treat & dispose
  - turning a major liability into an asset.

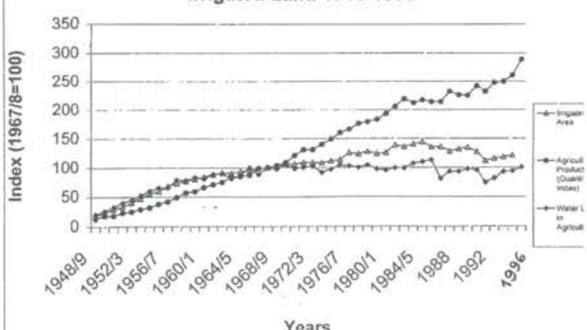
NETAFIM

Introduction

- Economic & Population growth & consumption pattern, led to number of environmental and economical problems.
- Waste water disposal and clean water scarcity, two major problems countries are seeking a solution for.

Waste water reuse

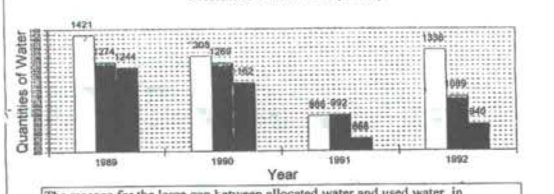
Figure 1: Agricultural Production Water Use and Irrigated Land 1948-1995



appendix: Just, Horowitz, Netanyahu - 1994

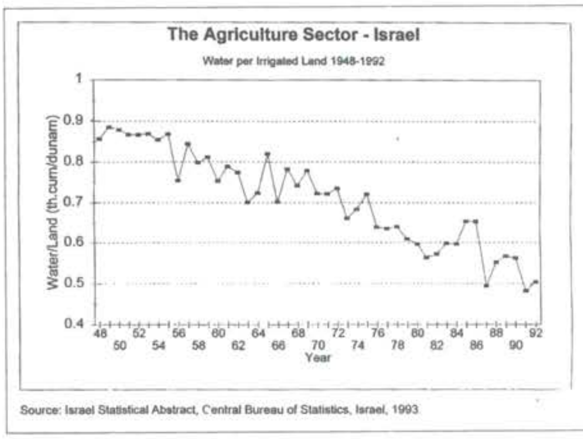
The Agricultural Sector - Israel

Allocation and Use of Water (in mcm)



The reasons for the large gap between allocated water and used water in 1992 are: (1) a particular rainy & long winter season, (2) high water prices, (3) a reduction in dunums planted due to low profitability.

Source: The Agricultural Sectors: 1991-2. Ministry of Agriculture & The Jewish Agency Israel January 1994

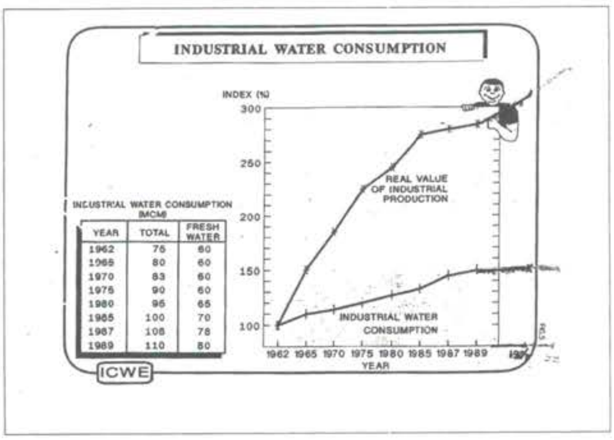


Industrial water conservation and cost- effectiveness, selected companies, San Jose, California.

Company	Water use: Before conservation	After conservation	Water savings	Payback period on investment
	(thousand cubic meters / year)		(percent)	(months)
IBM*	420	42	90	3.6
California Paper-Board Corp.	2,473	689	72	2.4
Gangi Bros. Food processing	568	212	63	10.8
Advanced Micro Devices	2,098	1,318	37	7.2**
Tandem Computers	125	87	30	12.0
Dyna-Craft Metal Finishing	193	140	27	2.4

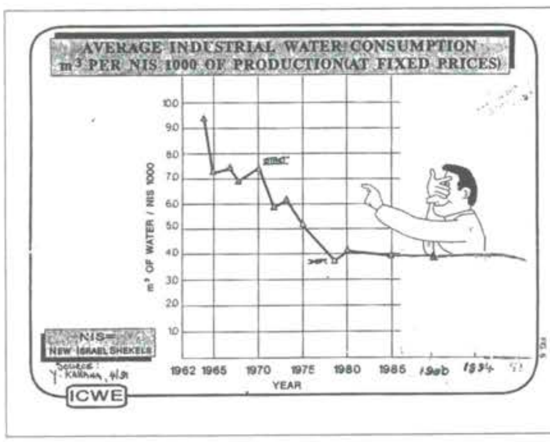
* Water use rates apply only to one or more processes involving conservation measures.
** Payback based only on that portion of water savings with which costs could be associated.

Source: City of San Jose, Brown & Caldwell consultants, and California Department of water resources, case studies of industrial water conservation in the San Jose Area (Sacramento, CA. Calif. Department of water resources, 1990).



INDUSTRIAL WATER CONSUMPTION (MCM)

YEAR	TOTAL	FRESH WATER
1962	75	60
1965	80	60
1970	83	60
1975	90	60
1980	95	65
1985	100	70
1987	105	75
1989	110	80



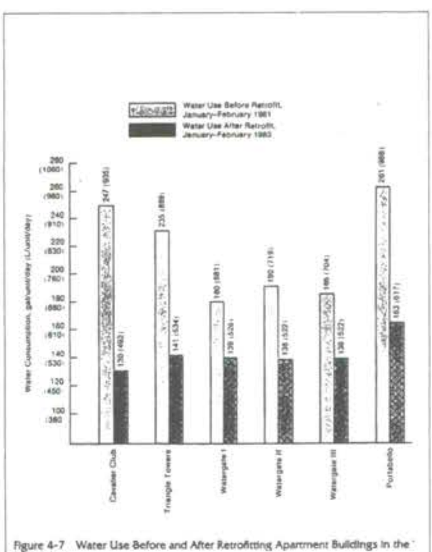


Figure 4-7 Water Use Before and After Retrofitting Apartment Buildings in the D.C. Area

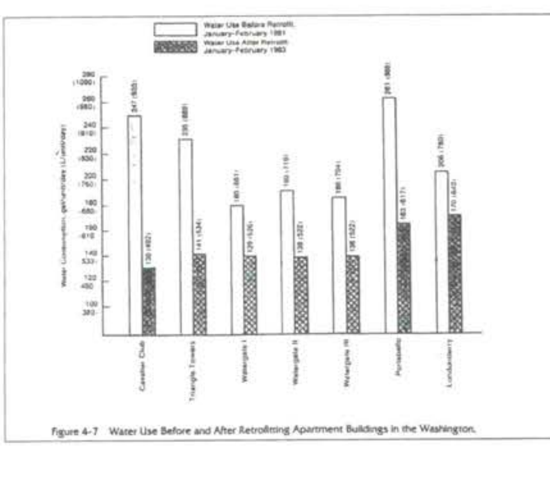
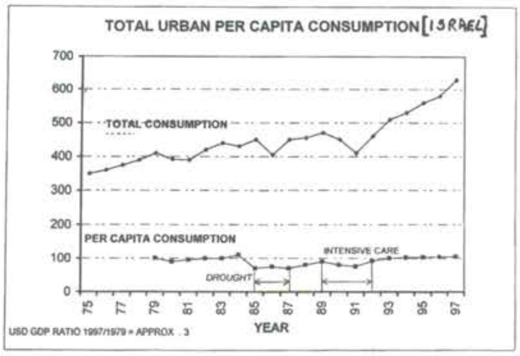


Figure 4-7 Water Use Before and After Retrofitting Apartment Buildings in the Washington.



Summary of Inside Water-Saving Devices

Devices applicable to new homes and installed at the time of construction are listed in Table 4-7. Also shown are the bases for estimating water savings.

The water savings associated with the most commonly available retrofit devices are tabulated in Table 4-8.

Table 4-7 Water-Saving Devices for New Construction

Application	Water-Saving Device	Function	Water Savings	Estimated Unit Water Savings gpcd (L/d per capita)
Toilet	Low-flush toilet—3½ gal/flush (13 L/flush)	Reduce flush volume	2 gal/flush (8 L/flush)	8.0 (30.3)
Toilet	Ultra-low-flush toilet—1½ gal/flush (6 L/flush)	Reduce flush volume	4 gal/flush (15 L/flush)	16.0 (60.6)
Shower	Reduced-flow shower head—2.75 gpm (10.4 L/min)	Reduce shower-flow rate	1.5 gpm (5.7 L/min)	7.2 (27.3)
Faucet	Aerator with flow control	Reduce splashing, enhance flow aesthetics, create appearance of greater flow	—	0.5 (1.9)
Appliances	Water-efficient dishwasher	Reduce water requirement	5 gal/load (19 L/load)	1.0 (3.8)
Appliances	Water-efficient clothes-washing machines	Reduce water requirement	6 gal/load (23 L/load)	1.7 (6.4)
Hot-water system	See text	Reduce hot water	—	—

Source: Brown and Caldwell Consult. Engrs., Walnut Creek, Calif. (1984).

Table 4-8 Retrofit Devices for Existing Housing

Application	Water-Saving Device	Function	Water Savings	Estimated Unit Water Savings gpcd (L/d per capita)
Toilets	Two toilet-tank displacement bottles	Reduce flush volume	½ gal/flush (1.9 L/flush)	2.0 (7.6)
Toilet	Water-closet dam	Reduce flush volume	1 gal/flush (3.8 L/flush)	4.0 (15.1)
Toilet	Toilet-tank bag	Reduce flush volume	0.7 gal/flush (2.6 L/flush)	2.8 (10.6)
Shower	Flow restrictor	Limit flow to 2.75 gpm (10.41 L/min)	—	3.7 (14.0)
Shower	Reduced-flow shower head	Limit flow to 2.75 gpm (10.41 L/min)	1½ gpm (5.7 L/min)	7.2 (27.3)
Faucets	Aerator with flow control	Reduce splashing, enhance flow aesthetics, create appearance of greater flow	—	0.5 (1.9)
Toilet leaks	Ballcocks, flapper valves	Stop leaks	24 gal/day/toilet (91 L/day/toilet)	

Source: Brown and Caldwell Consult. Engrs., Walnut Creek, Calif. (1984).

TABLE 1 : FINDINGS FROM A NUMBER OF SURVEYS ON THE SAVING OBTAINED FROM INSTALLATION OF "IN – HOUSE" WATER SAVING DEVICES

[illegible]	[illegible]	[illegible]	SAVING OBTAINED (%)	COMMENT
POLICE STATION & OTHER INSTALLATIONS	1989-4 MONTHS	FLOW-CONTROLED SHOWER HEADS AND FAUCETS DUAL – FLUSHING CISTERNS	50	LEAKAGES ALSO REPAIRED ; NO DEFECTS OR COMPLAINTS REPORTED
MIZRA BOARDING SCHOOL	1988-89 1 YEAR	FLOW-CONTROLED SHOWER HEADS	30	NO DEFECTS OR COMPLAINTS REPORTED; HOT WATER SAVING
APARTMENTS IN BAVLI AREA OF TEL-AVIV	1987-4 MONTHS	DUAL – FLUSHING CISTERNS	13.5	NO DEFECTS OR COMPLAINTS REPORTED
MA'ALE EFRAIM APARTMENTS (300)	1991	FULL RETROFIT SET	36%	NO DEFECTS OR COMPLAINTS REPORTED
EILAT 3500 APART.	1991	FULL RETROFIT SET	16%	NO DEFECTS OR COMPLAINTS REPORTED

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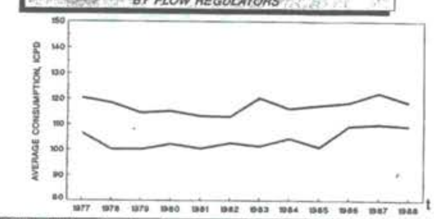
BE'ER SHEVA : WATER SAVING IN A RESIDENTIAL ZONE BY FLOW REGULATORS



CONSUMPTION LCPD	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
NO REGULATION	120.5	118.5	114.6	115.3	113.4	113.1	120.5	116.3	117.6	118.7	122.6	118.9
WITH REGULATION	106.6	[illegible]	100.2	102.3	100.6	102.7	101.5	104.6	101.1	109.4	110.2	109.9
SAVING LIT/DAY	13.9	18.3	14.4	13.0	12.8	10.4	19.0	11.7	16.5	9.3	12.4	9.4
SAVING IN %	11.5	15.4	12.6	11.3	11.3	9.2	15.8	10.1	14.1	7.8	10.1	7.9

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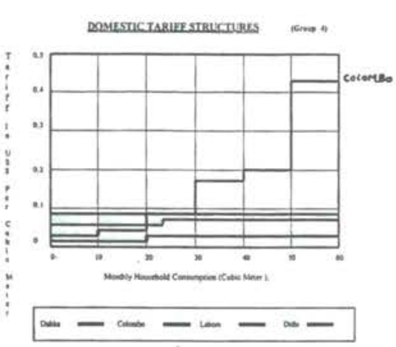
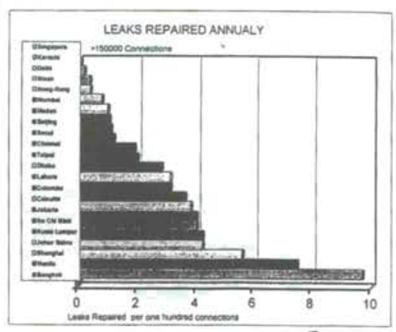
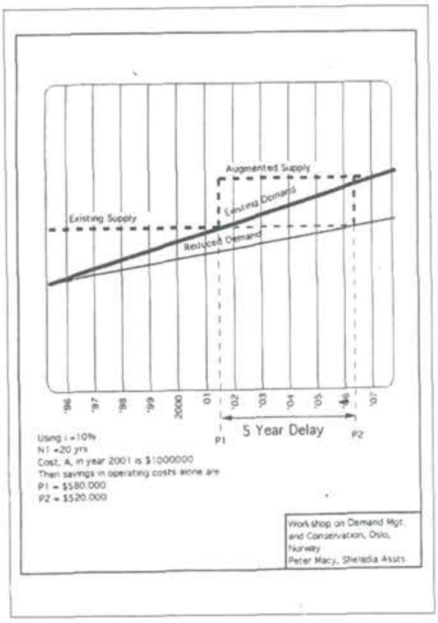
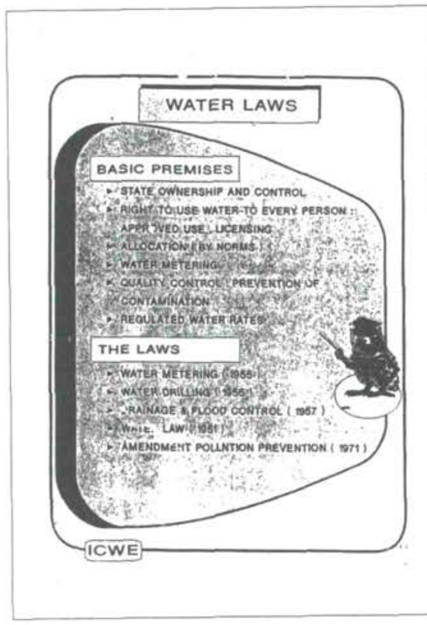




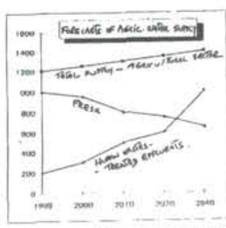




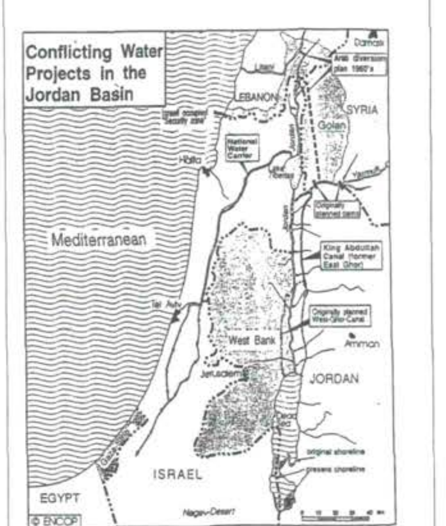
WATER CONSUMPTION FORECASTS

(ISRAEL + GAZA + WEST-BANK)
(MILLIONS OF CUBIC METER PER YEAR)

DEFICIT Shortage-tion	Sewage effluents Agric.	Fresh water Agric.	Existing resources Total	Sewage	Fresh	TOTAL	SECTOR Agric.	SECTOR Urban Domestic Industrial	POPULATION in millions	YEAR
-	200	1000	2000	200	1800	1900	1200	700	7.4	1990
60	300	860	2100	300	1800	2160	1260	900	8.9	2000
150	500	800	2300	500	1800	2450	1300	1150	10.9	2010
380	600	790	2400	600	1800	2790	1360	1440	13.4	2020
890	1000	650	2800	1000	1800	3440	1400	2040	19.18	2040



BASIS: (1) LIMITED DEMAND MANAGEMENT EFFORTS + IMPACT.
(2) CONTINUED TRENDS IN AGRICULTURE OF ISRAEL AND THE PALESTINIAN AUTONOMY.
SOURCE: WATER COMMISSIONER'S OFFICE, ISRAEL, 1995



NATIONAL WATER CARRIER + MAIN CONNECTIONS

Fresh water availability in the Jordan Basin region in 1990 compared to selectèd other countries in thr world

Country	Yearly per capita fresh water availability (in cubic meters)	Yearly population growth and expected population doubling (at current rates)
Palestine (West Bank/Gaza)	100	3.2 % / (22 yr.)
Jordan	220	3.4 % / (19 yr.)
Israel	370	2.6 % / (27 yr.)
Lebanon	1,780	1.9 % / (34 yr.)
Syria	2,830	3.5 % / (18 yr.)
Iraq	5,285	3.1 % / (21 yr.)
Egypt	1,100	2.1 % / (31 yr.)
Saudi Arabia	160	3.3 % / (20 yr.)
Qatar	55	2.3 % / (24 yr.)
India	2,440	1.8 % / (35 yr.)
Switzerland	7,565	0.6 % / (116 yr.)
USA	9,951	1.0 % / (70 yr.)

Figures on water availability consider only natural renewable resources. Note that in the case of upstream riparians of great rivers like Syria or Switzerland the national account includes water amounts which in reality are used or claimed by downstream riparians.
Sources: World Resources Institute (1992): World Resources 1992-93, New York, Oxford. Population projections according to UNDP (1994): Human Development Report 1994, New York, Oxford, own accounts.

TABLE 1. POPULATION PROJECTIONS
(in millions)

	1991	2000	2020	2040
Israel *	5.0	6.5	9.1	12.8
West Bank	1.0	1.4	2.6	3.8
Gaza	0.7	1.0	1.7	2.6
Jordan *	3.6	5.3	9.9	16.9
Total	**10.3**	**14.2**	**23.3**	**36.1**

* Median Projection

Source: World Bank estimates

PROBLEM STATEMENT

• *"WATER PROBLEMS EXIST WHEN WATER IS NOT AVAILABLE IN THE PROPER PLACE, TIME AND QUALITY"*

The water allocation system model General principles

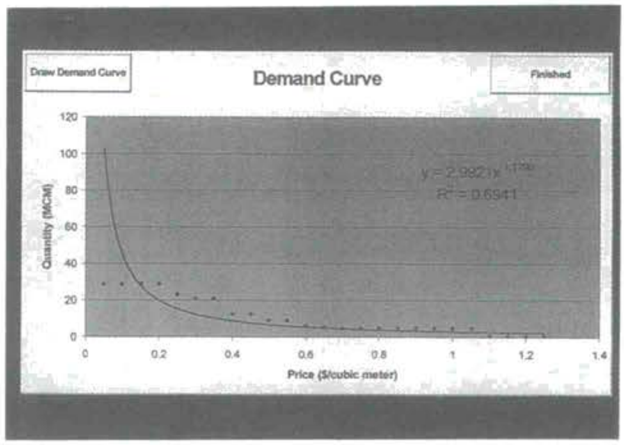
- Water is an economic commodity, once all social values are taken into account
- Issues of ownership and use are separate
- Allocation of water among consumers in a number of districts
- Consumers: urban, industrial, agricultural
- Two water qualities: fresh and sub-potable (recycled wastewater, floods, brackish, etc.)
- About 20 districts, corresponding to existing divisions

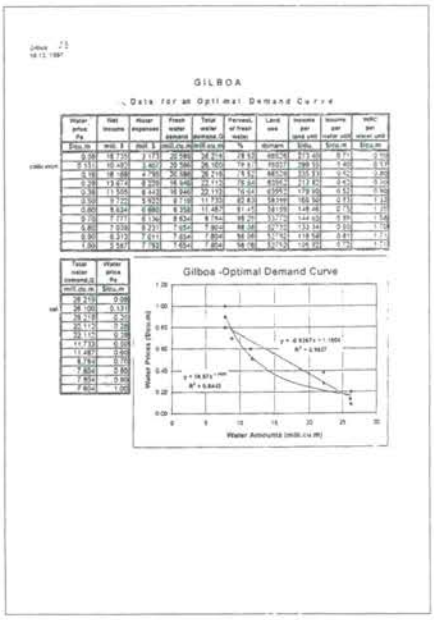
Model Use

- Can investigate the effect of different assumptions regarding the amount of water available to Israel from various sources, and hence of different arrangements with the neighbors

Agricultural Sub-model (AGSM)

AGSM provides an analytical tool to optimize the use of agricultural resources, especially water and land, in order to maximize the net income generated from agricultural crops.





Proposed Project Country Activities

General

The general project objective is to promote the improvement of efficiency of water use in the urban areas of Africa through joint activities in a number of selected and agreed cities, to introduce WDM measures and instruments at the city level.

The role and TOR of UNCHS / HABITAT is of a technical assistance nature, promoting and assisting in the implementation of actions to broaden city and nation wide understanding and support to the importance and potential costs / benefits of WDM policies and strategies of execution.

The project length and budgetary capacity is limited, it was therefor decided, following consultations with African decision makers and sector professionals, **to focus our joint actions on actions which can bear fruits in a relatively short period with a minimum capital investment** and to avoid those which demand lengthy decisions making process, and high capital investments.

Therefor the project will focus on promoting WDM plans, policies and strategies, demonstrating water conservation technologies (retrofitting) at the end user and **public awareness avoiding the expensive and lengthy operations like** Unaccounted for water reduction, replacement of worn pipes, installing or completing comprehensive water metering systems and introduction of significant changes in the water pricing policies. These activities are important and form integrated components of an effective urban water demand management, however fall out of the capacity and the scope of this project.

WATER IS FREE

Wherever you find it, water is free.
Deep in a well or out of the sea.
Get all you want wherever you go;
Read the simple directions below.

Put a barrel under the spout,
Collect the rain the clouds give out.
While it's falling, don't be placid;
Some of those drops are full of acid.

With a bucket you can bring
All you want from pond or spring.
But watch for wiggler or bacillus;
Some of those bugs are sure to kill us.

Put muddy water in a kettle.
Leave it for the mud to settle.
But that won't get rid of everything.
Better add a shot of chlorine.

Build a dam across a creek
And do it well so it won't leak.
Then lay a pipe, the cost ain't hay.
Be sure to get a right of way.

Dig a hole both deep and round;
That's where lots of water's found.
Pumps are needed, so are tanks.
You pay for them with more than thanks.

Your water works adds this last line:
Delivery is where we shine.
We can't sell water because it's free.
We sell pressure and purity.

Integrated Approaches to Efficient Water Use in South Africa

Dhesigen Naidoo & George Constantinides
Department of Water Affairs and Forestry, Republic of South Africa

It remains difficult to address any resource issue in South Africa without first considering the impact of the past 300 hundred years in general and the past fifty years in particular. The formal Apartheid years (1948 – 1994) and the preceding 250 years has left a legacy of inequitable access and development of resources. The current profile of water access and servicing in South Africa can to large measure be explained by this policy.

Some key features of the current profile are:

1. Prioritisation of water for commercial agriculture. Agriculture currently uses approximately 54% of available water primarily servicing white owned farms. This constitutes more than 83% of arable land. In many instances the question of most beneficial use of water arises.
2. The location of major industry far away from the major water river systems and the expansion of those industrial developments beyond the capacity of the existing water supply. This has meant that large expensive interbasin transfer schemes have become popular water solutions in the South African environment.
3. The third key characteristic is probably the most visible consequence of the social engineering that was Apartheid and that is the differential domestic servicing within the paradigm of South Africa's unique class system based on race. The net result is that we have reasonable reticulation efficiency in the white suburbs and quite the opposite in black townships where minimum nightflows of greater than sixty percent are not at all uncommon. In addition it is estimated that out of our population approximately 40 million people, 9 to 12 million of those people do not have reasonable access to potable water.

This describes the environment within which the South African water industry operates and some of the key factors that advised the development of the new water legislative framework for the new democratic South Africa. The cornerstones of this legislative framework are two recently promulgated acts – the Water Services Act (108 of 1997) that informs all decision-making around treated water and the National Water Act (36 of 1998)

The key features of the acts are:

1. The naming of the Minister as the custodian of all waters and water resources in South Africa on behalf of the South African people. This implies that the concept of water ownership and water rights fall away and rights of access to water and the resource have to be secured through a mechanism of fixed period conditioned licences for water use.
2. A new governance regime for water based on the catchment model has been introduced in a manner that allows maximum participation within the subsidiarity concept.
3. The embracing of water conservation and demand management as key drivers toward efficient water use.

WATER CONSERVATION AND DEMAND MANAGEMENT PARADIGM as the key driver to promote EFFICIENT WATER USE.

The realities of the new democratic South Africa necessitate improved management of our limited economic and water resources. South Africa is a developing country that is water scarce and water stressed. The implementation of WC/WDM paradigm is essential not only for the sustainability of water resources and the environment but also for economic efficiency and social development. The performance paradigm for water resource management in South Africa is currently changing significantly through the recognition of the principles of Integrated Resource Planning (IRP) which recognises the opportunities of WC/DM and the need to focus on the consumers.

Water resource planning in South Africa was, until recently, completely supply management driven. This was based on developing new water resources to meet water demand projections. The demand projections were often extrapolations of past trends. Demand analysis of existing water usage was ignored. Detail demand analysis was limited with very little understanding on the drivers of future demand and even less recognition and appreciation of existing inefficient water use. The objective was to meet the perceived growth in demand by developing the most cost effective water augmentation scheme. This approach ignored that the most cost effective water augmentation scheme may not be the most effective and efficient solution for the consumers, users, environment and society in general.

Another characteristic of the previous paradigm in South Africa (also consistent with the conventional international paradigm) is the conservation of water by preventing the waste of water to the ocean. This often meant the allocation of all available water resources to consumers and users with few regulations and restrictions associated with water permits. Consequently a large percentage of consumers use water inefficiently, particularly in the agriculture sector, often at the cost of the government due to subsidised water schemes. Furthermore this policy does not promote social equity as it is does not adequately consider the rights of new consumers and future generations.

WC /DM paradigm for Water Services Institutions

Until recently, Water Boards, Local authorities, and Services Councils were relatively unregulated by national government with regards to their functions to deliver water services. One of the major issues which made water services less important from a water resource perspective was the fact that less than 10% of the total water resources is used by the urban/domestic sector. This, however, is misleading because the development of future water augmentation measures over the last decade and for the future is directly related to the increase in demand of this sector. There is an acceptance in the South African context that the agriculture and mining sectors are moving into negative growth patterns.

The new paradigm requires that service providers become accountable and responsible to their consumers. This is not only because of the water scarcity constraints but also in terms of optimising economic efficiency and meeting the service delivery backlogs, which have accrued during the Apartheid years. Water institutions in the past have not been adequately held accountable for their performance. This combined with the social political past has resulted in significant financial losses and varying levels of services between communities.

The paradigm of WC/DM will shift the focus to the consumer by striving to achieve economic efficiency in order to ensure sustainable and affordable water services as well as allow the reallocation of water resources and capital infrastructure capacity from inefficient usage to meet the water demands of the new consumers.

INTRODUCTION TO THE WATER CONSERVATION AND DEMAND MANAGEMENT STRATEGIES IN SOUTH AFRICA

The Department of Water Affairs and Forestry (DWAF) is spearheading a process to develop national and regional strategies on water conservation and demand management in South Africa. The process has the following key steps:

Phase 1: Development of a WC/DM National Strategy Framework (NWCSF)

Phase 2: Development of sectoral strategies for the following water use sectors:

- Phase 2.1: Domestic water use / LA level
- Phase 2.2: Agriculture and Forestry use
- Phase 2.3: Industry,mining and power generation use
- Phase 2.4: Environment and water resource

Phase 3: Development of a model regional strategies to be incorporated into the catchment strategies

Phase 4: Consolidation of the WC/DM National Strategy Framework and the sectoral strategies for inclusion into the National Water Resources Strategy.

Phase 5: Development of regulations, procedures and guidelines For implementation

These processes have as their development partners all the significant role-players in the water sector to ensure both a practical strategy as well as buy-in of the implementation agents.

WC/DM Strategy

The terms Water Conservation and Demand Management are continuously referred to in South Africa because of their different meanings and emphasis. It is important to note that WDM is not limited to WDM measures but is considered in its wider concept as a strategy to meet various goals and objectives which do not refer only to efficient water resource management and ecological sustainability, but also to economic efficiency, social development and social equity.

The definition of water conservation adopted in the South African NWCSF is:

> **"The minimisation of loss or waste, the preservation, care and protection of water resources and the efficient and effective use of water."**

The definition of demand management proposed is:

> **"The adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability."**

A third concept which is integral to the new paradigm is Integrated Resource planning (IRP). IRP is the process that will determine the optimum mixture of demand side management or supply side management options.

The definition adopted for "Integrated Resource Planning" is:

> **" A way of analysing the change in demand and operation of water institutions that evaluates a variety of supply and demand factors to determine the optimal way of providing water services. A path is chosen that will ensure reliable services for the customers. This path must include: economic efficiency and stability, a reasonable return on investment for the institution, environmental protection and equity among ratepayers."**

The following objectives form the foundation of the WC/DM strategy currently been developed in S.A.

Objective A*: Create a culture of WC/DM within all water management and water services institutions*

Objective B*: Support water management and water services institutions to implement water WC/DM*

Objective C*: Create a culture of WC/DM for all consumers and users*

***Objective D**: Promote international co-operation and participate with other Southern African countries, particularly basin sharing countries, in developing joint WC/DM strategies.*

***Objective E**: Enable water management and water services institutions to adopt integrated resource planning (IRP)*

***Objective F**: To promote social development and equity*

***Objective G**: Contribute to the protection of the environment, ecology and water resources*

***Objective H**: Contribute the parameters of water economics to development planning processes*

An important point of application of these principles in a water management institution is the proposed Water Resource Development protocol being considered in DWAF. It introduces two new important phases to the classical protocol (Phase2 & 3). The first of these insists on the establishment of need in a supply area (Phase2). This includes assessing current reticulation efficiency using parameters like unaccounted for water as well as current use patterns judged against best practice benchmarks. An assessment of potential for WC/DM is to be conducted and the demand projections revised accordingly. This is followed in Phase 3 by the implementation of the prioritised steps of WC/DM as the first water augmentation option. Further assessments and evaluations will then advise the possibilities of infrastructure augmentation options viz. Dams, wiers and transfer schemes. (Appendix 1)

The following City case study illustrates some of the key elements of the NWCSF

URBAN CASE STUDY – Durban Metropole

The following is a case study in South Africa (S.A.) illustrating the benefits of implementing WDM measures and the benefits of introducing Integrated Resource Planning. The case study reviews the impact and potential of WDM in the Durban metropolitan area the second largest metropolitan area in S.A. situated in Kwazulu Natal province.

Background

"Durban Water and Waste" who receive the water from "Umgeni Water Board", (UW), and a bulk water supplier provide water services in the Durban Metropolitan area. Water demand by Durban Metro represents 80 % of the total sales of UW. The compounded growth rate of demand for the last ten years for Durban Metro has been approximately 6 % per annum reducing to 4% over the past five years. The population it serves is estimated at 2,6 million of which approximately 600 000 do not have access to adequate water services. The entire metropolitan area consists of both urban and rural settlements.

"Durban Water and Waste" is under the control of the Durban Metro Council. Prior to the change in the local authorities demarcation boundaries in 1995, water services in the Durban Metro were managed by a number of local authorities. Some of these local authorities did not have adequate capacity and resources for effective water services delivery, which resulted in high levels of unaccounted for water and inefficient water usage. With the consolidation of the smaller service providers with the much larger "Durban Water and Waste" the opportunities for effective service delivery management has increased considerably.

Water Demand Management Measures

Durban Water and Waste has undertaken and identified a number of WDM measures over the last two years which can be classified into the following five categories:

- Passive operational and maintenance measures on the distribution system
- Pro-active maintenance measures on the distribution system
- Customer demand management measures
- New consumer demand management measures
- Return flow management

Some of the measures described in the Customer Demand and return flow categories are in the planning phase and will be introduced fully in different phases over the next few years. The staggered introduction of some of these measures to prevent negative growth and therefore avoid the financial cost of foregone revenue by the service provider.

a) Passive operational and maintenance measures on the distribution system

The following measures have been developed over the last two years and are implemented as an ongoing programme:

- Computerised control room to manage reported leaks. There are 24 people on 24 hours standby and the target response time is 4 hours. Feedback is given to customers who reported the leaks in order to improve the image of the institution and improve the relationship with the consumers.
- The development of a centralised telemetry control of all reservoirs and pumps which minimises the pressure fluctuations and spillage.
- The introduction of water balancing between zone meters and consumer meters to determine the level of UAW in each zone or district helps to prioritise leak detection activities.
- Monitoring of minimum night flows. Data loggers are placed periodically on all bulk meters to evaluate the minimum night flow conditions and therefore assess the level of leakage.

b) *Pro-active operational and maintenance measures on the distribution system*

- Pressure zoning and pressure management. Pressure management is been introduced in a phased approach. The objective where possible is to reduce pressures to a maximum of 6 bar and reduce the fluctuation in pressures.
- Pipeline replacement programme
- Consumer meter management and replacement programme.
- Leak detection through sounding and calibration.
- Upgrading of mid-block distribution system in the "former black townships"

c) *Customer demand management measures*

- Introduction of rising block rate tariffs. The progressive increase of water tariffs can be periodically modified to impact on water demand. Studies are currently been done to assess the price elasticity of the various consumers.
- Zero rate on the basic lifeline tariff of 6kl per month per household. Although a zero tariff may appear to be the opposite of a WDM measure, the introduction it resulted in the overall reduction of water demand in a number of communities. The reason for this is because a large portion of the population which is poor now has the incentive of managing their water demand below 6 Kl/month without having to resort to illegal connections or resort to non-payment of services at the risk of been disconnected.
- Repair of plumbing within households of poor communities. A number of projects have already been undertaken together with the community to repair broken taps and toilets in the household of poor communities. There is still scope for such projects and it will be a number of years before all such areas are done.
- Increase in the frequency of consumer readings from once every three months to once every month. Although it is hard to quantify the effect of the recent increase in the frequency of meter readings is expected to have a decrease in demand for two reasons. Firstly consumers can manage their consumption based on their monthly bills more effectively and secondly because a consumer will be alerted to any abnormal high consumption caused by underground leaks on a shorter time scale.
- Introduction of informative billing. A new consumer bill format has been developed which is both informative and creative. The new format illustrates to consumers their current consumption trends, how they use water compared to other users, how the cost of water is calculated (with the block rate system) and allows for customised messages. This has only been implemented on a pilot project area and will be introduced to all consumers over the next few years. The pilot project indicated a potential reduction in demand of 7%.
- Credit control measures. Durban boasts a payment level for water services above 95%, which is one of the highest in the country. Up to 1000 disconnections of water are done each day to defaulting consumers.

d) New consumer demand management measures

The approach adopted in supplying communities with new water services in Durban has various options and is developed according to the affordability level and preference by that community. Various options of service delivery are given to new consumers and extensive public participation is done to ensure the acceptance of most people in that community. Community participation in the operation and maintenance of the system is also a key element of the approach adopted.

One example of is the non-pressurised water supply to poor communities through water tanks. Each consumer receives a 200 l water tank (or a multiple of tanks) which is filled by a water bailiff every day. This systems results in a low level of UAW due to low pressures and results in effective customer demand management. The overall water consumption through such a service delivery system is estimated to be up to 50% less than conventional systems to communities of similar profile.

e) Effluent return management

Durban Water and Waster following a detail economic and feasibility evaluation is currently developing a reclamation plant to treat 40 Ml/day and sell to the industrial consumer sector. This will result in a reduction of potable water demand by the same amount. Further phases of recycling effluent water will also be considered in the future.

Demand management targets

The introduction of WDM measures by Durban metro since 1997 have reduced the current demand growth to 0% and it is envisaged that the opportunities for WDM can offset the natural growth in demand and maintain a 0% growth for another 7 years. The UAW for water has been reduced from a calculated 41 % in January 1998 to 30 % by May 1999.

An additional reduction of up 35 % of the total consumption is assumed possible of which 15% will be from reducing water leaks and 20 % will be a reduction due the implementation of customer incentives and an increase in the efficient use of water. In addition to reducing existing water demand it is expected that the natural growth in demand will also be reduced from an estimated 4% to a maximum of 3%. The reduction in water demand by recycling to industry can also introduce further savings of up to 15%.

The economic value of the WDM measures

The are various economic tests that should be carried out from various perspectives. The two most important economic tests in evaluating the economic efficiency of a WDM measure are the Water Institution test and the total resource test. As an illustration to the economic viability of WDM the water institution test is illustrated below.

Water Institution test

The water institution test identifies the cost benefit to the water supply industry involved in the entire water supply chain in investing in demand management. In Durban there are three entities involved in the water supply chain, the Department of Water Affairs (DWAF) that develops the water resources, UW, and Durban Water and Waste. All three entities however are public or government institutions without any profit motives and for the purpose of the economic evaluation it is assumed that there is only one entity.

The cost evaluation is calculated using the following formula:

WIT = OS + IS – PC – FR

Where;

OS = PV (all operating cost savings by the Water Institution)
IS = PV (all savings due to deferred infrastructure capital costs)
PC = PV (all costs to implement the WDM measures)
FR = PV (Foregone revenue for the water institution as a result of reduced demand charges)

A detail analysis on the economic value of the WDM measures is currently been analysed but a rough estimated using approximate values is calculated using the following information:

- A discount rate of 7%
- The capital cost for further augmentation schemes over the next 15 years is R 1,5 billion. This is illustrated in table 1 below.
- The capital cost for further bulk infrastructure to meet the estimated under the current demand projections without any WDM measures is estimated at R 1,5 billion over the next 20 years. (It is assumed that the cost disbursement is equal over the next 20 years, i.e. 75 million per annum.
- The net operating cost of water supply is 70 cents per kilolitre. This includes treatment and electricity costs of both water supply services and wastewater services.

Table 1: Water Resource Infrastructure requirements

Infrastructure component	**Date required without WDM**	**Date required with WDM**	**Cost (R million)**
Midmar Dam rising	2000	2001	23.3
Mearns dam	2001	2004	87.5
Spring Grove dam	2003	2010	104.65
Impendle Scheme (Phase 1)	2008	2020	807.75
Impendle Scheme (Phase 2)	2016	2030	469.00
Nzinga Abstraction Works	2004	2011	5.92
Bulwer Dam	2006	2014	17.84

The calculations are illustrated in table 2 and are summarised as follows:

Present value of savings due to deferred water resource infrastructure capital costs for the next 15 years

= R 632,73 million – R 142,48 million
= **R 490 million**

Present value of savings due to deferred bulk supply infrastructure capital costs for the next 15 years

= R 708,5 million – R 304,3 million
= **R 404,2 million**

Present value of savings due to avoided operating costs for the next 15 years

= R 2978,83 million – R 2361,02
= **R 617.81 million**

Present value of foregone revenue
(If demand is not allowed to decrease and WDM offsets the natural growth in demand)

= **R 0**

The economic value to the water supply institutions to achieve the proposed WDM targets is therefore estimated at R 1 512.01 million over the next 15 years, or R 100.8 million per year, minus the cost of implementing the WDM measures.

Conclusions

South Africa is on the brink of a new era in integrated water resource management. This is a model based on increased efficiency in water management and use and guided by the participatory governance principle. This is done against a background of tremendous resistance from the industry; an overwhelming imbalance in the resources available to the demand side practitioners vs. the supply side practitioners and a largely uninformed and to some extent disempowered consumer community. The programme needs to reinforce an embryonic public awareness and capacity building campaign as the first step. This begins with embracing the opportunities presented by the new legislative framework.

Appendix 1

A proposal for a protocol for Water Resource Development.
In South Africa

Background

This protocol is being proposed within the context of the following key factors

- The new legislative framework for water resources provided by the National Water Act as well as the Water Services Act implications for WRM
- The transition of DWAF from operating with a dominant supply-side approach paradigm to an integrated one that increasingly adopts key water conservation and demand management principles toward the efficient supply, allocation and use of water
- The increased recognition of water scarcity and value of water in South Africa
- The commitment to the goal of reasonable and equitable access to water to all who live in South Africa
- The need to integrate water quantity and quality considerations in WRD

Proposed Protocol

This proposed protocol is composed with the full recognition that many of its elements are either in place or appropriate gestures are being made in those directions. It is not meant as an indictment on any competency in DWAF and depends on the full co-operation of all relevant role-players to enjoy any degree of success.
The protocol will be described in each of its phases.

Phase 1 Indicators of need.

In response to a variety of stimuli the department recognises that there may be a need for increased water availability in a given supply area. This may come from direct appeals from the Water Services Institutions or specific consumer groups or as an externality result of another initiative.
In the future this may come more formally after the classification of the river systems, the calculations of the social and ecological reserves and the completion of the water services development plans.

Phase 2 Establishment of the Need

The need needs to be established with and appropriate study that must include the following elements:

- Current water balance which will of course include current use by sector
- Current use patterns and demand patterns
- An assessment of reticulation and water use efficiency (use of parameters like UfW, comparison of actual water use to BMPs etc)
- Establishment of the potential for WC/DM
- Perform demand projections and build in the WC/DM curtailment options
- Consider revised projections and make judgements of requirements Vs demand Vs need. [strong application of "more beneficial use" criteria]

Key roleplayers: Client (bulk supplier, TLC, DC); CD:P (D:WRP); CD:WUC (D:WC, WU, WQM); CD:SS (D:SES); CD:WS, RD and in the medium term CMA

Phase 3 Implementation of WC/DM (step1) as 1st Augmentation option
- Complete situ analysis
- Develop WC/DM programme and plans with time frames and KPIs
- Establish commitment and resourcing from the executive authorities
- Implement priority components of the plan (should usually include a metering project, multi-tier tariffing and UfW projects associated with a comprehensive communications and awareness campaign.)

Key roleplayers: Client; CD:WUC; RD, CMA

The following phases are not necessarily sequential and may work best in parallel. Each of the phases, however, depends on a thorough evaluation of the previous phases as well as an appropriate cost-benefits analysis of the options being considered

Phase 4 Implementation of WC/DM (Step2)
- 2nd phase actions of the WC/DM programme. May include further UfW projects, retrofitting etc.
- Continuous aftercare and evaluation

Roleplayers as above. Further steps of WC/DM may be required

Phase 5 Planning of classical supply augmentation options (Dams, wiers, transfers)
- Developing a list of appropriate construction options
- Examing the feasibilty of the options
- Prioritisation and selection
- Planning and appropriate assessments

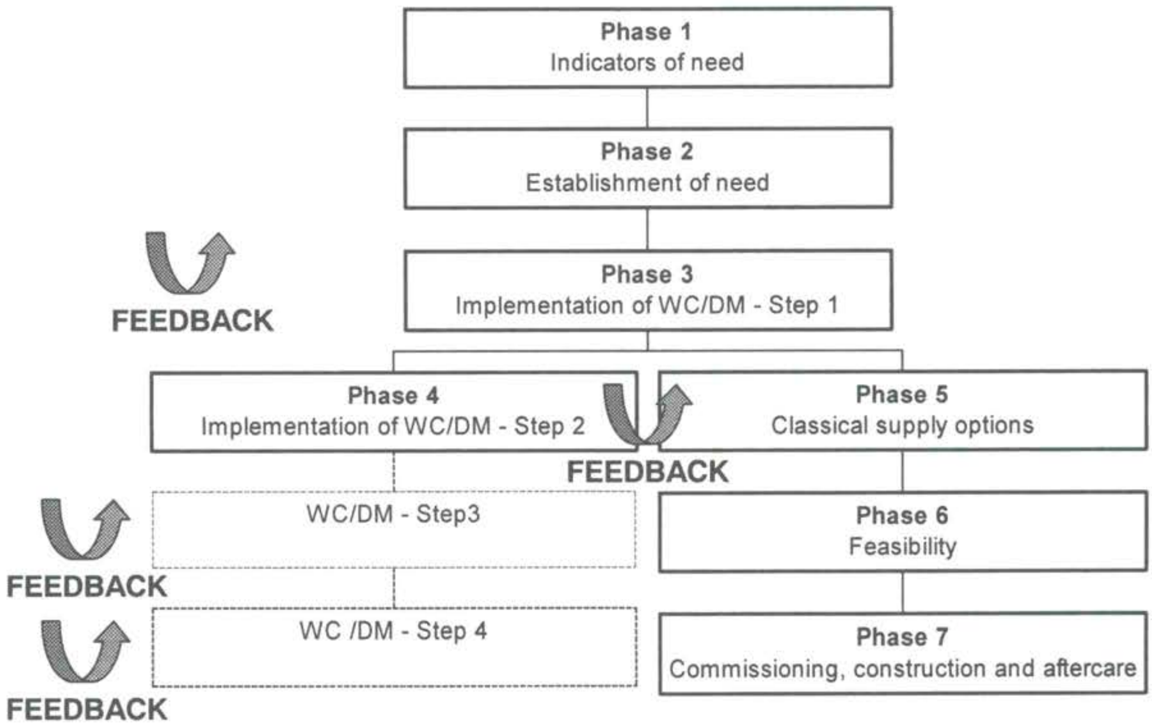
Key roleplayers : Client; CD:P; D:WRP, D:PP; CD:D; CD:SS; ENV AFF (national and provincial); RD, CMA, CD:WUC; D:WQM

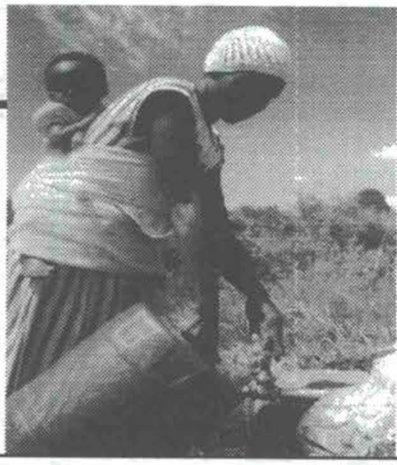
Phase 6 Commissioning, construction and aftercare
I would more help from WRP and PP to complete these sections.

Co-ordinating Structures

I is obvious from this protocol that a different engine of co-ordination **(EC)** may be required to drive it. This EC per water supply area may need to be a standing committee akin to Icomm whose role would be to review progress of the differenet phases of this protocol. The membership should include as a minimum representation from DDGs:P+R and D, CDs:WUC, D, P and SS. The different Ecs need to co-ordinated via a Water Resources Development committee (**WaReD**)

This may be useful in contributing toward our stated goal of Integrated Water Resource Management.





AN INTEGRATED APPROACH TO EFFICIENT WATER USE IN SOUTH AFRICA

Collaborators

- George Constantinedes (Greek)
- Tami Sokutu (Xhosa)
- Barbie Schreiner (German)
- Niel McCloed (Scottish)
- Charles Chapman (English)

Current Profile

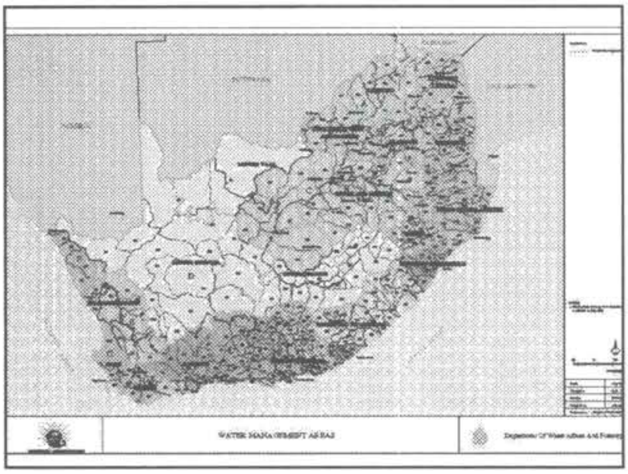
- Allocation profile - Agric prioritisation
- Developmental decision-making and the profile of water
- Inequitable access and servicing

New Legislative Framework

- White Paper on a National Water Policy
- Water Services Act (108 of 1997)
- National Water Act (36 of 1998)

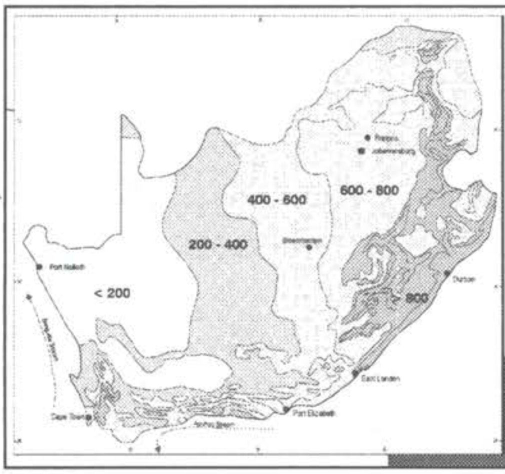
Key Legislative Features

- Water custodianship
- Use rights vs. ownership
- The reserve
- Catchment-based governance model
- Embracing of water conservation and demand management

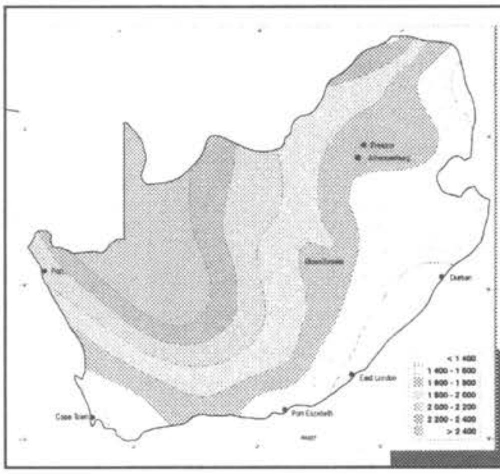


South Africa's Water Picture

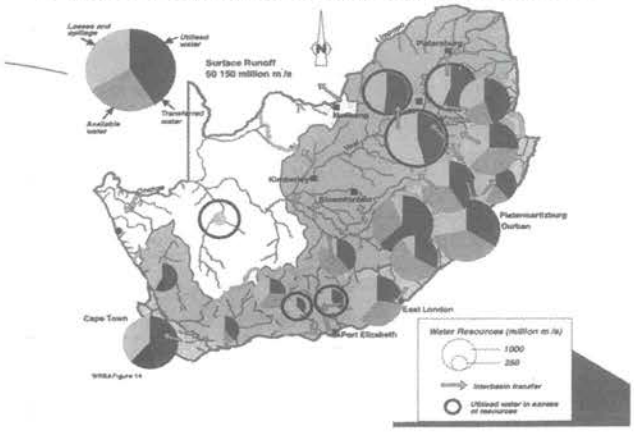
Variation in Precipitation throughout South Africa



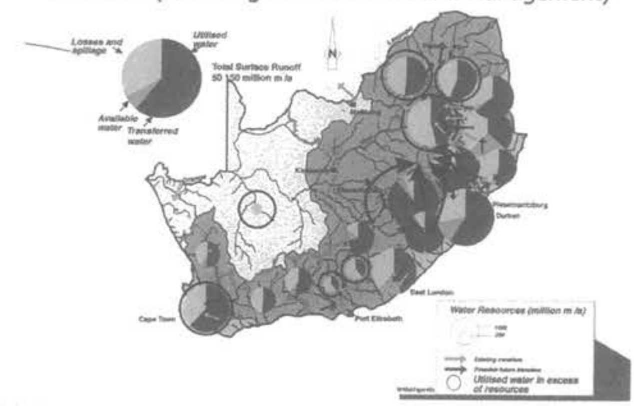
Potential Evaporation Throughout South Africa



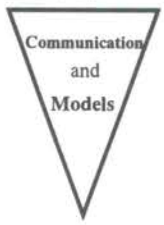
1996 Water Utilisation showing Interbasin Transfers

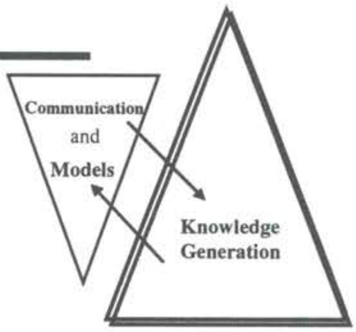


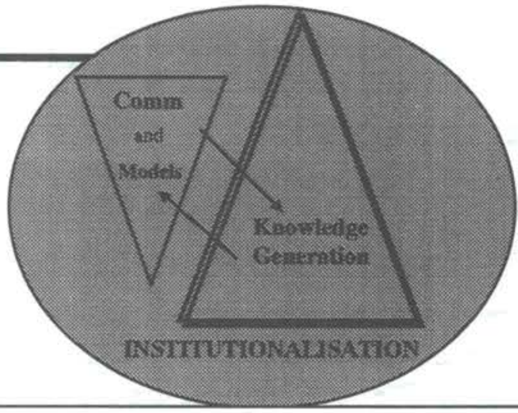
Future (2030) Water Utilisation showing Interbasin Transfers (assuming no Water Demand Management)



THE CHANGING PARADIGM OF WATER CONSERVATION AND DEMAND MANAGEMENT







Role of WC/DM

- *Sustainability of Resources*

  * Reconciling demand and supply

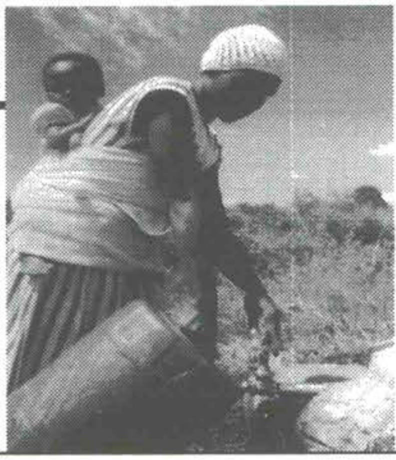
  * Protection of the environment and water resource

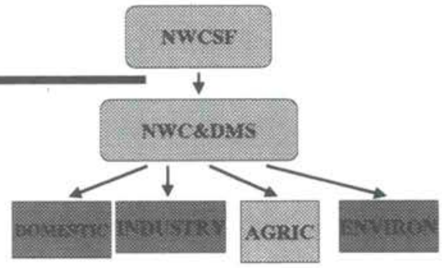
Role of WC/DM

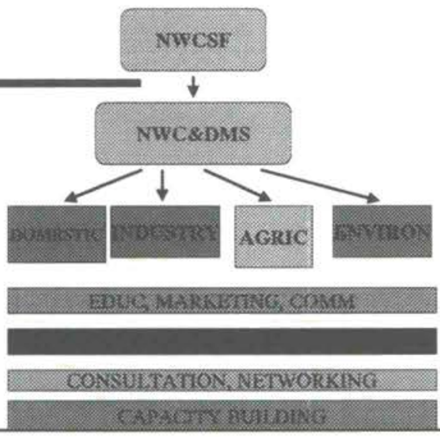
- *Sustainability of Services*

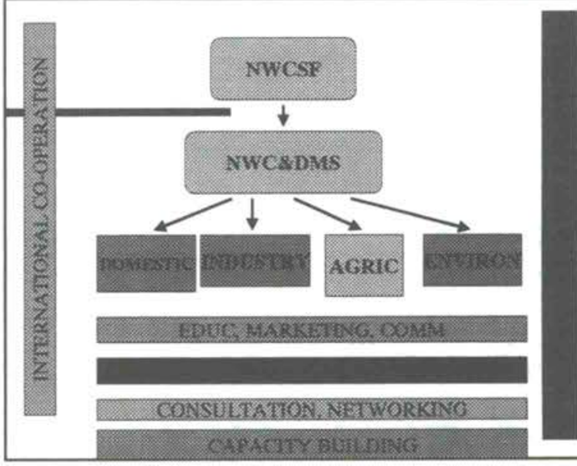
  *Maximise economic efficiency

  *Maximise social benefits (social equity and development)









Strategy Objectives

- Create a culture of WC/DM in all WMSIs

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- Create a culture of WC/DM in all WMSIs
- Support WMSIs in the implementation of WC/DM

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- Create a culture of WC/DM in all WMSIs
- Support WMSIs in the implementation of WC/DM
- Create a culture of WC/DM in all users
- Promote international co-operation

Strategy Objectives ctd

- Enable WMSIs to adopt IRP

Strategy Objectives ctd

- Enable WMSIs to adopt IRP
- Promote social development and equity

Strategy Objectives ctd

- Enable WMSIs to adopt IRP
- Promote social development and equity
- Contribute to the protection of the environment and water resource

Strategy Objectives ctd

- Enable WMSIs to adopt IRP
- Promote social development and equity
- Contribute to the protection of the environment and water resource
- Contribute parameters of water economics to development planning processes

WSA Impetus (Approach)

- Regulatory
- Incentive

WSA Impetus (Regulation)

- Water Services Development Plans
- Water Audit -
  * Measurement
  * Current use patterns
  * UfW and strategy for reduction

WSA Impetus (Regulation ctd)

- Pressure regulation
- Controlled water use
- Restrictions
- Recycling quotas

Urban Case Study Durban Metropole

Background

- 2nd largest metro in RSA
- Est population of 2.6 million
- ~600K without reasonable access to potable water
- Classical Apartheid planning

Water Services

- Water authority - Durban Water and Waste
- Is the 80% client of the bulk supplier - Mgeni Water
- Demand growth = 6% (last 10 years)
- Demand growth = 4% (last 5 years)

WDM Measures

- Passive O&M on the distrib system
- Proactive maintenance on ds
- Customer demand measures
- New consumer demand measures
- Return flow management

DM Targets

- Growth rates from 1997 -> 1999 = 0%
- Can be maintained at 0% for 7 years
- May be reduced to -10% with new recycling options for industry
- UfW 41%(Jan 98) -> 30%(May 99)

Economic Value of WDM
(INFRASTRUCTURE REQ)

■ Midmar Dam rising	2000 (2001)	23.3
■ Mearns dam	2001 (2004)	87.5
■ Spring Grove dam	2003 (2010)	104.65
■ Impendle Scheme 1	2008 (2020)	807.75
■ Impendle Scheme 2	2016 (2030)	469.00
Nzinga	2004 (2011)	5.92
■ Bulwer Dam	2006 (2014)	17.84
		R 1514.00

Economic Value of WDM
(SAVINGS)

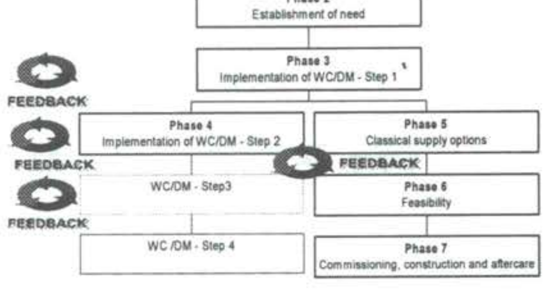
- PV from deferred capital costs =
  * R490 million from WR infrastructure
  * R404.2 mil from bulk supply infra
- PV avoided operating costs =
  * R617.81 million

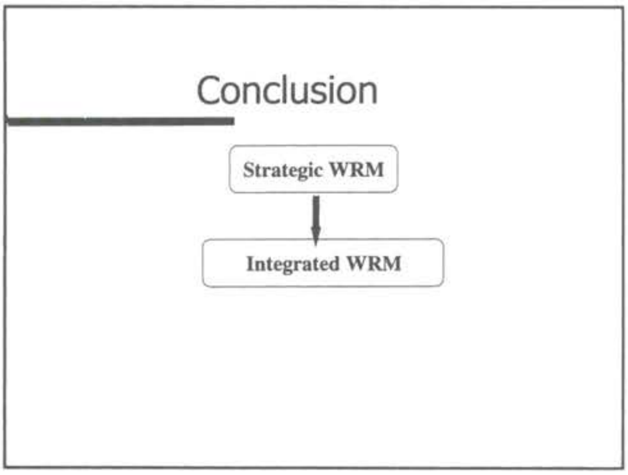
Economic Value of WDM
(SAVINGS)

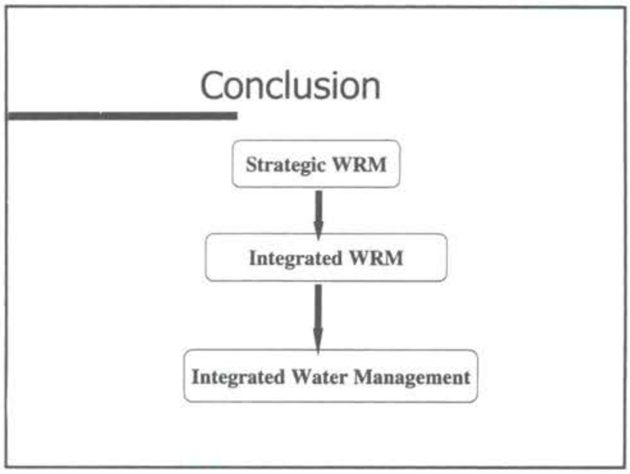
- R 1512.01 million over 15 years
- R 100.8 million per year

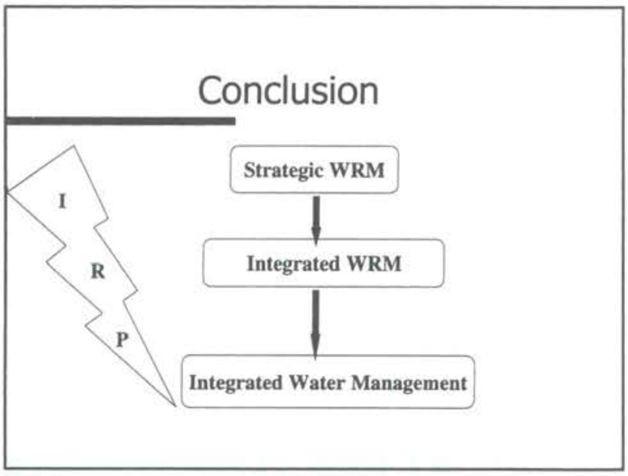
(# minus the cost of implementing WDM)

A new Approach to Water Resource Development




Conclusion
Strategic WRM
Integrated WRM


Conclusion
Strategic WRM
Integrated WRM
Integrated Water Management


Conclusion
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Strategic WRM
Integrated WRM
Integrated Water Management

INTEGRATED APPROACHES FOR EFFICIENT WATER USE IN BARBADOS

By John Bwalya Mwansa
Project Manager, Barbados Water Authority
Water Resources Management and Water Loss Studies

INTRODUCTION

Barbados is an island approximately 430 square kilometers in size with a resident population of approximately 260,000 persons. It is presently entirely dependent on groundwater abstracted from a coral-rock formation that covers about 84% of the island, for all of its water supply.

According to the 1997 Water Resources Management and Water Loss Studies, for an average rainfall year, the total amount of developable water resources available from all sources (groundwater, spring water and surface runoff) is 225,410 m^3/day, out of which 202,591 m^3/day is groundwater.

Current information from the Barbados Water Authority (BWA), the sole agency responsible for public water supply and management of all water resources, shows that their total water abstractions in 1998 (from 21 public water supply wells and 2 spring sources) fell to 140,909 m^3/day from a 1996 and 1997 high of 159,091 m^3/day. Other abstractions include that from privately owned and operated wells, for industrial and irrigation uses. The amount licensed for private abstractions is approximately 36,364 m^3/day. However, since only 30 of the approximately 120 operating wells known to the BWA, are metered, the abstraction figures used are based on pump-installed capacity rather than actual abstraction figures.

Based on these estimates, current groundwater abstraction levels either equal or exceed the developable and sustainable groundwater yields for most of the groundwater units. Furthermore, these abstraction levels cannot be met in the design drought year of either 1 in 15 year or 1 in 20 year without affecting the water quality through saltwater intrusion and experiencing some water outages. This was clearly demonstrated during the two (2) consecutive 1 in 15 year droughts of 1993 and 1994.

The public outcry and debate resulting out of the 1993 and 1994 water supply outages, plus the findings of the 1996 Water Resources Management and Water Loss Studies, forced Barbados to seriously look to approaches for more efficient usage and management of the limited water resources. These conditions also made the community more conducive to accepting and adopting these measures.

APPROACHES ADOPTED TO ENCOURAGE EFFICIENT WATER USE

The approaches adopted include:

1. IMPLEMENTATION OF A UNIVERSAL METERING PROGRAMME

Up until July 1997, approximately seventy percent (70%) of the domestic water use customers were on fixed rates and did not therefore concern themselves too much about the amount of water used. This made it very difficult to quantify and control water usage by this group of customers. However, all the commercial and industrial customers were metered.

In addition, most of the groundwater abstracted from private wells, even though supposed to be limited by license conditions, was not metered and had no other provisions to monitor or induce efficient water use.

A universal metering programme to be supplemented by a proposed change in tariff structure and policy, as well as regulations governing private well abstractions was recommended and approved by the government. However, whereas the BWA undertook to install the meters for all domestic customers, the private well owners lobbied and were allowed to be responsible for the installation of meters, meeting BWA specifications, on their wells. The latter, has met with less success, whereas the domestic meter installation programme is on target to be completed by September 1999.

The first part of the programme consists of the installation of 40,000 meters and ball valves, through a private contractor. This part is funded by a two million, eight hundred and fifteen thousand, six hundred dollars (US $2,815,600) loan, from the Inter-American Development Bank (IADB). The second part consists of 20,000 meters funded by the BWA and to be installed by in-house plumbing crews.

2. REDUCTION OF HIGH UNACCOUNTED FOR WATER (UFW)

The 1997 Water Resources Management and Water Loss Studies estimated the national average UFW level at 60%, using the metered records and estimates from samples of the 70% fixed rate customers. However, current 1999 data, where the ratio of fixed rate customers to metered customers has been reversed from 70% to 30% in 1996, to 30% to 70% in 1999, indicates that the UFW level is around 40%.

Based on the 60% UFW estimate, a target of reducing this to 30% by the year 2016, through intensified leak detection and repair work as well as mains replacement and rehabilitation programmes, was initially adopted. However, as a result of the more recent data, resulting from the universal metering programme, these targets are now under review and will be revised.

3. PUBLIC EDUCATION/PUBLIC AWARENESS CAMPAIGN

A number of approaches and activities have been undertaken and are ongoing in relation to water resource management and encouraging efficient water use. These activities have included:

- on-going water conservation messages in all media;
- national consultation meetings and workshops;
- Lectures and presentations to specific target groups by BWA personnel (i.e. primary and secondary schools, church groups, social clubs, government officials etc.),
- participation in radio call-in programmes and other discussion panels;
- Distribution of thirty thousand (30,000) low water use fixtures (showerheads and Kitchen tap aerators) to fully paid up BWA customers.

However, there has been no specific survey carried out to assess the success or failure of these activities. It is very clear though, that the level of awareness has risen, based on the increased number of letters and articles on water related issues, in the newspapers and discussions on call-in programmes.

4. IMPLEMENTATION OF WATER CONSERVATION PROGRAMMES TARGETED AT SPECIFIC USER GROUPS

- **West Terrace Primary School Water Conservation Project**
  This pilot project was a collaborative effort between the BWA, the Ministry of Education and a private company distributor of water fixtures. It is intended to be used to demonstrate the use of low water use fixtures and the potential savings derivable. The project consisted of retrofitting of the primary school's traditional wash basin bib taps with push taps (extended wall mounted wash basin type, with an average flow time of 11 seconds and flow rate of 6 l/min with water pressure at 2 bars), insertion of "water hogs" in the toilet cistern and retrofitting the male washrooms with battery operated urinal flush controls. The urinal control operates off of a 12-volt power supply with a 3-year lifetime. These water fixtures were donated by the private company and installed using BWA labour and expertise. Consumption was then monitored with the use of data loggers followed by leak detection and repair work and further monitoring.

  Except for the build up of coral-stone deposits affecting some of the push taps, both fixtures are considered to have functioned satisfactorily over the eight-month period of monitoring from August 1998 to May 1999. Consumption dropped by thirty-nine percent (39%) from a monthly average of 1551 cubic meters, before retrofitting, down to 943 cubic meters, Some leak detection and repairs were carried out prior to retrofitting. This has further been reduced to a monthly average of 317 cubic meters, after additional leak repairs to some galvanized pipes. Some leak repairs were also carried out prior to retrofitting.

- **Water Conservation and Management in the Hotel and Tourism Sector Project**
  This is an on-going collaborative effort between the Barbados Water Authority, Ministry of Health, Ministry of Tourism, Barbados Hotel and Tourism Association and the Caribbean Hotel Association, as implementing agencies. It is partially funded by the Pan- American Health Organisation (PAHO).

  The project is aimed at assessing the impact of water usage by this sector on the total water resources in Barbados, with a view to developing and implementing a coordinated plan of action for water conservation and management within the tourism sector.

  Started in March 1998 with a survey, this two-year project has now reached the stage of selecting the hotels, which will be used as pilot schemes based on the survey results and their willingness to bear the cost of retrofitting. Each participating hotel has also agreed to be used as a demonstration scheme for other participating members and to the publication of the results.

  It is intended to have schemes covering water usage in the following areas, landscaping and irrigation, laundry facilities, kitchen and restaurant facilities and hotel room and accommodation facilities.

5. CHANGE IN WATER TARIFF STRUCTURE

For the fixed rate customers, their charges are currently based on the total of Net Annual Value of their property plus the number of water fixtures on the property. These rates translate to US$6.5 to US$27.00 per month and bear no relationship to the volume consumed. The metered customers' charges are supposed to be based on the volume of water consumed. However, due to the existence of a minimum charge for domestic metered customers, customers using less water than the minimum charge value, end up paying an equivalent to a fixed charge of US$10.00 per month.

There is no documented evidence of how the minimum charge was arrived at, but it has been clearly demonstrated not to encourage water conservation, if this was part of the reason for metering. In addition, commercial and industrial water users are charged at one flat rate per cubic meter of water consumed, again providing little incentive to conserve.

Recognising the shortcomings of the present tariff structure the BWA in 1997 and 1998 proposed and made representations to government to change the structure to an increasing block tariff structure and to increase the tariffs. This is intended to encourage efficient water use as well as to improve the financial status of the BWA to meet all of its obligations.

The proposals have, however, been put on hold awaiting the establishment of a Fair Trading Commission by end of 1999, which is intended to oversee the operations of all utilities and will be responsible for reviewing and approving their tariff proposals. Currently, Cabinet approves water rates.

6. ADOPTION OF A BAN ON NON-LOW WATER USE FIXTURES BY THE YEAR 2000

In 1997, in a bid to encourage the use of low water use fixtures, the BWA offered and distributed, free of charge, to its fully paid up domestic customers, thirty thousand (30,000) shower heads and kitchen aerators. An informal survey later showed that only about a third of these were actually installed at the customers' premises.

To this end the BWA has recommended to government that, from the year 2000, only low water fixtures meeting specifications to be provided by the BWA and passing Barbados National Standards Institute (BNSI) testing should be allowed to be imported into the country. Some of the samples, from the bidders for supplying the 30,000 shower heads and kitchen aerators, failed to pass the BNSI testing. The logistics and regulations needed to achieve this, have yet to be worked out.

7. IMPLEMENTATION OF RAINWATER ROOF CATCHMENT REGULATIONS

The formal adoption and regulation of the use of these systems was achieved through a Cabinet approved amendment to the Town and Country Planning Development (Amendment) (No. 2) Order in 1995. The following regulations are therefore applicable for new constructions:

- Every house with a gross floor area of between 139.35 and 278.70 m^2 must have a rainwater storage tank of at least 13,638 litres capacity.
- Every house with a gross floor area of more than 278.70 m^2 must have a rainwater storage tank of at least 27,276 litres capacity.
- Every building other than a house that has a gross floor area of 92.90 m^2 or greater, must have a rainwater storage tank whose capacity is calculated at a rate of 195 litres per square meter of gross floor area.

Presently, these regulations do not apply to buildings predating the amendment and the collected water is supposed to be limited to non-potable uses. A tax rebate incentive is applicable to the minimum requirements. Older buildings are also eligible to claim for the tax rebate, but on a voluntary basis.

8. SUSTAINABLE BARBADOS 2000

This project, conceptualised by the Future Centre Trust (FCT), a non-governmental organisation, is a nationwide strategy for encouraging and achieving sustainable living. It has the motto "Taking Our Future Into Our Own Hands".

As one of its objectives, the project aims to promote and achieve the reduction of water demands by ten percent (10%) through the encouragement of gray water use and management and usage of water saving devices by the January 1, 2000.

To this end the FCT has set up demonstration projects, at its offices, for grey water reuse, rainwater roof and road runoff storage and drip irrigation, which are open to the public, for viewing. To achieve this objective, the FCT intends to work with individuals, families, schools, churches, community groups, government, private sector entities, NGO's and international agencies and organisations.

CONCLUSIONS

The general theme of the integrated approaches adopted to address the water supply and utilisation situation in Barbados has consisted of attempts to improve water supply and use efficiencies and moving towards meeting non-potable water demands from other than freshwater sources. It is anticipated that with a successful implementation of these measures and approaches there will be a decrease in water demand on the freshwater resources.

However, current efforts to improve water use efficiencies are hampered by a number of factors. These include the lack of a coherent and clearly articulated policy on the matter, inordinate delays by the BWA in responding to burst pipe reports and other public misconceptions about the nature of the problem. For example, from 1994 to date, six (6) golf course development proposals, ranging in size from 18 holes to 90 holes, have been approved, in the midst of messages to the public to cut down on water consumption. Many persons do not view the water outages as being related to the resource limitations, but rather as result of poor management.

It is also very clear that the current water tariff rates and structure are not conducive to water conservation. In addition, standards for various water uses need to be established and publicised to give people a chance to understand what constitutes reasonable use and what to aim for.

The adoption of efficient water use approaches by other government agencies, organisations and NGOs without the BWA's direct input or participation, augers well for the future. These approaches include the promotion of drip or trickle irrigation techniques by the Ministry of Agriculture and private irrigation equipment suppliers, supply of water saving devices and treated wastewater reuse by a number of hotel establishments for irrigation of lawns, plants and golf courses.

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BACKGROUND

- ▲ Barbados is a small island state located in the West Indies.
- ▲ Densely populated and high dependence on tourism.
  - Size = 430sq. Kilometers;
  - Resident population = 260,000
  - Tourists (long stay) = approx. 500,000/year

LOCATION OF BARBADOS

BACKGROUND

- ▲ Totally dependent on groundwater and susceptible to saltwater intrusion.
  - Total water resources = 225,410m^3/day
  - Groundwater resources = 202,592m^3/day
  - 1999 abstraction levels between 177 x 10^3 and 195 x10^3 m^3/day
- ▲ 1993,1994,1996 and 1997 abstraction levels greater than or equal to developable limits.

BACKGROUND

- ▲ Prolonged water outages experienced in 1993 and 1994.
- ▲ Classified as a water scarce country.
- ▲ Working to establish integrated water resources framework and policies.
- ▲ Need for adopting integrated approaches for efficient water use clearly demonstrated.

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ **UNIVERSAL METERING PROGRAMME.**
  - Started July1997, Finish September 1999.
  - Approximately 90,000 customers
  - 40,000 meters and ball valves by Contractor (US$2.815million IADB loan)
  - 20,000 meters and ball valves in-house (Estimated cost = US$1.6 million)
  - July 1997 - only 30% metered
  - February 1999 - 70% metered

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ **REDUCTION OF HIGH UNACCOUNTED FOR WATER LEVELS.**
  - 1997 estimated island wide average = 60%
  - 1999 estimated island wide average = 40%
  - Reduce from 60 to 30% by 2016 (target) (under revision)

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ Methodologies
  - – Intensified leak detection and repair, mains rehabilitation and replacement
  - – Pressure reduction
  - – Estimated cost (US$118 and US$6.5 x10^6)

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ PUBLIC EDUCATION/ PUBLIC AWARENESS CAMPAIGN
- ▲ METHODOLOGIES
  - – On-going Water Conservation Messages in all Media.
  - – National Consultation meetings and workshops.
  - – Radio call-in programmes.
  - – Lectures and Presentations to specific target groups
  - – Distribution of 30,000 shower heads,kitchen aerator and brochures with water conservation tips.
  - – Skits on TV.

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ WATER CONSERVATION PILOT PROJECTS
- ▲ WEST TERRACE PRIMARY SCHOOL
  - – Collaborative effort between BWA, Ministry of Education and Private Company(Distributor)
  - – Replaced traditional Bib Taps by Push Taps(set at 11secs.,6l/min., at 2bars)
  - – Inserted "Water Hogs" in toilet cisterns.
  - – Retrofitted male washrooms with battery operated urinal flash controls.

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- – All fixtures donated by the private company.
- – In combination with leak detection and repairs by BWA, consumption reduced from monthly average of 1551 m^3 before August 1998 to 317 m^3 in May 1999.
- – Approximately 15 to 20 percent of reduction due to fixtures.

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ HOTEL AND TOURISM SECTOR
- ▲ **On-going collaborative effort between BWA, Ministries of Health and Tourism, Barbados Hotel and Tourism Association (BHTA), Caribbean Hotel Association (CHA) and Pan-American Health Organisation (PAHO) as part sponsors.**
  - **– Started in March 1998.**

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- **– OBJECTIVES**
  - **◆ assess impact of water usage by this Sector on total water resources**
  - **◆ assess water use and management practices by Sector**
  - **◆ demonstrate efficient water use practices**
  - **◆ develop and implement a coordinated plan of water conservation and management for the Sector.**

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ **Participating Hotels to bear cost of retrofitting and allow access publication of results.**
- ▲ **To be made up of several demonstration projects at various sites:**
  - **Landscaping and irrigation**
  - **Laundry facilities**
  - **Kitchen and Restaurant facilities**
  - **Room and accommodation facilities**

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ **TARIFF STRUCTURE AND RATES**
- ▲ **CURRENT STRUCTURE**
- ▲ FIXED RATE (UN-METERED) CUSTOMERS -
- ▲ charge based on Total of Net Annual Value of Property plus value due to number and type of water fixtures on the property.
- ▲ Equivalent to US$6.5 to US$27.00 per month

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ METERED CUSTOMERS -
- ▲ Domestic-
  - First Block of 0 to 33m3/month charged at - US$0.75/m3
  - Second block of greater than 33m3 charged at US$1.06/$m^3$
  - For consumption below 13.3m^3/month minimum charge = US$10.00
- ▲ Commercial Customers
  - Charge rate = US$1.06/$m^3$

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ Current tariff structure does not encourage efficient water use.
- ▲ PROPOSED STRUCTURE
  - Four blocks increasing in blocks of 10m^3
  - No minimum charge
  - commercial customers to start at second block

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ **PROPOSALS FOR BAN ON IMPORTATION OF NON-LOW WATER USE FIXTURES BY THE YEAR 2000.**
  - Accepted by government
  - Specifications to be provided by BWA
  - Testing and certification to be done by BNSI

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

- ▲ **RAINWATER ROOF CATCHMENT SYSTEMS**
  - Regulations established in 1995
  - Compulsory for new buildings
  - Optional for pre-existing buildings
  - Tax rebate incentive provided.

APPROACHES ADOPTED FOR INTEGRATED EFFICIENT WATER USE

▲ **SUSTAINABLE BARBADOS 2000 PROJECT**

- **Conceptualised by the Future Centre Trust**
- **Nationwide strategy to encourage sustainable living.**
- **BWA participating in the promotion of use of water saving devices and grey water reuse.**
- **FCT Building to build demonstration projects**

INTEGRATED APPROACHES FOR EFFICIENT WATER USE IN BARBADOS

▲ CONCLUSIONS

- Approaches a combination of efficient use and substitution
- Not fully developed and accepted as necessary
- Some policies contradicting
- Tariff structure and rates not conducive to further adoption of approaches
- Need to establish standards

INTERGRATED APPROACHES FOR EFFICIENT WATER USE IN MALDIVES

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1. Introduction

The Maldives archipelago lies in the Indian Ocean; approximately 600 kilometres south-water supply and environmental sanitation of Sri Lanka. The islands are spread over a geographical area of some 90,000 square kilometres. The total land area is approximately 300 square kilometres.

The climate is tropical, warm and humid all year round. The temperatures fluctuate between a daytime maximum of 32 degrees Celsius and a night-time low of 26 degrees Celsius, with a mean annual temperature of 28 degrees Celsius. The mean annual relative humidity and the mean annual wind speed are 80 % and 4 m/s, respectively.

Unlike many small island nations, surface water such as lakes, rivers, ponds or streams are not available in Maldives. However, almost all the islands of the Maldives have groundwater aquifers. The quality of the water in these aquifers generally varies from very fresh to very saline. The quality may also be impaired by human activities such as mode of sanitary and wastewater disposal and agricultural practices. Until very recently, the people of Maldives have been dependent on the shallow groundwater aquifers for all their freshwater requirements, including drinking.

Historical records show that rainwater harvesting was not practised in Maldives until after 1906. And it was not widely practised until 1978, following the epidemics of cholera (1978) and shigella (1982). Although the country is blessed with a relatively regular and high rainfall, its usefulness as an adequate and dependable source of freshwater is rather limited. This limitation is imposed mainly by the unavailability of sufficient storage facilities and land space.

Desalination was first introduced into Maldives in 1985. Presently, all houses, institutional and commercial establishments have been provided with piped water. The basic cost of providing this water is US$ 4.64. Although it is now a major source of freshwater, especially for Male'- the capital of the Maldives and in the tourist industry, it is still considered far too expensive to be considered as an economically viable source of freshwater for most small island communities.

Freshwater is undoubtedly a scarce resource in Maldives. If scarcity is defined as less than 600m^3 per million people, then Maldives clearly falls under this category. The scarcity is both temporal and spatial. The problem is aggravated by saltwater intrusion and pollution of groundwater resulting from release of sewage, industrial effluents and poor agricultural practices. This makes integrated water resource management more urgent and more important in the Maldives.

2. Rainfall characteristics and rainwater harvesting

2.1. Rainfall characteristics

The Maldives is blessed with plentiful rainfall; over 1900mm a year. The mean annual rainfall is 1900 mm. The storms are normally of high intensity and of short duration. The frequency and intensity of these storms vary across the country. Except for the dry period, which normally occurs from January to March, the rainfall is very evenly distributed throughout the year.

An analysis of the rainfall records of the past 20 years shows that 43.86 percent of days in a year are dry days. The storms are normally of high intensity and of short duration. The frequency and intensity of the storms vary across the country. On an average, 8 - 10 percent of the storms occur at intensities higher than 25 mm/hr., and 2 - 4 percent of storms occur at intensities higher than 50 mm/hr. Since high intensity storms occur very rarely, rainfall harvesting is difficult to practice and its utilisation is very low.

2.2. Rainwater harvesting

The first concrete decision to provide safe drinking water to the people of the Maldives was made in 1904. This was in response to the recommendation of the 19th century British historian and writer, Mr. H.C.P. Bell, following his first visit to Male'- the capital of the Maldives. Between 1906 and 1909, the GoM constructed two rainwater tanks. The first tank was completed in August 1906 and the second tank was completed in June 1909.

In spite of the deteriorating condition of the groundwater, and the associated health risks involved, no serious attempt was made to even encourage people to harvest rainwater. This was perhaps that many were not convinced of the link between contaminated water and disease. This may also be that many were used to drinking groundwater, which at the time was good in terms of salinity and other chemical parameters. This may also be that many could not afford to build their own rainwater tanks. According to a study carried out in 1974[1], only 15 percent of the 2600 households in Male' had private rainwater tanks.

However, following the frequent outbreaks of cholera and shigella throughout the country, the GoM began to promote and invest in rainwater harvesting. Gradually people in Male' began to construct their own private rainwater tanks. In 1985 the GoM launched the first major water supply and sewerage project in the Maldives. The project allocated more than 2.5 million US Dollars; roughly 33 percent of the total project cost, for the construction of steel tanks with a total storage capacity of 9900 m^3 and the construction of 1154 private rainwater tanks in 1116 households providing a total storage capacity of 4157.5 m^3. The private tanks were provided on cost recovery basis, payable over a period of 5 years.

To provide freshwater for the rural population, the GoM, with financial assistance from UNICEF, constructed 1925 ferrocement tanks with a total capacity of 19,3000 for community use in 200 islands, serving a population of 234,008. In addition, 222 households have been provided with construction materials for the construction of private rainwater storage tanks. Since 1994, the program has focussed on providing HDPE tanks instead of the ferrocement tanks. Todate, 2914 HDPE tanks with a total capacity of 14,520 m^3 have been distributed free of cost for community use, and 1588 HDPE tanks with a total capacity of 3,176 m^3 have been distributed to the households on cost recovery basis.

[1] Binnie and Partners, March, 1975; Water Supply and Sewerage for Male', Final Report.

The HDPE tanks, because of its durability, ease of handling and mobility, are proving to be more acceptable and popular among the rural population.

3. Groundwater

Groundwater aquifers formed by the accumulation of the recharged rainwater on top of the saltwater are found in all islands. These aquifers normally lie at a depth of 1-1.5 meters below the surface. The thickness of an aquifer is normally dictated by several factors including net rainfall recharge, size of the island and permeability of the water through the soil column. Since these parameters vary from island to island, the quality of the aquifer also vary from island to island. Moreover, the proximity of the aquifers to the surface also makes them highly susceptible to pollution and contamination from human activities. Thus, the availability of the groundwater as a freshwater resource is also limited. This limitation is imposed by the quality of water rather than its quantity.

Presently 76 percent of the urban freshwater requirement and almost 98 percent of the rural freshwater requirement is met by these shallow groundwater aquifers.

4. Desalination

The history of desalination in Maldives began with the installation of a 200 cubic meter per day desalination plant in Male' in 1985. Ever since desalination has become very popular in Maldives, particularly in the resort islands. Today, the total production capacity has increased to more than 18,000 cubic meters per day, of which 2700 m^3 (15%) is produced by the Male' Water Supply and Sewerage Company (MWSC), 1000 m^3 (5.6%) is produced by the Vilingilli Water Supply and Sewerage Unit and 14300 m^3 (79.4%) is produced by the tourist industry. According to available statistics, approximately 24 percent of the freshwater requirement in Male' is now met by desalination. In the tourist industry, more than 90 percent of the freshwater requirement is met by desalination.

By 1998, MWSC has provided more than 9600 connections to its customers in Male'. This includes residential houses, institutional and commercial establishments in Male' have been provided with piped water. Although it is now a major source of freshwater, especially for Male'- the capital of the Maldives and in the tourist industry, it is still considered far too expensive to be considered as an economically viable source of freshwater for most small island communities.

5. Decade and post-decade experiences

The IDWSSD and Post-decade experiences are summarised as follows;

- Duplication & overlap of activities
- Fragmented responsibilities
- Diminishing community enthusiasm after start of project implementation
- Delay in decision making
- Lack of NGO involvement
- Inadequate and slow involvement of women
- Lack of incentives for employment conditions
- Insufficient health and hygiene education

6. Need for integrated water resources management

The experience from the national water supply and environmental sanitation projects and programs, over the past two decades, shows that the performance of the sector has been far from satisfactory. This is particularly so in terms of the waste of scarce resource investments and failures of the programs to deliver reliable and sustainable services. The most important factors contributing to this unsatisfactory performance are the top-down approach in decision making, plans based on technical considerations, lack of community participation in decision making and the government's policy of providing these services free of charge.

The top-down decision making approach implied that the beneficiary communities had no say in designing and determining the service levels, no financial stakes and no sense of ownership. Besides, no attempt was made to organize and develop the community to operate and maintain the facilities and systems.

MWSA has taken the initiative to press ahead with reassessing and bringing about the necessary changes to the present policies and strategies, and to lay a new emphasis on both the coverage and the quality of service provided. The driving forces for this transition is the poor performance of the sector over the past two decades, the strain on public resources, the changing roles of the government and the communities and the widening consensus on guiding principles for transition in the water and sanitation sector. To bring about the necessary transition, it is important to identify the position and issues relating to the implementing agency and other key ministries.

In view of our Decade and Post-decade experience, it is very clear that, if sector programs are to achieve results, then integrated water resources management is the answer to the problem and is the way to move forward. Such action requires a multidisciplinary approach. An essential aspect of this is sharing information. This implies the need for various key ministries and other key stakeholders to participate in developing concrete and visionary plans and participate fully in the implementation of strategies. It is also essential that the sector plans and strategies ensure that all available national resources are pooled and directed in achieving the national water and sanitation goals and objectives. It is also equally important that the capacity of MWSA be further strengthened to meet the growing need for safe water and sanitation.

In this endeavour, the Maldives Water and Sanitation Authority (MWSA) has completed the first draft of the national sector strategy for year 2000 and beyond. It has drawn heavily from the Decade and post Decade experience. This document attempts to identify key issues and proposes important policy and organizational changes that need to be brought about to effect the necessary changes in planning and implementation. Once complete, the document will provide a basis for decision makers to reconsider the present policies, and to make where necessary, relevant policy changes, such that the provision of these very basic services may be achieved with a higher degree of success, particularly for the rural population. Further, it also focuses on creating awareness and building consensus among the various stakeholders.

7. Over view of the management policies and strategies

As stated earlier, Government of Maldives (GoM) is committed to provide adequate supply of clean and safe water to everyone in the country. This is being achieved primarily by adopting low-cost, yet socially acceptable, indigenous technologies that could be installed, sustained, operated and maintained at the community level.

7.1. Policy issues

The following policy issues are under review and a decision is expected soon.

a) **Coverage & Level of services**
The coverage and level of services to be provided will be decided by the community based on prices they are willing to pay.

b) **Privatizing**
Since 1996, the government has initiated privatization of this sector, and has since entered into a joint venture with a Danish company to provide water supply and sewerage services for the population of Male'. A second contract has been made with an American company to provide water supply and sewerage services for the island of Vilingilli. The decision to privatise these services are showing good results. To attract more investors in this sector programs, better and attractive incentives will have to be offered to the private sector.

c) **Tariff**
Presently, a three-tier tariff structure is applied. The tariff though applied for water covers the cost of operating and maintaining the sewerage services. The present tariff also gives a subsidy for the first $2.7m^3$ of water consumed by every meter connection. A tariff indexation model has been developed to assist the regulator in reviewing proposals for the adjustment of tariffs by utilities.

d) **Cost sharing**
The government will not act as the sole provider. The community, based on the type, coverage and level of service will bear at least 20 percent of the capital cost or any amount in excess of the subsidy ceiling set by the government, and all recurrent expenses.

e) **Subsidy ceiling**
The subsidy ceiling is the amount that the government will provide per household for a basic level of service. This will be the most critical element of the financial policy. A ceiling is required to safeguard the social dimension of potable water and sanitation and to provide adequate incentives to the users to choose levels of service based on their affordability. If a community wants to improve services beyond this basic level, the community must bear the costs as stated in (c) above.

Since subsidy ceiling will directly affect the financial choices that communities make with respect to the service level, the subsidy ceiling must create the right incentives for communities to make financial choices that reflect demand. Alternatively, subsidy ceilings may be determined for each technical option. In either case, the subsidy ceiling must be transparent and equitable.

f) **Equity**
In line with the Government's policy of providing these services to all rural population, MWSA will place a high priority to expand these services to achieve the national targets for water supply and environmental sanitation coverage. Selection process will give a higher priority to those islands where poverty and disease are relatively high, incomes are marginal and water supply and environmental sanitation coverage is low. Priorities will also be given to those communities whose economic demand and commitment are high. Informed choices will be offered to determine service levels.

7.2. Specific management policies

- Integrating water resources management with national, economic and social policies, including planning of land use.
- Reducing infant and child mortality (127/1000 in 1985 to 34/1000 in 1993).
- Providing safe drinking water (Coverage by 1994: 100% urban, and 85% for rural) and hygienic sanitation facilities (Coverage by 1994: 95% urban and 25% for rural) to facilitate better management and control of diarrhoea and other waterborne diseases.
- Reducing disparities between urban and rural islands.
- Developing manpower resources needed for the sector through community participation in action programs.
- Awareness building and education targeted for all levels, through leaflets, newspaper articles and radio programs are in progress.

7.3. Goals:

The goals of the sector are a) to provide a clean environment for a healthy and productive life, b) to promote sustainable hygiene behaviour, c) to promote policies that empower people to make informed choices. These goals will be realised through decentralised, community-based management of planning, implementation, operation and initial and recurrent financing, together with consensus and knowledge-based behavioural change.

7.4. Objectives

The objectives of the sector programs are to;

- expand water supply and environmental sanitation to rural islands
- develop research and development capability
- protect groundwater aquifers
- reduce disparities between water and sanitation service coverage
- promote equity in terms of service and resource allocation
- relate water supply and environmental sanitation programs with other health programs
- build capacity at grassroots level
- preserve environment by promoting sanitation and safe water
- strengthen inter-agency and trans-sectoral collaboration
- forge alliances with private sector

7.5. Strategy

To achieve the above goals and objectives, MWSA is continuing to apply the following strategies in its programs. A key strategy is to apply a demand driven approach in the provision of water supply and environmental sanitation services.

A "demand" for a service is meant to exist when the beneficiaries demonstrate a willingness to buy the service they want at the price the service could be economically provided. To implement this strategy, the government is gradually changing its role from a 'provider' to a 'facilitator'.

Key indicators are now being developed to measure the demand-responsiveness of a project. These indicators include the actual resource commitments users make, and the level and extent with which users determine the design, service level and management arrangements.

7.5.1. Broad strategies

a) Advocacy

The water supply and environmental sanitation sector policy will ensure increased delivery and sustainability of water and sanitation services through effective advocacy. Such advocacy is essential for mobilization and redirection of sectoral resources. Advocacy is also essential to promote socially acceptable, technically sound and economically viable technologies and to integrate sanitation and hygiene education with water supply schemes and increased community involvement and participation and capacity building required for planning, mobilizing local resources, designing, implementation, operation and maintenance.

b) Promote sustainability

For the success of water and sanitation programs it is fundamental that all water and sanitation programs are sustainable. This will be achieved through creating the right policy environment, capacity building, developing partnerships, promoting health and hygiene education, promoting self-help and community contracting, providing financing options to improve affordability and promoting alternative technology.

- ***Capacity Building***

  For effective program implementation, MWSA will develop a comprehensive Human Resource Development (HRD) plan in collaboration with the Ministry of Health (MoH) and Maldives Institute for Technical Education (MITE). Opportunities for training and upgrading skills will be provided for both administrative and technical staff of MWSA and other key stakeholders, including community members. Such training will be an incentive and will be linked to needs, personal performance, talents and commitment to the institution.

  Apart from the upgrading of skills, MWSA will seek to provide leadership training to its senior staff. This is to help them seek innovation and identify staff hopes and concerns, and to translate them into plans and budgets which will be acceptable to the Ministry of Health.

- ***Development of partnerships***

  Development of partnerships is required to create efficiency, to address the inter-sectoral nature of water supply and environmental sanitation programs and to coordinate and collaborate with line ministries to reduce duplication of programs and thereby cut down expenses.

- ***Promoting health and hygiene education.***

  Health and hygiene education with emphasis on water supply and sanitation is considered as important as the facilities in breaking the link between water supply and diarrhoeal diseases. Personal cleanliness and sanitation are needed to reap the benefits of improved water supply and sanitation facilities.

- ***Promoting self-help and community contracting***

  Self-help and community contracting is another important means of helping communities to construct their sewerage systems, water tanks and toilets for their own health and convenience.

- ***Providing financing options to improve affordability***
  Providing financing options to improve affordability is essential to help communities to implement a water supply and environmental sanitation program to ensure that even the poorest family in a community is not deprived from the benefit of clean water and sanitary toilet.

- ***Promoting alternative technology***
  The inhabited islands of the Maldives exhibit wide-ranging differences in groundwater quality, population density and affordability. Hence, technology options have to be identified to suit a particular island community.

The above strategies recognize the fundamental importance of ownership for the success of a new generation of water supply and environmental sanitation programs. In addition, the application of these strategies will help MWSA to support this principle in three important ways by;

- promoting and guiding bottom-up planning and community based implementation and management.

- assisting inter-sectoral and donor coordination and collaboration.

- encouraging appropriate contributions from the community as owners and users and beneficiaries.

7.5.2. Specific management strategies include

- implement programs through partnerships with Island Development Committees (IDCs), Womens' Development Committees (WDCs) and Non-Governmental Organizations (NGOs).
- promote low-cost technologies on safe water and environmental sanitation.
- strengthen inter and intra-sectoral collaboration.
- adopting an integrated planning approach to optimise use of available resources, with emphasis on rainwater harvesting.
- implementing a nation-wide campaign to educate people on rainwater harvesting, wise-use of water, and their impact on health.
- promote social mobilization for safe water use and appropriate, safe sanitation.
- promote sustainability of water supply and environmental sanitation programs through community contribution, management and ownership.
- implementing policies to promoting economic use of water (Introducing costs and water saving technologies).
- ensure active involvement of local power structure in water supply and environmental sanitation programs.
- train local expertise to construct, operate and maintain water supply and environmental sanitation facilities. Such training aimed at building capacity in beneficiary communities to manage their own schemes on a sustainable basis has proven to be very successful.

8. Major obstacles/problems to integrated land and water management

- ***Geographic distribution***
  The 1190 islands of the Republic are spread over a geographic area of 90,000 square kilometers. Only 202 are permanently inhabited. The islands are very small (Largest bein roughly 5 square kilometers), and have very special physical, demographic and economic features. Transportation of goods and equipments are fairly high.

- ***Requires huge financial investments***
  To supply each and every individual community with adequate freshwater and hygienic sanitation facilities and to maintain them would require enormous financial investments.

- ***Scarcity of land and high population concentration***
  Although the country's mean annual rainfall is fairly high, unavailability of land itself is an obstacle to building adequate storage on densely populated islands.

- ***High maintenance costs***
  The very high concentration of sodium chloride in the air make it very corrosive, causing equipment and materials to deteriorate and fail rapidly - increasing maintenance costs.

- ***Shallowness of the groundwater aquifers***
  The water table of most groundwater aquifers are less than 1.2m below ground surface. The close proximity of these aquifers to ground surface make traditional sanitary and wastewater disposal practices pollute these aquifers easily. Further, uncontrolled use of fertilizers, herbicides and pesticides also cause groundwater pollution.

- ***Lack of local expertise***
  There are very few trained engineers and technicians. Often contracts have to awarded to foreign companies. This increases the cost of the projects.

- ***Insufficient funds***
  Often funds are insufficient or slow to come. This results in long delays and incomplete jobs.

- ***Procurement of goods and equipments***
  Very often almost all goods and services have to be imported. Also leads to long delays and increased cost of the project.

- ***Duplication of work***
  Duplication of work arises from ambiguity in sector responsibilities. This causes unnecessary waste of limited resources; human and material, and waste of time and effort. Responsibilities of individual sectors need to be very clear and well understood by all concerned. Well defined responsibilities will improve performance, quality of service rendered, and save time, effort and resources, thereby avoiding un-necessary delays in implementing sector programs and related projects.

9. Conclusion

Very small island communities such as in Maldives, have very unique hydrological and water resources assessment, development and management problems. They do not have surface water in an exploitable form. Further, their fresh groundwater resources are also very limited.

Their very small size and geological conditions further limit options for the development of freshwater resources such as surface storages. Thus, the conventional options for freshwater supplies on these islands are limited to groundwater development, rainwater harvesting and in limited number of cases desalination.

Wastewater treatment for re-use, although technically feasible for such purposes as agriculture, sanitary flushing and gardening, is not high priority at present, particularly for small island communities, due to public health concerns and public unwillingness to pay for such service. However, in the tourist resorts, treatment of wastewater is now being made mandatory. Re-cycled water are now being used for toilet flushing and watering the lawns.

Scarcity of capital resources, shortage of skilled labour, and poorly developed organizational structures are major factors that hinder implementation of integrated water resources management. Thus, development and management of water resources on these small islands call for techniques, methods and approaches unique to the socio-economic situation of these islands.

Experience from the past decade has shown that an 'integrated approach' to water resources management gives the best dividend. Such an integrated approach calls for a number of key issues, such as;

a) community participation at all levels, including planning, designing, construction, maintenance and financing,
b) provision of full cost recovery,
c) choice of appropriate technology that matches the resources available to sustain it,
d) institutional and capacity building programs to match the planned water supply and sanitation systems,
e) parallel programs in health education and sanitation improvements.

Health education with emphasis on water supply and sanitation is considered as important as the facilities in breaking the link between water supply and diarrhoeal diseases. MWSA's mission is to help reduce mortality and morbidity caused by water-borne diseases through provision of appropriate low-cost water and sanitation services based on demand driven, effective, efficient and uniform implementation strategy.

Finally, in small islands such as those found in Maldives, where the population density has surpassed the carrying capacity of the island, particularly with respect to available water resources, or where climatic and geologic conditions are not favourable for occurrence of sufficient natural (conventional) freshwater resources, integrated water resources management is not only necessary, but a must.

Maldives

	Urban	Rural
❑ **Area:**	**2.8 sq. km (>35% reclaimed)**	**300 sq. km**
❑ **Population:**	**68,000**	**220,000**
❑ **Water Supply**		
➢ **Population served:**	**100 %**	**80 % (Drinking Water)**
➢ **House connections:**	**95 %**	**0 %**
❑ **Sanitation**		
➢ **Population served:**	**100 %**	**40 %**
➢ **House connections:**	**95 %**	**8 %**

MWSA

THE ISLAND OF MALE

Usage	Rain Water/ Desalinated Water	Ground Water	Discharge in to Soakways
Domestic	664.0	7,546.0	1,625.0
Industrial	29	29.0	8.0
Commercial/ Institutional	100	1767.0	19.0
Total	773.0	8,342.0	1,652.0

❑ Goals

a) To provide a clean environment for a healthy and productive life

b) To promote sustainable hygiene behaviour

c) To promote policies that empower people to make informed choices

❑ Objectives

- Expand water supply and environmental sanitation to rural islands
- Protect groundwater aquifers
- Reduce disparities between water and sanitation service coverage
- Promote equity in terms of service and resource allocation
- Relate water supply and environmental sanitation programmes with other health programs
- Build capacity at grassroots level
- Preserve environment by promoting sanitation and safe water
- Strengthen inter-sectoral collaboration
- Forge alliances with private sector

Available Water Resources

❑ Groundwater

	Urban	Rural
■ **Estimated aquifer volume (1974):**	**20,000,000 cu. m**	**N/A**
■ **Avg. Chloride conc.**	**150 mg/l**	**N/A**
■ **Estimated aquifer volume (1996):**	**100,000 cu. m**	**N/A**
■ **Avg. Chloride conc.**	**9,000 mg/l**	**N/A**

- ■ **Attempts to recharge aquifer**
  Road paving with infiltration system

➢ ***Used for all purposes other than drinking***

❑ Rainwater

- ■ **Mean Annual Average:** **1,900 mm**
- ■ **Storage capacity (private):** **Urban: 28,000 cu. m (est.)** **Rural: N/A**

➢ ***Used primarily for drinking***

❑ Desalinated Water

- ■ **Production capacity:** **2,500 cu. m/d**
- ■ **Storage capacity (private):** **18,900 cu. m**

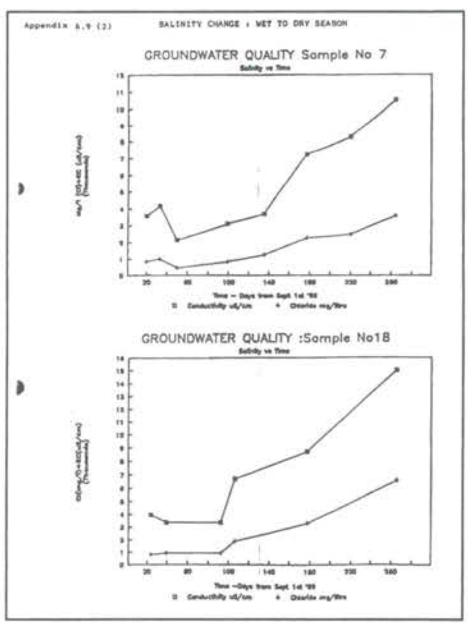
➢ ***Used for all purposes***

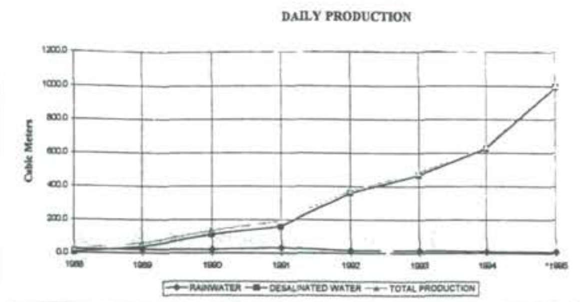
DAILY INTENSITY FREQUENCY ANALYSIS

BASED ON DAILY RAINFALL RECORDS (1985 - 1994)

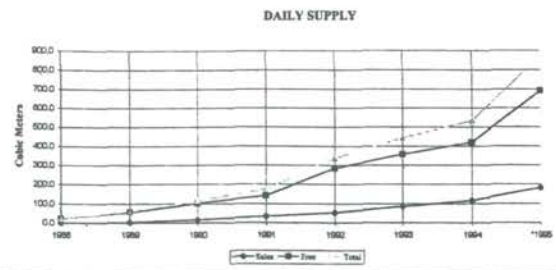
MALE', REPUBLIC OF MALDIVES

	(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	
INTENSITY (RANGE) / PARAMETERS	<=0.0	>0.0 <=10.0	>10.0 <=25.0	>25.0 <=35.0	>35.0 <=55.0	>55.0 <=75.0	>75.0 <=95.0	>95.0 <=125.0	>125.0 <=155.0	>155.0 <=200.0	SUM
FREQUENCY	1601	1497	306	106	81	32	13	10	3	1	3650
PERCENT (%)	43.86	41.01	8.38	2.90	2.22	0.88	0.36	0.27	0.08	0.03	100
CUMULATIVE (%)	43.86	84.88	93.26	96.16	98.38	99.26	99.62	99.89	99.97	100.00	
	100.00	56.14	15.12	6.74	3.84	1.62	0.74	0.38	0.11	0.03	





*1995 figures are upto April 1995
SOURCE: MALDIVES WATER & SANITATION AUTHORITY

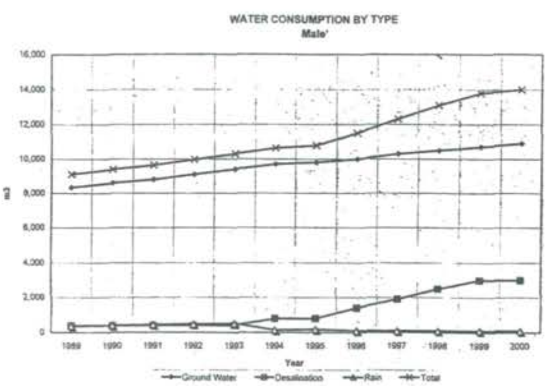


*1995 figures are upto April 1995
SOURCE: MALDIVES WATER & SANITATION AUTHORITY

MWSA

[illegible] FORECAST, MALE', MALDIVES

Year	Low population growth		High population growth	
	Rain/Desal. water	Ground water	Rain/Desal. water	Ground water
1989	773.0	8,342.0	773.0	8,342.0
1990	800.0	8,600.0	800.0	8,700.0
1991	820.0	8,800.0	840.0	9,000.0
1992	840.0	9,100.0	870.0	9,400.0
1993	870.0	9,400.0	900.0	9,800.0
1994	900.0	9,700.0	940.0	10,200.0
1995	910.0	9,800.0	980.0	10,600.0
1996	930.0	10,000.0	1,500.0	11,000.0
1997	950.0	10,300.0	2,300.0	11,400.0
1998	970.0	10,500.0	2,700.0	11,900.0
1999	990.0	10,700.0	3,000.0	12,400.0
2000	1,010.0	10,900.0	3,500.0	12,800.0



❑ Policy issues

- **Coverage & Level of services**
- **Privatizing**
- **Tariff**
- **Cost sharing**
- **Subsidy ceiling**
- **Equity**
- **Re-use**

Specific management policies

- Integrating water resources management with national, economic and social policies, including land-use planning.
- Reducing infant and child mortality (127/1000 in 1985 to 34/1000 in 1993).
- Providing safe drinking water to facilitate better management and control of diarrhoea and other water borne diseases.
- Reducing disparities between urban and rural islands.
- Developing manpower resources needed for the sector through community participation in action programs.
- Awareness building and education targeted for all levels, through leaflets, newspaper articles and radio programs are in progress.

❑ Strategy

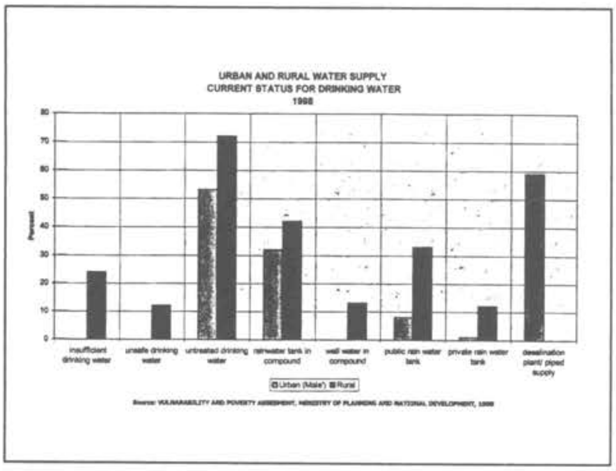
- **Adopt a "demand-based" approach**

A 'demand' for a service is meant to exist when the beneficiaries demonstrate a willingness to buy the service they want at the price the service could be economically provided.

To implement this strategy, the government is gradually changing its role from a 'provider' to a 'facilitator'.

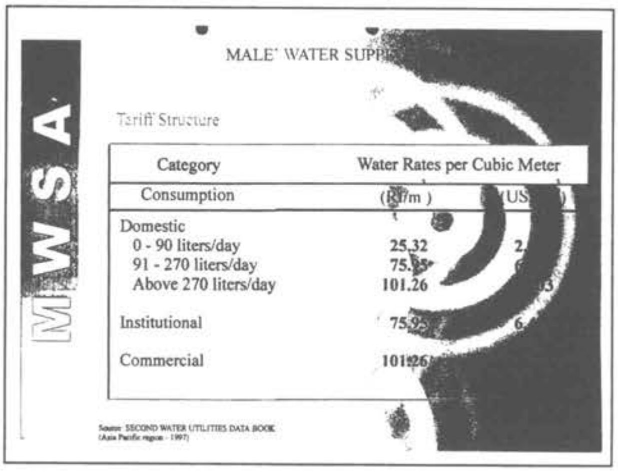
Key indicators are now being developed to measure the demand-responsiveness of a project. These indicators include the actual resource commitments users make, and the level and extent with which users determine the design, service level and management arrangement.

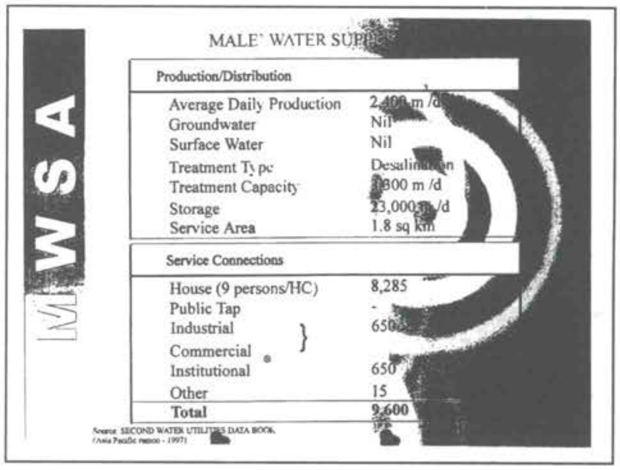
- **Advocacy**
  - Advocacy is also essential to promote socially accepted, technically sound and economically viable technologies.
  - To integrate sanitation and hygiene education with water supply schemes
  - To increase community involvement and participation in planning, designing, mobilizing local resources, implementation, operation and maintenance.
- **Promote sustainability**
  - Sustainability are been ensured through creating the right policy environment
  - Capacity building
  - Developing partnerships
  - Promoting heath and hygiene education
  - Promoting self-help and community contracting
  - Providing financing options to improve affordability
  - Promoting alternative technology and options

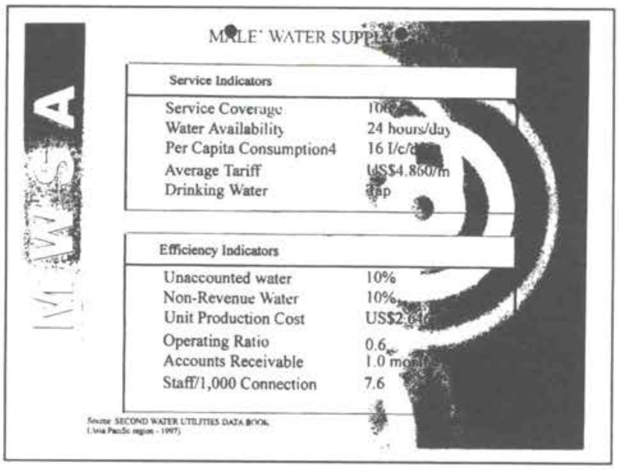


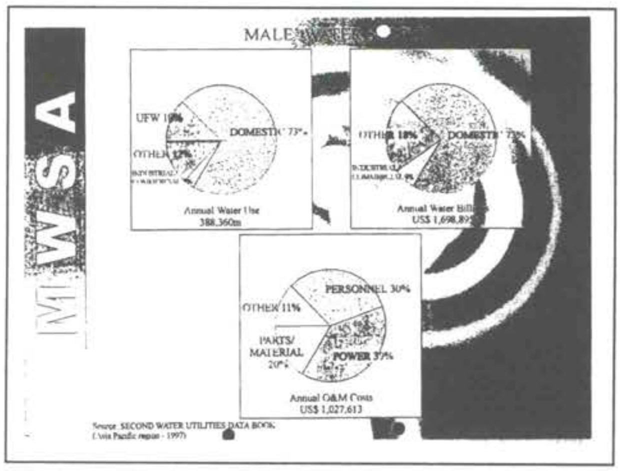
Privatization

Main issues	Partner's position	GoM's position	Compromise reached
1. Share holding	❑ Equal shares	❑ Majority shares	❑ GoM 70% ❑ Partners 30%
2. Concession period	❑ Minimum of 20 years	❑ Maximum of 20 years	❑ 20 years
3. Exclusive rights	❑ Exclusive rights for water supply	❑ Exclusive rights if water supply & sanitation are taken together	❑ Exclusive rights for water supply & sanitation
4. Private dug wells	❑ All private dug wells must be closed	❑ Private dug wells cannot be closed	Private dug wells shall remain
5. Rainwater harvesting	❑ Rainwater harvesting must discouraged	❑ Rainwater harvesting must not be discouraged	❑ GoM will not provide incentives for rainwater harvesting
6. Tariff	❑ No subsidy ❑ Periodic review	❑ Subsidy for the poor ❑ Fixed for 5 years	❑ 50% subsidy for basic water requirements ❑ 10 lcd/meter connection ❑ Fixed for first 3 years ❑ Remain fixed for next two unless company makes losses.
7. Management	❑ Management by partner	❑ Management for limited time period	❑ Management for first 5 years
8. RO plants	❑ Must be bought from partner	❑ Must be bought through open tender	❑ First 7 plants from partner ❑ Rest through open tender
9. Construction of distribution network	❑ Construction by partner	❑ Open tender	❑ Construction by partner
10. House connections	❑ No free connections	❑ A free connection for each consumer group	❑ One free connection for each consumer group for the first three years. ❑ Additional connections to be charged
11. Quality of water	❑ EU standard shall be maintained	❑ Minimum: shall comply with WHO guideline values	❑ WHO Guideline values.
12. Tap bays	❑ No tap bays	❑ Min of 10 tap bays	❑ 10 tap bays









Group 1: Water Issues

Problem Areas	Relationship to Health	Action/Solution	Responsible Office
Ground water Contamination	• Spread of intestinal & skin diseases • Intoxication • Food Contamination • Food Poisoning	• Create awareness through media, education & leaflets, posters, etc. • Regulation of waste (proper waste collection & disposal scheme) • Piped Water Supply • Provide rain water tanks	MoH&W MWSA DPH
Stagnant water	• Vector-borne disease	• Create awareness • Proper maintenance of drains	MoH&W Min. of F&A
Lack of safe water	• Unhealthy life-styles	• Provide safe adequate water at reasonable costs	MWSA

GROUP 3 – ENVIRONMENTAL HEALTH

POLICY ISSUE/AREAS	ESSENTIA ELEMENTS
Water: • Provide access to safe water • Promote cost-recovery of services • Introduce environmental/financial sustainability • Promote socially acceptable and economically viable technologies	1. Introduce • Water Act/MoHW • Standards/MWSA • Regulations/MWSA • Monitoring/MWSA • Enforcement/ 2. Ensure quality of water provided 3. Preserve and protect natural water resources • Conservation • Demand management • Waste water re-use • Groundwater recharge • Optimal use of natural resources (rain water, groundwater) 4. Promote socially acceptable, environmentally sound and economically viable technologies 5. Continuos assessment of sustainability and effectiveness of ongoing strategies • commercialisation of basic water supply • effectiveness of government's regulatory function • effective technology transfer from MWSC 6. Initiate and support relevant local research and development capability in the area 7. Promote community participation in all stages of development initiatives

Major obstacles/problems to integrated land and water management

- ***Geographic distribution***
- ***Requires huge financial investments***
- ***Scarcity of land and high population concentration***
- ***High maintenance costs***
- ***Shallowness of the groundwater aquifers***
- ***Lack of local expertise***
- ***Insufficient funds***
- ***Procurement of goods and equipment***
- ***Duplication of work***

❑ **Conclusion**

➢ Small island communities have very unique hydrological and water resources assessment, development and management problems.

➢ They do not have surface water in an exploitable form.

➢ Conventional options for freshwater supplies on these islands are limited to groundwater development, rainwater harvesting and in limited number of cases desalination.

➢ Their very small size and geological conditions further limit options for the development of freshwater resources.

➢ Desalination is not an economically viable option for small island communities.

➢ Wastewater treatment for re-use, although technically feasible, may not be economically viable for small island communities.

➢ Chosen technology options must match the resources available to sustain it.

➢ Institutional and capacity building programs must match the planned water supply and sanitation systems.

➢ Lack of reliable data, scarcity of capital resources, shortage of skilled labour, and poorly developed organisational structures are major factors that hinder implementation of integrated water resources management.

➢ Thus, development and management of water resources on these small islands call for techniques, methods and approaches unique to the socio-econmic situation of these islands.

➢ Finally, health education with emphasis on water supply and sanitation is considered as important as the facilities in breaking the link between water supply and diarrhoeal diseases.

INTEGRATED APPROACHES FOR EFFICIENT WATER USE IN FUKUOKA

Teruyoshi Shinoda, Fukuoka City Waterworks Bureau

ABSTRACT

Within Fukuoka's watershed area there are only small rivers and small-scale dams. As a result of this the city experienced a major water shortage in 1978 when water supply restrictions were enforced for a total of 287 days, causing considerable disruption to the lives of residents. Since that time Fukuoka has been pushing forward with water-resource development, and working hard to create a "Water Conservation Conscious City" a city where not a drop of water will be wasted.

As part of this effort, resources are being put into leakage prevention through surveys using the correlational leak detection method, the water leakage measuring method and the acoustic leakage sound detection method. At the same time, old distribution pipes and those with a history of leakage are being actively replaced to maintain distribution pipelines. The city has also created a water distribution regulation system, a leading-edge system that regulates pressure and flow in distribution pipes to promote the effective use of water.

This new system makes use of pressure gauges and flow meters that are installed all over the city and monitored centrally from the Water Distribution Control Center via telephone lines. On the basis of information received from these gauges and meters, motorized valves are opened and closed remotely from the Center, again via telephone lines, thereby regulating pressure and flow. Through this system, excess pressure is reduced, helping to prevent leakage.

In addition, efforts are being made to spread the reuse of reclaimed wastewater for flushing toilets, and the use of rainwater, as well as to promote the installation of water-saving plugs in faucets to reduce water wasted during opening and closing.

These various leakage prevention measures combined with other measures to promote the efficient use of water have established Fukuoka as Japan's leading water conservation conscious city. The main emphasis of this paper is on the regulation of water pressure in distribution pipes carried out from the Water Distribution Control Center, but also considers other measures being undertaken by Fukuoka for efficient water usage.

KEYWORDS

Leakage management, leakage prevention survey, distribution pipe improvement and maintenance, water distribution regulation system, efficient water use programs

INTRODUCTION

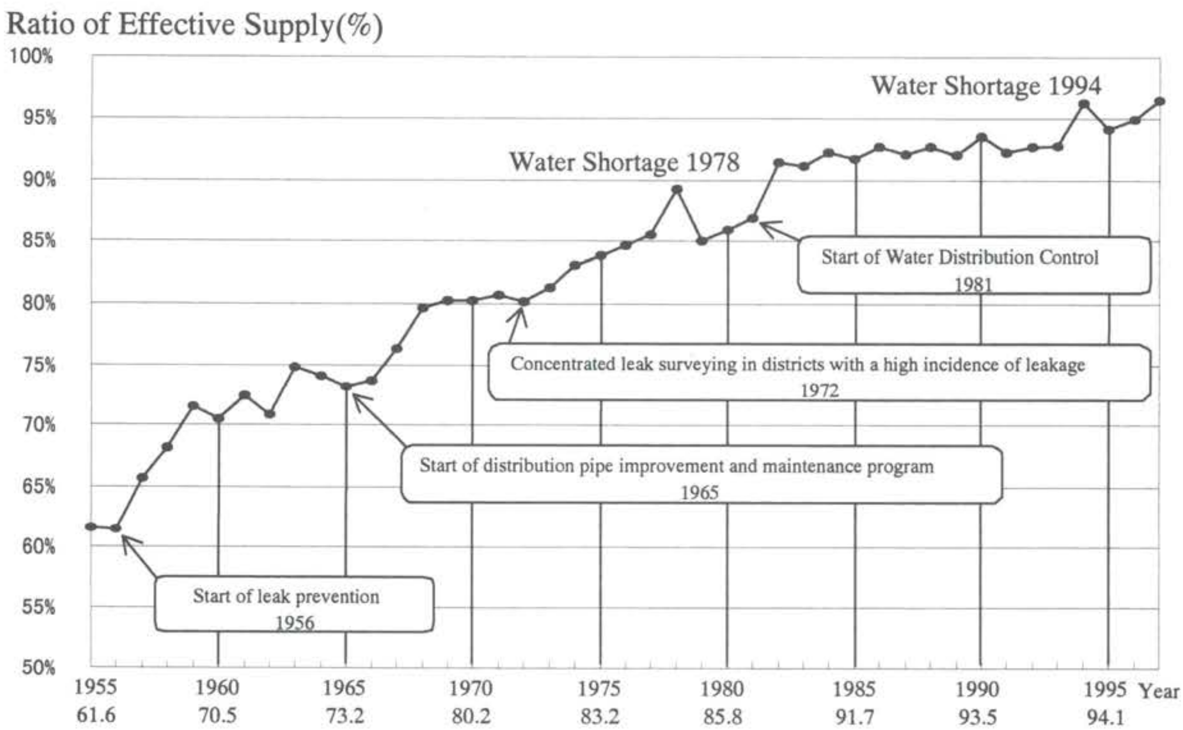
Fukuoka City supplies about 400 ML of water per day from 5 purification plants to its population of 1.3 million people, who have no other sources of water to meet their needs. The city has 7 dams and water is drawn from 4 rivers, but these operations are on a small scale. This together with the reality in recent years of reduced precipitation has meant that water shortages have become more common. To tackle this problem, the public and private sectors and residents have come together to work on projects that contribute to the effective use of water. For example, in addition to developing new water resources through seawater desalination and the construction of new dams, the reclamation of wastewater, the rationalization of agricultural irrigation together with the promotion of water-conserving plugs for faucets, and water-conserving toilets are also being undertaken.

WATER LEAKAGE MANAGEMENT

In Fukuoka, with its very limited water resources, the effective use of water is one of its greatest challenges. The following three measures are being taken as the foundation of its approach to counteract water leakage:

a. Leak prevention surveys: use of leak detectors etc. for the early discovery of leaks followed by rapid repair.
b. Distribution pipe maintenance: replacement of deteriorated pipes.
c. Water distribution regulation: managing water leakage through pressure regulation.

Through these measures the ratio of effective supply ((distributed amount – leaked amount)/distributed amount) rose to 96.5% in 1997 (see Graph 1), the highest figure for a major Japanese city.



Graph 1. Change in Fukuoka's Ratio of Effective Supply with Time

Looking at the change in the ratio of effective supply in recent years, the very rapid rise after 1965 was due principally to an increase in leakage detection work and a program for the systematic replacement of distribution pipes. The rise from 1972 was due to concentrated leak surveying in districts with high incidences of leakage, and the rises from 1981 have been due to the introduction of water distribution regulation, carried out from the Water Distribution Control Center, covered in more detail in below.

Leakage Prevention Surveys
Water leakage occurs out of sight, for example, under roads where the increase in traffic volume has been responsible for serious damage to pipes, and in other cases in which certain soil types cause pipe corrosion. Of the approximately 3,300 Km of distribution pipe laid by the city, 2,930 Km was laid 5 years or more ago and is subject to a systematic survey to locate and repair leaks as early as possible and so save valuable water (See Figure 1). The correlational leak detection method is applied to 30 Km of pipeline, while the water leakage measuring method and acoustic leakage sound detection method are applied to 2,900 Km of pipeline.

The correlational leak detection method is applied in places where water leakage could lead to a serious accident, that is, where distribution pipes are crossed by railroad lines or major roads. Every year, correlation type leakage detectors are used at 310 such locations over 30 Km of pipeline in nighttime surveys.

The water leakage measuring method is applied to 2,900 Km of pipeline in a 4-year cycle, so that 725 Km is subject to survey every year. Using transportable electromagnetic flow meters, nighttime surveys are conducted 1 "block" at a time (a block being equivalent to 1.7 Km of distribution pipeline, the whole city being divided up into approximately 1,600 blocks), with a norm of 3 blocks per night.

The acoustic leakage sound detection method is applied over the same 2,900 Km of pipeline in a 2-year cycle. Electronic leak sound detection bars are applied to division valves and other points to investigate the presence or absence of leak sounds over 5 blocks per day.

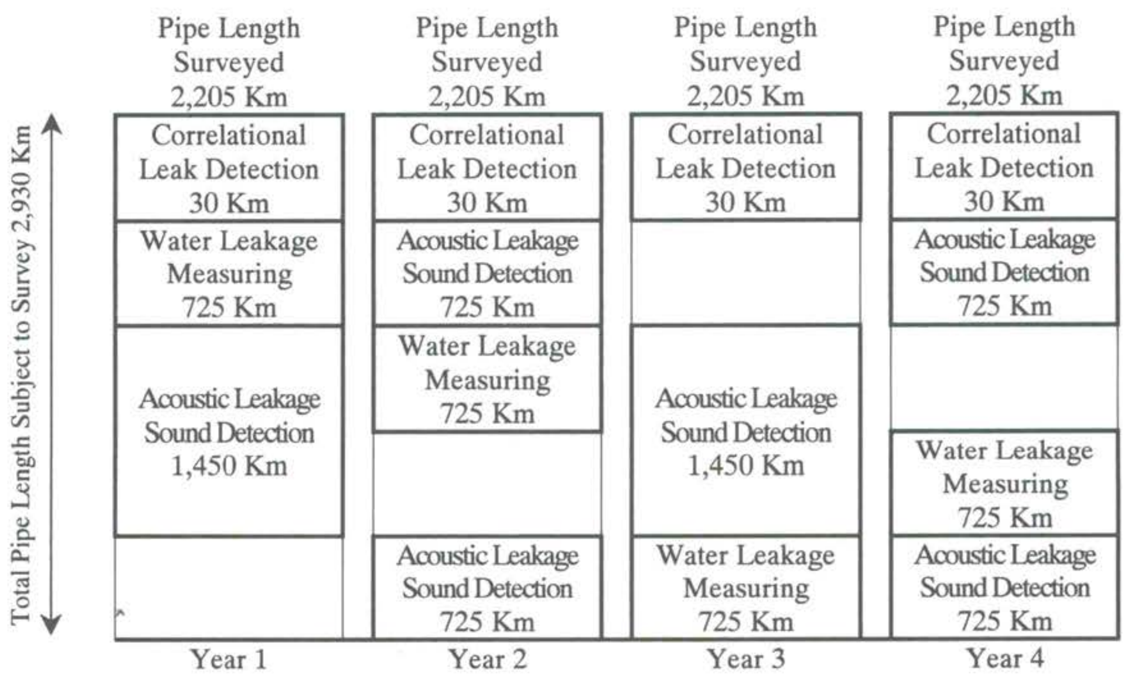


Figure 1. Leakage Prevention Surveys

Leak Repair
As a result of these leakage prevention surveys, about 800 leaks (or 1 leak per 4 Km of distribution pipeline) are discovered every year. In addition, the waterworks bureau receives 2,700 reports per year of natural leakage onto roads from its own patrols and residents, while accidents due to

construction and other work account for another 500 incidents of damage to pipes every year. A further 2,000 cases of service pipe leakage within private property are also reported by residents every year, making a total of approximately 6,000 incidents per annum. Each and every case is responded to with rapid repair effected, day or night, as part of the bureau's effort to reduce water lost to leakage.

Distribution Pipe Improvement and Maintenance

It is being said that Fukuoka is Japan's most dynamic city, and with this its population is growing every year. To cope with the rising demand for water that is accompanying the city's development, a program of distribution pipeline improvement and maintenance is being carried out. This includes the laying of new and larger bore pipeline, the relaying of deteriorated pipeline, and subsequent to the serious water shortage of 1978 the laying of pipeline between purification plants to provide inter-plant load distribution. In 1997, 70 Km of pipeline was laid, 30 Km to support increased demand and 40 Km to replace deteriorated pipeline.

Of the pipes that become deteriorated, many are cast iron without mortar lining. These are responsible not only for leakage, but also rusty water and poor discharge. For this reason, the waterworks bureau is actively replacing very old pipes and those with a history of leakage. Deteriorated pipes with a bore of 400 mm or more are being replaced with ductile iron pipes lined internally with cement mortar, and those with a bore of 350 mm or less with ductile iron pipes coated internally with fusion bonded epoxy.

In addition, as a result of the 1995 Kobe earthquake that damaged many water supply facilities, the installation of earthquake-resistant pipeline and construction of earthquake-resistant service reservoirs is now being planned.

WATER DISTRIBUTION REGULATION SYSTEM

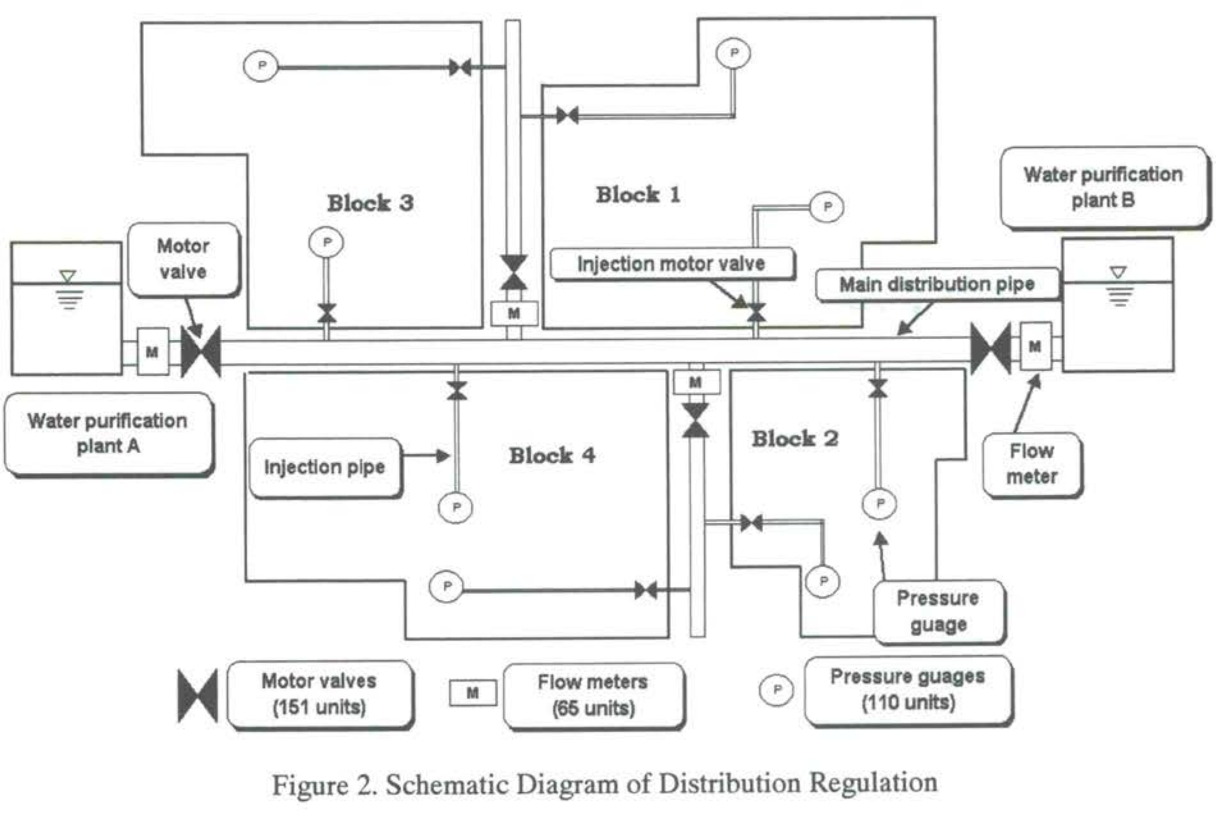


Figure 2. Schematic Diagram of Distribution Regulation

One of few such facilities in Japan, the water distribution regulation system (See Figure 2) operated in Fukuoka makes a very substantial contribution to the prevention of water leakage.

This system monitors information on pressure and flow in water mains on a 24-hour basis, from central monitoring and control equipment located in a facility called the Water Distribution Control Center. Information is transmitted to this central facility from pressure gauges and flow meters attached to water mains, via telephone lines. Further, on the basis of this information, this system allows motor valves installed in distribution pipes to be opened and closed by remote control via the telephone lines in order to regulate pressure and flow.

Taking into consideration separate water distribution areas, differences in land elevation, the location of rivers and railroads, and differences in water usage, the water distribution district is divided in 21 blocks in order to smooth the regulation of pressure and flow. There are now 110 pressure gauges, 65 flow meters and 151 motor valves installed as part of the water distribution regulation system.

Regulation of Water Distribution

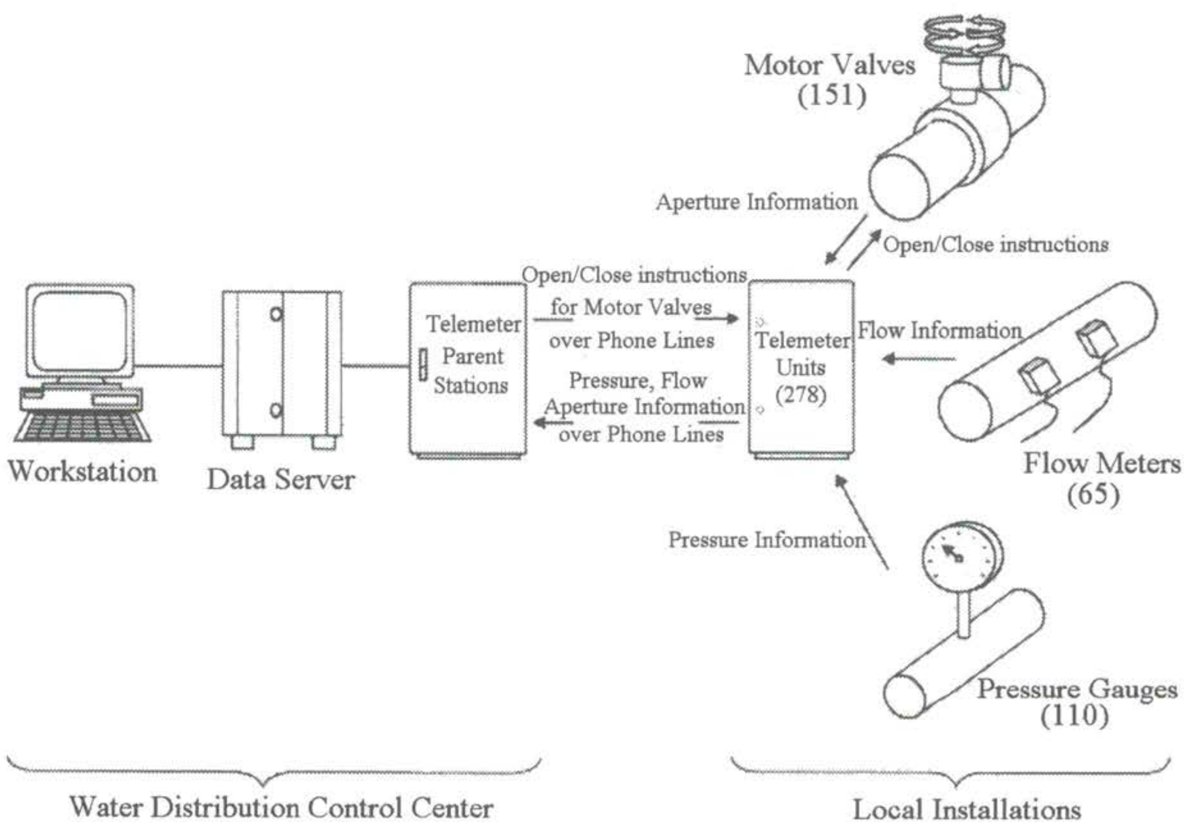
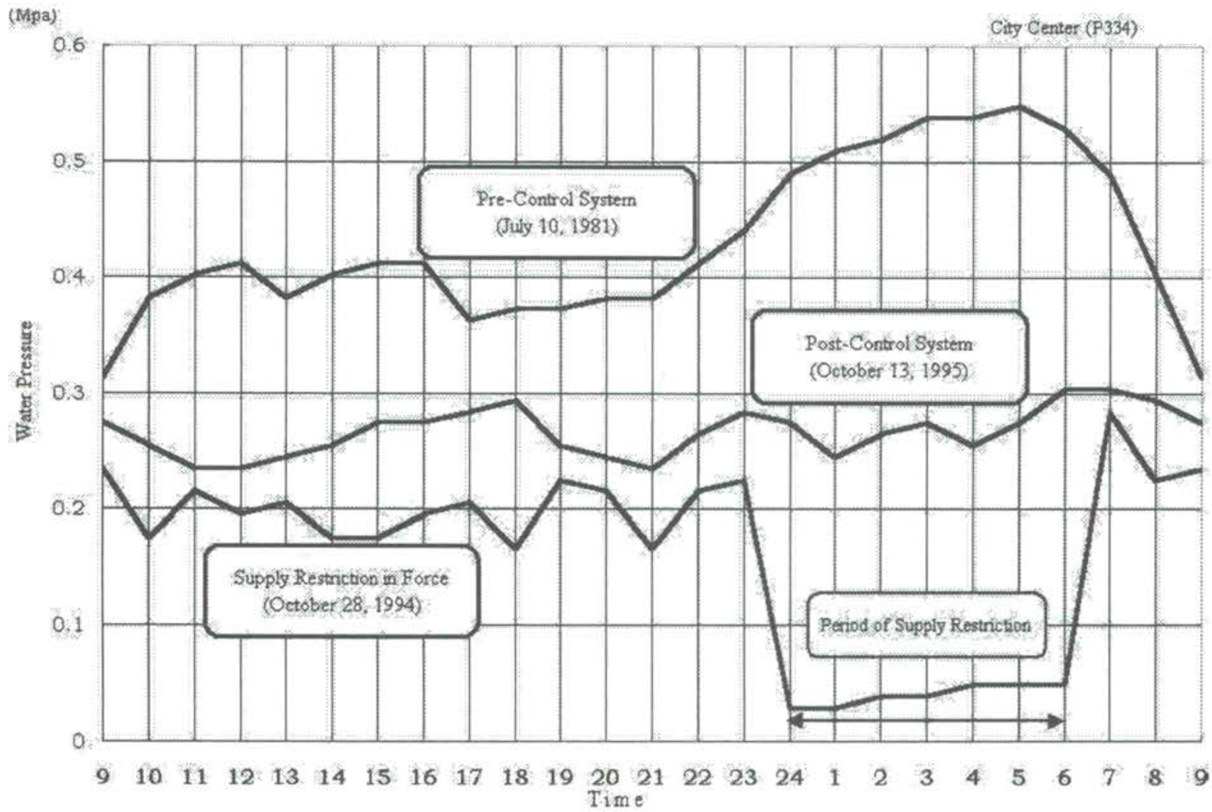


Figure 3. Schematic Diagram of System Signal Pathways

The regulation of water distribution (See Figure 3), through the operation of motor valves, works as follows: Information on pressure, flow and valve aperture is fed from pressure gauges, flow meters and valves installed in distribution pipes to one of 278 local telemeter units. In turn, this information is transmitted via telephone lines from the telemeter units to telemeter parent stations located in the Water Distribution Control Center before being collated by a data server in real time. Workstations then use the collated information stored in the data server to calculate appropriate values for pressure and flow which are then checked by an operator before it issues these values as instructions. These instructions are stored in the data server and then transmitted by the telemeter parent stations back to the telemeter units via telephone lines. The telemeter units then feed the instructions to motor valves for automatic adjustment of valve aperture.

Motor valve operations continue around the clock with the ultimate goal being to maintain distribution pipe pressure in the range 0.25 to 0.29 MPa (the average value for 1995 was 0.35 MPa). As a result of introducing valve operations to reduce pressure, it has fallen in value by 0.10 to 0.20 MPa (See Graph 2). With this, the number of incidents of natural leakage from distribution pipes has fallen by approximately 30%, and as expressions (1) to (4) below show, water saving due to pressure reduction amounts to about 5 ML per day.



Graph 2. Water Pressure Regulation Time Series Graphs

$Q_1 = (P/P_0)^{\eta} \times Q_2$ (1)

$Q_0 = Q_2 - Q_1$ (2)

Q_0: water conserved
Q_1: amount of water leakage converted
Q_2: amount of water leakage measured (in 1979 before establishment of Center 39.9 ML/day)
P : standard water pressure (average in 1995 subsequent to establishment of Center 0.35 MPa)
P_0: measured water pressure (average in 1979 before establishment of Center 0.46 MPa)
η : exponent (for orifice $\eta = 0.5$, for crack $\eta = 1.15$)

Substituting in measured values for Fukuoka:

$Q_1 = (0.35/0.46)^{0.5} \times 39.9 = 34.8$ ML/day (approx.) (3)

$Q_0 = 39.9 - 34.8 = 5.1$ ML/day (4)

Water Distribution Control Center

By regulating pressure and flow through remote operations the Water Distribution Control Center, located within the head office of Fukuoka City Waterworks Bureau, is responsible for preventing leakage and saving water. The Center has 5 objectives:

a. To adjust flow between water purification plants (inter-plant load distribution)
b. To limit water leakage through water pressure adjustment
c. To reduce manpower required for valve operations during water shortages
d. To make early discovery of distribution pipe abnormalities and respond rapidly by remote control
e. To gather and analyze information to make water distribution more efficient

Through these objectives, the Center supports Fukuoka's water supply operation by enabling centralized monitoring and control over water distribution, that is, flow and pressure from purification plants right up to faucets. As a result, the city is the best in Japan as measured by the efficient use of water resources.

Subsequent to the establishment of the Center, in 1994 water restrictions were imposed for a period of 295 days during which it demonstrated its usefulness in the following ways:

a. Close control over the proportion of water distributed from each purification plant, in accordance with the water resources available, made it possible to plan the efficient use of water resources.
b. By carrying out remote control to reduce pressure while monitoring pressure gauges installed all over the city, it was possible to reduce pressure evenly over the whole city, without the occurrence of poor discharge from faucets.
c. It was possible to carry out operations to suspend water supply by closing block injection valves through remote control, and therefore it was achieved rapidly and with very little manpower.
d. Because water pressure within the city was monitored 24 hours a day, even if pressure fell well below operational levels when supply was suspended, it was still possible to maintain pressure at safety levels. This prevented poor discharge of water flow, due to air entering pipelines, when water supply was resumed.

Table 1. Comparison of the Water Shortages of 1978 and 1994

	1978	1994
Serviced Population	1,028,000	1,248,000
Connected to Sewer System	37.3%	96.3%
Maximum Possible Daily Supply	478 ML/day	704.8 ML/day
Annual Rainfall	1,138 mm	891 mm
Water Supply Restriction Period	May 20, '78 – Mar 24, '79	Aug 4, '94 – May 31, '95
Water Supply Restriction Duration	287 days	295 days
Average Hours of Water Suspension	14 hours/day	8 hours/day
Mobilized Valve Control Personnel	32,434 person days	14,157 person days
Dispatched Water Trucks	13,433	0
Complaints and Inquiries	47,902	9,515

e. High land elevation and other factors mean that approximately 20% of the water supply district falls outside the area which can be managed by the Water Distribution Control Center. For this reason, division valves had to be closed and opened manually as part of operations for water supply suspension. In 1978, 113 personnel per day were required for manual operation, while in 1994 only 48 personnel per day were required, less than half of the previous figure.

f. During supply periods it was possible to offer a reliable supply. This meant that while in 1978 13,433 water wagons had to be dispatched, during the 1994 water shortage mobilization was unnecessary. In addition, the number of complaints from residents received during the 1994 shortage was only 1/5 of the number received during the 1978 shortage (See Table 1).

In addition, when accidents occur to distribution pipes or at purification plants, not only are the affected parts sealed off rapidly, but within a short time it is possible to carry out modification operations to the distribution area, water leakage is minimized, and modification operations can be completed with a reduced number of personnel.

OTHER MEASURES TO PROMOTE EFFICIENT WATER USE

In addition to undertaking leakage prevention measures, Fukuoka is also making efforts to reuse reclaimed wastewater and to use rainwater, to rationalize water for agricultural use, and to promote the use of water-conserving plugs and water-conserving toilets.

Reuse of Reclaimed Water

The City is active in promoting 3 different systems to reuse reclaimed wastewater for flushing toilets. First, the wide-area circulation system: reclaimed water is being supplied to a total area of 770 ha in the central part of the City which includes the main City Hall building as well as subway stations. Second, the district circulation system: there are several apartment complexes, outside the above 770 ha, equipped with their own treatment facilities that recirculate reclaimed water within the complexes. Third, the individual facility circulation system (See Figure 4): any large new buildings, that is those which are to be supplied through 50 mm bore or larger pipe, and/or those which will have a total floor area of 5,000 m^2 or more will incorporate individual facilities to reclaim non-fecal wastewater.

In 1996 384 facilities and 2 apartment complexes were reusing reclaimed wastewater which amounted to 7 ML per day. In addition to this, investigations into the possible use of rainwater for flushing toilets, and for watering trees and plants are being carried out.

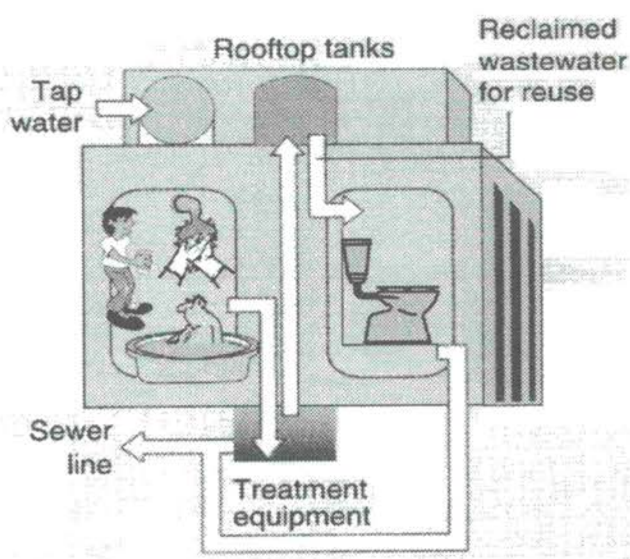
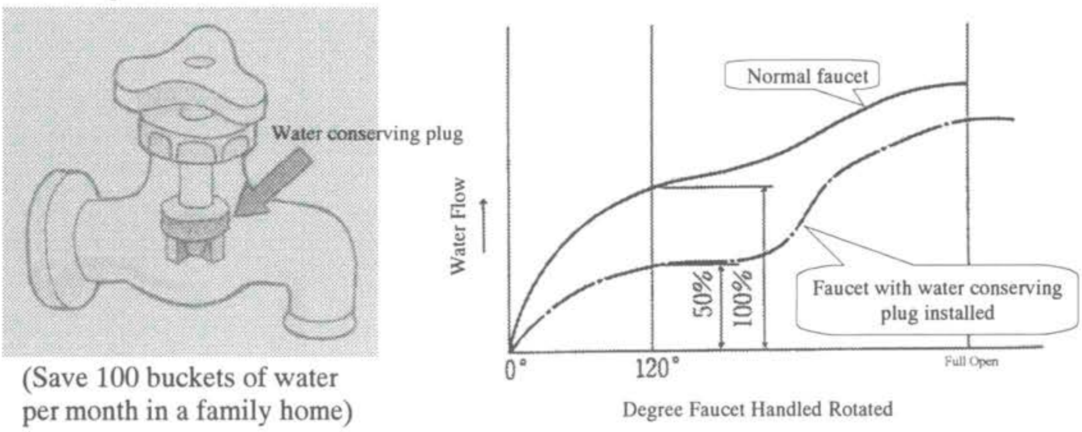


Figure 4. Schematic Diagram of Individual Facility Circulation System

Rationalization of Water for Agricultural Use
By replacing conventional open channels used for irrigation by pipe networks that carry water pumped under pressure to all agricultural production districts, permeation and evaporation that occurs in open channels is eliminated, and excess water needed to maintain water level is reduced.

Promoting the Use of Water-Conserving Equipment
Efforts are being made to spread the fitting of water-conserving plugs (See Figure 5) to frequently used faucets, such as those in the kitchen and on hand basins, to reduce wastage during opening and closing. For a family of four, the effect of fitting of water-conserving plugs is equivalent to approximately 100 10-liter buckets of water saved per month. Water-conserving plugs are now fitted to 94.1% of faucets in the City. In addition, the City is also working to promote the use of water-conserving toilets that use less water, and other water-conserving equipment such as bath heaters that can reheat bath water that has cooled, instead of supplying additional hot water to the bath.

The water conserving plug saves approximately one cubic meter of water per month in a four-person household.



(Save 100 buckets of water per month in a family home)

Figure 5. Water-Conserving Plug

ISSUES FOR THE FUTURE

Fukuoka is promoting the efficient use of water through various measures, but with water resources being very limited the city cannot afford to be complacent. To further promote the efficient use of water it is necessary to push forward with the following measures:

a. To develop effective techniques for the discovery of water leakage, and to advance measures that will prevent water leakage occurring, as well as furthering measures for water leakage prevention.
b. To plan the extension of automatic control from the Water Distribution Center into the 20% of the City area which is presently outside its control, in conjunction with equipment renewal for the 80% of the city already under its control.
c. To promote the efficient use of water, by establishing an integrated system for water supply control and management. This will involve not just the distribution regulation system. It is the aim to create a water intake system that will have the capability to monitor in a unified way, precipitation in the vicinity of dams, inflow and water stored in dams, and river flow in real time.
d. To enlarge/increase the number of districts that reuse reclaimed wastewater.
e. To promote understanding of the importance of water and raise water-saving consciousness amongst city residents by conducting tours of water supply facilities, and to carry out public relations activities through the distribution of pamphlets and via the Internet home page, thereby establishing on a permanent basis a city which values its water.

Measures for the future will be linked to ensuring a reliable water supply and increasing the efficiency of water supply management, so the bureau will carry out various investigations, increase effectiveness and actively develop a range of measures.

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WHOLE-SCALE REDUCTION OF WATER USE: THE MEXICO CITY PROJECT

Presented by Cristianne Chauvet-Urquidi *

MEXICO CITY AND ITS WATER RESOURCES

With an urbanised area of 1300 square kilometres, the Mexico City Metropolitan Area is an overall example of the challenge posed by nearly 20 million people and 45% of the country's commercial, services and industrial activity, to provide sufficient supply, proper allocation and disposal of water and wastewater services, efficiently maintain its infrastructure and manage through multiple institutions.

Situated 2,200 meters above sea level in the southern part of the Mexico Valley Basin, it is surrounded by mountains three to five thousand meters high. Once it had abundant surface and underground water resources, notably freshwater and saline lakes, rivers and springs. The Aztec city of Tenochtitlán, was founded in the fourteenth century on an island, growing over the main freshwater lake. They developed extensive engineering works for canal-ways, dykes for flood control and separate fresh from salt water, disposal of used water and an elaborate network of aqueducts to supply drinking water from numerous springs. The Spanish in the Sixteenth Century, continued to use many works for the new Mexico City, but the dykes were destroyed, making the area flood-prone. To control continuos flooding in the city, the basin was artificially opened in the XVIIth Century, draining the lake system. Springs provided fresh water up to the 1850's, when, on the discovery of potable ground water, hundreds of wells were built. By the early 1900's, increased ground water extraction and lake drainage dried natural springs and land subsidence became a serious problem. In the 1950's, many wells were closed down to deter subsidence and flooding. At this time the city had a population of 4 million people. Since then, major engineering works have been built to reduce flooding in sunken areas, deep sewer systems to expel used and rain water from the Basin and to import one third of the needed water into the Valley of Mexico, at great costs to population and public budget.

It is governed by two separate different political jurisdictions, the State of Mexico and the Federal District. The Federal District is the seat of Mexico City, the nation's Capital, with almost 10 million inhabitants. Mexico City is divided administratively and territorially into 16 delegations, with centralised water management services.

Ground water levels have been deepening and declining over the past century causing increasing regional land subsidence, reaching over 7.5 meters in the city centre. This phenomenon is exacerbating flood-prone conditions, damaging building foundations and infrastructure – mainly water and sewage systems -, becoming a public health risk from microbiological and chemical contamination of hazardous waste management.

In sum, water supply for Mexico City and its metropolitan area is becoming a major crisis.

Water provision, sources and difficulties

The total water provision for the Valley of Mexico is in average 62 m3 per second. 35 m3/sec. are assigned to the Federal District (Mexico City) and 27 m3/sec go to rest of the metropolitan areas.

There are three main water sources, the lesser supply only 2% from local surface springs. Over 1,100 wells underlying the metropolitan area provide 66% of the metropolitan water supply. And the third source of supply, of 34 % is brought into the valley from nearby basins, the Lerma and Cutzamala Rivérs and lake systems located 60 km and 127 km away. Importing water requires transporting and pumping it through canals, aqueducts and pipes over 1000 meter high mountain range at great costs of electricity and treatment plants. It is then distributed throughout Mexico City's 12,000 kms of primary and secondary lines that supply nearly 1,697,000 users. Additionally, very big users have well concessions with extraction quotas, also paying to use the sewer system.

Average per capita water use is estimated at 350 litres/person/day, including unaccounted for water, a very high consumption when compared to other cities, such as 280 lt.p.d. in Barcelona, 230 lt.p.d. in Hamburg or 160 lt.p.d. in Brussels.

Water loss and collateral effects

It is estimated that 37% of the total water supply of the Federal District is unaccounted for, mainly leaks in the public water lines, not including loss of water in private property. Aged and obsolete water pipes, deteriorated by corrosion or damaged by the continuos sinking of land levels, tectonic faults and earthquakes, heavy traffic and uncontrolled interference of the infrastructure (illegal connections), have had inadequate maintenance for years.

The city cannot have access to alternate water sources that can be exploited at reasonable costs. To exemplify, there is an ongoing project to import additional water by 5 m3/sec, with an estimated investment of one thousand million pesos per cubic meter/sec.

The best strategy is to save and prevent loss of water. Awareness and participation of the individual and collective consumer is as important as the recovery of unaccounted for water.

PLANNING AN INTEGRATED APPROACH FOR EFFICIENT WATER USE

Institutional Framework

A general prevalent attitude has been that water resources are state property, a constitutional right free of charge. As a result, water supply and drainage have been strongly subsidised for years, causing the sector severe financial deficits.

Water in the Valley of Mexico is managed by various federal, state, municipal and local institutions, loosely integrated and co-ordinated. Within the Federal District, bulk water allocation, initially regulated by the Ministry of Agriculture and Water Resources (SARH), was recently taken over by the National Water Commission (CNA); the Federal District's local utility is the General Direction for Water Construction and Operation (DGCOH), responsible for distribution. And up to 1995, the collection of water bills, meters, metering and the billing services were handled by the Treasury Department of the Federal District.

The various institutions involved in the water sector in Mexico City have become unable to deal with the magnitude of the problems of demand to expand water supply systems or improve services, repair leaks nor treat wastewater, deal with illegal connections and improper use deter pollution of underground water tables.

Water dues are regulated by Fiscal law, billed and paid on a bimonthly basis. Up to 1996 the Treasury Department of the D.F. was responsible for water billing, collecting and execute legal actions to recover owed dues, apply surcharge, penalties, recovery costs, and even seizure of property, hardly ever executed. Its water register listed 1,340,860 users, billed under two modalities: estimated metered daily consumption and fixed tariffs for different urban socio-economic conditions. Many had obsolete user, property and address data. Neither billing methods encouraged meter installation, efficient water use, domestic maintenance of installations nor payment of bills. The average bimonthly revenue was only 30% the emission value and an enormous overdue debt was accumulated. Payments in banks and in the Treasury's offices were not recognised opportunely in the users accounts. Only some 16,000 big users were being metered regularly and billed with metered service.

Mexico initiated in 1988, nation-wide major reforms for water resource allocation and management of water services, developing new laws and regulations, specific institutional structures, conservation measures, education programs and innovative conditions for public-private joint ventures, among others. The new National Water Law in 1992 called for State Water Commissions and local municipal operating organisms, with the intention that water become a common service, not a tax, as has happened in several cities.

The Mexico City Water Strategy Project

The Federal District Water Commission (FDWC) was created in 1992, to develop a new water management strategy, to improve public allocation and administration of potable water, drainage and treatment and reuse of residual waters and to promote a new cultural awareness of water as a finite resource to be paid for. The decree provided for privatising or allocating management and operation contracts for water services.

The FDWC began operating in 1992, requesting bids from private firms for the management of water distribution and billing. Ten year contracts were signed with four winning firms, joint ventures of leading Mexican construction companies and international water utility firms (French and English), each strategically contributing their expertise and state-of-the-art technologies in water-related services. 1/ The firms are paid according to offered unit prices for agreed activities. All activities and corporate image is conducted in the name of the FDWC and all revenues for water services are given to the Treasury.

This was the beginning of the Mexico City Water Strategy Project. Its main objectives are to assure the physical and financial sustainability of the hydraulic systems and guarantee the provision of water for future generations, following strategies to achieve the modernisation of the water management structure, enforce metered service billing to reduce immoderate use of water, stabilise the local aquifer, procure more revenue and improve all water services.

Three Stage Plan for Modernising Water Management

The Modernising Water Management Project was designed to be executed in three consecutive stages. To implement it, the Federal District - Mexico City - was divided into four zones of four adjoining delegations in average, assigned one to each water company, with roughly equal number of users and territory.

The First Stage was carried out from1993 to 1996, accomplishing three basic activities:

- An updated city-wide census to register all detected intakes and property. Current validated information detailed each property's characteristics, number of metered or non-metered intakes and hydraulic installations, type of ownership (private, rental, condominium), water use for domestic, non-domestic or mixed activities, non-domestic activity classification, among others. A geographic co-ordinate location identity was given to each property as a new account number.

- 1,630,000 properties and about 10% more intakes were registered in 1996, 26% more than the Treasury's.

- Intake regularisation and installation of new water meters with remote electronic/radio read devices and reconstructed meters, which included refitting intakes to receive the meters and update related data on type of materials, diameter and meter brand. Metered reading began almost immediately. The new long-range read electronic meters were adopted to lessen the need to enter the premises, thus avoiding insecurity factors and molesting its occupants. Meter installation was deferred in areas with poor water services and quality, mainly very low income sectors above high water levels.
  - Almost 900,000 meters were installed or exchanged in this period, to about 70% of the newly identified users. In 1999, the number of installed meters has grown to 1,151,000, covering 86% of the users' register.

- A digitised Intergraph map of more than 12,000 km of secondary and tertiary water and 11,000 km of sewage distribution lines systems, connections, valves, etc.

The Second Stage, labelled the "Commercial Stage", to be executed for the duration of the ten-year contract, began preparatory development in 1994 and became operable in 1996. It was designed to develop and operate the Water Users' commercial billing system on a two month cycle, to emit bills and collect payments, carry out meter reading, improve customer services and streamline water rates.

The Third Stage, begun in 1997, was designated to act on detection and repair of visible and underground leaks and the operation, maintenance, extension and rehabilitation of the secondary distribution systems, using state of the art technology.

MACRO-SCALE WATER USE MANAGEMENT

To guarantee sufficient water supply, good drinking quality, used water treatment, infrastructure maintenance and become cost efficient, the Water Commission's strategy considers that:

- Exact metered consumption billing
  - promotes efficient water use
    - added to prompt payment
      - plus infrastructure rehabilitation,

will result in an integral improvement of the hydraulic system.

Two basic factors have proved to be central to whole-scale reduction of water use, to be executed with the Second and Third Stage activities.

- billing by metered consumption, and
- repair, rehabilitation and substitution of infrastructure to recover water loss.

Second Stage - Water Users' Commercial System

A totally unprecedented new commercial system had to be created to manage the new water billing register. Such systems in other countries were not flexible enough to be adapted to the project's needs, the tariff and billing structure and the sheer size of the billing register and metered reading. Census and meters were the core to build and develop the Water Users' Commercial System, the main activity of Second Stage.

The most outstanding aspects of the Water Users' Commercial System are:

- Starting in 1994, it took over a year to prepare the basic specifications of the System. Each company developed its zone commercial systems to satisfy the FDWC's technical specifications for hardware and software platforms, operating systems, communications networks and connectivity features to connect with the also specially developed Commission' concentrating commercial system.

- New account numbers were allocated to each intake and property, based on geographic co-ordinates. These were correlated with the Treasury account numbers, in order to substitute the old users' register and receive five years' information. It took more than a year to complete a 95% correlation.

- Validating procedures were designed and installed in the Commission's commercial system to assure completeness, integrity and proper association of each zone's data bases (users, account and meter numbers, properties, billing methods, tariffs, etc.).

- Specific billing methods were designed to offer impartial billing in accordance with each property's characteristics, relating to number of metered or non-metered intakes and hydraulic installations, number of domestic and non-domestic units, type of ownership (private, rental, condominium), whether domestic, non-domestic or mixed uses, the type of non-domestic economic activity, in turn linked to its corresponding domestic, non-domestic, metered or fixed tariffs. Presumptive daily average consumption values for non-metered intakes, based on metered consumption of corresponding property types, use, ownership and economic activity in the same neighbourhood.
  Initially over forty billing methods were determined. They have been reduced to 18.
  At least every year the billing methods are revised and adapted according to current fiscal and income laws, or to correct conditions that affect billing types.

- A two month cycle to allow for reading all meters once and reread faulty data, pre-emission for information certification, production and printing of bills and distribution of bills prior at least 20 days for payment without surcharge on the last day of the following month. Only one printing firm was found to process with adequate technology, the large volume of billing forms, print user's billing data and bar-code and fold/seal the bill in ten days time at a reasonable price!

- Modern customer services facilities, different from common public sector offices were installed by the companies. At least one Water Commission Users Agency to each delegation to attend to 80,000 accounts each, some requiring three agencies. Features like distinguishing colours, comfortable assistance counters and waiting areas, computerised payment collection and data base account consultation, hot-line and telephone assistance centre, and of course, the efficiency and capacities of commercial systems, were competition factors among the four firms.

- Actual billing by the FDWC began the first bimester of 1996, to selected areas in almost totally metered neighbourhoods in four delegations. Two months earlier, users were sent two notices informing the change in account number, their corresponding billing method and average daily metered use previously registered to alert on above average consumption. Four Water Commission agencies were ready to receive users.
  By the 5th bimester of 1997, the whole new water users' register was finally billed by the FDWC.

- Reactions to metered consumption soon emerged after the first and second bills. Some upholding the need to care and pay for water resources, others mad and frightened with high bills yet not acknowledging the use so much water a day, and those opposed to pay for metered use, a situation quickly appropriated by political groups and local leaders. Metered billing had to be deferred for special fixed rates in some represented areas or to protect poorly serviced areas with fixed rates or minimum average consumption. Each batch of newly billed accounts presented similar reactions.

- In 1998, controlling 100% water accounts, the FDWC undertook an unprecedented action, that of recalling domestic users' with overdue water payments in the past five years, adding the Treasury' owed accounts and the Commission's. Over a million and a half debt-reminder letters, legal notifications and requirements have been sent urging users to pay or exhibit paid bills and clean their billing registers. The response has been massive.

The most significant indicators after almost five years developing and operating the Commercial Stage are:

Water Users' Register:
- The new water users' register in 1996 listed 1,637,243 accounts, meaning a 23% increase on the Treasury's water register of 1,300,449 in 1995.
- The User's Register for 1999 has reached 1,697,000 accounts
  90% are domestic users
  6% are non- domestic users
  4% are mixed, domestic and non-domestic use
  18,000 accounts belong to big users, over 400 m3 per bimester
- 86% users are billed with real metered and average area consumption.

Billing:
- The first emission for the 1st bimester of 1996 produced 192,548 bills and 745,875 accounts by the end of 1996; almost 50% of the total register.
- By mid 1997, the total users' register listed 1,637,243 accounts, with an average billing value $409 million pesos per bimester, sensibly 100% more than the Treasury's billing.
- During 1998 metered accounts were billed free of fixed-rate conditions in protected areas. Diverse measures were adopted mitigate the impact of high consumption and political pressure, for low-income users and poorly served areas.
- The average bimester in 1998 was worth $422 million pesos and $454 million in 1999
  30% of the total emission value comes from domestic accounts
  64% is the value for non-domestic consumption
  6% is from mixed users
  51% corresponds to big users.

Users Services:
- 24 Water Commission Agencies in 16 delegations, offering efficient updated information, guidance, site inspections, meter maintenance, cashiers, graphic information.
- 4 Telephone Assistance Centres with 24 hour service.
- Modern data base management, exploitation and communication systems.
- Prompt modification of users' information, claim resolutions and inspections.

Metered billing influencing efficient water use

Specific indicators have been obtained, with real metered data management and field observation, of decreasing consumption patterns of individuals and groups.

Collection of water dues.
- In 1996, only 36% of billing was paid. Awareness of real consumption and better services, facilities and information, have prompted punctual and back payment, steadily increasing. In 1998, water revenues from regular payment represented an efficiency of 76%, not including payment of arrears.

- In the past twelve months, more than 1,500,000 letters of invitation to pay owed dues have been issued. Over $90 million pesos have been recovered, equivalent to 270,000 bimesters of some 65,000 users.

Reduction in individual and collective consumption

- Areas billed with metered consumption markedly reduce the overall consumption from two to four months after receiving the first bills emitted with metered consumption. People soon become conscious of the effect that "more water the more expensive the bill", reducing their individual consumption by fixing leaks and using less water for domestic activities, for as much as 40 %. The average two-month consumption of a five member family has diminished from 60 m3 to 41 m3.

- Areas with fixed-rate billing (with or without metered intakes) do not modify their consumption habits, since there are no deterrents to use water freely or waste in faulty installations.

- It is possible to refer to area or group readings to determine factors that alter or define consumption patterns and average standards, such as seasonal and climatic conditions, supply interference, types of users, properties or economic activities, among others.

The experience derived from extensive metered-service billing confirms its effectivity for massive water saving and efficient use. It requires a permanent meter maintenance and substitution programme, continue with meter installations in interior or secondary intakes, promoting permanent educational and informative displays in schools and public media on saving and taking care of water, meters and domestic installations.

Third Stage – Infrastructure Upgrading Actions

The growing demand of water can only be satisfied at a reasonable cost, if it is salvaged from faulty lines. Recovering water is cheaper since it is closest, it is potable, it has been paid for in bulk.

For the first time in the history of Mexico City, in 1998 the most significant works of the present City's Government were implemented, with the Leak Detection and Repair Programme, expected to become a permanent activity to improve the city's water infrastructure and recover at least 80% of 12 m3/sec lost water, estimated to supply 3.6 million people.

Mexico City has approximately 12,000 km of water lines. It is estimated that about 34% of the water brought to the City is lost in leaks, of which 80% happens in site intakes. Based on leakage statistics and maintenance reports of past years and a district-metering pilot programme in 1997 to measure water use and loss as well as field observation, it has been possible to identify areas with large incidence of leaks, in which working programmes are being executed. The four contracting firms brought into play the latest technologies in the market for leak detection and pipeline repair and replacement, as offered in the bid, making it possible to notably increase the volume of executed works and to reduce time and costs.

The Leak Detection and Repair Programme

The Leak Detection and Repair Programme embodies the following activities:

- detection and elimination of leaks
- rehabilitation of water lines
- substitution of site intakes
- replacement of valves

Detection and elimination of leaks, both visible on the surface and non-visible.
Whether in the pipeline or intake, to detect a leak, electronic and acoustic equipments are used, capable of monitoring the vibration and sound of a possible trickle and indicate the approximate location. Detection of non visible leaks is seriously hampered by pressures found in the distribution lines, especially in areas with low pressure. Confirming the leak point, the repair method is defined by the state of the material in place, using compression couplings, fitting short spans of pipe or the total replacement of the pipeline or intake.

- During 1998, 10,110 leaks in intake and distribution network were repaired.

Rehabilitation of water lines.
High-density-polyethylene pipes are being used to replace whole sections of pipeline. Two technologies are employed, depending on terrain conditions and existing underground installations: the traditional open trench, but more often, hydraulic pipe bursting equipment is being used to introduce the new material into the old pipe, breaking everything in its wake. This option requires little excavation and labour. Polyethylene pipes are sticked together with heating thermo-fusion or electro-fusion devices, permitting street-long lengths to be placed in one go.

- 155 km of 2" to 6" pipelines have been replaced.

Substitution of site intakes.
Pneumatic equipment is being used to perforate underground along the intake line without digging trenches, convenient to reduce bothering the immediate population and less time employed. High-density-polyethylene pipes are also utilised, fitting the site intakes to the main pipes with the same fusion technologies.

- Nearly 28,000 intakes have been replaced so far.

Replacement of valves.

- It has been necessary to replace 3,159 valves that were totally inoperable, along the replacement lines.

Impact

- It is considered that at least 500 litres per second have been recuperated with the above activities. Areas benefited by pipeline and intake replacement, who suffered of low pressure and intermittent supply, have experienced the opposite almost overnight. As well, nearby areas, also with deficient supply are getting more water.

- It is estimated that 1 m3 of recuperated water is costing $500 million pesos, while bringing more outside water would cost about 1,000 million pesos.

EXPECTED RESULTS
It is calculated that 31,000 meters will be installed in 1999. Metered billing is still being contested. It is necessary to reinforce the advantages of metered consumption and take care to maintain meters and users services adequately.

The budget for 1999 will allow to double the accomplished activities, to reach a recovery of water of 1000 litres per second. It is expected that at the same rate, in five years time, 30% of the total unaccounted-for water would be put into service.

A New Water Culture is slowly but surely emerging. It is necessary to emphasise the urgent need to reduce consumption to a minimum, promoting saving and efficient water use habits in the population of all ages.

Many industries, sport facilities, public parks and greens are turning to treated water from the city's treatment plants or installing their own treatment units, for non potable needs.

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"Mexico City's Water Supply. Improving the Outlook for Sustainability". Academia de la Investigación Científica, Academia Nacional de Ingeniería, National Research Council. Ed. National Academy Press, Washington D.C. 1995

FDWC Federal District Water Commission (Comisión de Aguas del Distrito Federal

1/ UTLITY FIRMS:

- Agua de México, S.A. de C.V. - Joint venture of Grupo GUTSA –Mexico and United Utilities (United Kingdom).
- Servicios de Agua Potable, S.A. de C.V. - Joint venture of ICA (Mexico and General des Eaux - Vivendi (France).
- Industrias del Agua de la Ciudad de México, S.A. de C.V. - Joint venture of Servicios Ambientales de México, S.A. de C.V. Brittingham Sada (Mexico) and Severn Trent Water (United Kingdom).
- Tecnologías del Agua, S.A. de C.V. - Joint venture of Grupo Bufete Industrial (Mexico) and Suez-Lyonnaise des Eaux (France).

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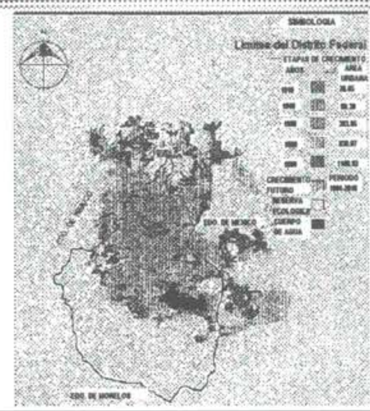
International Symposium on Efficient Water Use in Urban Areas
UNEP/IETC
8-10 June 1999 KOBE, JAPAN

WHOLE-SCALE REDUCTION OF WATER USE:

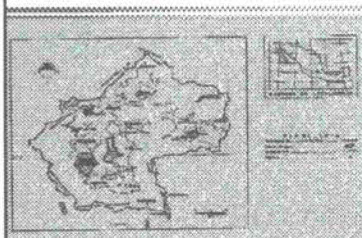
THE MEXICO CITY PROJECT

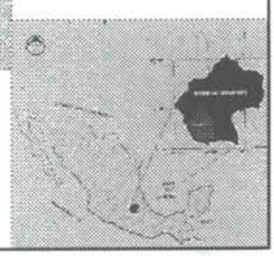
More water for Mexico City

Mexico City Metropolitan Area



The Valley of Mexico Basin





- **The Mexico City Metropolitan Area**

- **Tenochtitlan, founded in 1325 by the Aztecs**

- **Roads had both land and water ways**

- **The Aztec monarch Nezahualcoyotl built flood control dykes in 1450 and the Chapultepec Acueduct**

- **"Chinampas", artificial plots built on the lake for agriculture**

- New Spain's Mexico City was built over Aztec Temples

- The dikes were destroyed during the Spanish Conquest

Water related problems

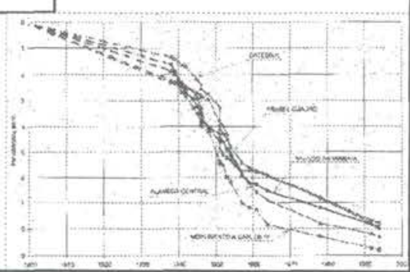
- To control flooding, lake drainage began in 1607

- Indiscriminate underground water extraction

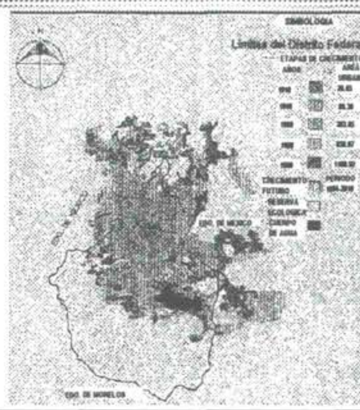
- The city center is now below lake level

Water related problems

- Land subsidence in several parts of the city center



Mexico City Metropolitan Area



Federal District Political Division

16 Delegations

Water provision and sources

- The Valley of Mexico receives 62 m^3 /sec
- 35 m^3 /sec are for the Federal District
- 27 m^3 /sec go to the conurbated metropolitan area of the State of Mexico

- 66% comes from local wells
- 9% is imported from the Lerma Valley, 60 km away
- 25% is imported from the Cutzamala Valley, 127 km away

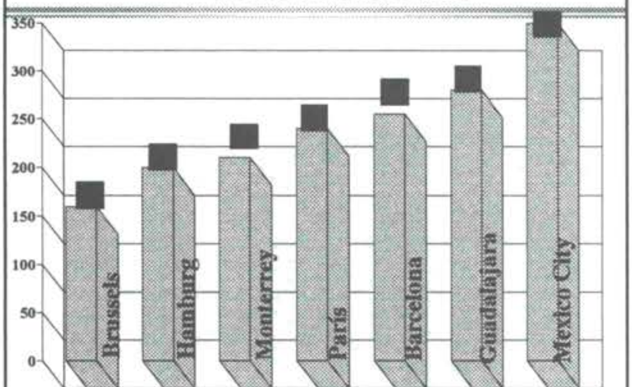
Lerma and Cutzamala Systems

Lerma and Cutzamala Systems

- Conveyed in canals and pipes
- 19 tons/sec of water pumped 1000 meters high over the Valley's mountain range

- Distributed throughout 11,000 km of lines and into 1,690,000 intakes

Average liters/person/day

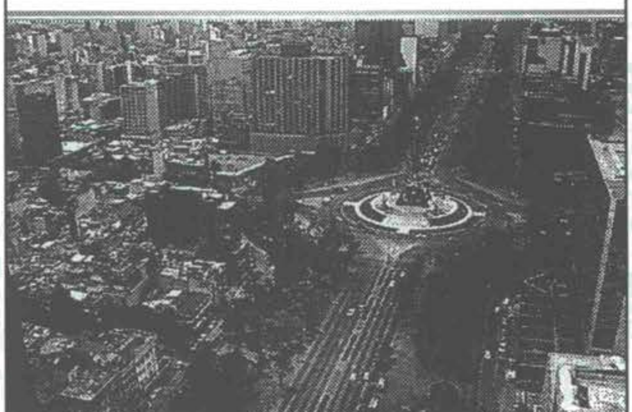


Unaccounted for Water

37% water is lost in aged, obsolete, fractured, intercepted and inadequately maintained pipelines

Unaccounted for Water

The City needs more water



Mexico City
Water Strategy Project

- **Save water**
  Prevent waste
- **Recuperate water**
  Prevent loss

Water Management Problems

- Indiscriminate waste and loss of water
- Defective distribution systems
- Insufficient resources for main works
- Excesive subsidies
- Administrative overlapping
- Generalized non-payment

Water Management Structure after 1992

	FEDERAL DISTRICT	STATE OF MEXICO
NATIONAL Whole-sale water allocation	NATIONAL WATER COMMISSION	
REGIONAL (Basins) Introduced and extracted water	MEXICO VALLEY WATER COMMISSION	
LOCAL		
Coordination	✧Federal District Govmt	✧State Water Comission
System O & M	✧Hydraulic Operation and Construction General Direction	✧Operating Organisms
System rehabilitation	✧Hydraulic Operation and Construction General Direction ✧F. D. Water Commission	✧State goverment ✧Municipal government ✧Operating organisms
Users register & billing	✧ F. D. Water Commission	✧Operating organisms
Collection	✧F. D. Water Commission ✧F. D. Treasury Dept.	✧Operating organisms

Mexico City
Federal District Water Commission

- Decentralized agency created in 1992, with technical, operative autonomy and fiscal attributions, to:
  - Manage the water users' register, bill and collect
  - Manage, operate and preserve the hydraulic systems
  - Contract services with third parties

Federal District Water Commission

Strategic Objective

- Attain the physical and financial sustainability of Mexico City's hydraulic systems

Federal District Water Commission
Mexico City Water Strategy Project

SERVICE CONTRACT BID

Servicios de Agua Potable
(ICA/General des Eaux-Vivendi)

Tecnologia del Agua
(Bufete Industrial / Suez Lyonnaise des Eaux)

Industrias del Agua
(Servicios Ambientales / Severn Trent Water)

Agua de Mexico
(GUTSA / United Utilities)

Mexico City Water Strategy Project
Specific Objectives

- Draw users to efficient use with fair dues
- Guarantee future water supply
- Manage the ground-water aquifer
- Increase due collection
- Enforce 100% metered service
- Improve water services
- Reduce unaccounted for water

Mexico City
Water Strategy Project

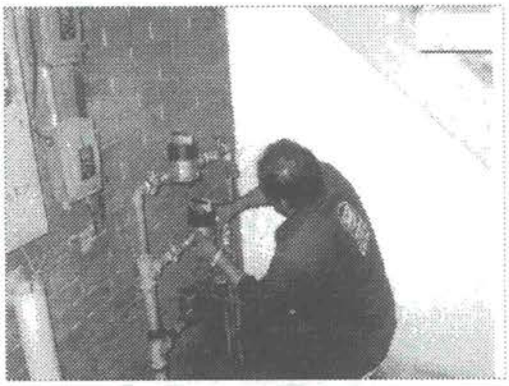
First Stage
1993 - 1996

- Users' Census
- Intake regularisation and meter installation
- Hydraulic Systems Mapping

RESULTS

- 1,630,000 updated users
- 1,700,000 updated intakes
- 900,000 meters installed
- 12,000 kms mapped water system
- 11,000 kms mapped sewer system

First Stage
Intake regularization & meter installation



Mexico City
Water Strategy Project

Second Stage
1996 →

- Meter reading
- Billing and distribution
- Collecting
- Users services

RESULTS

- New efficient commercial system
- 86% metered service billing
- 100% users register
- 24 services agencies
- 100% bimestral emission
- 76% collection efficiency
- Waste reduction awareness

Mexico City
Water Strategy Project

Third Stage
1997 →

- Leak detection and repair
- Infrastructure repair and rehabilitation

RESULTS

- Improve water distribution
- Recover unaccounted for water
- Reduce operating costs

Mexico City
Water Strategy Project

Water Use Management
Lines of Action

Exact metered consumption + Water saving

Infrastructure rehabilitation + Prompt payment +

= Improved Hydraulic System

- Metered billing
- Water recovery

Second Stage
Water Users' Commercial System

- 4 Commercial Systems with ± 450,000 users intakes, readings, meters, billing, payments each
- New account numbers
- Billing methods by type of property, use, metering:
  - metered service billing
  - average area consumption on same type of metered service
  - fixed rates

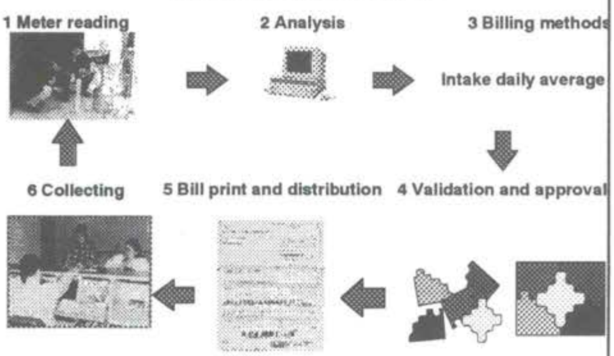
Second Stage
Water Users' Commercial System

RESULTS

- New efficient commercial system
- 86% metered service billing
- 100% users register
- 24 services agencies
- 100% bimestral emission
- 76% collection efficiency
- Waste reduction awareness

Second Stage
Water Users' Commercial System

Two-month emission cycle



Second Stage
Water Users' Commercial System

Users Services Agencies

Accesible and comfortable

Second Stage
Water Users' Commercial System

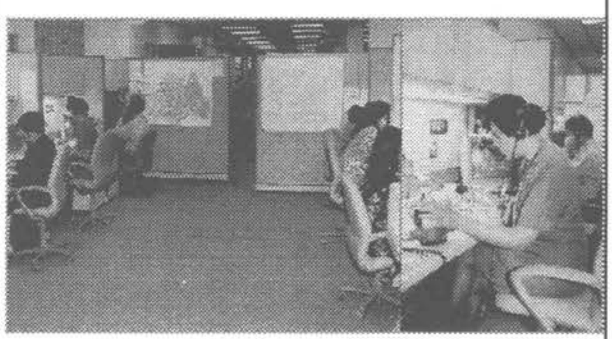
Users Services Agencies

Hot-line communication information system

Comercial system services for payments, update data, work orders

Second Stage
Water Users' Commercial System

Telephone Service Center



Second Stage

Water-users Register

1995 1999

ZONA	DELEGACION	PADRON TESORERIA 1995	PADRON CADF 1999	INCREMENTO
ZONA A	AZCAPOTZALCO	69,460	80,573	16 %
	CUAUHTEMOC	116,260	148,203	27.5 %
	GUSTAVO A. MADERO	187,630	207,729	10.7 %
ZONA B	BENITO JUAREZ	87,740	110,569	26 %
	COYOACAN	126,500	153,681	21.5 %
	IZTACALCO	69,090	75,583	9.4 %
	V. CARRANZA	79,420	89,335	12.5 %
ZONA C	IZTAPALAPA	232,290	334,912	44.2 %
	MILPA ALTA	8,880	13,337	50.2 %
	TLAHUAC	31,000	56,064	80.9 %
	XOCHIMILCO	39,320	60,911	54.9 %
ZONA D	ALVARO OBREGON	106,090	121,907	14.9 %
	CUAJIMALPA	13,650	23,425	71.6 %
	M. CONTRERAS	27,300	33,409	22.4 %
	MIGUEL HIDALGO	63,960	80,017	25.1 %
	TLALPAN	82,250	107,445	30.6 %
		1,340,860	1,697,100	26.57 %

Second Stage

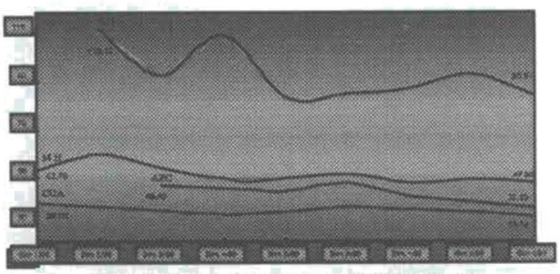
Water use by Delegation

Delegation	Domestic	Non Domestic	Mixed	Total
Alvaro Obregon	110,941	5,399	5,567	121,907
Azcapotzalco	71,074	4,077	5,422	80,573
Benito Juarez	90,528	13,530	6,511	110,569
Coyoacan	142,367	5,740	5,574	153,681
Cuajimalpa	21,081	842	1,502	23,425
Cuauhtemoc	119,290	20,192	8,721	148,203
Gustavo A. Madero	185,677	8,263	13,789	207,729
Iztacalco	65,004	4,383	6,196	75,583
Iztapalapa	309,280	15,648	9,984	334,912
Magdalena Contreras	30,739	811	1,859	33,409
Miguel Hidalgo	68,588	9,432	1,997	80,017
Milpa Alta	12,905	429	3	13,337
Tlahuac	54,640	1,368	56	56,064
Tlalpan	99,064	3,690	4,691	107,445
Venustiano Carranza	75,498	6,016	7,821	89,335
Xochimilco	57,532	1,885	1,494	60,911
TOTAL	1,514,208	101,705	81,187	1,697,100

Second Stage

Metered consumption patterns

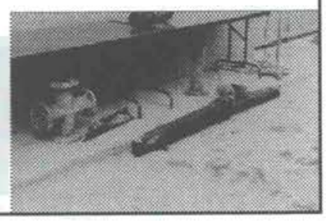
Bimestre	Bim 1/96	Bim 2/96	Bim 3/96	Bim 4/96	Bim 5/96	Bim 6/96	Bim 1/97	Bim 2/97	Bim 3/97
Azcapotzalco			46.42	45.53	44.37	47.68	41.83	39.53	37.19
Cuauhtémoc	39.06	37.44	35.65	34.44	35.26	37.27	36.14	35.56	33.34
Miguel Hidalgo	52.79	59.71	53.94	49.82	49.67	51.34	47.47	49.12	47.83
Alvaro Obregón		112.17	92.56	109.25	83.33	84.86	87.25	92.87	83.81



Reduced water use by 40%with metered service

Third Stage
Infrastructure upgrading

State of the water infrastructure



Third Stage
Infrastructure Upgrading

Leak detection and repair

- Detection and elimination of leaks, visible and non-visible
- Rehabilitation of water lines
- Substitution of site intakes
- Replacement of valves

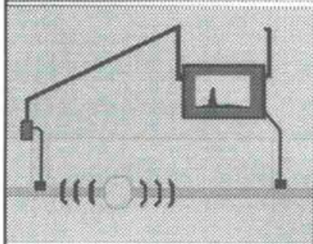
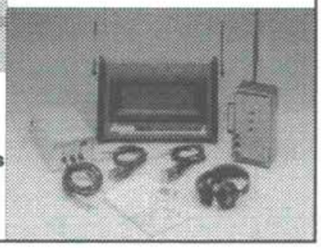
with
State-of-the-art technologies

Third Stage
Leak detection

Detecting visible and non-visible leaks with modern technologies

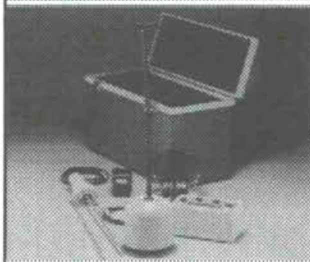
Listening Stick

Third Stage
Leak detection

- Correlator
- Sound and pressure sensors

Third Stage
Leak detection

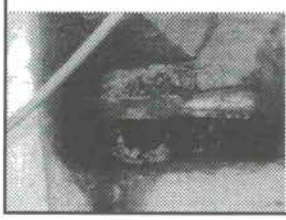
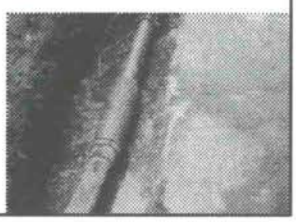


- Surface microphone

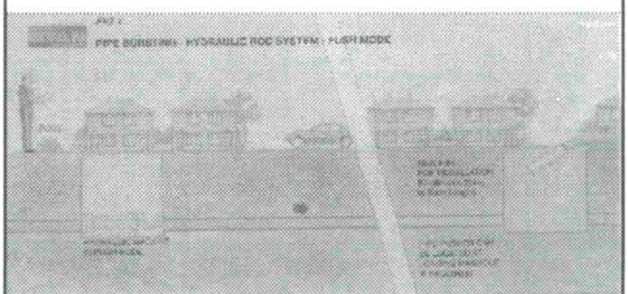
- Tube and cable locator

Third Stage
Water pipes repair and replacement

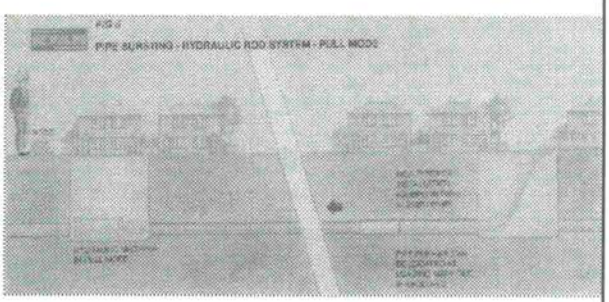
- Pipe bursting technologies and pipe replacement

Third Stage
Water pipes repair and replacement

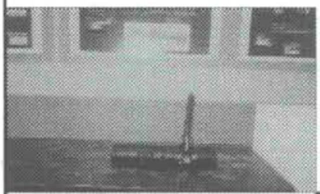


Third Stage
Water pipes repair and replacement



Third Stage
Water pipes repair and replacement

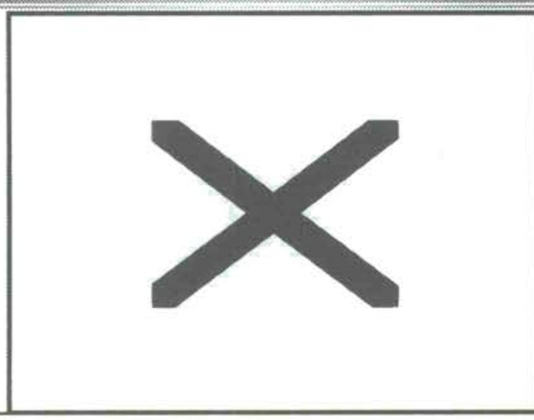
Third Stage



High density polyethylene pipe

Thermo-fusion connection

Third Stage
Intake replacement and connection



Third Stage
Impact

Water Recovery 1998

- 10,110 repaired leaks
- 155 km replaced 2"-6" lines
- 28,000 intakes replaced
- 3,159 valves replaced
- Illegal intakes cancelled

Recovered water 500 lts/sec to supply 42,000 people

Third Stage
Impact

Water Recovery for 1999

- 10,196 leaks to be repaired
- 10,000 non visible leaks to be detected
- 14,761 intakes to be substituted
- 106 km of lines to be rehabilitated
- 900 valves to be replaced
- 30,865 new meters to be installed

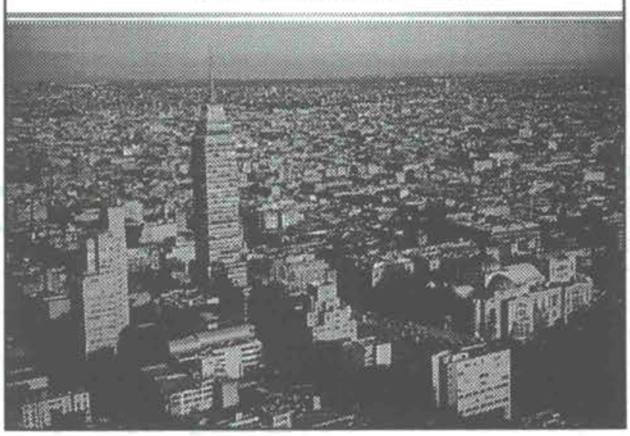
Expected water recovery 500 lts/sec more

Expected Results
New water culture

- Brush your teeth with a glassful
- Wash your car with a bucketful
- Sweep your sidewalk
- Inspect your water installations
- Use 6-liter toilets

Pay your bill on time

Water is everyone's responsibility



International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
Kobe, Japan, 8-10 June 1999

Session 8: Summary and Conclusion

CONCLUDING REMARKS

by Mr. Masaharu Yagishita
Director, Planning Division, Global Environment Department, Environment Agency of Japan

On behalf of the Environment Agency of Japan, I would like to say a few words before the concluding remarks of Ms. Lilia Casanova, Deputy Director of UNEP-IETC.

Since the industrial revolution, humankind has consumed vast quantities of fossil fuels and other resources, and has produced waste in far greater quantities than can be absorbed by natural ecosystems. The effects of population growth and urbanization have exacerbated the destruction of nature and the deterioration of living conditions, including a decline in the quality of our freshwater supply.

For a solution to such a situation, we must try to reduce stress on the environment by fostering environmentally sound life cycles and lifestyles. We must try to understand the mechanisms of nature, and conduct our activities in a way that enable us to live in harmony with the natural world.

In developing regions, the first priority must be to provide sustainable livelihoods—giving due attention to water issues--by enhancing technology transfers and development, and by strengthening the development of human resources.

To that end, United Nations organisations like UNEP have made ongoing efforts and achieved steady progress. The international community is looking to UNEP for guidance in coping with worldwide environmental problems. The Japanese government supports UNEP's efforts.

The mandate of UNEP-IETC is to accumulate information on environmentally sound technologies and disseminate them to where demand and need for them exists, especially in developing regions.

The topics covered by this symposium on the "Promotion of Efficient Water Use in Urban Areas" provide practical information to show us the way towards realizing environmentally sound lifestyles based on alternative water resources development, and a more efficient form of water use. I am confident that this symposium gives us all a chance to promote our activities aimed towards tackling environmental problems as they relate to urban water issues.

Before I conclude my remarks, I would like to express my sincere appreciation to the staff of UNEP-IETC, to the various officials who made enormous efforts to make a great success of this symposium, and to the expert participants who came here from more than 40 countries.

Thank you very much for your kind attention.

V. APPENDICS

APPENDIX 1: Summary of Post-Symposium Questionnaire

Summary of Post-Symposium Questionnaire

Number of Total Responses: 80
Number of Names identified: 64
Number of Names unidentified: 16

Q1. Which sessions did you attend?

Session 2	(8 June)	Room A	Harvesting and Utilization of Rainwater	35
Session 3	(8 June)	Room B	Water Reuse for Non-potable Applications	38
Session 4	(9 June)	Room A	Augmentation of Groundwater Resources through Aquifer Recharge	36
Session 5	(9 June)	Room B	Leakage Control and the Reduction of Unaccounted-for Water	43
Session 6	(9 June)	Plenary	Water Demand Management	67
Session 7-I	(10 June)	Room A	Integrated Approaches for Efficient Water Use I	46
Session 7-II	(10 June)	Room B	Integrated Approaches for Efficient Water Use II	27

Q 2. Which presentation(s) were most interesting/useful to you?

Session 2	(8 June)	1	Economic and Water Quality Aspects of Rainwater Catchment Systems	19
		2	Rain Water Utilization: Facilities and Equipment	25
		3	Creating a Rainwater Utilization based Society for Sustainable Development	12
Session 3	(8 June)	4	Wastewater Reuse for Non-Potable Applications: An Introduction	30
		5	Case Studies of Domestic and Industrial Water Reuse for Non-Potable Applications	19
		6	Health Implication of Efficient Water Reuse	21
Session 4	(9 June)	7	Advantages of Aquifer Recharge for a Sustainable Water Supply	22
		8	Groundwater Recharge with Reclaimed Municipal Wastewater – Regulatory Perspectives	25
		9	Aquifer Storage and Recovery in Urban Areas – Technology Risks, and Implementation issues	15
Session 5	(9 June)	10	Advantages of Leakage Control and the Reduction of Unaccounted-for Water	31
		11	Monitoring and Managing Unaccounted for Water	31
		12	Leakage Control and Unaccounted-for Water Analysis	24
Session 6	(9 June)	13	Water Demand Management	46
		14	Approaches for Water Demand Management: Water Saving Devices and Appliances	34
		15	Residential End Uses of Water and Demand Management Opportunities	31
		16	Water Demand Management and the Urban Poor	36
Special Speech	(10 June)	17	Changing the Concept of Sewage Works for Sustainable Society – Separation of Urine and Feces for Recovery of Useful Materials and Stopping Contamination of Water Bodies	47
Session 7-I	(10 June)	18	An Integrated Approach for Efficient Water Use in Singapore	40
		19	Potential of Water Harvesting in India: Some Case Studies	23
		20	Integrated Approach for Efficient Water Use – Case Studies	24
		21	Integrated Approaches for Efficient Water Use in South Africa	26
Session 7-II	(10 June)	22	Integrated Approaches for Efficient Water Use in Barbados	10
		23	Water Resources Management in Maldives	6
		24	Integrated Approaches for Efficient Water Use in Fukuoka	10
		25	Whole-Scale Reduction of Water Use: The Mexico City Project	7

Q3. How was the overall arrangement of the Symposium?

Excellent	49	More time should have been given for disuccions and conclusions on approaches, discuss and problems. Too many parpers in a short time. .
Very good	30	Very handicappedd program, tuff to follow up. Very short time for the subjects, expers, speakers.
Good	7	
Acceptable	2	
Poor	0	

Q4. What do you think UNEP IETC shoud do differently in the future for further improvement in organizing this kind of symposium?

Programme
This type of 3 days program shoud be changed. It is really difficult to digest 29 keynotes in 3 days. The program need be spreaded over a week having discussions in the morning and "Field Trip" in the afternoon.
Incorporate androgogy (art of adult learning) in various programs, e.q. guidelines for speakers and participatory learning. Brain stoming events must be incorporated.
Allow time for participating countries to give an overview of their activities during plenary or in committee room.
Interaction/sharing of information/expereinces among the participants is to be conserned. It was felt because of the time for Q&A. It is suggested that in future activities of such tipe more of sharing experience will help deliver a better strategy.
More time for discussion should be provided.
Have more sessions where presenters can meet with participants interested in their topics for further discussions.
A mechanism has to be developed to increase the participants involvement while the sessions are going on. (Time allocated for questions were limited).
Give more time for discussions and include exercises in groups, so that the fundamentals and knowledge can be exercised.
More wide-spread presentations would be arranged in organizing the symposium in the future and unnecessary repeated presentations would be avoided even if the presentation was given by the seniors.
Closer collaboration with other organization like Environment Agency from initial stage.
Organise a program that makes provision for greater delegate participation. Perhaps fewer presentations of a generic nature (we know most of the material anyway) and much more discussion/workshop time.
The subject matters were closely related to each other. There would be no need for separated sessions. Shorter and more efficient (compact) presentations were possible.
Have some group work so that all participants are active and there is better share of experiences.
Program steering committee.
Topic oriented technical workshops, seminars.
Topics
Organizing Symposium where countries facing similar problems either due to size of geographical characteristics, i.e. small islands (Cypros, Malta, etc.) to exchange ideas and experiences.
There are international professional and scientists organizations on water issues. However, there are many crevices among them in terms of targets that are remaining issues. IETC can formulate topics to fill the crevices.
It was a stretch to combine issue of countries having water for all and the need to conserve with countries not even having reached all their citizens. With water from an audience interest perspecive.
UNEP/IETC should do detailed symposium including practice (local) improvement.
Importance and necessity irregations for agricultural purposes were stressed without however touching on the best and most inexpensive sources of the water needed
The only further improvement I can picture is that IETC take up where they left off in the symposium and carry out more detailed, specific seminars on the more vital key issues related to efficient water usage.
Focus on specific problems with case studies and with field visits.
Presentations
Inviting more lecturers from different countries specially Africa.
The organization of papers (themes) was rather poor. Please concentrate on lessons/experiences that can be used for learning rather than academic abstracts with little relevance to developoing world issues.
To have more case study in the seminar.
Increase more case studies.
More speakers from deveroping country. Clearer focus as many presentations were not applicable for developing countries.

More of this and invite more developing countries.
Include more presentations from developing countries.
Invite other global organisations such as ADB, World Bank, collaborative council on influencing for a holistic approach on the 21st centruy development vision.
Greater input from all participants (too little input of low-income country perspectives)
Consult with the experts outside of the UN system. The UN systems are often too bureaucratic, and, thus, difficult to attract the best.
More illustrations, than visual aids should be introduced.
Venue and Participants
Hold such symposium in other countries with attendance from local/national organizations
I think for many reasons it is better for these symposium to be held in the different countries and better if in developing countries. It then would be more useful for many other eager but not able experts.
Sharing other countries
There is the need to get to the grassroots so as to ensure some tangible results. I would suggest the follow-up takes the form of workshops /lectures by experts so that working solutions can be arrived at.
UNEP/IETC can organize this kind of symposium for local government experts such as the mayors or even the lower officialsin the local government unit.
If possible, "efficient use of urban water" discussed among cities with municipal water system fully implemented is interesting.
Field Trip
May incorporate field visit to any success story sites relevant to symposium.
Add some field trips/case studies in the program
In order to enrich our sight and experience, it would be better to include field trip to some concerned places, for example, water treatement plant.
The duration is very short and there was no visit program with related subject.
If site inspection with related filed be added in further, it will be more beneficial.
Beyond case studies, perhaps a site visit or a field trip?
By incorporating exhibitions of tools and devices (investrs/markets)
Others
Form discussion groups on specific topics. The discussion can be facilitated by UNEP-IETC in the Web after the symposium.
Papers should be circulated to participants in advance if possilble.
Rapporteur should report during plenary session.

Q5. What subject(s) related to water management would you suggest UNEP IETC take up in the future?

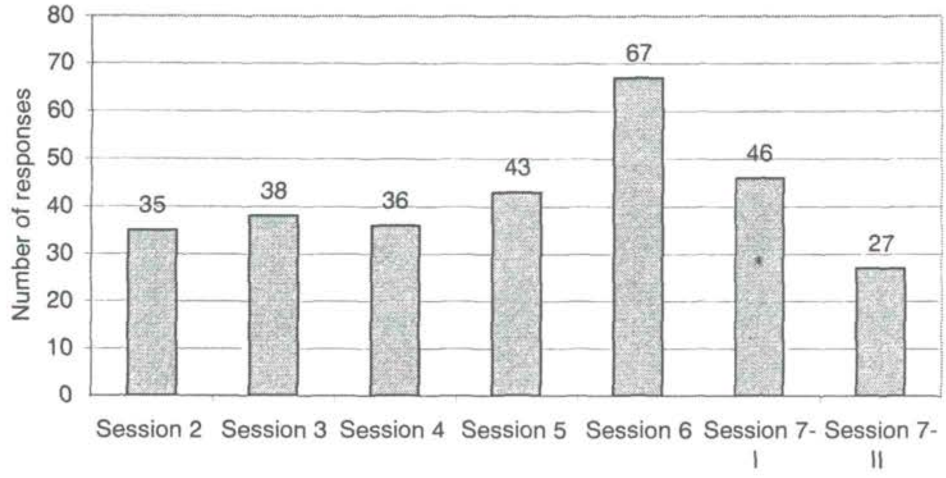
management of water resources, water resource pollution, strategies and policies on water resources management and water pollution control, resources management and sustainability, exploitation & protection of water resources in water management, reservoirs management, river protection, improved management and operation of river basin facilities	8
water demand management, WDM integrated approach, WDM advocacy, practical applications of WDM	8
technology for water treatment, water quality control for urban water supply, quality control in water treatment and distribution systems, improvement of dirnking water quality, quality of water to influence human health, potential disease caused by drinking water, water disinfection, appropriate/low cost potable water treatement, advanced water treatment technologies and techonological development of equipment in water supply systems	7
technology for sewage and waste water treatment, industrial waste water treatment, new approaches and new methods, Energy recovery potential from waste water, resources recovery from wastes, urban sanitation	7
waste water reuse and recycling, water reuse for municipal/industrial purposes, recycling of process water in industry	6
water conservation measures, effectiveness of water conservation measures, how to improve plumbing materials	6
leakage control, unaccounted for water, distribution system management and operation techonologies, instruments used in this field	6
Institutional aspect of water management, effective institutional/organization strategies for providing water and sanitation services, management of urban water supply and sanitation agencies, guide to decision makers in the local government unit, training methods (institutional, users)	5
water management and povery, water management for the urban poor, providing potable water to urban poor, new schemes for poor people in urban areas, reaching the unreached	5

public awareness, role of local communities, consumer awareness, poor community empowerment, educating the people to pay their water bills on time	4
water management for medium and small cities and towns, to encourage pilot projects in line with water management issues, envrionmental assessment in water management and planning, integrated approach of water management	4
harvesting & utilization of rainwater, rainwater catchment systems as applied to urban areas, efficient rainwater harvesting (rooftop), reaching of aquifer by rainwater	4
low cost sanitation, low cost techonologies for waste water treatment and reuse, sanitation as applied to third world countries, economical methods of waste water treatment regarding to climatical and technological capabilities.	4
cost benefit analysis/socio culture and economic aspects, tariff, financial management, measures of water allocation-economic efficiency,	4
desalination (options and cost/benefits), utilization of seawater in the coastal cities, health aspects of long-term use of disalinated water	4
urban water management with respect to megacities, problems of "mega-cities" with all necessary infrastructures, integrated planning on wate resources utlization in agglomeration	3
water pollution and quality	3
recharge of aquifers in developing countries using more appropriate technology	2
groundwater management, groundwater modeling and salinity control (salt water intrusion)	2
indigenous techonologies, technologies suitable to the typical conditions of developing countries	2
management of water supply and sanitation systems, how to manage water supply and waste water works on the good coordination for saving water, enrgy and protect water envrionment.	2
GIS application, integrated water management system supported by GIS	2
interaction among water, solid and air, relationship between water and activities of soil	2
correlation among water, sewage and waste	1
water policy and implementation	1

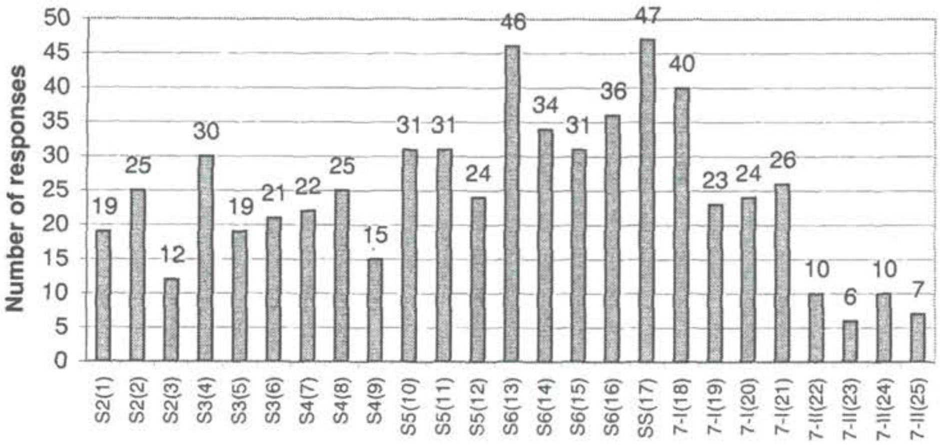
Q6. Any other comments

There should be more campaign & publicity with particular attention to tropical and developing countries.
For rainwater, some institutinal preparedness should be recommended as below: 1. Transformation of traditional to conventional government program. 2. Home scale low cost treatment device for rainwater drinking. 3. Incentives for pilot projects/ technoogy users.
Water management is very important in operating water supply in the municipality; included financial and technical and non-techinical aspects (administrations).
People in the world should strictly about biological activities in soil.
IETC can generate many interesting themes for its own symposiums. South countries cannot send engineers to international conferences organized by professionals of advanced countries.
There is a possiblity of looking into following; a. More case studies from developing/under developed countries will make the symposium more meaningful and help arrive in better solutions. b. While discussing such important subject, ground should have more reflatins for which there is a need to have more time for Q&A session and also more speakers from the developing world.
Please take into account the countries with an economiy in transition that means hundreads millions of inhabitants from EEC and CIS and a very special situation. I suggest a workshop for Eastern European countries on the integrated approach of water management.
More focus on one theme and more carefully selection of papers/speakers.
It is also suggested to make available more information on practical apploaches of areas such as "Demand Management", "Aquifer Recharging." Further development of Maestro will be of solution.
Harvesting rain water is a new theme for me and my organization. This would be applicable for my city in order to prevent flooding. Waste water re-using for toilte flushing would also be applicable once the industry is ready to manufacture appropriate units.
Establish discussion group in the Web.
There were significant "perception" gaps among the symposium attendees. We, from the USA, were out of "loop" in the UN bureaucracy - Maybe it is good thing.
IETC org. and staff and help was truly excellent. Also Japan EA is to be complemented for its forsight and leadership in helping to finance such a conference.
The interface with professionals of the global market was very rewarding.
For us Japanese who use water as we wish, presentation by people from African country were very precious advices and gave us different advices to manage supplied water.

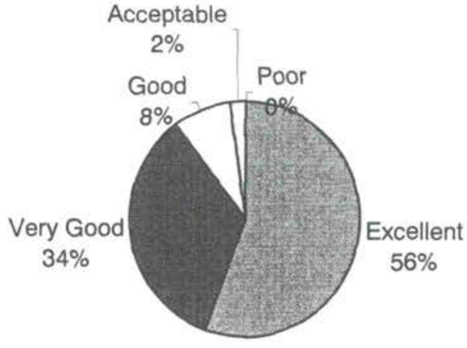
Q1. Which sessions did you attend?



Q2. Which presentation(s) were most interesting/useful to you?



Q3. How was the overall arrangement of the Symposium?



International Symposium on Efficient Water Use in Urban Areas
8-10 June 1999, Kobe, Japan
Evaluation Questionnaire

Please fill in this questionnaire and return it in the questionnaire box at the registration desk on the last day of the Symposium. Your feedback will enable us to improve our products and make them more relevant.

NAME:

Please tick the applicable boxes (□)

Q 1. Which sessions did you attend?

□ Session 2 (8 June): Harvesting and Utilization of Rainwater (Room A)

□ Session 3 (8 June): Water Reuse for Non-potable Applications (Room B)

□ Session 4 (9 June): Augmentation of Groundwater Resources through Aquifer Recharge (Room A)

□ Session 5 (9 June): Leakage Control and the Reduction of Unaccounted-for Water (Room B)

□ Session 6 (9 June): Water Demand Management (Plenary)

□ Session 7-I (10 June): Integrated Approaches for Efficient Water Use I (Room A)

□ Session 7-II (10 June): integrated Approaches for Efficient Water Use II (Room B)

Q 2. Which presentation(s) were most interesting/useful to you?

Session 2 (8 June):

1. □ Economic and Water Quality Aspects of Rainwater Catchment Systems
2. □ Rain Water Utilization: Facilities and Equipment
3. □ Creating a Rainwater Utilization based Society for Sustainable Development

Session 3 (8 June):

4. □ Wastewater Reuse for Non-Potable Applications: An Introduction
5. □ Case Studies of Domestic and Industrial Water Reuse for Non-Potable Applications
6. □ Health Implication of Efficient Water Reuse

Session 4 (9 June):

7. □ Advantages of Aquifer Recharge for a Sustainable Water Supply
8. □ Groundwater Recharge with Reclaimed Municipal Wastewater – Regulatory Perspectives
9. □ Aquifer Storage and Recovery in Urban Areas – Technology Risks, and Implementation issues

Session 5 (9 June):

10. □ Advantages of Leakage Control and the Reduction of Unaccounted-for Water
11. □ Monitoring and Managing Unaccounted for Water
12. □ Leakage Control and Unaccounted-for Water Analysis

Session 6 (9 June):

13. □ Water Demand Management
14. □ Approaches for Water Demand Management: Water Saving Devices and Appliances
15. □ Residential End Uses of Water and Demand Management Opportunities
16. □ Water Demand Management and the Urban Poor

PLEASE PROCEED TO THE QUESTIONS ON THE REVERSE

Special Speech (10 June):

17. □ Changing the Concept of Sewage Works for Sustainable Society – Separation of Urine and Feces for Recovery of Useful Materials and Stopping Contamination of Water Bodies

Session 7-I (10 June):

18. □ An Integrated Approach for Efficient Water Use in Singapore

19. □ Potential of Water Harvesting in India: Some Case Studies

20. □ Integrated Approach for Efficient Water Use – Case Studies

21. □ Integrated Approaches for Efficient Water Use in South Africa

Session 7-II (10 June):

22. □ Integrated Approaches for Efficient Water Use in Barbados

23. □ Water Resources Management in Maldives

24. □ Integrated Approaches for Efficient Water Use in Fukuoka

25. □ Whole-Scale Reduction of Water Use: The Mexico City Project

Q 3. How was the overall arrangement of the Symposium, including travel, transport, accommodation, facilities, registration, general support by secretariat staff, etc?

1.□Excellent 2.□Very good 3.□Good 4.□Acceptable 5.□Poor

Any comments [ ]

Q 4. What do you think UNEP IETC should do differently in the future for further improvement in organizing this kind of symposium?

Q 5. What subject(s) related to water management would you suggest UNEP IETC take up in the future?

Q 6. Any other comments you may wish to make?

International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
Kobe, Japan, 8-10 June 1999

APPENDIX 2: List of Pariticipants

International Symposium on Efficient Water Use in Urban Areas
– Innovative Ways of Finding Water for Cities –
Kobe, Japan, 8-10 June 1999

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International Symposium on Efficient Water Use in Urban Areas
---Innovative Ways of finding Water for Cities---
Kobe, Japan, 8-10 June 1999

APPENDIX 3: Information Sources on Efficient Water Use

Information Sources on Efficient Water Use – Institutions

Arizona State University (ASU) – National Center for Sustainable Water Supply (NCSWS)

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Associate Professor/Center Director
Phone: +1-480-965-1734
Email: peter.fox@asu.edu

Topics Covered: Water Reuse
Groundwater Recharge

Institution Type: Research Institute
Geographical Scope: Global
Language: English
(Many others on individual basis)

Profile:
The Center recognises most surface water resources have been utilised to their full extent. Therefore, research focuses on groundwater recharge and indirect potable reuse.

Centre for Groundwater Studies (CGS)

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Topics Covered: Water Reuse
Groundwater Recharge

Institution Type: Research Institute
Geographical Scope: Global
Language: English

Profile:
The Centre for Groundwater Studies is an international cooperative research and education venture with strong focus on processes of groundwater recharge, discharge, contamination, remediation and management. It addresses major land and water resources issues in Australia and overseas through interdisciplinary research by its member organisations, agencies and companies.

The Centre will focus its activities on:

- Contract Research and Development for its partners and clients
- Postgraduate Education and Specialist Training
- Specialist Advice and Consulting for Australian Companies and involving Centre partners, particularly overseas.

Company for Craft Technology and Innovation (HATI)

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Contact: Mr. Peter Thomas
Managing Director

Topics Covered: Rainwater Utilisation
Water Reuse
Water Demand Management

Institution Type: Research Institute
Geographical Scope: Global
Language: German, English, French, Spanish

Profile:
The fundamental concern of the HATI company is to develop specific, easy to handle tools for electronic documentation and qualification. It supports working processes, for example in the field of ecological sanitation and heating systems.

Furthermore, HATI focuses on the development of electronic information systems for special branches to support craftsmanship.

Another main activity of HATI is the initialisation and co-ordination of scientific- and development projects. These initiatives often narrowly relate to the introduction of new technologies in craftsmanship.

Since the foundation of HATI we developed the multimedia author system "HyperTool", which is used for supporting presentations, consultancy, reference documentation and maintenance activities. In the meantime this system is already available in 6.0 version. This author system produces qualification building stones as well as professional information systems.

Fachvereinigung Betriebs- und Regenwassernutzung e.V. (fbr) – Professional Association for Water Recycling and Rainwater Utilisation

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Topics Covered: Rainwater Utilisation,
Water Reuse

Institution Type: NGO/NPO
Geographical Scope: Europe
Language: German

Profile:
frb is a nation-wide professional association of people, companies, local authorities, offices, specialised trading companies and institutions interested or already actively involved in water recycling and rainwater utilisation. The association is a registered non-profit-making organisation with headquarters in Darmstadt, Germany.

fbr has set itself the objective of promoting water recycling and rainwater utilisation and bringing together everyone actively involved and interested in this sector.

The purpose of fbr is to promote water recycling and rainwater utilisation, save drinking water and reduce sewage. Its responsibility lies in the creation of a provision against future contingencies, while at the same time taking into account all aspects of environmental protection, science and research. Within the association, members are active in work groups dealing with all topics on water recycling and rainwater utilisation.

International Rainwater Catchment Systems Association (IRCSA)

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Topics Covered: Rainwater Utilisation

Institution Type: NGO
Geographical Scope: Global
Language: English

Profile:
IRCSA is a association aiming to link those with an interest in the direct collection of rainwater and its storage for domestic and agricultural supply. IRCSA hopes to attract membership both from organisations and individuals who are implementing rainwater catchment technologies and from those researching all aspects of design, construction, water quality, operation, implementation, user education and related areas.

Objectives of IRCSA

1. The promotion and advancement of Rainwater Catchment Systems Technology with respect to panning, development, management, science, technology, research and education world-wide.
2. The establishment of an International form for scientists, engineers, educators, administrators and al others who are, directly or indirectly, concerned in rainwater catchment system programs to link all those working in this field so that information and experiences can be shared.
3. The drafting of international guidelines on the use of Rainwater Catchment Systems technology and the updating and dissemination of this information.
4. The collaboration with and support of International Programmes in the field of Rainwater Catchment Systems including cooperation with other organisations having activities in common.
5. The support and continuation of the International Rainwater Catchment Systems Conference series.

IRC International Water and Sanitation Centre

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URL: http://www.irc.nl/

Topics Covered: Water, Sanitation

Institution Type: International NGO
Geographical Scope: Global
Language: English, French, Spanish, Portuguese

Profile:
IRC is an independent, non-profit organisation supported by and linked with the Netherlands Government, the United Nations Development Programme (UNDP), the United Nations Children's Fund (UNICEF), the World Health Organization (WHO), the World Bank and the Water Supply and Sanitation Collaborative Council.

IRC's mission is to help people in developing countries to get the best water and sanitation services they can afford. Working with partners in developing countries, IRC aims to strengthen local capacities by sharing information and experience and developing resource centres. IRC emphasises the introduction of communication, gender, participation, community management and affordable technologies into water and sanitation programmes.

Areas in which IRC's work in water and sanitation is concentrated at present include

- community-based technologies
- participation and community management
- gender awareness
- hygiene promotion
- operation and maintenance
- monitoring and evaluation
- information management
- community water resources management
- resource centre development.

Pacific Institute for Studies in Development, Environment and Security

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Director of Communications

Topics Covered: Water Reuse
Water Demand Management

Institution Type: Research Institute
Geographical Scope: Global
Language: English, some Spanish

Profile:
The Pacific Institute for Studies in Development, Environment, and Security is an independent, non-profit organisation to conduct research and policy analysis in the areas of environment, sustainable development, and international security. Underlying all of the Institute's work is the recognition that the pressing problems of environmental degradation, regional and global poverty, and political tension and conflict are fundamentally interrelated, and that long-term solutions require an interdisciplinary approach. The Institute's work on global climate change, freshwater resources, sustainable forestry, and environmental security has received a good deal of attention in the media, among analysts working in these areas, and in regional, national, and international agencies. Among the most significant activities have been formulation of a new vision for long-term water planning in California and internationally, the development of a new approach for valuing well-being in the Sierra Nevada, a concentration on transborder environment and trade issues in North America, analysing ISO 14000's role in global environmental protection, the clarification of key concepts and criteria for sustainable water use in the lower Colorado basin, recommendations for reducing conflicts over water in the Middle East and elsewhere, assessment of the prospective impacts of global warming on freshwater resources, and programs to address pubic participation and environmental justice concerns in poor communities and communities of colour.

UNDP-World Bank Water and Sanitation Program (WSP)

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1818 H Street, N.W.
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Phone: +1-202-473-9785
Fax: +1-202-522-3313 or 3228
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URL: http://www.wsp.org/

Topics Covered: Water, Sanitation

Institution Type: UN International Agency
Geographical Scope: Global
Language: English, French, Spanish

Profile:
The Water and Sanitation Program is an international partnership to help the poor gain sustained access to improved water and sanitation services. The Program works with partners in the field to seek innovative solutions to the obstacles face by poor communities and strives to be a valued source of advice to achieve widespread adoption of these solutions.

Together with partners in government, donor agencies, the private sector and NGOs, the WSP helps countries to strengthen their sector policies; and to improve the effectiveness of investments that are strategically important because they are innovative or will reach large numbers of people. The WSP generates and communicates knowledge acquired from the field, supports and influences innovative policies and investment projects, and, provides partners with cutting-edge knowledge.

Currently the Program has nearly 100 staff working in over 30 countries. The WSP's decentralised organisation reflects the fact that its primary rationale is global field leaning and communicating experiences and lessons. Resources are deployed mainly at the country level and managed primarily at the regional level. The Program has five regional offices in Africa, Asia and Latin America. These offices are supported by a team located in Washington, DC.

United Nations University (UNU) – Environment and Sustainable Development Programme (ESD)

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Topics Covered: Water Reuse, Groundwater Recharge, Water Demand Management, Global Environment, Air, Energy, Hazardous Waste, Cleaner Production, Pollution, Land and Agriculture, Coastal Areas, Small Islands

Institution Type: UN International Agency
Geographical Scope: Global
Language: English, Japanese

Profile:
The UNU Environment and Sustainable Development Programme focuses on the interactions between human and the natural environment, and the implications for the sustainable management of natural resources. It is concerned with environmental governance and the monitoring tools required for designing and implementing effective environmental policies.

The activities undertaken by UNU cover a broad range of issues related to the water crises. A major emphasis area deals with monitoring and management of water pollution in coastal areas. The general objective is to identify coastal areas which are threatened by pollution, recognise the potential land-based sources for such pollution and develop guidelines for management of pollution sources and for rehabilitation of degraded environments. This approach agrees quite well the Washington Action Plan (1995) adopted by the UN to protect coastal areas for land-based sources of pollution.

United Nations University – International Network on Water, Environment and Health (UNU/INWEH)

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Topics Covered: Water Reuse, Groundwater Recharge, Water Demand Management, Global Environment, Solid Waste, Cleaner Production, Information, Community

Institution Type: UN International Agency
Geographical Scope: Global
Language: English

Profile:
The International Network on Water, Environment and Health (UNU/INWEH) is a new member of the UNU family of organisations. It was created by the UNU Governing Council in 1996 with core funding provided by the Government of Canada. Its purpose is to strengthen water management capacity, particularly of developing countries, and to provide on-the-ground project support. It is headquartered at McMaster University, Hamilton, Ontario, Canada.

UNU/INWEH is a growing, interdisciplinary and global Network of water pollution and management experts, NGOs, academic institutions, UN and other multilateral bodies, and private sector companies. Resources available through the Network are applied to conceive, develop, implement and manage programs and projects that address water problems in developing countries. The Network takes a multi-disciplinary, ecosystem approach to water and watershed management.

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Topics Covered: Water Reuse, Groundwater Recharge, Water Demand Management, Global Environment, Air, Energy, Solid Waste, Hazardous Waste

Institution Type: Research Institute
Geographical Scope: U.S.A.
Language: English

Profile:
University of California is the pre-eminent system of public higher education and a leading teaching and research institution in the U.S.A. University of California at Davis is one of nine campuses of the University of California, located near Sacramento, the state capital.

The Department of Civil and Environmental Engineering in the College of Engineering is committed to improving human health, well-being and management of environmental resources by conducting instruction and research on systems that provide clean air; potable water; clean and efficient transportation systems and alternatives; modern housing and other structures; and freedom from disease-carrying waste.

Water Supply and Sanitation Collaboration Council (WSSCC) – Operation and Maintenance Working Group

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Topics Covered: Water Supply, Sanitation, Leakage Control

Institution Type: Collaborative Agency
Geographical Scope: Global
Language: English, French, Spanish

Profile:
The O&M Working Group, which is coordinated by WHO, is one of the working groups set up by WSSCC to advance the development of the sector. Members of the O&M Working Group are experts, professionals and consultants from national governments, multilateral and bilateral agencies, and nongovernmental organizations in both developed and developing countries, representing different interest groups in the sector. The strategy of the Working Group is to help O&M reach its full potential by improving:

- policy formulation;
- sector collaboration and coordination;
- the profile of O&M at both the national and global level;
- services management; and
- availability of O&M data.

The Working Group has developed a series of tools which can be used at the country level to improve O&M performance. The tools have been developed in response to the demand for practical solutions to the sector's problems. They include guidelines, manuals, training packages, and case studies.

Water, Engineering and Development Centre (WEDC)

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Topics Covered: Water, Solid Waste, Construction and Engineering

Institution Type: Research Institute
Geographical Scope: Global
Language: English

Profile:
WEDC is involved with education, training, research, and consultancy relating to the planning, provision, and management of physical infrastructure for development in low- and middle-income countries.
WEDC emphasises simple, sustainable, low-cost and labour-intensive methods, especially for treatment processes such as mixing, flocculation, sedimentation, disinfection and control. Rapid filters, too, can be greatly simplified by declining-rate operation and inter-filter backwashing. Detection of leaks and reduction of unaccounted water are especially important where resources (of water and finance) are limited. Where supplies are intermittent, leak detection poses special problems. Analysis of distribution networks using computers is seen as an important tool to ensure satisfactory supply pressures and good management of assets.
Water supply practice for low-income urban communities often differs from the conventional in two principal ways - the use of slow sand filtration (which is equally applicable to rural areas) and distribution by public standpipes to people who cannot afford house connections. WEDC has expertise in these matters, recent research being concentrated on pre-treatment of turbid water. Good management of urban systems has been shown to be critical. Particular attention is focussed on the importance of revenue generation and the management of operations and maintenance functions.

Water Environment Federation (WEF)

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Contact: Mr. Barry Eisenberg
Public Information Manager
Phone: +1-703-684-2480
Email: beisenberg@wef.org

Topics Covered: Water

Institution Type: Public Body
Geographical Scope: Global
Language: English

Profile:
WEF is an international not-for-profit educational and technical organization of more than 40,000 water quality experts. Members include environmental, civil, and chemical engineers, biologists, chemists, government officials, students, treatment plant managers and operators, laboratory analysts, and equipment manufacturers and distributors. WEF's mission is to preserve and enhance the global water environment.

WEF and its Members:

- research and publish the latest information on wastewater treatment and water quality protection;
- provide technical expertise and training on issues including nonpoint source pollution, hazardous waste, residuals management, and groundwater;
- sponsor conferences and other special events around the world; and
- review, testify, and comment on environmental regulations and legislation.

WEF offers Continuing Education Units for successful completion of training programs and jointly sponsored workshops and seminars. Self-paced and classroom courses for entry and advanced-level training are provided as well as interactive CD-ROM-based training courses for operators.
WEF provides a range of materials for the general public describing today's water quality issues, including the cost of clean water, biosolids recycling, and watershed management.

The World Bank – Water and Sanitation Division

1818 H Street, N.W.
Washington, D.C. 20433
United States

URL: http://www.worldbank.org/html/fpd/water/
Contact: Water Help Desk
Phone: +1-202-473-4761
Fax: +1-202-522-3228
Email: whepdesk@worldbank.org

Topics Covered: Water, Sanitation

Institution Type: UN International Agencies
Geographical Scope: Global
Language: English, French, Spanish, Russian

Profile:
The World Bank Group's activities in water and sanitation include financial services; advice to governments and cities on sector policies and programs; knowledge services supporting the sharing of successful approaches and lessons from experience across countries; training through the World Bank Institute; and partnerships with other donors, non-governmental organizations and private industry. Given the sector's huge needs for investment and performance improvement, emphasis on opportunities for partnership and leverage have become increasingly important in all the Group's programs.

The World Bank is committed to capturing and sharing the knowledge it has gained through decades of development experience. The Water Help Desk provides an entry point into this knowledge base for anyone involved in the water and sanitation sector. The Water Help Desk provide:

- Referrals to water specialists in and outside the World Bank
- Access to Bank documents, such as policy documents, publications, electronic resources
- Updates on water conferences training events, thematic seminars and workshops
- "Hotline" support for the infrastructure web site, project databases and other relevant Bank web sites
- Current information on the World Bank's activities in the water supply and sanitation sector

World Bank Institute – Water Policy Reform Program

1818 H Street, N.W.
Washington, D.C. 20433
United States

URL: http://www.worldbank.org/html/fpd/water/
Contact: François-Marie Patorni
Coordinator
Phone: +1-202-473-6265
Fax: +1-202-676-0978
Email: fmpatorni@worldbank.org

Topics Covered: Water, Sanitation

Institution Type: UN International Agencies
Training Institute
Geographical Scope: Global
Language: English, French, Spanish, Russian

Profile:
The World Bank Institute (formerly Economic Development Institute of the World Bank) provides training and other learning activities that support the World Bank's mission to reduce poverty and improve living standards in the developing world. The Institute's programs help build the capacity of World Bank client countries, staff, and other partners in the skills and knowledge that are critical to economic and social development.

The Water Policy Reform Program helps countries prepare and implement policy reforms leading to environmentally and socially sustainable water resources management, through capacity building and learning activities of various types. The Program reaches out to a wide range of influential stakeholders, from policy makers to parliamentarians, community representatives, private sector leaders, NGOs, journalists, users' associations and the public. The Program concentrates on the environmental, institutional, economic and social aspects of water resources management. Particular attention is given to the cross-sectoral water resources issues and on priority policy areas within the three main water-using sub-sectors: water for household and urban use (water supply and wastewater), water for food production (irrigation and drainage), and water for ecosystems and the environment.

World Meteorological Organization (WMO) – Hydrology and Water Resources Department (HWRD)

7bis, avenue de la Paix
CP 2300, CH-1211, Geneva 2
Switzerland

Phone: +41-22-730-83-55
Fax: +41-22-730-80-43
Email: dhwr@gateway.wmo.ch
URL: http://www.wmo.ch/
Contact: Dr. Arthur J. Askew
Director of the Department
Email: Askew_A@gateway.wmo.ch

Institution Type: UN International Agency
Geographical Scope: Global
Language: English, French, Spanish, Russian

Profile:
The Hydrology and Water Resources Department (HWRD) provides support to Members in response to their national regional and international needs so that they might make the best use of their water resources and provide effective protection from flooding. In this, the Department also seeks to promote the roles of both WMO and the national Hydrological Services and equivalent agencies as authoritative voices in the field of hydrology and water resources.

WRc plc

Frankland Road, Blagrove
Swindon, Wiltshire, SN5 8YF
UK

Phone: +44-1793-865000
Fax: +44-1793-865001
URL: http://www.wrcplc.co.uk/
Contact: Cheryl Fulker
Secretary
Phone: +44-1793-865055
Email: solutions@wrcplc.co.uk

Topics Covered: Leakage Control, Water Demand Management

Institution Type: Research Institute
Geographical Scope: Global
Language: English

Profile:
WRc is a leading international independent consulting and environmental research organisation which concentrates on the needs of the water industry throughout the world.

Using its wide range of specialist scientific, engineering, and associated skills it delivers quantifiable business solutions to utility, regulatory and industrial customers in the UK and overseas.

WRc offers reliable and informed advice to help clients define problems and opportunities at both strategic and tactical levels. Areas include water supply, effluent and supply management, pipeline technology, waste minimisation and disposal, land use including contaminated land, environmental management systems and risk assessment.

Information Sources on Efficient Water Use – Publications

Title: Water Harvesting: a guide for planners and project managers

Topic Covered: Rainwater Utilisation

Authors: Michael D. Lee and Jan Teun Visscher
Publisher:
IRC International Water and Sanitation Centre

Date of Issue: 1992
ISBN Number: 90-6687-020-6
Language: English, French
Number of Pages: 106 pages
Price: Dfl. 49.00/US$ 25.80
Developing countries: Dfl. 34.00/US$ 17.90
Order Number: English version: TP 30-E
French version: DT 30-F
Contact:
IRC International Water and Sanitation Centre
Publications, PO Box 2869, 2601 CW Delft
The Netherlands
Fax: +31-15-219 09 55
Email: publications@irc.nl

Brief Description of Contents:
Describes key issues in planning water harvesting systems and shows the main features of the arid and semi-arid lands environment, including landscape profiles. Provides a description of the main water harvesting systems. Emphasises community involvement, which is crucial to the development of sustainable systems.

Target audience:
Planners, decision makers and project managers involved in community water supply development

Main contents:
- Approach to water harvesting
- The arid and semi-arid lands environment
- Water harvesting technology options
- Assessing water harvesting potential
- Programme development with the community
- Financial and economic issues
- Rooftop harvesting systems
- Surface catchment systems
- Groundwater dams

Published with financial support from the Ministry of Foreign Affairs, Danida (Danish International Development Assistance).
Technical Paper no. 30.

Title: Water Harvesting in Five African Countries

Topic Covered: Rainwater Utilisation

Author(s): M.D. Lee and J.T. Visscher
Publisher:
IRC International Water and Sanitation Centre

Date of Issue: 1990
ISBN Number:
Language: English
Number of Pages: 108 pages
Price: Dfl. 24.00/US$ 12.60
Developing countries: Dfl. 17.00/US$ 8.90
Order Number: OP 14-E
Contact:
IRC International Water and Sanitation Centre
Publications, PO Box 2869, 2601 CW Delft
The Netherlands
Fax: +31-15-219 09 55
Email: publications@irc.nl

Brief Description of Contents:
Reviews the status of water harvesting in Botswana, Kenya, Mali, Tanzania and Togo. Focuses on appropriate technologies, socio-economic aspects, project methodologies and prospects for the 1990s.

Target audience:
Staff of organisations concerned with the application of water harvesting

Main contents:
I: Overview for the five African countries
  Water harvesting systems
  Socio-economic aspects
  Intervention strategies
  Conclusions and wider considerations
II: Individual country reviews

Prepared at the request of the UNICEF Environmental Sanitation Team and published with financial support from UNICEF.
Occasional Paper no. 14

Title: Rainwater and You: 100 Ways to Use Rainwater

Topic Covered: Rainwater Utilisation

Author(s): Group Raindrops

Date of Issue: March 1995
ISBN Number:
Language: English
Number of Pages: 146 pages
Price: JP¥ 2,000
Contact: Japan People for Promoting Rainwater Utilisation
1-8-1 Higashi-Mukojima, Sumida City
Tokyo, 131-0032 Japan
Fax: +81-3-3611-0574
Email: sumikan@sepia.ocn.ne.jp

Brief Description of Contents:

1. Explains everything about rainwater utilisation in Japan and some other countries.
2. Overflows with innovative ideas of collecting, storing, purifying and supplying rainwater.
3. Provides numerous examples of individual houses, public facilities and large buildings to illustrate the major points in design and maintenance.
4. Guides readers in the proper use of rainwater.

Title: Rainwater Catchment Systems for Household Water Supply

Topic Covered: Rainwater Utilisation

Author: John E. Gould
Publisher:
Environmental Systems Information Center (ENSIC), Asian Institute of Technology (AIT)

Date of Issue: December 1991
ISBN Number: ISSN 0125-5088
Language: English
Number of Pages: 63 pages
Price: US$ 23.00
Contact:
Environmental Systems Information Center
Asian Institute of Technology
P.O. Box 4, Klong Luang
Pathumthani 12120 Thailand
Fax: + 66-2-524-5870/5875
Email: enreric@ait.ac.th

Brief Description of Contents:
This review examines the most significant aspects of rainwater catchment systems technology for household water supply and its implementation. These include consideration of its technical feasibility, appropriate design and construction methods, implementation strategies, and water quality and social and economic factors. Case studies from Asia, Africa and Australia are provided.

Environmental Systems Reviews No. 32

Title: Sustainable Use of Water: California Success Stories

Topic Covered: Rainwater Utilisation
Water Reuse
Water Demand Management

Editors: Owens-Viani, L., A.K. Wong, and P.H. Gleick
Publisher: Pacific Institute for Studies in Development, Environment, and Security

Date of Issue: 1999
ISBN Number: 1-8937-9000-2
Language: English
Number of Pages: 372 pages
Price: US$ 20.00
Order Number:
Contact: PACIFIC INSTITUTE
654 13th Street, Preservation Park
Oakland, CA 94612 USA
Fax: +1-510 251-2203
Email: pistaff@pacinst.org

Brief Description of Contents:
The report is the culmination of a two-year study of efforts to establish sustainable water policies in the state of California.

The 40 case studies focus on successful programs in the areas of water conservation, water recycling, agricultural programs, watershed management to protect ecosystem, and groundwater management. Some of the successful strategies discussed include the use of alternative water pricing structures, e.g. ascending block rate structures to encourage more efficient use of water, innovative programs in the agricultural sector to reduce water use, including crop shifting and drip irrigation, and groundwater banking.

The study emphasises the new spirit of cooperation between previously combative stakeholders and an emphasis on local and regional approaches.

Title: Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture

Topic Covered: Water Reuse

Publisher: World Health Orgnization

Date of Issue: 1989
ISBN Number:
Language: English, French, Spanish
Number of Pages: 74 pages
Price:
Order Number: WHO. TRS. 89-131
Contact:
World Health Organization, Distribution and Sales
CH-1211 Geneva 27, Switzerland
Fax: +41-22-791-48-57
Email: bookorders@who.ch (to place orders)
publications@who.ch (for questions about publications)

Brief Description of Contents:
WHO Technical Report Series, 778

Report of the WHO Scientific Group on Health Aspects of Use of Treated Wastewater for Agriculture and Aquaculture, Genva, 18-23 November 1987

Title: Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture: Measures for Public Health Protection

Topic Covered: Water Reuse

Authors: D. Mara and S. Cairncross
Publisher: World Health Orgnization

Date of Issue: 1989
ISBN Number: 92-4-154248-9
Language: Chinese, English, French, Russian, Spanish
Number of Pages: 187 pages
Price: Sw.fr. 35.00/US $31.50
Developing countries: Sw.fr. 24.50
Order Number: 1150324
Contact:
World Health Organization, Distribution and Sales
CH-1211 Geneva 27, Switzerland
Fax: +41-22-791-48-57
Email: bookorders@who.ch (to place orders)
publications@who.ch (for questions about publications)

Brief Description of Contents:
Presents and explains the full range of practical and technical factors that need to be considered when planning, designing, and implementing schemes for the safe reuse of wastewater and excreta in agriculture and aquaculture.

Chapters in the first half of the book explain why human wastes are increasingly regarded as a safe and valuable resource for use in crop irrigation, soil fertilization, and aquaculture. Readers are given detailed information on both potential and actual health risks posed by each of 30 excreta-related pathogens. The second half of the book provides richly detailed guidance on technical options for health protection and on the legal and financial components of project planning and implementation.

Target audience:
Senior professionals in the various sectors relevant to wastes reuse, including planning, public health, sanitary engineering, water resources, and agriculture and fisheries.

Title: Using Reclaimed Water to Augment Potable Water Resources

Topic Covered: Water Reuse

Author(s): Water Environment Federation, American Water Works Association
Publisher: Co-published by WEF and AWWA

Date of Issue: 1998
ISBN Number: 1-57278-125-4 and 0-89867-949-4
Language: English
Number of Pages: 347 pages
Price: US$ 92.00 (non-member price)
US$ 69.00 (member price)
Order Number: P07114HD
Contact: Water Environment Federation
601 Wythe Street
Alexandria, VA 22314-1994 USA
Fax: +1-703-684-2492
Email: pubs@wef.org

Brief Description of Contents:
As the preeminent organisations in the water and wastewater industries, this publication draws on the technical expertise from WEF and AWWA. This joint effort demonstrates strong cooperation in addressing a topic important to the membership of both organizations.
This publication is intended to assist water resource planners who, after evaluation of nonpotable options, wish to evaluate indirect potable options.

Topics include:
- Overview of current reuse practices,
- Planning indirect potable reuse,
- Health and regulatory considerations,
- Treatment technologies,
- System reliability,
- Public information outreach programs, and
- A summary of current projects

Title: Wastewater Reclamation and Reuse: Water Quality Management Library – Volume 10

Topic Covered: Water Reuse
Groundwater Recharge
Water Demand Management

Editor: Takashi Asano
Publisher: Technomic Publishers Company, Inc.

Date of Issue: June 1998
ISBN Number: 1-56676-620-6
Language: English
Number of Pages: 1,528 pages
Price: $159.95
Contact: Technomic Publishing Company, Inc.
851 New Holland Avenue, Box 3535
Lancaster, PA 17604 USA
Fax: +1-717-295-4538
Email: customer@techpub.com

Brief Description of Contents:
Wastewater reclamation, recycling and reuse are presented from planning to implementation with a wide range of topics, which were written by 70 international experts. The tenor of this monumental and comprehensive book is that water reuse is here and growing and that it can be done safely if proper procedures are followed. This book has a wealth of information and is highly recommended to anyone interested in sustainable water resources development, from the concerned citizen to the design engineer and planner, worldwide.

Title: Using Water Efficiently: Technological Options – World Bank Technical Paper 205

Topic Covered: Water Reuse
Leakage Control

Authors: Mei Xie, Ulrich Kuffner, and Guy Le Moigne
Publisher: The World Bank

Date of Issue: May 1993
ISBN Number: 0-8213-2455-1
Language: English
Number of Pages: 61 pages
Price: US$ 22.00
Order Number: #12455
Contact: The World Bank
P.O. Box 960
Herndon, VA 20172-0960, USA
Fax: +1-703-661-1501
Email: books@worldbank.org

Brief Description of Contents:
For development projects that use water resources, the World Bank's emphasis on environmentally sustainable development means making the transition from water consumption to strategies that save water.

This paper explores options for using--and reusing--water more efficiently. It arose from a policy review of the World Bank's projects with components promoting irrigation and drainage, water supply and sanitation, and flood control.

The allocation of water among various sectors of the economy is drawn from statistics from several countries and regions. Estimates of water use efficiency (WUE) are presented using data from dozens of applications worldwide. Technological and managerial options are discussed, and costs are compared.

Title: Towards Efficient Water Use in Urban Areas in Asia and the Pacific

Topic Covered: Water Reuse
Water Demand Management

Publisher:
United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)

Date of Issue: 1998
ISBN Number: 92-1-119846-1
Language: English
Number of Pages: 146 pages
Price: free to governmental organisations
Order Number: ST/ESCAP/1874
Contact:
Water and Mineral Resources Section
Environment and Natural Resources Development Division
ESCAP
United Nations Building, Rajdamnern Avenue
Bangkok, 10200, Thailand
Fax: + 66-2-288-1059
Email: enrd@unescap.org

Brief Description of Contents:
Contains selected background and country papers presented and discussed at the Regional Seminars on Efficient Water Use in Urban Areas held in Singapore from 21 to 23 October 1997. In addition, the seminar recommendations for enhancing national financial, institutional and legal capacities for water conservation and demand management activities are published.

Title: Artificial Groundwater Recharge for Water Supply of Medium-Size Communities in Developing Countries

Topic Covered: Groundwater Recharge

Author(s): E.H. Hofkes and J.T. Visscher
Publisher:
IRC International Water and Sanitation Centre

Date of Issue: 1986
ISBN Number:
Copyright:
Language:
Number of Pages: 41 pages
Price: Dfl. 20.00/US$ 10.50
Developing countries: Dfl. 14.00/US$ 7.40
Order Number: OP 9-E
Contact:
IRC International Water and Sanitation Centre
Publications, PO Box 2869, 2601 CW Delft
The Netherlands
Fax: +31-15-219 09 55
Email: publications@irc.nl

Brief Description of Contents:
Provides practical information to assess the potential for application of artificial groundwater recharge schemes in rural water supply programmes or projects, particularly for medium-size communities.

Target audience:
Planners and engineers

Main contents:
- Artificial groundwater recharge schemes for community water supply
- Planning and organisational aspects of artificial groundwater recharge schemes
- Types of artificial groundwater recharge schemes
- Basic design of artificial groundwater recharge schemes
- Field experience and costs of artificial recharge schemes

Study carried out with financial support from the Netherlands Ministry of Housing, Physical Planning and Environment.
Occasional Paper No. 9

Title: Operation and Maintenance of Urban Water Supply and Sanitation Systems: A Guide for Managers

Topic Covered: Leakage Control

Publisher: World Health Organization

Date of Issue: 1994
ISBN Number: 92-4-154471-6
Language: English, French
Number of Pages: 102 pages
Price: Sw.fr. 23.00/US $20.70
Developing countries: Sw.fr. 16.10
Order Number: 1150416
Contact:
World Health Organization, Distribution and Sales
CH-1211 Geneva 27, Switzerland
Fax: +41-22-791-48-57
Email: bookorders@who.ch (to place orders)
publications@who.ch (for questions about publications)

Brief Description of Contents:
Describes a systems approach to the operation and maintenance of drinking-water and sanitation services in urban areas of developing countries. Addressed to managers and other personnel with decision-making responsibilities, the book responds to ample evidence that poor management has had the greatest single negative impact on the quality of water supply and sanitation services.
Particular emphasis is given to:
- Defining priority programmes and projects for the planning and control of operation and maintenance;
- Identifying the priority O&M functions and responsibilities of managers at different levels within the organisation;
- Establishing a management information system with performance indicators; and
- The need for continuous monitoring and evaluation of the service provided.

While most attention is given to projects for controlling water loss, the book also covers programmes for controlling the production and quality of drinking-water, and for sewage collection, treatment, re-use, and disposal.
Of particular practical value is a five-page tabular presentation of performance indicators that can be used to assess the effectiveness of specific activities.

Title: Financial Management of Water Supply and Sanitation: A Handbook

Topic Covered: Leakage Control

Publisher: World Health Organization

Date of Issue: 1994
ISBN Number: 92-4-154472-4
Language: English, French, Spanish
Number of Pages: 83 pages
Price: Sw.fr. 20.00/US $18.00
Developing countries: Sw.fr. 14.00
Order Number: 1150419
Contact:
World Health Organization, Distribution and Sales
CH-1211 Geneva 27, Switzerland
Fax: +41-22-791-48-57
Email: bookorders@who.ch (to place orders)
publications@who.ch (for questions about publications)

Brief Description of Contents:
Describes a range of financial principles and methods for improving the management of water supply and sanitation services. Addressed to decision-makers, the book shows how financial mechanisms, such as cost recovery, cash raising, and cost containment, can be used to ensure that services are financially sustainable and able to meet users' needs. With this goal in mind, the book helps readers to think through all costs and responsibilities associated with each stage in a project's life span, and then to use this information to set objectives and calculate costs and benefits.
The book has two parts. Part one introduces some of the underlying principles for ascertaining that all resources required for services are identified and available. Information ranges from a list of obstacles commonly encountered in developing countries to tips on how to reduce costs and increase revenue. The second and most extensive part provides a practical guide to methods of cost recovery. Using numerous checklists, charts, examples, and schedules for calculating projected costs, chapters offer a step-by-step explanation of the financial and related activities required to achieve cost recovery at each stage in a project's life span, moving from planning and construction, through operation and maintenance, to eventual replacement.

Title: Leakage Control: Source Materials for a Training Package

Topic Covered: Leakage Control

Publisher: World Health Organization

Date of Issue: 1997
Language: English
Contact:
World Health Organization, Distribution and Sales
CH-1211 Geneva 27, Switzerland
Fax: +41-22-791-48-57
Email: bookorders@who.ch (to place orders)
publications@who.ch (for questions about publications)

Brief Description of Contents:
This package has been developed for training trainers to run workshop programmes on how to control leakage in water supply systems. The package contains individual modules that link together to form a training course that comprehensively covers the key aspects of controlling water loss. Each module contains text which can be used as course material, overhead transparencies, and 35 mm pictorial slides.
Once trained, trainers can use the package as a base for developing their own training courses tailored to local conditions and to the needs of different course participants.
The package has been designed for course participants to learn the theory behind leakage control and how to put it into practice in real life. Thus, an integral part of the course involves participants developing plans to put a leakage control programme into action in their own systems.
This package focuses on the practical application of new principles and techniques. In doing so, it aims to equip O&M personnel with the skills necessary to optimise water supply services by implementing their own comprehensive leakage control and management programme.
The package is flexible and can be adapted to suit the needs of O&M personnel at every level within a water supply authority. It can also be used by other sector participants to gain a fuller understanding of the issues that influence the performance of water supply systems.

Title: Water and Revenue Losses: Unaccounted-for-Water

Topic Covered: Leakage Control

Author: Lynn P. Wallace
Publisher: AWWA Research Foundation and American Water Works Association

Date of Issue: December 1987
ISBN Number: 0-89867-417-4
Language: English
Number of Pages: 198 pages
Price: is $32.00
Order Number: #90531
Contact: AWWA Customer Service
6666 W. Quincy Avenue
Denver, Colorado 80235 USA
Fax: +1-303-347-0804
Email: bookstor@awwa.org

Brief Description of Contents:
This report helps utility managers, operators, and financial consultants evaluate water loss problems. This report assesses the value of the various methods used t measure and monitor lost water and discusses the causes of water loss. The report demonstrates how effective water management can result in substantial cost savings.

Title: Leaks in Water Distribution Systems

Topic Covered: Leakage Control

Publisher: American Water Works Association

Date of Issue: 1987
ISBN Number:
Language: English
Number of Pages: 48 pages
Price: US$ 28.00
Order Number: #20236
Contact: AWWA Customer Service
6666 W. Quincy Avenue
Denver, Colorado 80235 USA
Fax: +1-303-347-0804
Email: bookstor@awwa.org

Brief Description of Contents:
This book presents a general discussion of leak detection and repair techniques, and includes an overview of the steps needed to implement an effective program. The informative text is supplemented with case histories.

Title: Water Audits and Leak Detection (M36)

Topic Covered: Leakage Control

Publisher: American Water Works Association

Date of Issue: 1998
ISBN Number: 0-89867-485-0
Language: English
Number of Pages: 96 pages
Price: US$ 55.00
Order Number: #30036
Contact: AWWA Customer Service
6666 W. Quincy Avenue
Denver, Colorado 80235 USA
Fax: +1-303-347-0804
Email: bookstor@awwa.org

Brief Description of Contents:
This manual helps utility managers and consultants establish guidelines for conducting a water audit and establishing a leak detection program. The manual provides step-by-step instructions for conducting a system-wide water audit, including sample worksheets and forms for each step of the process. It details leak detection-repair programs and how they work, and helps determine if a leak detection survey is feasible and cost-effective. Instructions for conducting the survey are provided, including how to pinpoint leaks, estimate losses, record costs, and evaluate program effectiveness.

Title: Full Set of Leakage Reports

Topic Covered: Leakage Control
Water Demand Management

Author(s): Engineering & Operation Committee
Publisher: WRc plc

Date of Issue: 1994
ISBN Number: 1-898920-21-4
Language: English
Price: £225 for the full set of Leakage Reports
Order Number: NS90
Contact: WRc Publications
Frankland Road, Blagrove, Swindon
Wiltshire SN5 8YF UK
Fax: +44-1793-514562
Email: publications@wrcplc.co.uk

Brief Description of Contents:
The following series of leakage reports can be purchased individually or as a set.

- Managing Leakage – Summary Report (Report A), 68 pages, ISBN 1-898920-06-0, NS81, £90.00
- Reporting Comparative Leakage Performance (Report B), 73 pages, ISBN 1-898920-07-9, NS80, £30.00
- Setting Economic Leakage Targets (Report C), 125 pages, ISBN 1-898920-08-7, NS83, £40.00
- Estimating Unmeasured Water Delivered (Report D), 51 pages, ISBN 1-898920-09-5, NS84, £30.00
- Interpreting Measured Night Flows (Report E), 63 pages, ISBN 1-898920-10-9, NS85, £40.00
- Using Night Flow Data (Report F), 38 pages, ISBN 1-898920-11-7, NS86, £15.00
- Managing Water Pressure (Report G), 145 pages, ISBN 1-898920-12-5, NS87, £30.00
- Dealing with Customer Leakage (Report H), 34 pages, ISBN 1-898920-13-3, NS88 £15.00
- Leakage Management Techniques, Technology and Training (Report J), 59 pages, ISBN 1-898920-14-1, NS89, £25.00

Title: Managing Water Leakage: Economic and Technical Issues

Topic Covered: Leakage Control

Authors: Allan Lambert, Stephen Myers & Stuart Trow
Publisher: Financial Times Energy

Date of Issue: May 1998
ISBN Number: 1-84083-011-5
Language: English
Number of Pages:
Price: £ 395.00/US$ 632.00
Order Number: ELM98
Contact: FT Energy
Maple House
149 Tottenham Court Road
London W1P 9LL UK
Fax: +44-171-896-2275
Email: info.energy@ft.com

Brief Description of Contents:
This report provides an analysis of all the key issues, including:
- An assessment of active leakage control, pressure management, infrastructure management and the costs involved
- Leakage management timescales, including short-, medium- and long-term options, and the role of simulation modelling
- Technical performance indicators for leakage management with reference to key parameters
- Measurement systems and models to assess rates and volumes of leakage
- Costing and valuing leakage from licences and taxation to environmental and political costs
- Applying economics to leakage management including small supply systems, pressure and infrastructure management

The report includes six detailed case studies from the UK, Germany and Brazil describing the practical application of economics to different aspects of leakage management:
- Subsidised repairs of leaks on customers' pipe
- Pressure management
- Leakage reduction during a server drought
- Leakage management by sectorisation with telemetred night flows
- Defining a strategy for attaining economic leakage levels
- Specific targeting of mains and services for rehabiitation

The UNEP - DTIE International Environmental Technology Centre (IETC)

Established in April 1994, the International Environmental Technology Centre (IETC) is an integral part of the Division of Technology, Industry and Economics (DTIE) of the United Nations Environment Programme (UNEP). It has offices at two locations in Japan - Osaka and Shiga.

The Centre's main function is to promote the application of Environmentally Sound Technologies (ESTs) in developing countries and countries with economies in transition. IETC pays specific attention to urban problems, such as sewage, air pollution, solid waste, noise, and to the management of fresh water basins.

IETC is supported in its operations by two Japanese foundations: The Global Environment Centre Foundation (GEC), which is based in Osaka and handles urban environmental problems; and the International Lake Environment Committee Foundation (ILEC), which is located in Shiga Prefecture and contributes accumulated knowledge on sustainable management of fresh water resources.

IETC's mandate is based on Agenda 21, which came out of the UNCED process. Consequently IETC pursues a result-oriented work plan revolving around three issues, namely: (1) Improving access to information on ESTs; (2) Fostering technology cooperation, partnerships, adoption and use of ESTs; and (3) Building endogenous capacity.

IETC has secured specific results that have established it as a Centre of Excellence in its areas of speciality. Its products include: an overview on existing information sources for ESTs; a database of information on ESTs; a regular newsletter, a technical publication series and other media materials creating public awareness and disseminating information on ESTs; Local Agenda 21 documents developed for selected cities in collaboration with the UNCHS (Habitat)/UNEP Sustainable Cities Programme (SCP); advisory services; Action Plans for sustainable management of selected lake/reservoir basins; training needs assessment surveys in the field of decision-making on technology transfer and management of ESTs; design and implementation of pilot training programmes for adoption, application and operation of ESTs; training materials for technology management of large cities and fresh water basins; and others.

The Centre coordinates its activities with substantive organisations within the UN system. IETC also seeks partnerships with international and bilateral finance institutions, technical assistance organisations, the private, academic and non-governmental sectors, foundations and corporations.

UNITED NATIONS ENVIRONMENT PROGRAMME - INTERNATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE

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