O V2

China – UK, WRDMAP
Integrated Water Resources Management Document Series

Overview Paper 2:
Water Demand Management – an International Perspective

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CHINA WATER

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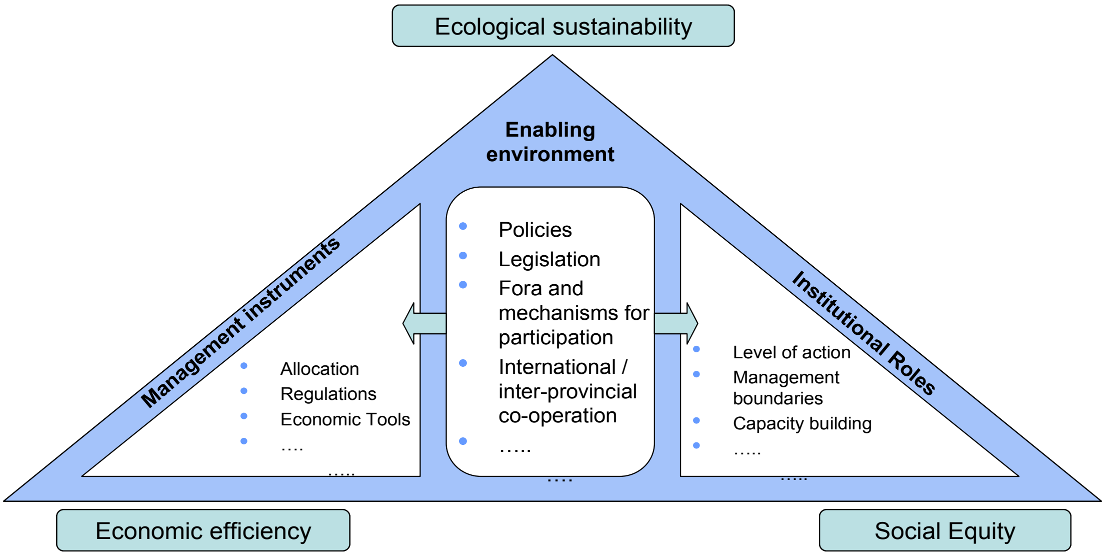
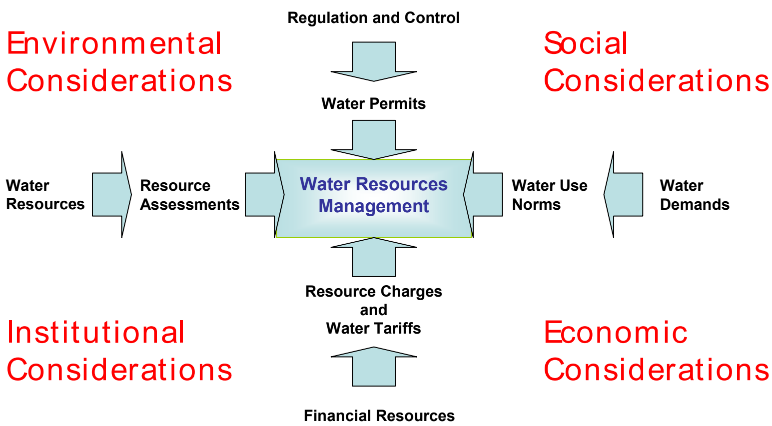
Integrated Water Resources Management (IWRM)

(Based on Global Water Partnership)



Driving Elements of Integrated Water Resources Management



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Preface

This document (OV2 – Water Demand Management [WDM]) is one of a series that have been prepared to help inform water resources professionals at various levels of government and different organisations of the basics of water demand management, including its relationship with integrated water resources management (IWRM). These documents are intended to provide guidance in support of existing national and provincial standards and documents.

This particular document is classified as an overview (OV) document that helps provide the framework and setting for the other documents in the series as is presented in the tabular section below. These other documents provide more detailed on specific topics and are also referred to in this document, where appropriate.

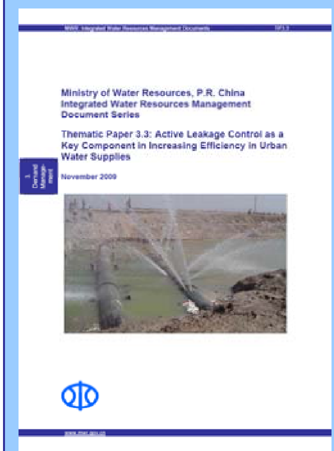
It should be emphasised that the document series has a focus on dry season water resources management although IRWM encompasses all aspects of water sector development and management including flood management. The document series has a strong focus on water demand management, and this is synthesized in this document/

The documents have been produced in Chinese and English with the former being in both hard copy and digital formats and the latter being only in digital formats. The digital versions are available at the websites listed on the back page of this document. In total there are over 70 documents in both languages. A full list of the document series is presented in Appendix E.

Examples of the document series are presented below.

Overview Documents on IWRM and Water Demand Management

Thematic Paper



Advisory Note

Manual

PLUS Examples

Thematic Paper (TP):

These are position papers related to selected topics of water resources management: they cover international best practice; background to the topic from experience in other countries; and current practices and issues as are believed to exist in China.

The thematic papers are intended as a source of information and to provide material or a basis for the development of Advisory Notes.

Advisory Note (AN):

These are a major output of the project and should be seen as the backbone of the IWRM or WDM dissemination programme.

The ANs are subject matter related and provide a structured compendium of advice on issues related to the topic, covering how to undertake or perform a particular aspect of water resources management at the municipality and county levels. This is classed as being the operational level of water resources management.

Example (EG):

The examples are provincial level case study reports related to different topics. Some of these have been developed into concise documented examples to support the Advisory Notes.

Manual (M):

The Manuals are more comprehensive documents related to topics that have been investigated in considerable depth.

A full list of the document series is presented in Appendix E.

The Ministry of Water Resources have supported the Water Resources Demand Management Assistance Project (WRDMAP) to develop this series to support WRD/WAB at provincial, municipal and county levels in their efforts to achieve sustainable water use.

SUMMARY

S.1 Introduction

The severe pressure on water resources, particularly in the north and north-west of the country, is widely recognised. It is no longer possible to augment supply to meet the full demand. There is now a strong need to manage demand and increase the productivity of water. Water demand management (WDM), however, is much more than simple application of conventional technical measures for water saving - it also addresses the incentives to adopt these technical methods and ensures that individual activities contribute to the overall objectives. WDM may also be strongly influenced by other programmes or policies. For example; policies and incentives for industrialization will have an impact on demand for water. It should be noted that WDM has been a major area of activity in many western countries for the last 10 to 20 years. The switch from supply side development and management to (water) demand management resulted from the realisation that continuous resource development was unsustainable, being often the worst option in economic term whilst also being environmentally damaging.

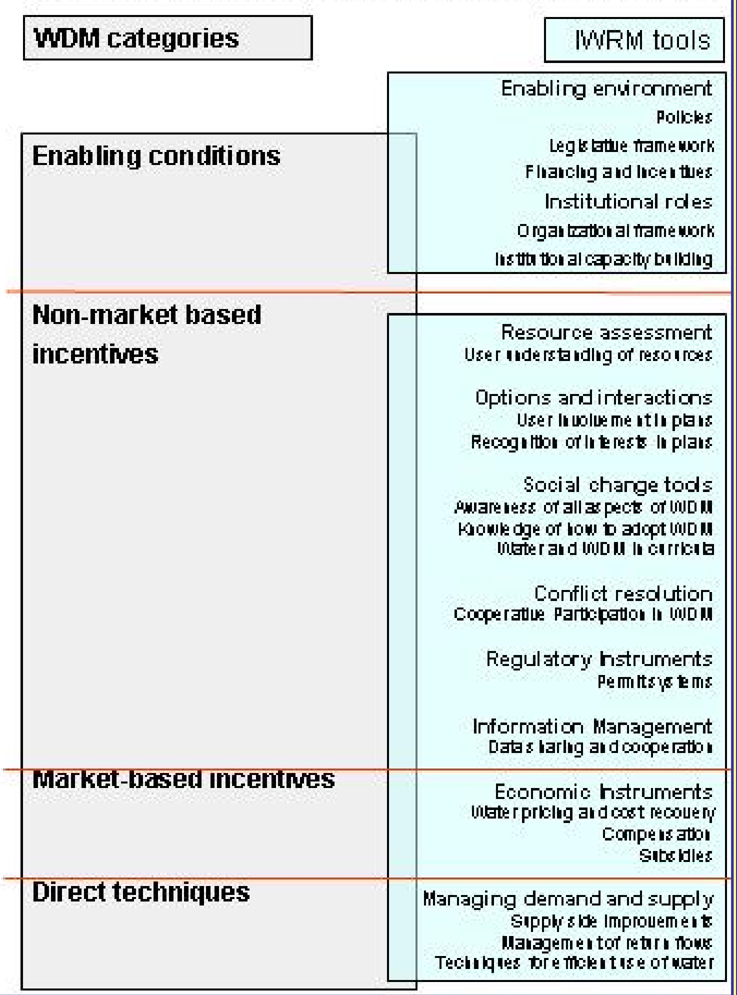
Water demand management is defined as **"***The adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social equity, environmental protection, sustainability of water supply and services, and political acceptability*"

Aspects of water demand management can have adverse social or environmental impacts. It is important that these are identified, so that appropriate mechanisms can be put in place to avoid these impacts and help people improve their livelihoods even with less water. These measures need to be an integral part of the WDM plan.

This document takes a comprehensive view of WDM, covering the conditions and management instruments needed to implement it effectively. These are closely related to the concepts of IWRM (see Figure S.1) and include:

- Enabling conditions – legislation, regulations and organisational framework.
- Non-market instruments - assessment of resources and uses; rights, norms and abstraction permits; stakeholder participation; and information exchange.

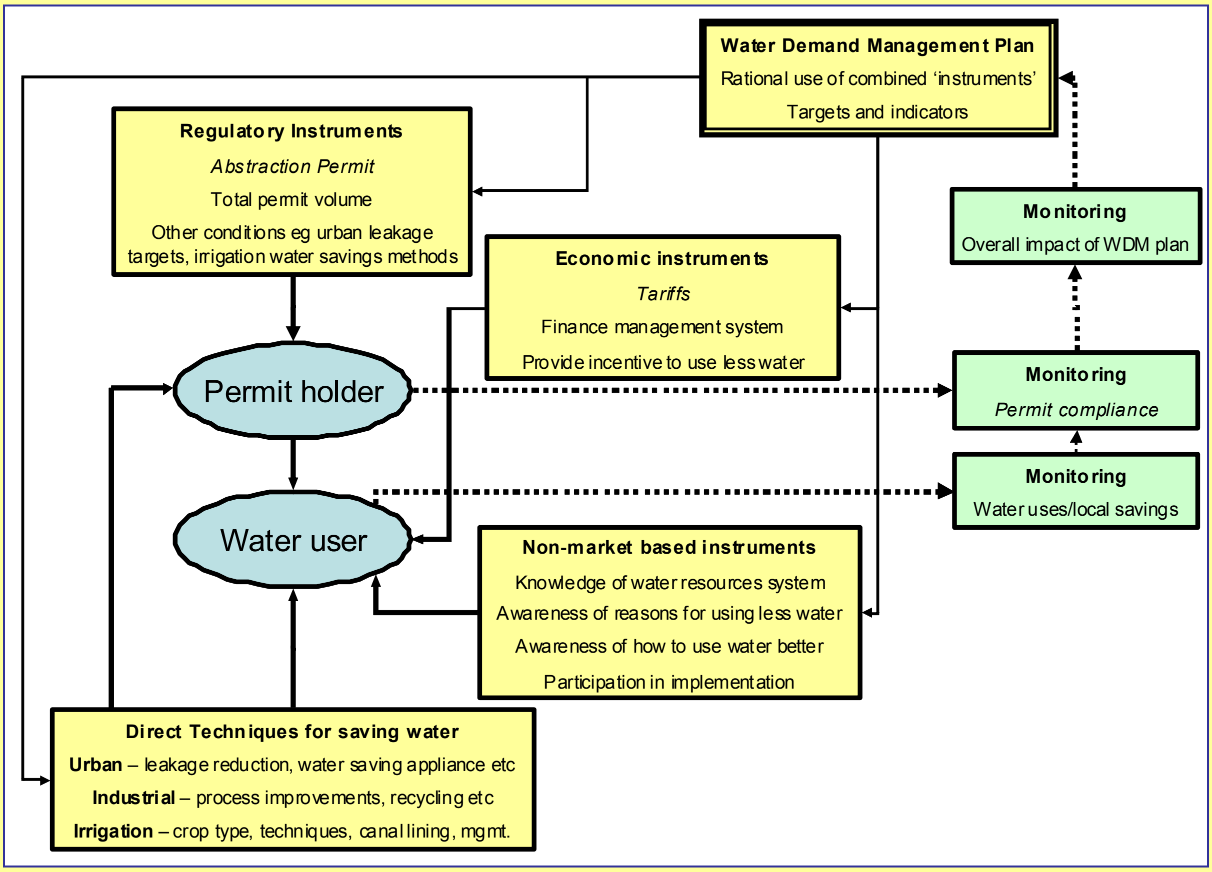
Figure S.1 WDM requirements and incentives



- Market-based incentives – water charges, water markets, etc
- Direct controls – these include pressure management, leakage control, irrigation techniques, new crops, etc

This document also covers the drivers, incentives and constraints to WDM, and stresses the importance of monitoring progress and updating plans in accordance with this monitoring. It is important that there is a good understanding of WDM from highest-level, with excellent cooperation between relevant organisations including civil society, and strong champions at all levels to implement the changes. The relationships between the application of these instruments for WDM is illustrated in Figure S.2.

Figure S.2 Relationship between management instruments for WDM



S.2 Administrative instruments – permits and allocations

One of the most important aspects of WDM is the use of administrative instruments such as water rights and water abstraction permits (WAPs). These should be based on a sound assessment of the resource availability, and a rational allocation of these resources between users and sectors. Well-defined water rights give water users the assurance that they will received a fair and agreed share of the available water. Farmers and other water users can then plan for the best way use this water which fits in with their livelihoods, and they may even sell their right to others.

The WAPs must be consistently and strictly enforced, and audited. The entire system of managing permits (including the costs of monitoring the water resources as well as administering the permit process) needs to be well-financed, and this should be one of the main reasons for introducing water resource fees.

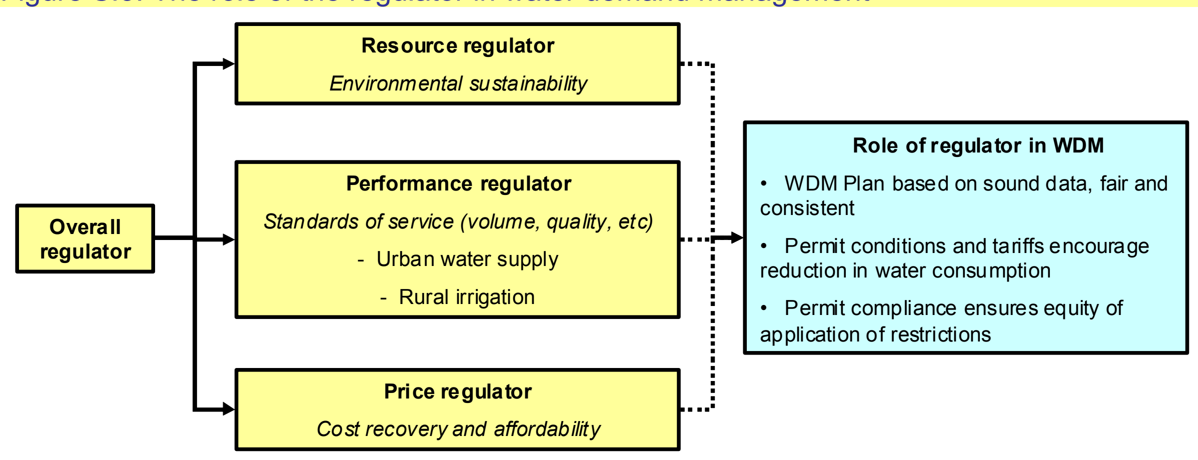
Abstraction permits are a 'negative' tool, in the sense that they place restrictions on what users may do. They need to be supported by positive encouragement to use less water – through technical skills, reduction of conflict, awareness and so on. In the past abstraction permits have not been actively used for irrigation demand management, but this needs to change. Permits are more widely used for industrial and urban water management, where they may be supported by other administrative measures such as building regulations and river quality regulations.

Water supply is a natural monopoly, which creates the risk that supply organisations will exploit their control with high tariffs or inequitable service delivery, or governments can keep water charges too low for sustainable management for political reasons. The regulator should be distinct from the service provider, and has three roles:

- Resource Regulator - allocation of water resources, and water quality,
- Performance Regulator – service delivery standards, and
- Economic Regulator - water charges

There should not be a specific regulator for WDM, but demand management objectives should be incorporated within the normal regulatory system, as illustrated below (Figure S.3).

Figure S.3: The role of the regulator in water demand management



S.3 Economic instruments – water resource fees and service charges

Economic instruments are widely seen – in China as in the rest of the world - to play a critical part in achieving WDM. They have had a useful impact in the urban and industrial sectors, but have had a much smaller impact in the irrigation sector. Economic instruments remain important in the irrigation sector, but their nature and impact is rather more complex than stimulating a reduction in demand as a direct result of an increase in price.

The main value of water charges is in ensuring that the systems for managing water are adequately resourced and financed.

Full cost pricing is widely recommended, but externalities and opportunity costs of water greatly exceed the direct costs, usually by a factor of ten or more, and it is rarely possible to recover these. The short term priority should be for water resource fees to cover the costs of water resource management, irrigation service changes to cover irrigation O&M and urban and industrial charges to cover the full supply costs.

Water markets are a topic of considerable interest both internationally and in China. There are many examples of water trading, but this is generally informal exchange of water between adjacent irrigators. But, as with the case of full cost pricing, there are many constraints and it will be many years before water markets are widely adopted.

S.4 Direct technical interventions – urban

Direct technical interventions are the most obvious form of demand management, and include such as measures as leakage control in pipe networks or canal lining in irrigation systems. These techniques are very important and in many cases are the actual method by which water is saved. Regulations, incentives and awareness are all used to encourage people to adopt them, but it is the application of the actual water-saving technique which is ultimately needed.

Urban water demand management has a fairly clear and direct beneficial impact – reduction in losses saves on the cost of treatment, the capacity of pipe networks, pumping costs and so on. This is a saving of water and energy, and this reduces also the carbon footprint of the water services industry. Urban uses of water are generally smaller in volume than irrigation uses, so the potential for saving is less. But it is still very important, and with rapid urbanisation it is growing in importance. The value of the water saved in economic terms is normally higher, since in most situations it is treated and potable water that is being 'saved'. Additionally, in many countries urban demand management has received more attention since it is linked to private sector investments and associated returns where finance and economics are taken into greater account in decision making.

The aims of urban water demand management are to:

- Prevent wasteful use of water, limit consumption and minimise investment
- Ensure an equitable distribution of potable water supplies to all customers
- Ensure water supply systems are sustainable
- Ensure an efficient and equitable distribution of available water resources

This can be achieved by a combination of

- Delivery-side Measures (pressure management, active leakage control, pipeline replacement, etc)
- Demand-side Actions (restrictions on use, assistance by WSC to customers to reduce water use, and user-led actions)

S.5 Direct technical interventions - irrigation

Although agriculture uses more water, agricultural water demand management has a more indirect impact since many of the 'losses' can be reused further downstream. This does not mean that water use efficiency should not be improved, but it does mean that the WDM measures have very different impacts at local level and on water resources in the basin as a whole are not the same. The overall basin 'efficiency' may be quite high already, even if the individual systems are 'inefficient'.

The concept of ET (evapo-transpiration) management has been introduced in parts of China. This is a valuable approach which focuses efforts on reducing consumptive use of water, and placing less emphasis on reducing losses which are available for reuse. It requires a reduction in irrigated areas and a reduction in losses which result in seepage to saline aquifers or the sea, or in unproductive evaporation.

Typical methods for agricultural water-savings include

- Crop types and physiology - new crop types and varieties
- Agronomic measures and irrigation techniques
    - Cultivation techniques including land levelling and use of mulches

- Mechanisation to reduce labour cost of water saving
- Soil water monitoring, and optimisation of irrigation application methods (both gravity and pressurised irrigation)
- Regulated deficit irrigation

- Infrastructure type, condition and management
  - Canal maintenance
  - Irrigation modernisation – automatic canal controls, with use of real time information in canal management
  - Auditing water use and losses at all levels
  - Managing systems more responsively to crop and user needs

Many of these techniques will not actually reduce the amount of water consumed, but they will increase the local productivity of water. This in turn increases the value of water and thus makes it even more important and difficult to restrict the amount of water used. Those investing in these improvements will want to maximise the returns to their investment. Irrigation improvements must therefore be accompanied by a strengthened regulatory system. It is also essential to address the social and economic aspects of irrigation demand management which may have negative impacts in the short term.

S.6 Non-market based instruments – supporting instruments

Administrative instruments such as abstraction permits, need to be financed through the use of economic instruments and supported by a range of other non-market-based instruments and incentives as well as the direct techniques outlined above. These supporting instruments include:

- Assessment of resources and needs (to ensure permits are soundly based)
- IWRM plans (to reconcile resources and demands from different sectors, ensure stakeholder acceptance, and lead to sustainability of the resources)
- Social change (awareness of WDM and its rationale and impacts; and understanding of local conditions and participation in management)
- Conflict resolution (to reconcile competing uses and mitigate adverse impacts arising from WDM which could result in conflict)
- Information management (to share information and knowledge between organisations)

These should not be regarded as optional ‘extras’ to be used, or not used according to individual interest or preference, but they are an integral part of WDM.

S.7 Drivers for water demand management

‘Drivers’ are factors which stimulate change. In a highly stressed water resources situation, the drivers for WDM can be grouped into several categories, such as:

- *Environmental*: resolving the mismatch between supply and demand, and the need to allocate water to reverse environmental decline
- *Social*: improving equity of access to water, whilst protecting livelihoods
- *Financial*: the need to avoid or delay major capital investments; and to improve cost recovery for O&M

- *Economic*: the need to maximise the productivity of water
- *Political*: the need to avoid repetition of high profile environmental disasters, such as the drying up of the Lop Nur

Although the drivers are strong, so are the constraints. It is important to review the incentives for each group of stakeholders (including national and local political leadership; the water sector administration; other government sectors and organisations; private sector companies; civil society, and water users). WDM actions need to be designed in ways which give stakeholders positive incentives to participate. A combination of quick and simple actions (‘quick wins’), with a longer term programme for the more difficult actions is required.

The constraints which need to be overcome include:

- Institutional (difficulties of effective co-operation and data sharing between departments; knowledge management; human resources; etc)
- Financial (sufficiency of resources for WDM actions)
- Technical (data availability; the interrelationships between actions; difficulty in quantifying impacts and designing measures to meet targets, etc)

S.8 Water demand management plans

The approaches outlined above should be synthesized into a WDM plan (in consultation with stakeholders throughout), which will describe the techniques and the implementation arrangements, including:

- Analysis of water resources and uses (including water audits) to identify critical issues, constraints and opportunities;
- Assessment of institutional setting and capacity, and capacity building needs;
- Formulation of targets; identification of WDM options, costs and impacts;
- Selection and prioritization of options, taking account of institutional financial, economic, social and environmental criteria;
- Implementation schedule and financing arrangements; and
- Institutional arrangements for implementation, monitoring and evaluation

The programme should include some quick win activities for immediate implementation which can be expected to have visible impact and few constraints to implementation. Other longer term activities will be more difficult to implement and take longer: a system of adaptive management will allow these actions to be taken incrementally in response to needs.

S.9 Impacts of water demand management

Successfully implemented water demand management should have positive impacts on the environment, whilst ensuring social equity and sustainable use of water resources. However there is a risk that some social groups will suffer through the introduction of WDM. The impacts both positive and negative need to be identified, analysed and if necessary mitigated. If this is done, the benefits should include:

- Social – reliable access to an agreed and socially equitable share of water; this may be less than in the past, but livelihoods will be protected
- Environmental – increased flows in critical sections of rivers at critical times
- Economic – financially sustainable management systems, whilst ensuring water management meets wider economic objectives

S.10 Key messages for effective, sustainable water demand management

- WDM needs a holistic approach, based on thorough understanding of resources and uses. There needs to be consideration of what water savings will be used for, and how water demand management relates to water allocation policies
- Many 'losses' are reused. Reducing these losses will not create water which can be used elsewhere. WDM should concentrate on reducing non-recoverable losses.
- There needs to be commitment at all levels (both political and technical) to implement WDM, with 'champions' committed to driving the process.
- Water is too valuable to rely on voluntary controls, and successful demand management will further increase the value of water used. A strong regulatory system is essential for WDM.
- Both technical and institutional measures are needed: there are many valuable innovations in flow measurement and computer applications, which need to be used within a more responsive management system. The content of the plan should be technically rigorous and achievable.
- Water charges should finance water resources management and encourage awareness of value of water.
- As well as public awareness, WDM programmes need to address the skills and incentives to save water and ensure that the wider context makes it possible for people to put their awareness into practice. Active participation in the programme by users is critical.
- There are many potential adverse impacts which need to be identified, mitigated or compensated for. These actions need to be included in the WDM plan. Reductions in allocations to certain social groups are particularly problematic: poor farmers find it most difficult to cope with reductions and need to be given strong support
- Water savings targets are often aspirational and over-optimistic, and unrelated to the actions needed to achieve them. Norms should be reduced on a rational basis, and not simply on arbitrary percentage reduction.
- WDM actions and programmes must be monitored, both to assess compliance with specific measures and to assess the impact on water resources.
- The WDM plan needs review and updating on the basis of monitoring data.

Mr Chen Lei, Minister of MWR, strongly advocated the approach of **water demand management** in his speech '**To implement the strictest water resources management system to ensure sustainable socio-economic development'** given at the Annual Water Resources Conference in 2009. As stated by Mr Chen, the dualistic approach (of supply side and demand side management), also follows the requirement of the 17th National Party Conference to implement the 'Scientific Concept of Development'

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1 Introduction

1.1 Background

Water demand management is a high priority in China. It is a requirement of the 2002 Water Law, and it was highlighted in Minister Chen Lei's speech as the first of six transitions in February 2009. The severe pressure on water resources, particularly in the north and north-west of the country, is widely recognised. There is a strong need to manage demand and to increase the productivity of water.

1.2 What is water demand management

> *"Water demand management (WDM) is a management approach that aims to conserve water by influencing demand. It involves the application of selective incentives to promote efficient and equitable use of water. WDM has the potential to increase water availability through more efficient allocation and use. This is guided by economic efficiency; equity and access; environmental protection and sustainable ecosystems functioning; governance based on maximum participation, responsibility and accountability and political acceptability". (IUCN, 2000).*

Water demand management (WDM) aims conserve water and to use it more wisely – protecting the resource for future generations, ensuring sustainability and equity, and raising economic efficiency The drivers for WDM are usually water scarcity, concern over environmental impacts or social inequity in access to water, and shortage of funds for large scale infrastructure. It is a contrasting approach to supply management, which aims to augment the supply of water.

The Global Water Partnership (GWP) provide a good introduction to water demand management, highlighting the major shift which it represents in its approach to water resources management. WDM moves the focus away from traditional supply development (construction of physical infrastructure to capture more water for direct use) to an improvement in efficiency of use, conservation, recycling and reuse of water. More specifically, WDM looks into influencing demand for water in order to promote a more rational, cost effective and sustainable use of water. It is not a complete substitute for supply management, but it can reduce the need for physical or infrastructure investments. It works best in an IWRM framework which looks across sectors and makes proper links between policy instruments and impacts.

Demand management can be applied at several different levels: at river basin level, at the level of large users of water (utilities, industry), and at the level of agricultural users and households and communities. While different approaches and techniques may be used at each level, the concept is similar. Like IWRM as a whole, demand management relies on a combination of administrative regulation, economic incentives and technical methods, and it also depends fundamentally on changes in human behaviour. It is linked closely with social change instruments, conflict management and communication and knowledge. Serious and determined effort is required to achieve effective demand management since many (if not most) water users believe they have a right to use (and waste) water freely, without appreciating the impacts of wasteful water use on society and the environment.

Demand management is much more than conventional technical measures for, for example, reducing irrigation losses by canal lining - it also addresses the incentives to adopt these technical methods, and ensures that individual activities contribute to the overall objectives. GWP cite some successful case studies of WDM - in Tunisia, for example, "*promotion of water users' associations, an increase in the price of irrigation water, and the use of incentives to adopt technologies that save water at field level. The strategy also introduced a number of supporting actions such as strengthening of applied research, improved agricultural marketing and capacity building in the irrigation sector. The integrated strategy has resulted in a marked and sudden increase in national awareness of water scarcity, and the value of water*[1]

Other examples of demand management cited by GWP indicate some of the differences in approach according to location and context. For example, another case study (in Ethiopia[2]) states that water demand management is:

> *"a combination of measures to motivate people and their activities to regulate the amount, cost and manner in which they access, use and dispose off water, thus alleviating pressure on freshwater supplies and protecting quality. It is in fact conserving water by controlling demand through the application of measures such as regulatory, technological, economical and social. Demand management reflects a major shift in the approach to water resources management, away from traditional supply development (construction of physical infrastructure to capture more and more water for direct use) to an improvement in efficiency in using, conservation, recycling and reuse of water. Improvement in water use efficiency requires setting up of mechanisms for changing people's attitudes and behavior towards water use.*"

Demand management should be closely linked to water allocation. If water is saved as a result of WDM measures, this is available for other uses – which may include leaving more water in the river to enhance the environment. This reallocation may not be explicitly planned, and may just result in a better distribution of water within an individual irrigation district and reduced inequity between head and tail of the system. However, it is recommended that demand management is planned explicitly in conjunction with water allocation. It is only through a rigorous process of demand management, demand forecasting and water allocation that the full benefits can be identified and achieved.

Some examples of the ways in which water might be reallocated are given in Table 1.1, but these need to be carefully defined for each situation.

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1 http://www.gwptoolbox.org/images/stories/cases/en/cs%2019%20tunisia.pdf

2 http://www.gwptoolbox.org/images/stories/cases/en/cs_365_demand%20management%20ii.pdf

Table 1.1 Reallocation of water in a water saving society

Use category	**Change in water allocation and use**	
	Low GDP country	**High GDP country**
Urban domestic	Increases due to population growth, greater connection between slums and formal urban areas	Stable / declining due to population stability, more environmentally-conscious population, and use of efficient appliances
Industry	Increases due to industrialization, gradually declining as water efficient processes introduced	Declines due to water efficient processes and recycling, and more effective stakeholder pressure for 'green industry'
Agriculture	Reduction in use, and redistribution of use between farmers to achieve greater equity.	Abstraction declines due to efficient irrigation, but beware risk of increase in consumption (due to enhanced profitability of improved agriculture)
Recreation	Incidental use of water	Increases, with growing demand for water-related recreation in an environmentally-aware society
Environment / residual	Aim to increase quality and quantity of environmental flows, but will take time	Environmental flows enhanced (quantity and quality), GW level and quality improved, as a result of growing awareness and concern for the environment
OVERALL	Transfer from rural to urban areas, greater access by urban poor, rural poor protected by better managed irrigation and growth in alternative livelihoods	Net transfer to environmental (and possibly recreational) uses, and corresponding reduction in other uses

The definition of WDM given in this chapter indicates several different objectives: economic, social, and environmental. However, they are not all considered to be equally applicable everywhere. Different countries will have different priorities, and priorities more change with time even within the same country. For example, the relative weighting could be as in Table 1.2. The measures applicable in each case will be different.

Table 1.2 Priority of objectives for water demand management

Objective	Policy 1	Policy 2
	Low GDP 'developing' economy priority to growth	High GDP, stable economy, priority to environment and social equity
Economic	80%	20%
Social	10%	40%
Environmental	10%	40%

It is apparent from this brief introduction that a wide range of management tools are needed to introduce effective WDM. The toolbox developed by GWP for IWRM is also applicable WDM. Most of these instruments are important for WDM, as indicated in Figure 1.1, and they will need to be used in varying ways and combinations to achieve the desired objectives. They must, however, be used in a comprehensive manner as part of a coherent plan and implementation programme, and not selected and applied in isolation.

The term 'toolbox' is a little misleading in this respect, in that it implies that a single tool can be used to solve an single problem. As the Environment Agency of England and Wales note "*changes in technology and behaviour both reduce demand, and metering is a prerequisite for both – but the biggest impact is when they all happen together*": it is the integrated nature of the concepts of IWRM and WDM which is critical to their success.

Box 1.1: Water conservation in Hermanus, South Africa

Hermanus is a small coastal town located 120 km east of Cape Town. A dam supplied water, but demand rose beyond the water allocation from the dam, particularly during the peak tourism season, when the population triples. In response, the local authorities designed and implemented a water conservation programme in 1996. The programme included water loss management, clearing of alien vegetation (efficient use of green water), promotion of water-wise gardening, communication campaigns, education and school water audits, retrofitting, and escalating block tariffs and informative billing. The results: a drop in water consumption of 16.5% one year after the project implementation and a drop of 25.5% during the peak seasons (November-February).

The results exceeded expectations. Water audits and water loss management proved very effective. The audits led to a 50% decrease of school water consumption. Water losses decreased from 18 to 11%. Informative billing was appreciated by end-users; retrofitting proved expensive and unpopular.

Source: IUCN, 2000

It should be noted that IWRM covers many aspects of water resources, including:

- Supply-side development and management
- Demand management
- Drought management
- Flood control and management
- Water quality and management
- Water-related aspects of water quality management
- Aspects of catchment management
- Coastal zone and estuarine management.

Water demand management is thus just one part of IWRM, but the management instruments developed in the IWRM toolbox can be applied in varying degrees to all aspects. In each case, IWRM tackles surface water and groundwater, water quantity and quality in an integrated manner taking social, economic factors into account.

Figure 1.1: Application of IWRM processes to WDM

IWRM	**Water demand management**
• **Enabling environment** – Policies – Legislative framework – Financing and incentives • **Institutional roles** – Organizational framework – Institutional capacity building	**Enabling environment** All IWRM conditions required
• **Management instruments** – **1 Assessment of resources and needs** • Water resources knowledge base • Water resources assessment • Modelling in IWRM • Water management indicators • Ecosystem assessment	User understanding of resources
– **2. Options, interactions (for IWRM)** • Basin Management Plans • Risk assessment and management • Social, Env and Econ. Assessment	User Involvement in plans Recognition of interests in plans
– **3. Managing demand and supply** • Efficiency of use • Recycling and reuse • Efficiency of supply	Supply side improvements Management of return flows Techniques for efficient use of water
– **4. Social change instruments** • Education curricula • Communication • Awareness raising	Awareness of all aspects of WDM Knowledge of how to adopt WDM Water and WDM in curricula
– **5. Conflict resolution** • Conflict management • Shared vision planning • Consensus building	Cooperative Participation in WDM
– **6. Regulatory instruments** • water quality • water quantity • water services • Land use	Permit systems
– **7. Economic instruments** • Pricing of water and water services • Pollution and environmental charges • Water markets • Subsidies and incentives	Water pricing and cost recovery Compensation Subsidies
– **8. Information management** • Information management systems • Data sharing data	Data sharing and cooperation

Although the IWRM management instruments are relevant for WDM, one - tool C3 - specifically focuses on demand management. The description of this tool makes very clear the wide-ranging nature of even this one aspect of demand management:

> *"The key to improved efficiency lies in setting up mechanisms for changing peoples' attitudes and behaviour towards water use. Such mechanisms include:*
>
> - *Education and communication, including programmes to work with users at school, community and institutional level;*
> - *Economic incentives including tariffs and charges for water use (domestic, industrial, agricultural) and for provision of environmental services;*
> - *Subsidies or rebates for more efficient water use can be useful"*

However, as this paper will make clear, WDM is much more even than this one management instrument and there are other equally or more important aspects such as regulatory and economic instruments.

Demand management is a key element of water resources management in most countries across the world. Box 1.2 summarises some approaches to WDM in the parts of the UK. This is a region where agriculture uses of the order of 1% of total water use.

Box 1.2 The water resources strategy for England and Wales (UK),

The UK strategy sets out demand management actions that will:

- promote incentives to reduce demand;
- allow water companies to address affordability issues with customers;
- allow people to use water more efficiently, and improve the efficiency of fixtures, fittings and appliances;
- provide better information on a product's water efficiency;
- allow more effective communication so that people can make more informed choices; and
- increase investment in technology for all types of use, including agriculture and industry

Source: http://publications.environment-agency.gov.uk/pdf/GEHO0309BPKX-E-E.pdf

The situation in southern Europe is very different from UK, and agriculture can use up to 80% of water. A definition and statement of objectives of WDM in the Mediterranean region is given in Box 1.3.

Box 1.3 Demand management in the Mediterranean region

Water demand management includes all the measures aimed at improving technical, social, economic, institutional and environmental efficiency in the various water uses. As a complement to the supply-side policies (dams, pumping, long distance transfers, desalination, etc.), water demand management is the main way to help to reach two objectives at the heart of the concept of sustainable development….

Water demand management aims at:

- Reducing losses and bad uses of water;

- Optimising water uses by ensuring well thought out allocation of resources to the different uses, while taking into account the ecosystem requirements, protecting the quality of resources as well as development of in-stream water uses (recreational activities, aquaculture and fishing, energy);
- Creating more sustainable development for each unit of resource mobilised;
- Permitting substantial financial savings and economy of facilities for rural and urban areas, and for industry;
- Anticipating and avoiding the crises which could be expected if "business as usual" continues to be practised;
- Contributing to reductions in the pressure on resources, notably by reducing or stopping unsustainable uses (over-use, useof non-renewable resources, groundwater mining)
-

WDM has, therefore, the potential to become an **essential component of integrated water management,** and of the **urban, rural, agricultural and industrial policies**. This involves undertaking a range of management activities (preparation of strategies, policies and plans, use of economic, institutional and regulatory instruments; information and awareness-raising campaigns; and coordination.

"…such a definition does not look very "snappy" but it does show how complicated water demand management is, particularly in the Mediterranean region…".

Plan Bleu, 2007

1.3 What is demand?

Before discussing demand management, it is first necessary to define demand: this is a more complex concept than it might first appear. There is no absolute figure for 'demand', as demand is always constrained to some extent by supply. Demand management is implicit even in the design of most conventional irrigation schemes, which sets an upper limit on the amount of water that farmers can 'demand'. Farmers would like more water than they can receive – an ample supply reduces management and labour costs, and it gives them freedom to select the most profitable crops. Even without a formal programme of WDM, farmers will 'demand' less than they would really like.

Demand is variable and usually seasonal, although the impacts of variability on total demand can be smoothed out by provision of storage, and it will vary according to climatic factors - rainfall and (to a lesser extent) temperature. Some water demand is consumptive (eg agriculture) and some is non-consumptive (eg hydropower), and many uses are partly consumptive and partly non-consumptive

The demand may be greater than can be supplied at present, in which case there is an 'unmet' demand – which will be reflected in reduced crop yields or poorer standards of hygiene and health. One objective of demand management is to influence patterns of water use in order to reduce the 'unmet' demand. In this situation the 'managed demand' can be met in full, rather than there being a residual 'unmet' demand.

Demand forecasts whether short term for operational planning or long term for water resources development need to make due allowance for these factors, as well as future demand management programmes. Demand is therefore not a static, fixed quantity, but something which will increase or decline in accordance with a range of variables such as:

- Weather (Rainfall, Temperature, Evaporation rates)
- Population (natural growth, migration, urbanisation)
- Food security (individual and national)
- Livelihood security (crop choice, job choice)
- Service delivery standards
- Health and epidemiology
- Political development
- Economic development

A prerequisite for a sound demand management plan is a clear knowledge of existing demand and the trends in demands that will result from changing needs and the impact of specific demand management activities, as well as from broader changes in policy. The demand forecast and the demand management plan are inextricably linked.

1.4 Need for demand management

The global and local stresses on water resources should make the need for demand management abundantly evident,. The need is widely stated in international literature: Turton (1999) notes that "*over exploitation of water … can lead to two forms of disasters … :*

- *Ecological disasters arise from the progressive over-use of natural resources that results in the ultimate crossing of the threshold of sustainability.*
- *An economic disaster arises through the decline of a community into terminal poverty as the direct consequence of inadequacy of resources in the face of increasing demands over time."*

In addition over-exploitation of water can lead to conflict – local, regional or international. Not surprisingly, Turton concludes that demand management is an essential step to avoiding these catastrophes. He also notes that this becomes easier as economies develop, since they tend to strengthen and diversify, which in turn makes it possible to pursue ever more efficient water allocating options, including the adoption of demand management policies and practices. This is because

> "*During the initial phases of economic growth, there is a tendency to over-exploit and even degrade renewable natural resources such as water. At a later stage of development, possibly influenced by an increasingly vociferous environmentally based agenda, a more diverse and stronger political economy can begin to contemplate the reconstruction of resources that were previously degraded*" (Allan, 1996).

The rationale for demand management is superficially obvious, and many of the techniques and their local impacts are well-known, yet they are still not applied as widely as expected. The reasons for this are probably that:

- The obstacles are institutional and social rather than technical, and implementation depends on behavioural change as much as technical knowledge – this change is difficult to introduce (see section 1.7)
- The losses which demand management would save remain in the hydrological system, and may still be re-used – the water may only be available at different times or locations, or of inferior quality, but it still exists. Many uses of water in arid regions, such as North China, rely on such resources. At a regional level the losses are reused, so that demand management has a very different impact to that expected at a local level (see section 5.2).

Until a resource constraint or funding crisis is reached, it is both easier and more effective to augment supply than to limit demand, which is politically contentious and difficult. This is true even though developing new supplies is usually considerably more expensive than demand management.

It is not surprising that the need for demand management was first promoted in very arid environments. It has, for example, long been a matter of national policy in Israel – as a result there has been no increase in per capita water use since 1948 despite a significant growth in GDP. This has been achieved by integrating key elements - pricing and economic policies, agricultural policies relying on imports of low value water-hungry crops and large scale effluent reuse for higher value ones, and general water conservation policies.

The need for demand management is widely recognised in China. The NDRC, with the Ministries of Science and Technology (MoST), Water Resources (MWR), Construction (MoC) and Agriculture (MoA) developed the China Water Conservation Technology Policy Outline in 2005 to provide guidance to the development and application of water conservation technology, to push forward the progress of water conservation technology, to enhance the efficiency of water use and its benefits, and to promote the sustainable utilization of water resources. (NDRC Announcement 2005 No.17 – included as Appendix A to this document)

More recently, the importance of demand management system was the highlight of a speech at the National Water Resources Working Conference by Minister Chen Lei of MWR (14th Feb 2009). Mr Chen introduced the concept of the six 'transitions' in water management in this speech. In the first transition' he states that we should:

> "*Speed up from water supply management to water demand management in the managing concept. Water supply management and water demand management are two ways to achieve balance of water resources between supply and demand. Water supply management refers to improving supply capability and meeting demand by managing water supply; water demand management means to improve efficiency and benefits of water use, inhibit unreasonable demand and balancing demand and supply through managing demand. Adopting demand management to balance demand and supply is a general international practice to scarce resources. Shortage of water resources, limited exploitation potential and prominent environment problems make us can't adopt the traditional old way. So we need to seep up to promote from water supply management to water demand management, reflect the concept of water demand management in all aspects such as planning,*

> *allocation, conservation and protection of water resources, implement total amount control, forbid unreasonable water demand, improve water use efficiency and benefits and take the mode of intensive development*".

This speech thus strongly advocated the concept of water demand management, and should lead to a major change in the way water resources are managed in the country. He also highlighted the challenges in achieving this new model, and the importance of ensuring that it suited the local context:

> *We must …make great efforts to address institutional obstacles that constrain sustainable utilization of water resources, set a modern water resources management system with sound institutions, rational mechanisms and an all-inclusive legal system thereby creating a new water resources management model with Chinese characteristics".*

Demand management is not only important in extreme environments – it is also strongly promoted in the UK in the new water resources strategy, as it "*will also lead to less wastewater, resulting in less energy being used on treatment to maintain the water quality in the receiving waters…. Demand management options generally have a lower carbon footprint, thus helping limit the extent of future climate change*" (EA, 2009). In Massachusetts, USA, a combination of leakage, asset maintenance and metering policies with practical water conservation initiatives, ambitious plumbing codes and educational campaigns has significantly reduced levels of abstraction despite population increase and helped avoid costly resource development.

In South Africa, the Government, as public trustee of the nation's water, has the responsibility to ensure that water resources are protected, utilized, developed, conserved, managed and controlled in a manner which will be equitable, sustainable and beneficial to all. It has prepared a National Water Conservation and Demand Management (WC/WDM) Strategy based on the premise that present water users can utilise water more efficiently but at the same time still maintain their present quality of life and meet their desired water needs - this is to be achieved through behavioural changes and water-saving technologies (Wilkinson and Malubane (2004)).

The needs for WDM in South Africa are different in some key respects from other countries, including China, which need to transfer water from agriculture to industrial sectors whilst protecting the livelihoods of farmers. The situation was slightly different in South Africa, where a change was needed from protecting the interests of heavy industry to supporting the rural and urban population in general. Heavy water use by the agriculture and the mining industries, and rapidly escalating requirements because of population increases and urbanization – meant that decision makers had to start thinking about water management in new ways. However, it was also the government's social, moral, and historical obligations to the neglected majority that guided early water policy and implementation efforts. In essence, South Africa needs to restructure its water philosophy and policies so that a few individuals (or industries) use less water so that more individuals have access. While the traditional water management thinking still exists today, as with construction of the Lesotho Highlands Water Project, South African water managers at local and national levels have been investigating the potential of WC/WDM. (Brooks, nd).

1.5 Relationship between demand management and water saving

Introduction

Demand management and water saving are not synonymous – although they are often used interchangeably. There is overlap between the two concepts but they should be distinguished: demand management does not necessarily mean that less water will be used – but it should be used more wisely. WDM is a much broader concept that water conservation, as should be clear from the following definitions from South Africa.

Water conservation is defined in South Africa as "*The minimisation of loss or waste, the preservation, care and protection of water resources and the efficient and effective use of water*." This differs in important ways from the definition of WDM, which is defined as "*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*." (RSA, 1999).

Water demand management

Demand management means managing demand to meet a range of objectives. This can be achieved in a variety of ways – depending on the specific local objectives - by using less water, by sharing the same amount of water in different ways between the various stakeholders, by using waters of different qualities, by adjusting the timing of water use, or by a combination of these methods.

This may result in an overall saving of water, but it is more likely to result in a more equitable, more productive or more sustainable use of the available water. Linkages between WDM and water saving probably differ according to the wealth of the country. In Israel and richer nations, water withdrawals have been decoupled from population and economic growth, resulting to stable or even declining absolute levels of water use. In contrast, in Palestine and other poor nations, water withdrawals will not only track population and economic growth but, for some time, will increase more rapidly to meet unmet needs. However, specific water use (the volume of water need for some task) will decline as end-use efficiency increases in the domestic and agricultural sectors. (Gleick, 2003).

Water savings, and the concept of a water saving society

The concept of a water saving society has recently been developed in China, and has been widely promoted throughout the country over the past decade. Water saving means a water user consuming less water. This is done for several reasons – so that water can be transferred to other more beneficial uses, so that the environment can be protected, or so that costs can be reduced.

A water-saving society (WSS) is, however, broader than this and covers the concept of society itself and relations of production - ownership and control of assets, and socio-economic dependencies. As Karl Marx stated: "*the totality of these relations of production constitutes the economic structure of society, the real foundation, on* *which arises a legal and political superstructure and to which correspond definite forms of social consciousness. The mode of production of material life conditions the general process of social, political and intellectual life*." Control and management of water is thus fundamental to society as a whole. Changes to society as well as to individual behaviour are envisaged, to ensure that all benefit and not just one group at the expense of another. This builds on the social change tools and the requirements for an enabling environment in the GWP toolbox, but should take them to a higher level

The concept of a water saving society in China includes the requirement to implement demand management measures – particularly reducing inefficient uses of water; increasing the economic and ecological productivity of water; developing unconventional water resources (including wastewater treatment and reuse, water use, rainwater harvesting, poor-quality water use); and adjusting the industrial structure to reduce demand for water. If as a result of these measures, water is transferred from one user to another, this transaction needs to be managed by the WSS so that both parties are satisfied.

It is important to be clear what the purpose of the saving is: for example is water saved in irrigation to be used to extend the area of irrigation, to enable industrial development or environmental enhancement, as was indicated earlier in Table 1.1.

1.6 Status of demand management in China

As indicated earlier demand management is now a high priority in China, and this is reflected in numerous recent policies and activities. Minister Chen Lei outlined the priorities for demand management in his speech in February 2009, in which he identified six transitions which need to be speeded up:

1. From water supply management to water demand management.
2. From development and utilization to conservation of water resources.
3. From post-treatment to prevention of polluting or damaging activities.
4. From over exploitation and disordered development to rational and ordered development.
5. From extensive utilization to effective utilization.
6. From administrative management to integrated management

Great importance has been given to water conservation for some time, and this is evident in the China Water Conservation Technology Policy Outline issued in 2005 by NDRC, MOST, MWR, MOC, and MOA to provide guidance to the development and application of water conservation technology, to enhance the efficiency of water use and its benefits, and promote the sustainable utilization of water resources and give relative consideration to medium and long-term water conservation technology (NDRC, 2005).

The need for WDM is equally evident in targets set for the 11th Five-year Plan (2005-2010), which include:

- water use per 10,000 yuan of GDP will be reduced by 20%,
- water use per unit of added industrial water output will be reduced by 30%
- agricultural irrigation water efficiency will be increased from 0.45 to 0.5.

The requirement for WDM is an explicit part of the concept of a water-saving society which was put forward in 2000 by the Central Committee of CPC in the 10th Five-year Plan. The 2002 Water Law [Article 8] requires "*that the state shall carry out water saving and devote major effort to implementing water saving measures, popularizing new water–saving technologies and processes, and developing water-saving industry, agriculture, and services*" This was followed by instructions by MWR on implementation of pilot projects for water-saving society construction (circular 558 [2002] and circular 634 [2003]) which led to national pilot projects at Zhangye Municipality in Gansu Province, Mianyang Municipality in Sichuan Province, Dalian Municipality in Liaoning Province, and elsewhere, and a large number of provincial level pilot projects.

1.7 Constraints to implementation of demand management

Water demand management is widely encouraged but it is not easy to implement. The reasons for this are partly political, because it is only through effective political institutions that leaders will have the confidence to direct measures which will affect water resource allocation and management to develop economically and ecologically sustainable policies. It is also difficult from a technical point of view – apparent wastage or excessive demand may be difficult to reduce (because improved processes for the major users may be uneconomic), or may have less impact on overall water resources than anticipated (because losses are re-used).

Turton (1999) outlines the stages which many countries go through in introducing WDM. Most countries start from a perception that there should be adequate water provided by the state. However, as arid regions have sensitive water ecosystems, so excess use of water will have long-term debilitating effects on the environment, the economy and socio-political spheres of life. As countries develop, they need to mobilize increasingly more water resources. This is usually through supply-side management, which becomes increasingly complex until a crisis is reached and they can no longer meet the growing demand.

Such a crisis can however allow for the broader hydro-political issues to be re-negotiated, bringing in concepts of sustainability and hence a strategy of demand management. The initial stages of demand management can be politically stressful as they involve the re-allocation of resources away from established and often privileged users.

For this reason, the successful transition to the demand management era needs strong political institutions, supported by the political will to make the necessary policy changes in a socially acceptable manner, aimed at clear and achievable objectives.

In some cases, demand management has been assumed to be too easy, resulting on a focus on one tool without considering the complexities or links with other social and institutional factors. For example, the focus on irrigation charging and the introduction of unfamiliar concepts such as water rights in Sri Lanka without the broad-based comprehensive approaches required for IWRM led to the failure of many attempts to introduce IWRM and, more specifically, WDM Well-designed tariff structures are necessary but are an insufficient instrument to achieve effective WDM on their own.

In Sri Lanka, IWRM was

> "*seen by some civil society groups as steps towards 'commodification' and privatisation of water. The focus on efficiency and increasing tariffs was seen as a threat to paddy cultivation and small farmers, causing public anger, while endogenously-designed strategies for water conservation were ignored as possible alternatives to entitlements and demand-management. In short, in the eyes of its critics the policy privileged efficiency at the expense of equity. Combined together these factors generated major civil society opposition to the whole policy reform process, even though parts of the policy could have brought real benefits to poor people through more integrated and sustainable water management….*
>
> *A lack of stakeholder consultation and poor communication of the policy also helped to undermine the process. Strong consultation did take place around the water policy but mainly targeted those already supportive of the process, while public consultations around the new water law were rushed"* (Aryabindu, 2008[3].).

This does not undermine the concept of IWRM – indeed it reinforces the need to implement it comprehensively and thoroughly, with ample stakeholder participation.

The social and cultural context is of critical importance. Approaches in one place will not necessarily work elsewhere, and local culture needs to be considered. Attempts to improve water management in the Yemen, for example, were rejected as there was *"such an element of structural scarcity in existence that the efforts may be perceived by the ecologically marginalized people to be only to the benefit of the rich and powerful*." (Lichtenthaler G & Turton AR 1999).

1.8 Alternatives to demand management

The traditional alternative to demand management is supply management – augmenting supply, by developing new sources, constructing reservoirs, building inter-basin transfer channels, or tapping unconventional sources – such as desalination. These are expensive and become increasingly expensive, uneconomic or unsustainable as the water resources become over-exploited. At the limit they become simply impossible. Some countries have already reached the practical and economic limit of supply development, whereas others still have economically viable potential sources which can be developed.

[3] http://www.gwptoolbox.org/images/stories/cases/en/cs_350_srilanka.pdf (Aryabindu, 2008)

Although supply management can be expensive, it should not be assumed that demand management is cheap or easy. The political decisions are hard and enforcement of demand management measures can be extremely difficult in any environment.

The third alternative – if supply management is too expensive or impossible, and demand management is politically too hard or unenforceable – is simply a crisis. Demand will exceed supply some users will suffer, others will get what they need. This is a crude and unacceptable approach, resulting in sub-optimal use of resources, social inequity and environmental breakdown.

In situations of water scarcity, it is not a question of making a simple choice between augmenting supply or managing demand, but a carefully balanced package of measures to bring supply and demand into equilibrium. In the UK, for example, there is a debate around the need to develop expensive and energy-intensive desalination plans, or reservoirs which occupy otherwise valuable land, and the options for demand management.

Demand management can also usefully be adopted to defer expensive supply-side actions that will later be required. Deferring such investments can be highly beneficial from an economic and financial point of view.

This report outlines the approaches that can be used for managing demand.

1.9 How WDM fits into the IWRM framework

The definition of WDM given above indicates how WDM is a critical part of IWRM. IWRM is defined by GWP (http://www.gwptoolbox.org) as a coherent approach to managing water which has "*three key strategic objectives.*

- *Efficiency to make water resources go as far as possible;*
- *Equity, in the allocation of water across different social and economic groups;*
- *Environmental sustainability, to protect the water resources base and associated eco-systems".*

Although GWP note that *"it may seem much easier and certainly politically safer to maintain current policies and practices*", they stress that "*doing nothing is not an option; problems will simply get worse and more difficult to tackle*". Water demand management is a key part of solving the problem of unsustainable use of water.

IWRM is a much broader concept than WDM, but many of the processes and instruments used for IWRM are applicable to WDM. Unfortunately this does lead to confusion in some literature between the terms 'water demand management' and IWRM.. This is very misleading and it would be more accurate to describe WDM as part of IWRM. The figure earlier (Figure 1.1) indicates the conditions and management tools for IWRM and relates these to the institutions and processes for WDM, thus indicating clearly how WDM falls within the wider context of IWRM.

Another way of looking at the relationship between IWRM and WDM is to consider the applicability of each of the IWRM tools to WDM. This is a subjective judgement and varies from place to place, but an indication by the density of shading against each tool in the following figure (Figure 1.2).

Figure 1.2: Importance of each IWRM tool for WDM

1.10 Structure of this report

This report is structured around the enabling environment and management instruments which are needed for WDM. These are derived from the GWP IWRM toolbox, but they are grouped here into a smaller number of categories, as has been adopted for WDM on WRDMAP (WRDMAP, 2006) - the relationship between these categories of WDM and the IWRM tools is shown in Figure 1.3 below:

- Enabling conditions – legislation, regulations and organisational framework.
- Non-market instruments include a range of issues such as reliable assessment and analysis of resources, information sharing between agencies, metering of major consumers; review of norms; review (and reduction) of permits and licences; social change methods such as ensuring availability of information on water use and savings, and demonstration of suitable methods. To reflect their relative importance, these tools have been dealt with in two chapters: regulatory instruments, and supporting instruments. The supporting instruments are described after the chapter on direct controls
- Market-based incentives – introduction or modification of fees (administrative fees for permits, resource fees for abstraction of water, tariffs to recover all or part of costs involved in delivering water, and there may be scope for establishing water markets so that water can be transferred from one user to another)

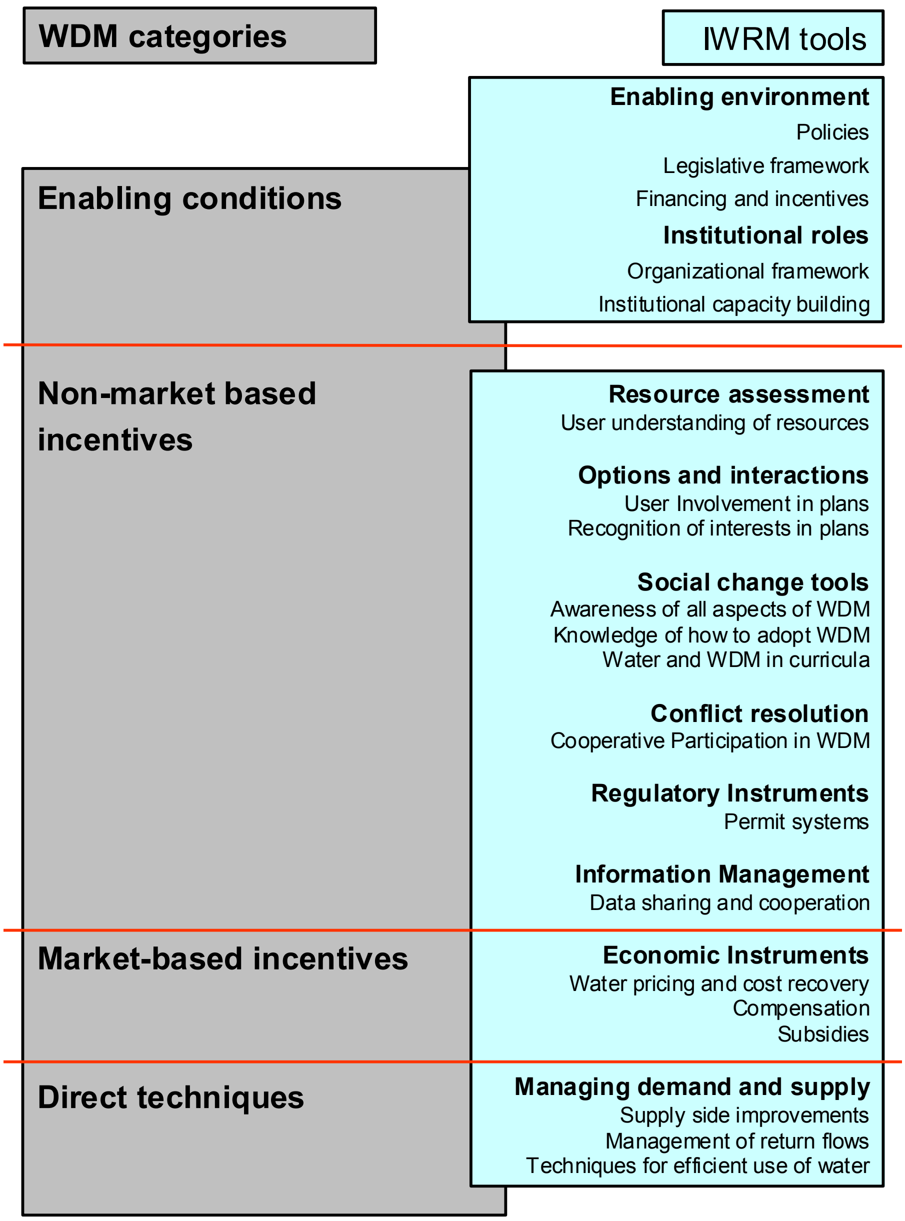
- Direct controls include canal lining, irrigation techniques, new crops

This approach has been adopted to define the structure for this report. Following these chapters giving an overview of the techniques, there are two further chapters presenting more details of the direct techniques applicable to rural and urban settings.

The remainder of the report covers the impact and implementation of water demand management, including topics such as:

- Social and environmental impact of WDM
- Drivers, incentives and constraints to WDM
- Implementation arrangements, costs and risks of WDM

Figure 1.3: General approaches for water demand management



It should be noted that this classification is not universal. ESCWA[4], for example, classify tools for water demand management into three categories:

- Economic instruments,
- Legislative and institutional instruments, and
- Awareness raising and capacity building.

In this case, the legislative and institutional tools should be complemented by mechanisms to encourage coordination between various water agencies and enforcement bodies. They should also promote decentralisation and participation of stakeholders so as to broaden role of the civil society in water management as water demand management strategies develop. The underlying methods are the same, but the way they are grouped together is slightly different.

In yet another structure, James Winpenny categorised demand management measures as follows:

- Direct interventions (e.g. investment, spending programmes and targeted interventions to encourage the use of water-efficient and water saving measures);
- Incentives (policies, market and non-market based measures which influence the behaviour of users directly by providing them with the incentives for using the resource more carefully); and
- Enabling conditions (changes to institutional, legal and the economic framework).

However, whichever way different organisations package the various elements of WDM, the basic objectives are the same. No one structure is universally correct, and the best arrangement depends on the local context. But is important that the overall package is effectively implemented.

[4] UN economic commission for West Asia. http://www.escwa.un.org/divisions/sdpd/wssd/pdf/14.pdf

2 Enabling Conditions

2.1 Enabling environment

The enabling conditions for WDM are essentially the same as those for IWRM and include both the legal environment and the organisations and their capacity:

- Enabling environment
    - Policies
    - Legislative framework
    - Financing and incentives
- Institutional roles
    - Organizational framework
    - Institutional capacity building

These conditions are described in more detail in WRDMAP OV1 (IWRM Theory and Practice – International Perspective) and are equally applicable to the requirements for WDM. This information is not repeated here. It is possible, however, to be more specific and detailed in terms of some of these conditions as related to WDM. There is a need, in particular, to ensure:

- ***High-level understanding of water demand management***. The importance of water demand management is easy to understand, but a real appreciation of how to achieve effective savings through demand management is more difficult. This requires consideration of technical issues of water saving – an understanding of the hydrological cycle and the nature of water 'losses' – as well the incentives to implement WDM and the institutional actions needed for this. This high-level understanding needs to be translated into activities – the role of 'champions' or strong and committed leaders at each level is critical for ensuring the concepts are put into practice.
- ***Cooperation between organisations***, so that demand management measures are applied and enforced consistently across sectors and at different levels. The lead organisation should be seen to be unbiased, so that the new process is truly equitable and gives appropriate weight to environmental and social concerns. There is a long-established management structure within the water administration, with links to the People's Government at various levels, which is being transformed to suit the new legislation and regulations. Consideration now also needs to be given to the establishment of cross-sectoral or multi-stakeholder working groups. In addition communication plans need to be drawn up to involve and disseminate information to stakeholders outside these organisations, including the growing numbers of civil society organisations.
- ***Capacity and resources within organisations.*** The changing focus of water management requires new skills and new ways of working. This depends on training existing staff, and ensuring that academic training for future staff includes the required skills. There may be new areas of work which were not

important in the past – a key additional activity is the role of the regulator (see section 2.5)

- ***Framework for economic support,*** This is needed, for example, so that financial support can be given to poor water users or to protect the environment, without either undermining the role of economic tools in regulation or increasing the burden on the poor. This is achieved in the UK by decoupling agricultural subsidies from individual crop decisions and thereby encouraging environmentally sound practices.

This chapter focuses on three key areas which are important for creating an effective environment for demand management:; the current institutional limitations to the scope of demand management; the willingness to make use of the enabling conditions to achieve demand management; and the role of the regulator in protecting the interests of stakeholders and in achieving equitable and sustainable access to water.

2.2 Institutional co-ordination and cooperation

There are many organisations and individuals involved or interested in water management. This results in a need for coordination and cooperation, to develop and institutional arrangements within government, and between government and society.

Governance and capacity building have not received the same investment attention as technical issues and infrastructure development. Falkenmark (2006) notes that:

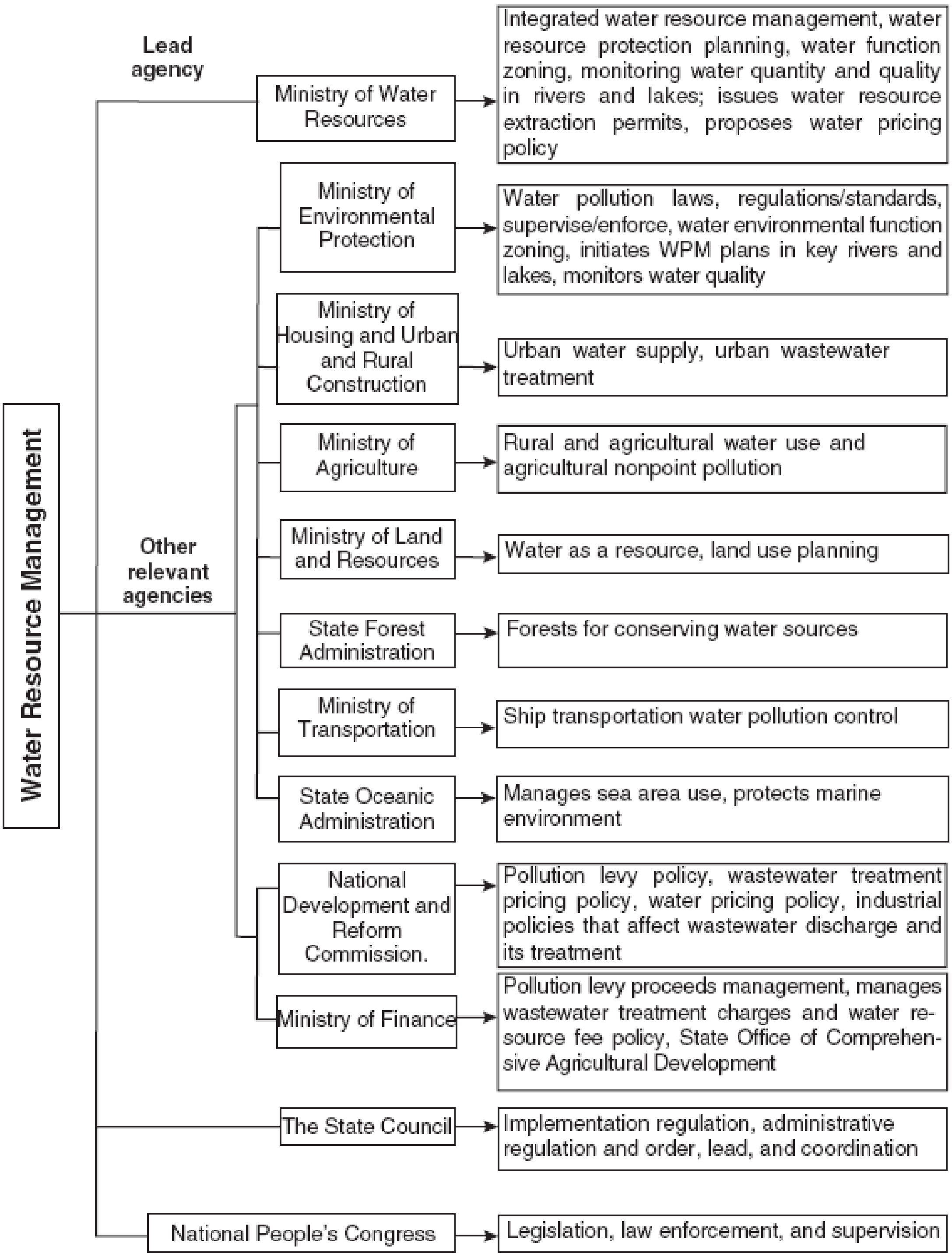
> *Water decisions are anchored in governance systems across three levels: government, civil society and the private sector. Facilitating dynamic interactions – dialogues and partnerships – among them is critical for improving water governance reform and implementation."*

Developing these interactions and partnerships is not easy, but is fundamental for successful implementation of WDM (as well as wider water management activities). Tasks include:

- Establishing principles such as equity and efficiency in water resource and services allocation and distribution, water administration based on catchments, the need for integrated water management approaches and the need to balance water use between socio-economic activities and ecosystems.
- The formulation, establishment and implementation of water policies, legislation and institutions.
- Clarification of the roles of government, civil society and the private sector and their responsibilities regarding ownership, management and administration of water resources and services, for example: inter-sector dialogue and co-ordination, stakeholder participation and conflict resolution, water rights and permits, price regulation and subsidies and tax incentives and credits.

There are many organisations involved in water governance, illustrated in the case of China in the following figure (from World Bank, 2007) – although of course not all of these are involved in WDM. It is not surprising that effective coordination is difficult to achieve, particularly where it is perceived that one organisation is taking responsibilities and resources from another. It should not be a 'zero-sum game' where one 'wins' at the expense of another, but a mutually beneficial process. Nevertheless this is difficult to achieve since there will inevitably be some who resist change, and this can undermine the entire process of effective water management.

Figure 2.1 Ministries and authorities involved in water resource management in China

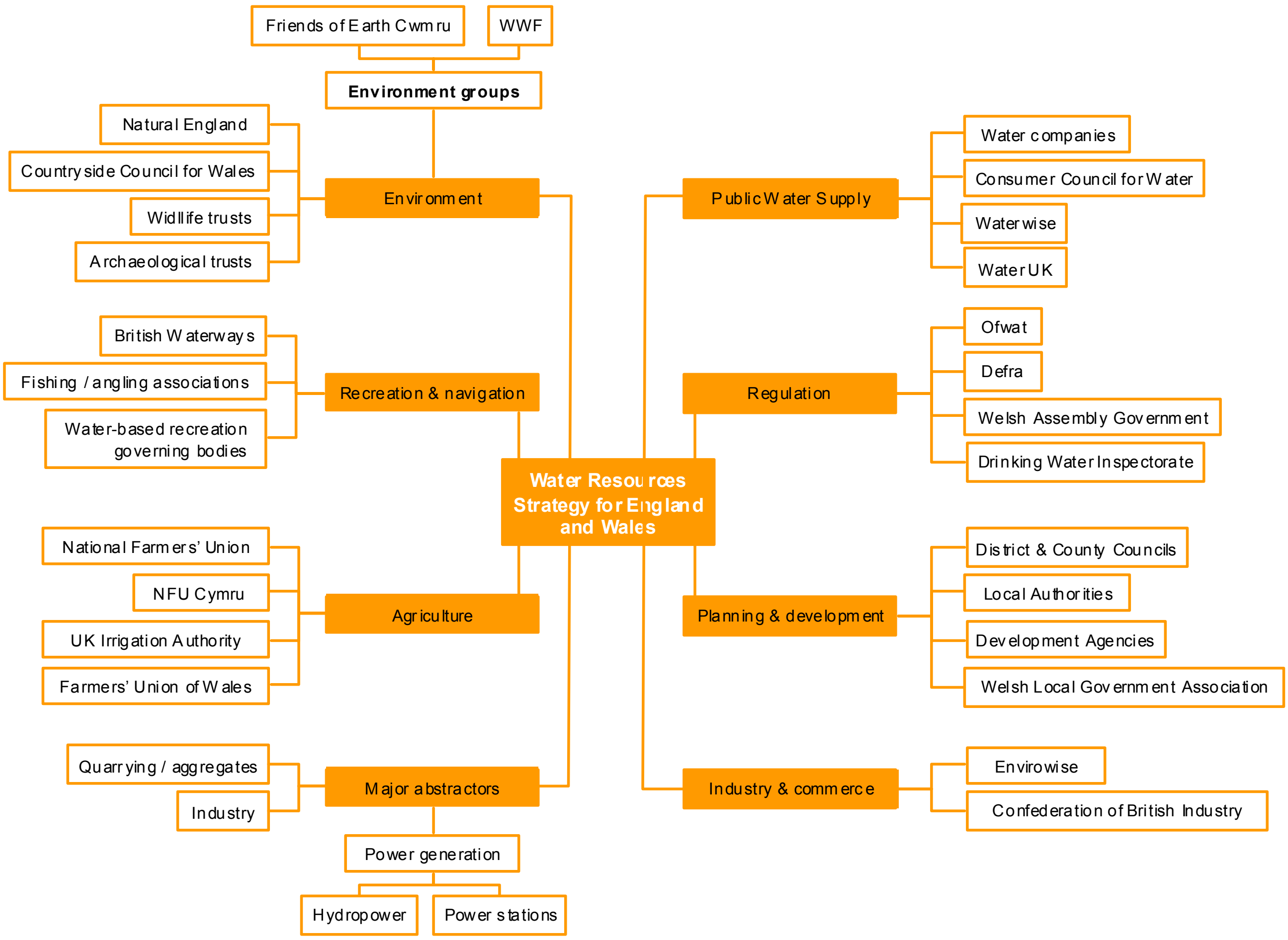


A comparable magnitude of complexity can be seen in the UK, although the details are quite different (Figure 2.2), and the Environment Agency note that

> "*Many individuals and organisations are involved in, or have an interest in, water resources management. There is no single or simple solution to the pressures that we face, and it is essential that all organisations work together…. There is enough water for people and the environment, but it will take a lot of hard work to make sure that we use and manage this precious resource in a way that protects the environment for future generations and allows water to be used efficiently and enjoyed (EA, 2009[2])*".

Many but not all of these are involved in water demand management.

Figure 2.2 Organisations involved in water management in the UK



In a global review, the World Water Development Report (WWDR) reported that many institutional systems are unable to adapt to current and future challenges because of such factors as political power monopolies, unilateral steering by government and bureaucracy, hierarchical control, top-down management and institutional fragmentation. These institutional characteristics also prevent political decision-makers from being fully informed by water sector managers.

Despite this, many developing countries and economies in transition are transforming their water management systems, incorporating concepts of decentralization (subsidiarity), stakeholder participation, partnerships (public-private, public-public, public-community/civil society) etc. Probably less progress has been achieved with coordination with related sectors (agriculture, industry, energy and so on) which is vital since the current sectoral approaches inevitably lead to fragmented, uncoordinated development and management. The WWDR team found fragmented institutional frameworks and overly complex coordination mechanisms in the water sector in many countries. The lack of appropriate links between ministries and agencies encourages competition for larger shares of water resources, to boost economic development or satisfy national production needs. WDM is important aspect of this sharing of water between sectors, and equally inter-sectoral coordination is a pre-requisite for effective WDM.

In addition to a need for coordination at central level, among ministries, many countries have found the need for inter-sectoral coordination of water users at each levels of decision-making. One common approach is to establish water councils, including high-level national water councils, river basin councils, sub-national (provincial, district) councils and water users associations to develop links and structures for managing water resources across sectors and involving water users and stakeholders in planning and strategy development and WDM.

A first step in improving services is to assess their institutional and human capacities and ability to deliver more effective services and to prepare for future uncertainties. Their capacity and incentives for WDM are an important part of this. Improving a weak institutional environment is not a linear process. It often requires efforts on several fronts, focusing on alleviating acute problems while creating the conditions for more favourable change over time.

The approach to achieving the required co-operation is discussed further in TP2.2 (stakeholder participation). This is based on a combination of experience from other countries and from project-based work in WRDMAP in Gansu and Liaoning

Key elements of this include:

- Political leadership, committed to demand management
- Forums for interactions between stakeholders, at all levels
- Agreed objectives and responsibilities
- Willingness to adapt, stimulated through a process of change management in stakeholder organisations

2.3 Limiting conditions to WDM

Progress towards water demand management will take time and a gradual re-orientation of approaches and attitudes at all levels in government and society. There are many constraints to WDM, some of which are indicated in Table 2.1, and these can gradually be overcome but this process will take time.

It should also be recognised that there are limits to water saving for any particular application. Attempts to reduce demand below this level may result in that activity being discontinued. Initially it may be easy to reduce demand, but this will become increasingly difficult as the theoretical minimum is reached. For some users, the 'cost' of saving may exceed the benefit so they may discontinue the use at a higher level – for example some farmers may find that the labour cost of water saving is less than the value of their labour in other industries, whereas others will find it worthwhile to use less water and grow some higher value crops. This will depend on a combination of individual circumstances and local economic conditions.

Water demand management, particularly as it comes close to these limits, may have adverse impacts. For example, reducing irrigation water applications may increase salinity; increasing local irrigation efficiency may reduce groundwater recharge and accelerate decline in groundwater levels.

2.4 Obstacles and willingness to make use of enabling conditions for WDM

The first column in the following table was presented at the start of the WRDMAP project to highlight the constraints to demand management, based largely on experience in South Africa (*Department of Water Affairs and Forestry).* These have been found to be largely applicable to China. WDM does not make life easier for water management or service organisations – rather, it is likely to add complexities and difficulties. There will inevitably be a resistance to change, which must be addressed through capacity-building programmes, but an over-arching regulator will be needed to ensure that WDM is adopted by all organisations.

This has now been adapted to indicate possible solutions to these obstacles, and measures to increase the willingness to adopt WDM. This table is not a complete list, but it is indicative of the issues and potential solutions.

Table 2.1 Institutional obstacles and solutions for water demand management

Generic obstacles and constraints to demand management	Possible solutions
• Financial constraints. Money is mainly available for supply side initiatives	• Review of emphases for investment planning, with more focus on economic and financial aspects and greater use of such information in decision-making • Integrated analyses (not just short-term economic analysis) of all options • Better cost recovery for development and management of water • Restructured subsidies in water and related sectors • Introduction of a regulator

Generic obstacles and constraints to demand management	Possible solutions
• Resistance to change by water institutions	• Political leadership, committed to demand management • Greater effort in changing perceptions • Forums for interactions between stakeholders, at all levels. Establishment of WDM advisory body • Agreed objectives and responsibilities • Willingness to adapt, stimulated through a process of change management in stakeholder organisations • Introduction of a regulator
• The principle often adopted in water resources management is to allocate all available water to consumers irrespective if water is not used efficiently	• Benchmarking and targets • Calculation of the value of water in various uses • More environmental awareness
• Officials and industry sectors protect their personal interests	• Forums for interaction at each level • Integrated plan, with components implemented by relevant line agency • Introduction of a regulator, with targets set for organisations
• Most engineers and local development organisations serving the water supply industry promote the development of infrastructure without adequately reviewing DM/WC measures as alternatives	• Capacity building • Awareness of methods and their importance • Reorientation in water bureaucracy • Targets set for WDM
• Water institutions own supply side measures	• Accountability via regulator and consumer councils
• Water conservation measures are perceived only as drought relief mechanisms	• Integration into IWRM plans
• Fears that water conservation will result in reduced service levels	• Improved skills and technology • Dissemination, awareness, training, subsidies • Demonstration projects • Introduction of regulator
• Supply side management options appear easier to implement	• Fuller analysis of costs and benefits (not just simple economics) • Low cost supply side options complete, constraints to further supply side options (eg compensation for resettlement) become too great • Information and dissemination • Introduction of regulator
• Supply side development has a greater political attraction plus perceived greater employment generation	• Societal awareness changes political priorities • Recognition of skills and needs for people to work on demand-side management • Introduction of a regulator

Generic obstacles and constraints to demand management	Possible solutions
• Existing planning practises choose the cheapest solution in implementation without regard to operating and running costs. (i.e. new housing developments)	• Improve and enforce building regulations • Data collection, analysis and dissemination
• Lack of understanding of principles, scope and potential of demand management	• Awareness at all levels
• Demand management strategies are often incorrectly perceived and implemented as punitive measures to the consumers	• Education and awareness programmes • Participation in design • Introduction of regulator
• Lack of integration and co-operation between the various institutions in the water supply chain, particularly in the water services sector	• Establishment of inter-sectoral working groups at all levels
• Lack of integration and co-operation of the water services functions within different departments of the service provider	• Improved internal coordination within service provider
• Lack of knowledge and understanding of the consumer and water usage patterns	• More systematic data collection and analysis of current and forecasted demands, and comparison with resources. • Greater awareness of issues, stimulated by better graphical and visual presentation of resources and use. Imaginative use of GIS outputs.
• Lack of adequate knowledge of the drivers causing the growth in demand	• *Covered by above*
• The relatively low price of water, particularly in the agriculture sector	• Use of non-economic measures as primary means of agricultural demand management – ie regulatory methods and appropriate technical methods to increase the productivity of water supported by greater awareness and understanding • Subsidies for water savings equipment
• The low level of payment for services by a significant number of consumers and users	• Greater transparency in the process for setting and using fees, fees related to actual requirements and expenditure • More efficient collection arrangements (appropriate delegation), separation of water from other fees
• Lack of awareness of the true inefficiencies in each sector	• More water use data, analysis, benchmarking • Establishment of a water saving advisory body

2.5 Regulation - the need for a regulatory system

Access to water in most countries has been managed by organisations within the government. This has changed in recent years, with a much greater diversity of roles and interests amongst stakeholders. This has created the need for a strong regulatory system, as is apparent from the table above.

Regulation is needed because water supply is often a natural monopoly – enabling supply organisations to exploit their control with high tariffs and inequitable service delivery, or governments to keep water charges low for political reasons. High charges lead to high profits, but social unrest, whereas low charges do not even cover basic operations and maintenance, let alone expansion of services to marginal areas where the poor are concentrated. The need for a regulator is widely recognised in the urban water supply sector, but less commonly in the rural sector. The regulator also needs to cover more than just pricing – for example, they also need to act as a watchdog to ensure good service delivery.

Regulation should include:

- Resource Regulation - allocation of water resources, and water quality,
- Performance Regulation – service delivery, and
- Economic Regulation - water charges.

These three aspects of regulation are central to demand management, although they are not set up primarily for that purpose. The regulatory system in the UK is summarised in Box 2.1.

Box 2.1 The regulatory system in the UK

The **water regulator** in the UK, Ofwat is a non-ministerial department of the government, audited by the national audit office (NAO), and financed by corporate operating fees from water supply and sewerage companies, (although to avoid conflict of interest, it is not paid directly by the companies). As a non-ministerial government department it is not subject to direction from Ministers, but is accountable to Parliament and regularly provides evidence to Parliamentary select committees

Ofwat aims to ensure that water companies provide a good service:

- making sure that the companies provide customers with a good quality, efficient service at a fair price;
- monitoring the companies' performance and taking action, including enforcement, to protect consumers' interests; and
- setting the companies challenging efficiency targets.

http://www.ofwat.gov.uk/

The **environmental regulator** in the UK, the Environment Agency, works to meet ever-higher environmental standards which are increasingly expected by society and required by legislation. The approach is based on the relative risks posed by different activities: this ensures society and the environment are protected in an efficient way, and the burden of regulation on businesses is minimised.

The EA follow five principles of better regulation:

- transparent – with clear rules and processes
- accountable – we explain our performance
- consistent – the same approach is applied within and across sectors
- proportionate – our actions are governed by the environmental risk
- targeted – we focus on the most important environmental outcomes

http://www.environment-agency.gov.uk/business/regulation/31993.aspx

Further organizations promote the interests of the consumers and water utilities:

- Consumer council for water (www.ccwater.org.uk): a non-departmental organisation representing water and sewerage consumers which is ultimately responsible to Parliament. It acts an influential and effective consumer champion to make sure the consumers' collective voice is heard in the water debate.
- Water UK (www.water.org.uk): a private organisation representing the water industry to, provide a framework engagement with government, regulators, stakeholder organisations and the public - to ensure benefits all customers, particularly those on low incomes

A regulator should operate within a framework that is structured around:

- **Regulatory rules:** The body of laws, regulations, guidelines, licenses and contracts that define expectations and acceptable conduct; consistent with a basic standard of living, with an emphasis on protecting the interests the poor.
- **Regulatory bodies:** Those institutions responsible for administering these rules.
- **Regulatory processes:** The procedures a regulator body must follow when carrying out the rules and their responsibilities.

Regulators became common with the advent of private sector participation in water, but they are equally necessary for public sector management. However, they are at risk of 'regulatory capture' when they become dominated by supply companies. They may face other problems which need to be guarded against with good governance arrangements (ADB, http://www.adb.org/water/actions/REG/regulatory-bodies.asp).

These requirements apply equally for regulators for irrigation and for urban or industrial supply:

- **Clarity of roles and objectives.** The regulator should have a clear mandate of its functions and objectives. It should likewise have a clear role vis-à-vis the other government agencies involved in the sector.
- **Autonomy/Credibility.** A regulator should be free from political influence and commercial intervention, be well-funded and have fixed tenure for the regulatory board members.
- **Participation.** Key stakeholders should be consulted and involved.
- **Transparency.** The regulator should follow clear rules and guidelines, and explain to stakeholders how and why decisions were made. Those decisions should also be published.
- **Accountability.** Decisions should be written and accessible. Regulators should be open to appeals courts and international arbitration to resolve disputes, and be subject to independent audits.
- **Predictability.** Operators need to be able to invest confidently, assured that "rules of the game" will not suddenly change, putting their investments and serviceability at risk. Decisions should be targeted and proportional to the scale of the problem

- **Capability.** Regulators should be staffed by competent and well-trained professionals, who receive continuous training and human resource development.

External regulators are commonly acknowledged in urban contexts, but current trends in rural water governance place considerable emphasis on self-regulation by WUAs. Their combination of local knowledge, locally defined norms, common interests and incentives paces them in a good position for this. However, these self-regulated organizations do need to be externally accountable, since there is no separation between the regulated and the regulator. This is of particular concern when there are substantial externalities and social costs – where the performance of the organisations has significant impacts on people outside them (Ogus, 1998). If the externalities are very great, public regulation, and strict compliance with externally imposed rules may be essential.

Although such externalities are commonly found in the water sector in China, Ostrom (2000) does suggest that self-governance is indeed possible, and has identified characteristics for this. She has found evidence that, self-regulation can lead, through direct participation and self-regulation, to a strong democracy where water users participate not to defend their individual interests but to ensure the fairness of decisions and fair process (Barber 1984). This reduces conflict and tendencies to take water out of turn and can lead to significant reduction in water use. it is thus an important part of WDM.

2.6 Recommendations

A sound enabling environment is a key feature of successful demand management. There are many constraints and obstacles which need to be analyzed and resolved. Referring back to the structure of WDM in Figure 1.3 important elements include:

- Policies and legislative framework
  - Clearly statement commitment to WDM in relevant policies
  - Legislation and regulations which define requirements for WDM
- Financing and incentives
  - Financial arrangements for all components of WDM
  - Analysis of incentives for organizations involved in WDM
  - Analysis of impact of explicit and implicit subsidies related to water use
- Organizational framework
  - Strong political commitment and leadership for demand management
  - Stakeholder analysis and development of forums for collaboration
  - Independent regulator for the water sector (and sub-sectors) is required - this needs to be independent, accountable and trusted
- Institutional capacity-building for WDM planning and implementation
  - New attitudes and skills are required; there may be resistance to change
  - More complete data collection and analysis is needed to support WDM.

3 Administrative Instruments – Permits and Allocations

3.1 Introduction

Administrative instruments – particularly abstraction permits – are some of the most important aspects of demand management. These provide a limit to the amount of water which an individual or organisation is allowed to abstract. These permits must be based on a clear understanding of the resources and uses of water, and anticipated trends in these.

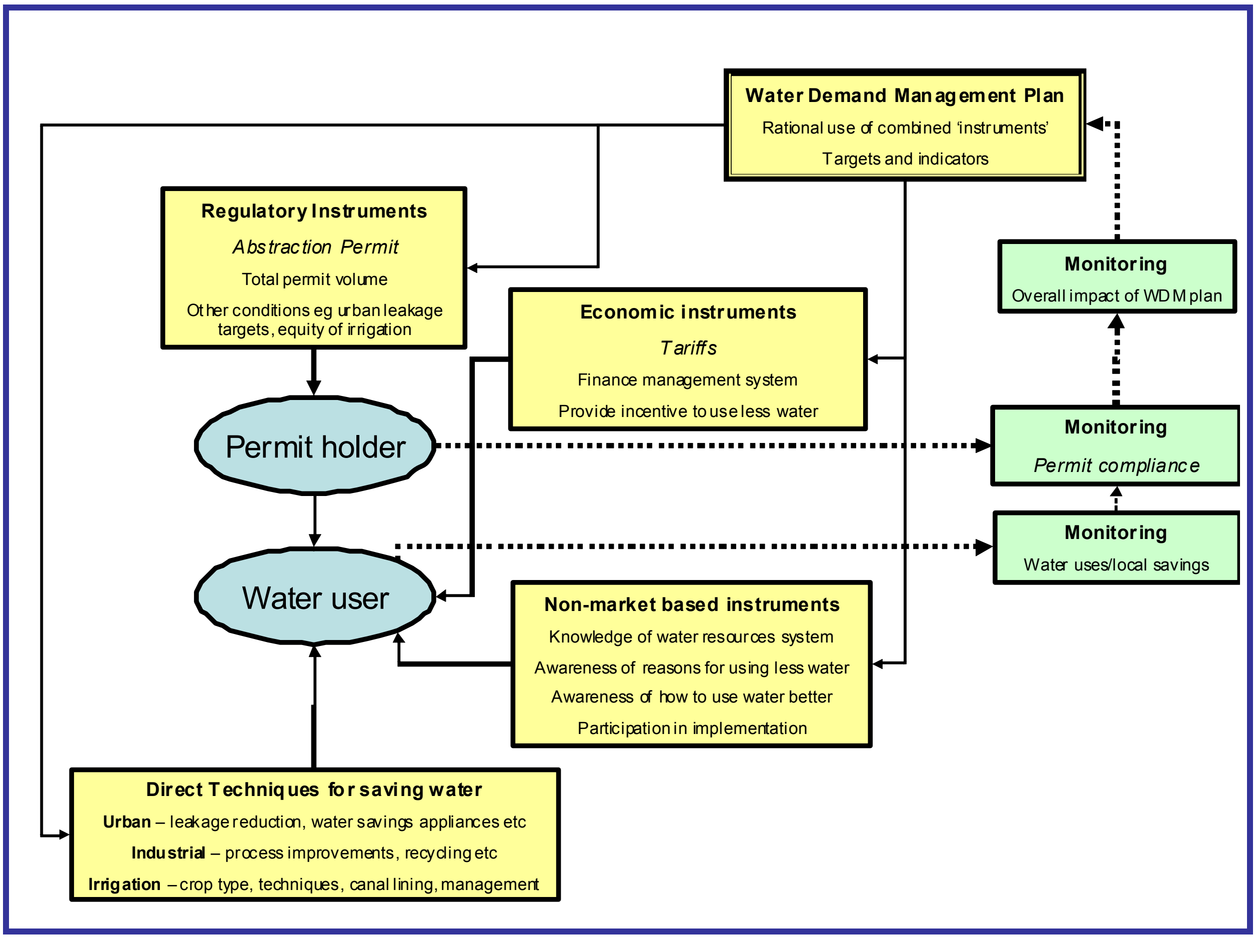
Effective enforcement of these permits will depend on the users understanding the limitations to the resource and the reason for the restrictions being imposed. In order to cope with the restriction, users will need to adopt some of the direct methods described later, but the abstraction permit is needed as a way of persuading them to do so. It is, however, unrealistic to expect anyone or any organisation to reduce their use of water unless they understand clearly and consistently the limitations to the availability of the resource. Demand management depends on changing the attitudes of users and other stakeholders. This can only be achieved if they understand the resources and the conflicting demands and pressures on the resource (see section 6.2 for further information on this).

Administrative instruments are a key feature of demand management throughout the world. Water rights and abstraction permit systems exist or are being improved in many countries, and these are seen as a pre-requisite for more advanced demand management approaches such as water markets. In addition to administrative restrictions, such as abstraction permits, it is possible to encourage self-regulation via community management and public awareness through measures such as benchmarking, provision of accurate information and controls over false or misleading information,

These methods are linked to and should be financed by economic instruments which also provide other options for demand management, through incentives to change behaviour, raising revenue to help finance necessary investments, establishing user priorities and, in many cases, achieving management objectives at the lowest possible cost. These are described separately in Chapter 0.

The relationship between the various categories of management instrument is presented schematically in Figure 3.1. This is a simplification of the process, but it indicates the main elements of WDM. The whole process needs to be undertaken within a strong supporting environment, as outlined in Chapter 2.

Figure 3.1 Relationship between management instruments for WDM



Several topics need to be considered under the heading of administrative instruments. These include water rights (and transfer of rights), abstraction permits, land use planning and building regulations, and environmental regulations. These should cover both urban and rural settings, but the requirements can be quite different for these two environments and thus they care considered separately here.

Although administrative instruments are some of the most important single actions in demand management, it should be remembered that they are essentially negative in nature – they require restrictions on what individuals or organisations can do. Thus they need to be accompanied by education and awareness of the reasons for the restrictions, technology and skills to comply, and incentives to follow them. There must be enforcement (and penalties for failing to comply, which requires that the regulatory authorities are well-governed and adequately financed. These issues are covered in other sections of this guideline.

This negative nature of administrative methods has encouraged a view that alternative measures, such as economic methods or social incentives, should take priority. However, these other methods will only be effective if they are place in strong regulatory context. For this reason administrative methods are pre-eminent in this document and the other instruments are described subsequently.

3.2 Water rights and transfer of rights

Water rights

It is widely recognised that clearly defined water rights are a pre-requisite for sound water management: the demand for water varies according to the confidence that a user has in receiving water when needed. For example, legally enforceable rights will give a user the security needed to justify investing in water saving technology or irrigation practices.

The value of secure rights applies at all levels, from international down to individual user. The basis for rights varies from place to place: it may depend on priority of appropriation from the source, or location along the river; or rights may have been reallocated by Governments to be on a more equal basis, often transferring priority from irrigation to domestic water supply. There are various systems which are used – see for example Box 3.1, which distinguishes implicit from explicit systems for allocating rights. The greater security to individual users resulting from explicit allocation is important for WDM. This is easy to achieve where individual or groups of users abstract water directly (an industry, or a group of farmers sharing a small well), but more difficult for large scale surface irrigation. In the latter case, WUAs can be useful for ensuring security of rights for individual users.

The nature of water rights is discussed further in TP4.1 (water abstraction licensing systems) and TP2.7 (water allocation). These documents also indicate the difference between land-based and use-based rights. Land-based or riparian rights are based on land ownership, and are only transferable when the land title is transferred. Use-based rights, by contrast, do not require land ownership but only legal access to the water source: these rights are fully transferable.

Box 3.1 Water rights and allocation systems

There are several different approaches which can be used: ***implicit allocation systems*** provide water through top-down, government-driven planning processes, in which the quantities of water for specific development projects or sectors are determined and then become accepted practice but only gives users limited security and few opportunities for redress when water is reallocated for another use; whereas ***explicit allocation*** is a system of time-bound licenses or permits to specific users, whose supply is then secured for a defined quantity of water for a stated period. Current practice is often a mixture of these two approaches, but the linkage is often not as transparent as it should be.

User-based allocation is generally more flexible than state allocation, but collective action is not equally effective everywhere; it is most likely to emerge where there is strong demand for water and a history of cooperation. ***Market-based allocation*** is an emerging approach which depends on the economic value of water for various uses. This can lead on to tradable property rights in water which may ease the process of inter-sectoral reallocation by compensating the "losers" and creating incentives for efficient water use in all sectors.

Influence of water rights on water demand management

Water rights influence water demand in many ways: the nature of rights has many implications for water demand management and can significantly reduce demand. This is illustrated below for agricultural water use.

Firstly, problems of unfair water distribution can be addressed more easily if the rights of users are clearly defined, transparently allocated, and recorded and protected by law. In large irrigation schemes, for example, secure rights to water would help define the obligations of the service provider to the users and reduce head-tail problems, where those at the head of a system take too much water, while those at the end are left with little or none at all. It is often the case that such a redistribution of water, in accordance with rights, will reduce the total amount of water used.

Secondly, if rights are insecure, or if there is disagreement or conflict over rights, farmers are less likely to reduce their current use of water, even if it is more than they actually require.

Thirdly, farmers are more likely to invest in improved land and water management if they have a secure right to water (and land) – this can increase water productivity.

Fourthly, farmers are better able to exploit employment opportunities in the wider economy if rights are secure, and enforcement improves reliability of access to water. This saves farmers from wasting time unproductively on capturing or guarding supplies, which in turn wastes water. Livelihood diversification is particularly important for poorer farmers because it helps spread risk and reduce vulnerability.

Finally, clearly specified rights can provide the foundation for other reforms – both regulatory and market based, which will further enhance WDM. In addition, the establishment of formal water rights can give rise to strong pressure for improving the data and monitoring systems needed for demand management.

These observations suggest that allocating rights to individuals should have a profound impact on the amount of water used: water rights are now being allocated to each household in many parts of China. In some places these rights are recorded on household water rights certificates, although this is a new approach and it is not yet clear how widely it will be adopted. These cards are not ‘water rights’ as normally understood internationally as they do not have an enforceable legal status but they do give some assurance to the certificate holder even if it is not the guarantee needed for long term planning or investment in agriculture.

The normal approach, in China as well as elsewhere in the world, is for water rights to be defined in the water abstraction permits or licences. These licensing systems vary in detail and in their rigour. A typical system is that used in England and Wales, where an abstraction licence gives the right to take a certain quantity of water from a specified source and guarantees that no one else can take the share of water that is already allocated to you. It does not guarantee that the amount authorised for abstraction will always be available – this will often depend on the weather, climate and other factors outside the control of the licence issuer. Water users may obtain insurance, for example ‘prevented planting’ or crop damage insurance, to cover the risk of drought[5]. However, the right will ensure that no one else will be able to take

[5] As described later, crop insurance will provide a farmer with confidence that his livelihood will be assured even if there is a drought and this means that he is less likely to attempt to take more water than allocated. This is a relatively new concept in China, but it is being actively promoted now and coverage is expanding rapidly.

water allocated to another person – this provides the security which can lead directly to a reduction in demand as described above.

The value of secure rights is undeniable, but it is not easy to set up a system for managing water rights. Garduno (2005) drawing on extensive experience on setting up the system in Mexico, commented that:

> "*it is neither a simple process nor can it be achieved overnight. …the process to adjudicate surface water rights in the state of Texas, USA, through detailed procedures including field inspection and determination of each right, which included the participation of the Judiciary, took twenty years, and it relied on public and private organizations with strong capacity... In Mexico… it took eight years to design the implementation tools as well as receive and register applications for water entitlements and for wastewater discharge permits from existing users and wastewater dischargers, following a simplified, user-friendly approach*".

This process depends on political support at the highest level since strong economic and political interests are usually affected when allocating or reallocating water resources.

Transfer of rights

Transfer of rights is seen by many as important for optimising use of water, and is thus often regarded as a key component of WDM. Users in one place or sector can be encouraged to save water and transfer water to other users. This gives water users a financial incentive to implement demand management. There are significant practical and theoretical difficulties in achieving effective tradable water rights, but it is widely regarded as very important for the future even if the impact to date is very small in most places.

For example in the UK, proposals are being developed to transfer rights (Box 3.2) so that water can be used more efficiently.

Box 3.2: Proposals for water trading in England and Wales

At present, efficiency in the water industry is almost totally driven by economic regulation by Ofwat, and each water company operates largely independently - the legal and regulatory frameworks of the industry encourage companies to be self-sufficient. However, both resources and demands vary across the country, and it would be more efficient to encourage greater trading of water between surplus and deficit areas, coupled with tariff reform, demand-side measures, better leakage control, the optimisation of new resources and the entry of new companies. This requires market and regulatory frameworks that encourage both head-to-head competition – where companies seek to replace each other to gain market share - and collaborative competition – where groups of companies work together to attract new customers. This requires that abstraction licences are fully tradable subject only to modification for direct environmental impacts and the impact on other users from a change of use or location.

Cave recommended that in order to free up the abstraction licence market for trading, and to protect the environment in those catchments where licensed volume levels are unsustainable, legislation should empower the Environment Agency to facilitate the return of licences through reverse auctions and negotiated agreements. Legislation should be altered to allow revenues from abstraction charges to rise above that required for cost recovery, rather than being capped at cost recovery levels as they are now. Revenues raised from the charge could be used to support environmental enhancements and vulnerable consumers.

Such an approach would support the efficient and sustainable abstraction of water across England and Wales by encouraging incumbents and others to exploit differences in availability and price of water and alternative measures (such as leakage control and demand management) to meet supply at lowest economic and environmental cost. This would include not only the optimisation of water resources within company boundaries, but also between companies through the transfer of raw and treated water.

Cave (2009) Independent Review of Competition and Innovation in Water Markets: Final report, DEFRA, 2009 www.defra.gov.uk/environment/water/industry/cavereview

Shortage of water and the resulting need to manage demand has led many countries to enable transfer of rights and encourage water markets. These include Australia, Chile and USA (Box 3.3). Further information on experience with these water markets and recommendations are given in section 4.5, and Appendix C.

These approaches are also gradually being developed in China, where Wang *et al* (2009) regard it as the best approach for ensuring efficiency in water use whilst maintaining social equity. It has indeed been effective in some places. For example, in Inner Mongolia a demand management programme by the Government "*has facilitated a series of water-savings initiatives within large irrigation districts…this saved water has then been transferred to industrial users, with the industries in turn paying the cost of the canal lining and ongoing maintenance.*" (Speed, 2009)

However, Wang (*op cit*) acknowledge that it is still a long term target in China, concluding that "*in view of the fact that water markets are not yet firmly established in China, allocating rights based on existing patterns of water use, with future adjustment towards an optimum via trading is unrealistic. Hence it is more appropriate and rational to allocate initial water rights based on detailed water resources plans and future projections of water use.*" Water trading thus appears to be a form of demand management which has the potential to be important in the future, but the conditions are not yet in place for it to be effective on a large scale.

Box 3.3: Water trading – international experience

In countries that recognize water trading rights, many cities have met their growing water needs by purchasing farms or properties with water rights and taking over the rights. Some non-governmental organizations 'compete' on behalf of the environment by purchasing the rights to a certain volume of water in a river or lake, which they then leave in the water body. These are examples of one-off transactions.

But in certain regions (Chile, parts of Australia, some western states of the United States) the conditions have been created for regular water trading. There, water markets are commonly used by farmers wanting supplementary water for valuable crops during drought conditions or by cities to create reserves in anticipation of impending droughts. Prices set in these markets signal the marginal values of water in these different uses, which are usually much higher than average values.

3.3 Abstraction permits - general

Introduction

Water rights are generally defined in water abstraction permits (WAPs)[6]. These are issued to ensure that water use does not exceed the environmentally-safe yield of the resource. Monitoring water use and compliance with permits and provides important information for managing demand.

For this approach to be effective, however, the limits need to be calculated carefully, and they need to be enforced. These requirements are easy to state, but they depend on a number of complex factors (availability of water; needs for water; agreed principles for sharing this resource, coping with variability and uncertainty; awareness and understanding of the permits; enforcement and dispute management procedures). The sharing of water resources in areas where these very resources are a pre-requisite for prosperity has long been a major cause of disputes: all of the factors listed above are potentially contentious.

International experience

International experience with abstraction permits is summarised in TP4.1 Abstraction Licensing Systems – International Experience, and key findings are presented in Table 3.1 below. That document provides considerable detail on many relevant aspects, including

- Water rights
- Permitting systems
    - Scope of an abstraction permitting regime
    - Legal source
    - Legal status and duration of abstraction permits
    - Application procedure
    - Determination of permit applications
    - Abstraction permit conditions (general and specific)
    - Permit registers
    - Suspension / modification
    - Inspection and Enforcement
- Implementation Issues
    - Institutional Issues
    - Technical information
    - Awareness of Water Rights
- Role of Abstraction Permit Systems in Water Resources Management

[6] In some countries permits are referred to as licenses

- Abstraction management strategies
- Groundwater management
- Protection of the environment
- Application determination
- Using permit conditions (Volume control and priority, Self-monitoring, Specific conditions)

This information is not repeated or summarised here, beyond that presented in Table 3.1. Document TP4.1 should be referred to further details of international experience of these issues. The sections below relate to the application of permits for demand management in practice.

Table 3.1 Key findings from international literature on abstraction permits

Issue	International Practice
Purpose of WAP	• To define water right • to enable rational allocation between uses/sectors • to provide security for users • to provide mechanism for water resource management: ▫ legally backed - so that state has interest in enforcement ▫ permit holders have interest to ensure legal rights met ▫ compliance is more likely than with top-down short term licences • Many functions need to be distinguished (consumptive, non-consumptive, altering river regime/quality)
Exemptions	No intrinsic need for exemptions, but may need to reduce administrative burden (beware cumulative effective of small permits may be large). Examples are: • Spain/Australia - livestock, domestic • Canada – minimum land size • UK – minimum volume (20 m^3/d)
Enforcement	• Water rights established as valuable binding rights • Legal offence, punished through primary legislation
Legal requirements: specify	• circumstances requiring a permit • function of permit • application procedure • minimum contents/duration of permit • who can apply for permit
legal status/duration	• must not breach existing permits, without paying compensation • uphold through courts • similar to land rights • allow for uncertainty in flows • limited duration to allow for future reallocation (Aus 10 UK 12 yrs)
Application procedure	• written application (with EIA) • application fee • inspection by permitting agency • publication of applications so that objections can be filed

Issue	International Practice
	• allowance of period for objections • review of application by the permitting agency • decision
Link to water resource plan	• River basin / water resource plans should be prepared • Management priorities, balance needs of societies and of the environment. • Planning process as important as the plans themselves; involving stakeholders helps give plans legitimacy, acceptance and helps compliance • Coping with variability in flows ▫ fraction of flow (Chile) ▫ volumetric flow (Mexico) - though reverts to fraction in practice annual ▫ notification of proportion of permit which can be used (Australia)
General Conditions	• To pay fees relating to the abstraction permit ▫ creates 'user pays' principle, ▫ provides revenue for state, ▫ covers WRM costs • To make use of the water that is subject to the abstraction permit • To use the water for the purpose for which it was allocated • To measure the volume of water that is abstracted and/or used • To take measures to protect water resources • To treat any waste water prior to its discharge • To return unused or excess water to the water course from which it was abstracted.
Specific Conditions	• user maintain records of abstractions/uses • agency monitors routinely, esp. at times of drought, to ensure accuracy • agency monitors aquifer/river flow • location of abstraction and return flows • type of use (eg sprinkler rather than surface irrigation)
Records	• Public registers, to ensure transparency

Overall approach for use of permits in demand management

Current and recommended procedures for issuing and managing permits in China are described in other documents TP4.1 (Abstraction Licensing Systems) and TP2.7 (Water allocation). The permits are issued with a typical validity of 5 years, and have generally been based on official water use norms rather than on the resource availability. It is recommended that future permits should be related to the resource availability, although this may take some time and the allocated volumes may need to be reduced gradually to match the sustainable yield of the resource over a period of years depending on the degree of stress in the river basin, and in accordance with WDM practices. Subsequently (in accordance with State Council Decree 460) permit holders can save additional water and sell the right to this saved water to other users.

In the case of surface irrigation – the dominant user – water is generally allocated top-down in accordance to accepted practice, irrigation system characteristics, and water availability rather than individually determined rights although this is gradually changing. It can thus be seen that China is in a transition phase between implicit and explicit allocation systems (as defined in Box 3.1), and it is believed that this should improved the scope for WDM.

There should be clarity on the hydrological basis for permits and allocations, and they need to take account of:

- Hydrological variability and uncertainty,
- Changes and uncertainties in demands, and growing recognition of environmental requirements, and
- Reuse of return flows and losses.

Demand for water generally rises at the times when it is most scarce – the need for irrigation is higher if there is low rainfall, but there will be less water in the river system at that time. Licensing conditions generally make it clear that although an amount of water is specified for extraction from the source, this is not a guaranteed amount. Also regulatory frameworks usually do not provide for compensation to water users for shortfalls because of the effects of extreme climatic conditions. This would generally fall under separate programs for drought relief, including crop insurance. The rights framework should thus provided a degree of security of access to water and encourage WDM to make best use with the volume allocated, but other actions such as insurance will be needed to provide further protection.

The mere existence of a regulatory system is not sufficient: compliance with abstraction permits does need to be ensured in order to ensure that WDM measures are implemented and excess water use prevented. This requires that water use should be monitored explicitly: it is not sufficient to assume that actual volumes are the same as permit volumes. This is described in AN 4.1 (WAP auditing).

In many advanced WAP systems, responsibility for the compilation of water management data lies with the water user, and the data are then submitted to the supervising water management agency to hold and analyse. The water management agency would normally also carry out independent checks on the information provided, with the authority to penalise if inaccurate information is provided. This is by far the most cost-effective system, and can be implemented as part of the conditions attached to the permit for water use. Elsewhere, the data is collected by water management agencies, but this can be very time-consuming and expensive, and in some countries 'shortcuts' are often taken which undermine the value of the process.

However the data is collected, it will need to be analysed as part of the administration of the permit system, to make sure permit conditions are met, and the appropriate fees collected for use of the water, or as penalty for breach of permit conditions (see Table 3.2 regarding the arrangements for different types of use). Enforcement of permit conditions is a fundamental aspect of WDM[7].

[7] The data collected on water use and other factors related to each permit is not required just for permit enforcement (and hence WDM), but should be fed into hydrological databases and information processing systems to improve understanding of the river and groundwater hydrology, and hence water resources planning

Enforcement of permits depends on availability of information and the authority to act on it. This is relatively easy in the case of urban and industrial use, where installation of meters is practicable. This ensures that adequate information is available, but it can still be difficult to enforce restrictions. There are also potential problems due to meter breakage, bypasses etc (and resulting costs and incentives to repair these. In the case of irrigation, both data collection and enforcement is likely to be more difficult. Permit management takes rather different forms in the case of surface and ground water and is considered in more detail in the following sections. The primary responsibility for data collection is with the permit holder, but the permit issuing authority is required to monitor the reliability and quality of data collection, and audit a sample of permits to ensure overall compliance (see AN4.1 – abstraction permit auditing).

Table 3.2 Monitoring and enforcement of permits and allocation

Use	Typical Permit holder	Data collection	Respon-sibility	Compliance with permit total volume	Compliance with allocation to individual user
Urban	Water supply company	Easy	WSC	Easy	Medium
Industrial	Individual industry	Easy	Industry	Depends on ‘influence’ of industry	Same as permit
Surface water irrigation	Irrigation District	Easy	WAB	Easy	Difficult
Groundwater irrigation	Tubewell, village or WUA	Medium	Well operator or WUA	Difficult	Difficult

3.4 Water abstraction permits for WDM in agriculture

Introduction

Abstraction permit systems are not often applied to agriculture in developing countries. This is probably because, historically, large-scale surface irrigation systems have been developed and managed by central governments, typically by the same agencies that would be responsible for issuing and managing permits. Thus the permit issuer and holder would both be within the same Government department. Modern systems of government, however, lead to recommendations for more rigorous approaches and separation of responsibilities between water users, water resource managers, and the regulator. This reflects the change from implicit to explicit allocation processes, described in the preceding section, and is needed for effective WDM.

SCD 460 requires that “*in order to draw water, any unit or individual shall apply for a water drawing permit and pay water resources fee*” [Article 2], that this *must accord with comprehensive water resources plans, comprehensive river basin plans, mid to long term water demand and supply plans and water function zoning plan…*” [Article 6], and that “*the total amount of water consumption with approved water drawings in* *a river basin shall not exceed the amount of exploitable water resources in the river basin*" [Article 7].

In the context of WDM, the permit application should indicate what water conservation and savings methods will be used [Article 13]. This will be taken into account in the assessment of the permit application, which takes account of availability of water as well as the impact of return flows [Article 20].

Role of permits and water allocation for demand management in surface water irrigation

There is usually a single permit for an entire irrigation district, issued by Provincial WRDs or Municipality WABs to the WMD. This is a curious situation as both the issuer and the holder are both part of the water administration. There is not the separation of responsibilities which is normally found with water abstraction permits. By contrast, the actual users (WUAs or individuals) do not hold permits as they do not abstract water from the river, but are allocated part of the water under the permit by the WMD.

The permit system can be used to limit demand by the irrigation district as a whole, but it cannot be used directly for demand management by individual users. However, there should be conditions regarding how the water is used: the approach adopted for this in some places is to allocate water, within the permit, to the various WUAs and agree water supply contracts between the water management divisions (WMDs) and WUAs. In other places, including parts of Xinjiang and Gansu, specified volumes are allocated to households.

These contracts between the permit holder and the WUA then define its rights. The volumes allocated can be gradually reduced as part of a WDM programme. However, the weakness of this system is that the contract needs to be negotiated with the WMD, and is likely to be short term and not provide the security which is needed.

A stronger system is found in some parts of the world, notably the Murray Darling Basin, in which ***individual*** farmers (as well as the irrigation district as a whole which manages the abstraction) hold long term rights to water. This gives them legal security, subject only to climatic variability.

Monitoring compliance with surface irrigation permits

There should be little difficulty in monitoring compliance with total abstraction permit volumes as this simply requires verifying the annual allocation of water and the actual quantity delivered through the main irrigation headworks where there should be a reliable measurement structure and adequate technical skills (within WABs and WMDs) for monitoring the flows and managing the data. Where demand management programmes result in reduced allocation to the district, this total reduction can be relatively easily enforced by the WAB/WMD.

The difficulty with water demand management in this situation is in ensuring equitable distribution of water *within* the area covered by the permit or within the contracted allocation to the WUAs. Implementation of water savings techniques and is often a condition of the permit. This will need to be enforced on an equitable basis and monitored if the users are to be satisfied with the water management system (which in turn is important for ensuring compliance). Such acceptance by stakeholders is recognised to be an important requirement in the context of IWRM (see section 6.5).

Although in some places, allocations to WUAs have been enshrined in water supply contracts between WMDs and WUAs, this is not an easy task since both the losses in the system and the destination of return flows are difficult to calculate or measure. The relation between allocation at the headworks and the allocation to individuals is not straightforward. Return flows from surface irrigation can be very high but they are difficult to quantify as they are diffuse and variable in time, they may be reused internally within the irrigation district, and they may occur at many locations in the tail of the system.

It is also necessary to ensuring that there are no other unlicensed abstractions (eg tubewells) also being used for part of this area.

It is thus necessary to monitor the flows into the WUAs and compare this with the allocation. However this monitoring is done by the WMD which is the permit holder – so it is simply monitoring itself. The WUA needs to be involved in this as well, and needs to be satisfied with the accuracy of the measurements. If an independent regulator were to be introduced to the irrigation sector, he would need to ensure that this monitoring is done rigorously.

A further complication is that the actual configuration of canals and the boundaries of WUA may make it difficult to define the points where flows should be monitored – the WUA may receive water from several canals and some water may go on downstream to other WUAs. This is much easier to solve if WUAs are defined on hydraulic rather than administrative boundaries. Flow rate measurements can be inaccurate, and total flow volume measurements are usually even more inaccurate. If total flow volumes to a WUA have to be aggregated from several measurement points the errors are cumulative.

It is important that the accuracy of measurements is improved, that farmers and managers understand the methods and limitations to accuracy – and they may need training in this.

It should be apparent from the above that it is still difficult to use permits effectively for managing surface irrigation. Surface irrigation is the largest single consumptive use of water in many countries, so this is a topic which needs further development. There is also often strong resistance to change in the way irrigation is managed.

Role of permits and allocation for demand management in groundwater irrigation

The situation with groundwater is very different, with large numbers of small abstractions. The problems are very different from surface irrigation, but It is very hard to achieve compliance with permits in groundwater systems for different reasons. It is not easy to monitor let alone control the total amount abstracted from large numbers of small wells, even though individually there is no great difficulty. Effective permit compliance and hence demand management relies on either:

- monitoring and enforcement at each tubewell by water management agencies (very costly and time-consuming), or
- encouraging and auditing self-regulation (by WUAs), but they have little incentive to do this (and there are inherent problems with self-regulation as noted earlier.

Flows from pumps can be measured fairly accurately by meters installed in the pipework, but these are costly. Alternative methods include estimating according to duration of pumping or to electricity consumption. These methods rely on calculation of conversion factors between time or electricity and water volume, which will vary according to depth to table and pump condition and will need to be checked periodically. Technically, the methods are reliable and straightforward, but the administrative arrangements are more problematic

In practice, farmers, well operators or WUAs control the amount of water which is pumped. They are reluctant to limit their water use as their livelihoods are dependent on water, and thus a key to demand management is to develop with them a combination of:

- Effective flow measurement techniques
- Knowledge of techniques for coping with less water
- Cooperation between users so that they are confident that all farmers within a WAP area are equally limited in their access to water
- Incentives for saving water and monitoring compliance with permits, and
- Systems for auditing permits, and penalties for those who fail to comply.

These are discussed further in various sections in this chapter, with additional information on flow measurement and of techniques for coping with less water in Chapter 7.

In some places, physical limits on abstractions to no more than the allocation are being imposing through:

- limiting electricity supplies to wells, by cooperation with the electricity supplier so that electricity supplies would be curtailed once farmers has exceed their electricity quota; or
- installing IC cards to switch off pump controls once the permitted volume has been pumped or number of units of electricity has been used.

For more details about the different options, particularly for IC card management, refer to Advisory Note 6.1/1(*Role of WUAs in Water Savings in Groundwater).* These are technically simple methods, but the administrative requirements for effective implementation are potentially complex, given the large numbers of individual users.

The limitations and conditions of the WAP need to be enforced by the permit issuer, typically the County WAB, but they need to delegate parts of this task to WMDs and WUAs and audit the effectiveness of the process.

Norms and quotas for irrigation

Water demand norms represent the recommended volume and schedule of water deliveries for each crop. If calculated rationally, these provide a powerful tool for demand management as they provide information to farmers on optimum water use practices. Norms should be reduced on a rational basis taking account of the impact on crop production and recommendations for agricultural practice, and they may need to be accompanied by awareness or capacity-building programmes to ensure that production is optimised with this volume of water.

It is important to remember that norms per unit area (and hence water quotas per household) are usually defined as the amount of water that should be pumped from a well or delivered to the head of a tertiary canal, rather than the amount delivered to an individual field. The various types and definitions and method of calculating norms, and the rationale or implications of reducing norms is discussed in a separate advisory note (AN/1.8/2).

Norms and quotas can be presented on an area or volumetric basis, with the latter being normal in China. Elsewhere, water quotas for agriculture are often expressed on an area basis, as it is easy to observe crop areas and this is simpler than measuring volumes of water.

In Spain, for example, various different approaches to water quota calculation and management are used, as described by Lopez-Gunn [2003] and Luis Martinez Cortina and Lopez-Gunn [2005]. Some of the advantages and disadvantages of volumetric and area-based methods are outlined below.

Table 3.3: Comparison of Volumetric and Area-based Methods for defining quotas

Advantages	Disadvantages
Volumetric quotas and fees (based on total land area held by household, and expressed as a volume)	
• Easily related to household water rights and to the volumetric water fee. • Gives an incentive to save water, or to maximise production with a given amount of water	• Need to measure water volumes to monitor actual water used (requires numerous measurements of flow rates and durations with the possibility of inaccuracies and problems of data management) • Return flows are neglected • Might result in less efficient water use if areas authorised for actual cropping are being reduced (fallow land causes unproductive evaporative losses)
Area quotas and fees (based on the area of each type of crop that is allowed, expressed as an area).	
• In effect a quota for water consumed rather than for water pumped/delivered. • Can monitor crop type and area as	• Gives no encouragement to farmers to save water or to practice deficit irrigation. • Difficult to implement in areas where cropping is very diverse (the total water consumption

Advantages	Disadvantages
a proxy for actual use (easier to measure than volume of water). • Transparent – those exceeding the quota can easily be seen and charged or penalised accordingly.	would need to be calculated by converting the area data for each crop into an equivalent volume of water using crop norms.)

3.5 Abstraction permits for demand management for urban and industrial use

Urban and industrial use accounts for a relatively small proportion of total water use, in comparison to agriculture, but the proportion is growing and there is considerable scope to improve management of this and reduce the demand – this can be stimulated through sound permit administration. There is scope for water saving through, for example, influencing domestic water use patterns etc, and encouraging industrial water use efficiency and recycling.

Permits are issued to bulk water suppliers (the WSCs) who sell on water to domestic and non-domestic users. Permits conditions should stipulate:

- water use quotas and purposes of water abstraction;
- locations where water is returned, quantity and quality of return flow;
- recycling of wastewater
- water saving requirements (both in the delivery system and within properties);
- measures for restricting water abstraction under special conditions
- monitoring requirements..

Some of these conditions can be met by the WSC directly (eg. leakage targets), but others rely on actions by the users. Except in the case of some large individual users, the link between the demand management targets in the permit conditions and the individual customers is therefore indirect, since the WSC stands between them. In similar way to surface irrigation, the permitting authority can only influence customer water use through the activities of the WSC (the permit holder). However, the WSC has an incentive to encourage WDM activities by the users since the WSC and is obliged to meet the WAP conditions which depend partly on user behaviour.

For the permit to achieve the desired results in terms of demand reduction, some the actions needed to meet the permit conditions should be translated to the users and implemented. The permits thus need to be supported by appropriate economic instruments (Section 4), advice on technology (Section 8) and communication/ awareness (Section 6.5). Water abstraction permits can then be an effective part of WDM in the urban setting.

The WSC may thus need to promote water savings measures actively, and provide advice or even appropriate household technology for reducing demand (such as free or subsidised adaptors for reducing toilet flush volumes). It will then be possible for the WSC to provide smaller total volumes of water to meet the WAP volume (whilst ensuring that all users can access this fairly) and improve the quality of waste water (which may require better operation, upgrading or construction of treatment works).

Permit auditing (section 3.3) should reveal the extent to which the conditions are complied, any difficulties in compliance, and this information should be available to both users and permit holders.

Large industrial users who abstract water directly and hold their own permit are a special case. The permit holder can respond directly to the permit conditions and can be expected to reduce water use and improve waste water quality in accordance with best practice. But it is important that the permit issuer monitors and enforces compliance. Large companies may be very influential, particularly if they related to national priority industries and may resist permit conditions imposed by local licensing authorities. But this should be no excuse and their very size and importance should make them more able and willing to comply. It is very important that they are seen to comply.

3.6 Land use planning and building regulations

Land use planning

In some countries land use planning includes consideration of access to water and some restrictions on development may be driven by concerns about available resources. This may lead to some difficult economic choices since many important urban centres are in areas of water scarcity, but it is important that these choices are faced and resolved in a rational manner. Strong land use planning is essential for this. This is an efficient aspect of WDM.

Poor urban planning or enforcement of existing land use regulations can exacerbate water management problems in cities. Low-lying areas can be inappropriate for development and are vulnerable to riverine and storm-surge flooding. Illegal settlements on precarious sites, including floodplains and unstable slopes, are at risk from mass land movement and other water-related disasters, and are exceedingly difficult to provide with services. Governments must become increasingly proactive and cross-sectoral in their planning and reform - simultaneously dealing with risks to physical infrastructure, threats to public safety, and sustainability of critical habitats and resources while still providing water supply and sanitation services.

Box 3.4 Role of structure plans and local plans in WDM in UK

Good land use planning can ensure that developments are planned to minimise their impact on the water environment – be locating them where water is available and waste disposal is least harmful. Consideration of water issues in regional development plans should ensure that potential problems are avoided and that water issues are integrated into all planning activities. For example, a key theme in the Kent structure plan in the UK is environmental protection, including "*protecting and enhancing Kent's land, air and water environments; ensuring that development does not create unacceptable levels of pollution and that development that would be sensitive to pollution is protected from it; protecting high quality agricultural land; conserving and enhancing Kent's natural habitats and biodiversity; using and managing water and other natural resources wisely…*"

Building regulations

New development should meet the latest building regulations and these should incorporate the latest thinking on such issues as rainwater harvesting, water efficiency standards for sanitary fittings, possibilities for grey-water recycling, etc. The full effect of such regulations is of course only felt over time as more new properties are built and more people have their bathrooms and toilets refurbished. However, this is an effective and economic means of reducing water consumption, and is another component of WDM.

Where rapid urban development is occurring it is particularly important to have regulations that will ensure that water efficiency is high to counteract the impact of many new consumers adding to demand. Older properties, which in places like Europe could be more than 85% of the housing stock, present a more difficult problem since the latest building regulations can only be enforced when new work is done on an older building and then only to the new structure.

Standards for water-efficient sanitary and washroom fittings can also drive water efficiency in the home and in business premises. Local preferences will dictate the most popular design but kite-marking schemes can identify the most efficient options on the market. Sanitary fittings are particularly important in achieving water saving but clearly health and safety implications must be fully addressed. In the UK it has been estimated that about 30% of domestic consumption can be attributed to toilet flushing. The volume of water to flush a toilet safely and hygienically has been progressively reduced in recent years: the cistern capacity is now governed by regulations in UK (Water Supply (Water Fittings) Regulations 1999).

Box 3.5 Role of building regulations as described in the UK water resources strategy:

Regulations are seen as a key area in delivering water efficiency. The Strategy supports a whole-building performance standard that can be developed for non-household buildings, both as a regulatory level and a voluntary code above that. Developers should work in partnership with water companies and others to explore the feasibility of achieving ‘water neutrality’ when new housing developments are proposed, within the context of a water cycle strategy. To help drive this ambitious and regular reviews of the Water Fittings Regulations will be crucial as technological advances take place and a wider range of products are included. The Strategy also supports appliance labelling schemes that improve consumer choice by making information available on the water efficiency of a product when it is bought, an approach advocated by the All Party Parliamentary Water Group. Further incentive should be developed especially by removing or reducing VAT on water efficient products.

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Similarly in New South Wales Australia the Building Sustainability Index (BASIX) is a major initiative to reduce the amount of drinking water consumed and greenhouse gas emitted by new homes and smaller apartment blocks. In Sydney, the BASIX policy includes a requirement that new dwellings must be built to use 40% less drinking water than the state average. BASIX offers maximum flexibility by recognising a range of water saving measures to suit individual household budgets, homes and lifestyles, and surrounding environmental conditions. It is mandatory to obtain a BASIX certificate before building. The 'Code for Sustainable Homes' launched in 2009 in the UK similarly implements a whole house performance standard within the building regulations.

However, developers are often reluctant to comply with such improved systems as they can increase prices to such an extent that profitability declines. For this reason, building regulations need to be obligatory and enforced. An increasingly environmentally-aware society can also help ensure that developers can still make a profit by complying with other voluntary requirements for water efficiency in buildings.

3.7 Environmental and water quality regulations

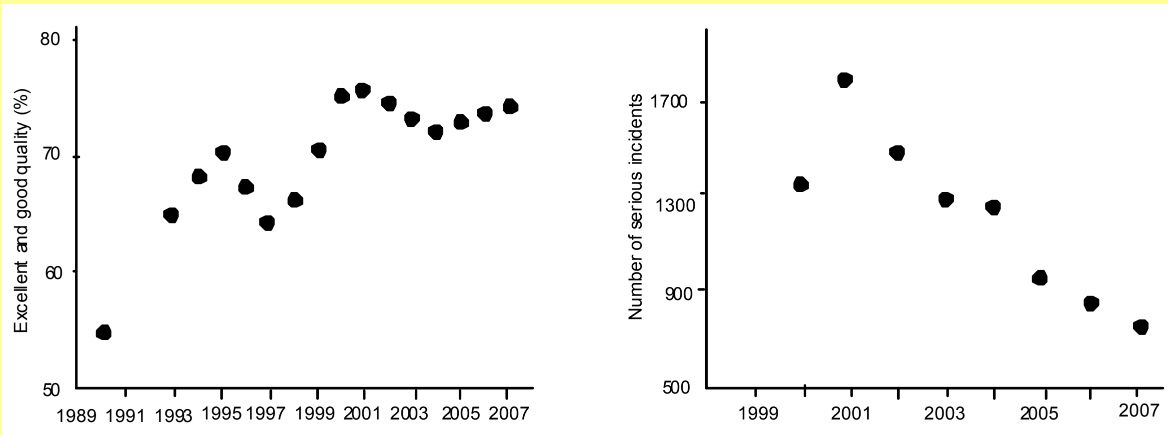
Environmental regulations are fundamental for demand management. The requirements for river quality limit how much water can be abstracted and the quality and quantity of waste which can be disposed in it. The need to meet these regulations is an important driver for the whole range of demand management activities.

In Europe the key environmental regulation is the Water Framework Directive (WFD), which requires all countries throughout the European Union to manage the water environment to consistent standards, achieving good condition in aquatic ecosystems, promote sustainable use of water, improve water quality, and contribute to mitigating the effects of floods and droughts. Demand management can reduce the amount of water abstracted, and thus the WFD is an important driver for WDM.

Box 3.6. Impact of establishing an environmental regulator in the UK

Until the establishment of the National Rivers Authority in 1989 (later the Environment Agency), monitoring was undertaken by the water industry, which was also one of the main abstractors and main polluters. Controls on abstractions and discharges, enforced by an independent regulator, have had a substantial impact on river quality, as can be seen from the following graphs. This is an important influence on WDM in the UK.

River Quality in UK since the establishment of the Environment Agency.



Successful river water quality improvements are usually achieved where regulators focus first the control of major polluting activities, gradually moving from point-source pollution which is now largely well controlled throughout much of the industrialised world, to control of diffuse sources.

http://www.workingwithwater.net/view/3227/environmental-regulation-improving-river-water-quality-/

3.8 The role of the regulator

Overview

As noted earlier (Section 2.5), a strong regulatory system is needed to ensure sound management of water. Water is not a commodity which can be managed purely by market forces, and there is a need for a regulatory system to cover the processes of resource allocation, environmental protection, service delivery performance, and financial charges. In the context of this document, the regulatory system is important for ensuring effective water demand management. The institutional framework for regulators was described in section 2.5; this section covers their operating rules and procedures. Further details of the regulatory system are given in Appendix B.

Regulators should be given powers which enable them to:

- **Set standards** for water quality, environmental conditions, customer service levels
- **Set tariffs** to allow for cost recovery or with a rational subsidy policy (to benefit the poor and maintain service sustainability
- **Gather information** to monitor the operator's performance.
- **Enforce rules** by imposing penalties for non-compliance.
- **Arbitrate** to settle disputes between consumers and operators and between the operators and government.

Key issues include incentives and access to information: ensuring that the regulator is independent of the regulated, has equal access to relevant information, has an appropriate incentive to regulate, and that regulation is separated from political interests. This is not always easy to achieve and even actions to improve regulation, such as consultation (which is essential for improving flow of information, transparency and accountability) can increase the opportunity for corrupt transactions. This is avoided in the USA, by ensuring that all private meetings and communications between officials and third parties are placed on the official record.

In both rural and urban situations, regulation should ensure that the sector is well-managed by:

- Protecting consumers against monopolistic abuse
- Protecting operators against government intervention (or intervention by other parts of government)
- Benchmarking performance
- Promoting efficiency through service targets

Criticism of the regulator is always possible over particular decisions, but legitimacy will be achieved when the regulatory institutions are generally accepted within society as they are in the water sector in UK. Achieving this public acceptance takes time, as public confidence in the regulators is built. This acceptance can be encouraged by adopting good regulatory practices which include:

- Transparency, or openness to public scrutiny
- Accountability, to the public and the government
- Targeted, so that decisions do not have adverse impacts on other sectors
- Proportionality, to the scale of the problem
- Consistency, and predictability of the regulator's actions.

Although strong regulatory regimes have been developed in some countries, it is not easy to transfer these to others (Minogue and Carino, 2006). The temptation to transfer 'best practice' models of regulation rooted in the different economic, social and political conditions should be resisted, but such models should provide guidance on developing locally appropriate solutions. In particular, technical capacity is often limited with most skilled people working in the regulated industry rather than in the regulator. This can be mitigated by internal institutional assessment and capacity-building aimed at strengthening the autonomy of the regulator (both from the industry and political pressures), but takes time to resolve.

The existing system for regulation of the water sector in China is very 'light touch', and is best regarded as supervision rather than regulation: the supervisory agencies rarely set challenging targets for the water companies. This is reviewed in TP4.3: Regulation of Small and Medium Sized Water Supply Companies. Experience in other countries indicates that it can take 5 to 10 years for the Regulator to develop sufficient capacity and experience to establish a regime that is effective in promoting economic efficiency while at the same time protecting the interests of consumers and the financial viability of efficient suppliers. The regulatory regime will need to be strengthened in order to make WDM more effective (as well as improve service delivery).

The regulator and water demand management

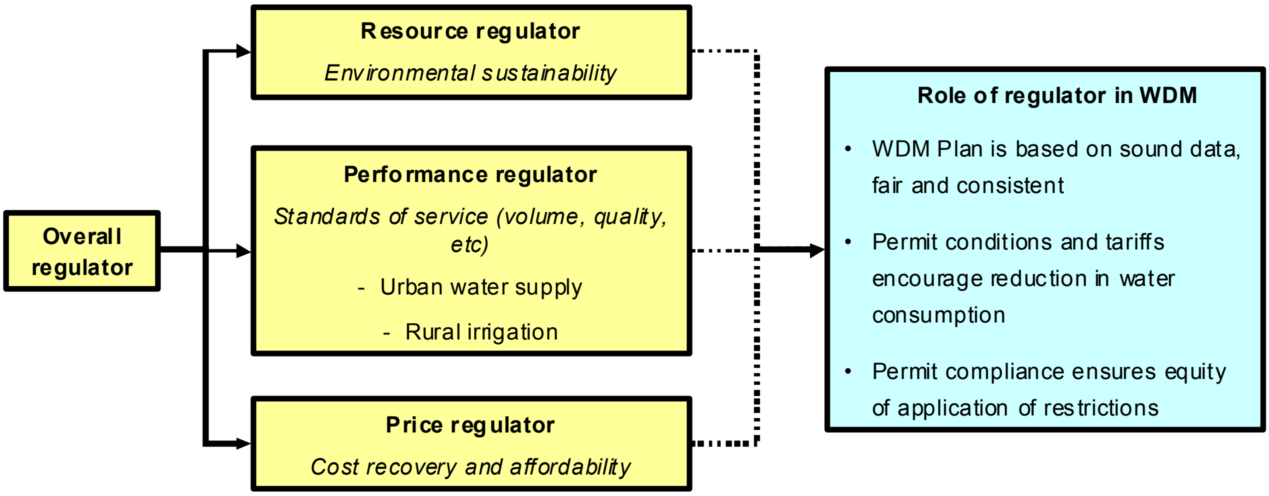
Demand management is not the only or even the primary reason for establishing a regulatory system – this is required for environmental sustainability, ensuring performance standards, fair tariffs and so on. However, a regulator can also have an important impact on demand management.

This should not be a specific regulator for WDM, but demand management objectives should be incorporated within the normal regulatory system, for example as illustrated below (Figure 3.2). This will require the regulator to ensure that the:

- WDM Plan is based on sound data, fair and consistent
- Permit conditions and tariffs encourage reduction in water consumption
- Permit compliance ensures equity of application of restrictions

Irrigated agriculture is such an important water use in China that there is a need for a regulator for this, which cannot easily be covered by the urban water supply regulator because of the differences in the institutional arrangements and responsibilities. In all cases, the regulator should be distinct from the organisation managing service delivery to avoid conflict of interest although this may be difficult to achieve in the short term.

Figure 3.2: The role of the regulator in water demand management



4 Market-based Instruments - Economic Instruments

4.1 Introduction

Economic instruments are widely seen – in China as in the rest of the world - to play a key part in achieving WDM. They have had a useful impact in the urban and industrial sectors, but the benefits have largely failed to materialize in the irrigation sector, despite considerable efforts in many countries since the 1990s specifically for limiting water use, The difficulty in using price for irrigation demand management is view is now widely recognised in international literature. For example, Molle and Barker[8] state:

> "*… common wisdom that water is wasted because it is not adequately priced is a widespread fallacy. This causal link may be valid for tap-water and for systems where users have no constraint on the amount of water they may use, but not for water-short situations, where supply remains much under demand. In such cases, the value of water is already manifested by its very lack and users have been pushed to adjust to the situation. If the objective is allocation in response to scarcity, rationing (i.e., assigning water to specific uses either within system or at basin level) represents an alternative mechanism for coping with water shortages where demand exceeds supply. Rationing also makes scarcity manifests and elicits adjustments in water use more efficiently than pricing would do*".

Economic instruments remain important in the irrigation sector, but their nature and impact is rather more complex than stimulating a reduction in demand as a direct result of an increase in price.

There are several approaches for the use of economic instruments in the water sector as a whole:

- Recovering costs of management – by improving the quality of management, this can indirectly affect demand;
- Influencing demand directly by changing prices, as a consequence of the price elasticity of demand;
- Setting agricultural policies, subsidies and support systems in ways which will promote agricultural water saving;
- Using cost-effectiveness and economic analyses for optimising the allocations to various water uses;
- Discharge and effluent permits and associated charges; and
- Use of tradable abstraction permits.

The first two of these methods are related to water resource fees (TP5.3 Water resource fees) and service charges (described in TP5.2 Irrigation Service Charges

[8] Molle and Barker (www.agnet.org/library/eb/543/)

and AN5.4 Urban Water Supply Tariffs). The third method is related to wider economic policies which can influence the demand for water, which is briefly outlined in this document. For example, in Europe subsidies may be paid to farmers who adopt environmentally sustainable practices. The fourth method is used, for example in deciding the proportion of water which will be allocated to irrigated agriculture and how much will be diverted to industry. This is described in AN2.8 economic analysis for IWRM and TP7.1 Multi-criteria analysis. Charges and permits for effluent discharge are covered in TP4.2, and use of tradable permits is covered briefly in this document.

Internationally, recent emphasis has been given to the principles of regarding water as an economic good and of allocating it among the sectors accordingly, with water markets used to maximise the economic efficiency of water use. The reasons for this are not difficult to see: the value of water services is enormous. In the UK, the replacement cost of water that the Environment Agency licences is worth some £72 billion, with its true value to society being incalculable.

Water markets are a controversial topic, which have generated much international debate, and have not proved easy to implement but some progress has been achieved in some countries. They depend on secure water rights and the ability to transfer rights within a pre-designed framework within the regulatory system (as described in section 3.2). Some experiences are described in section 4.5.

The role of economic instruments in water resource management has been prominent since the Dublin Principles were agreed at the International Conference on Water and the Environment in Dublin, 1992, which recognised that (as one of four principles) water has an economic value in all its competing uses and should be recognized as an economic good.

This principle goes on to state that "*Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources*".

The principle also states that "*it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price*".

In accordance with these principles, economic instruments in general should help achieve protection of the resource, equity in use, and a basic right to water. As a scarce and productive resource, water should be allocated according to economic principles of efficiency and equity, taking account of the broader cost to the economy. This does not mean that water services must be sold at a market price. Market failures, divergences between social and private costs and values of water, and social or environmental imperatives may well justify setting water prices that focus on equity concerns (as a matter of policy) over efficiency concerns (as a consequence of market forces). But even in such cases, however, it is important for policy makers to understand the economic costs and implications of their decisions (UN-ESCWA, 2004).

4.2 Elasticity of demand

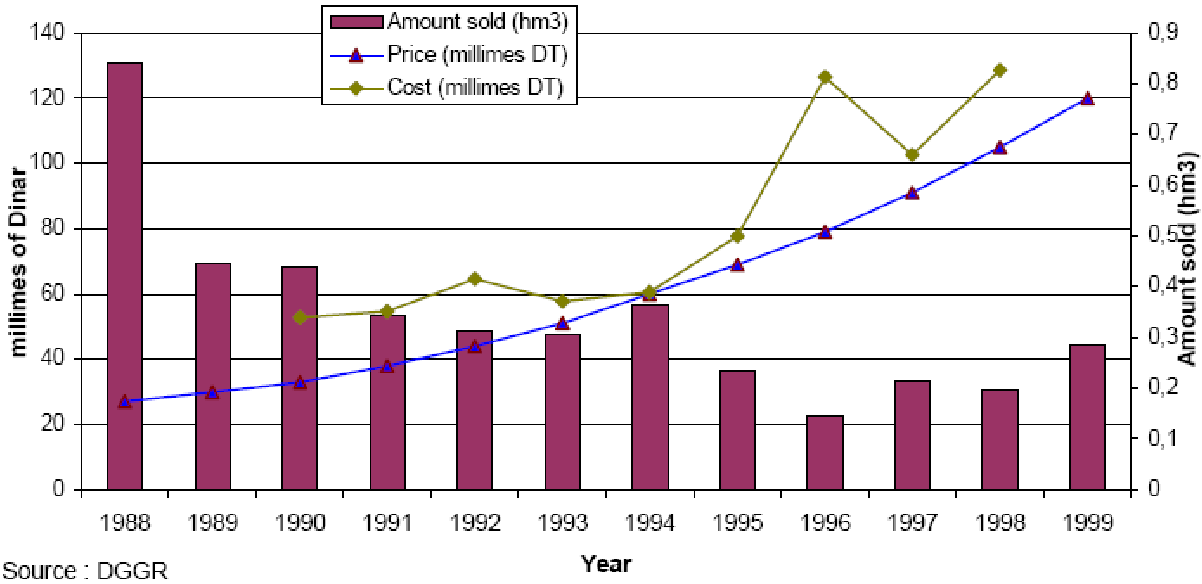
The impact of prices in general on demand for water can be assessed by consideration of price elasticity of demand. This elasticity refers to the percentage change of quantity demanded as a proportion of the percentage change in price. Demand for drinking water is very inelastic, in that people still need to drink the same amount of water regardless of how much it costs; other components of urban water supply are more elastic, so that overall demand for urban water decreases as charges are increased.

Irrigation water, however, is relatively inelastic at the fee levels typically charged, since reducing water use has a much greater impact on the value of production than it does on the cost of water saved unless the cost is increased by a very large and politically unacceptable amount. Unlike urban water costs, which may cover all direct costs to the point of sale, irrigation charges often only cover O&M costs and may be an order of magnitude lower than the urban water costs. Although this may not apply if prices are high – for example in Tunisia or Israel – it does in virtually all cases of irrigation worldwide (Molle & Berkhoff, 2008).

This elasticity of demand can be calculated from theory, but is not always easy to observe in practice since prices are not usually changed in isolation from other measures to influence demand and thus although there may be an observed relationship between price and demand (see Figure 4.1, for example), this is usually not a causal relationship. Prices are generally increased at the same time as other administrative restrictions are imposed and in order to ensure adequate cost recovery, unit prices need to increase as the volume consumed decreases. Furthermore, irrigation systems are generally designed for supply management[9], and farmers may not be able to respond individually to price signals.

[9] Modern irrigation schemes are increasingly designed for demand management are more expensive, for various reasons, but it can be difficult and expensive to convert existing infrastructure from supply management to demand management

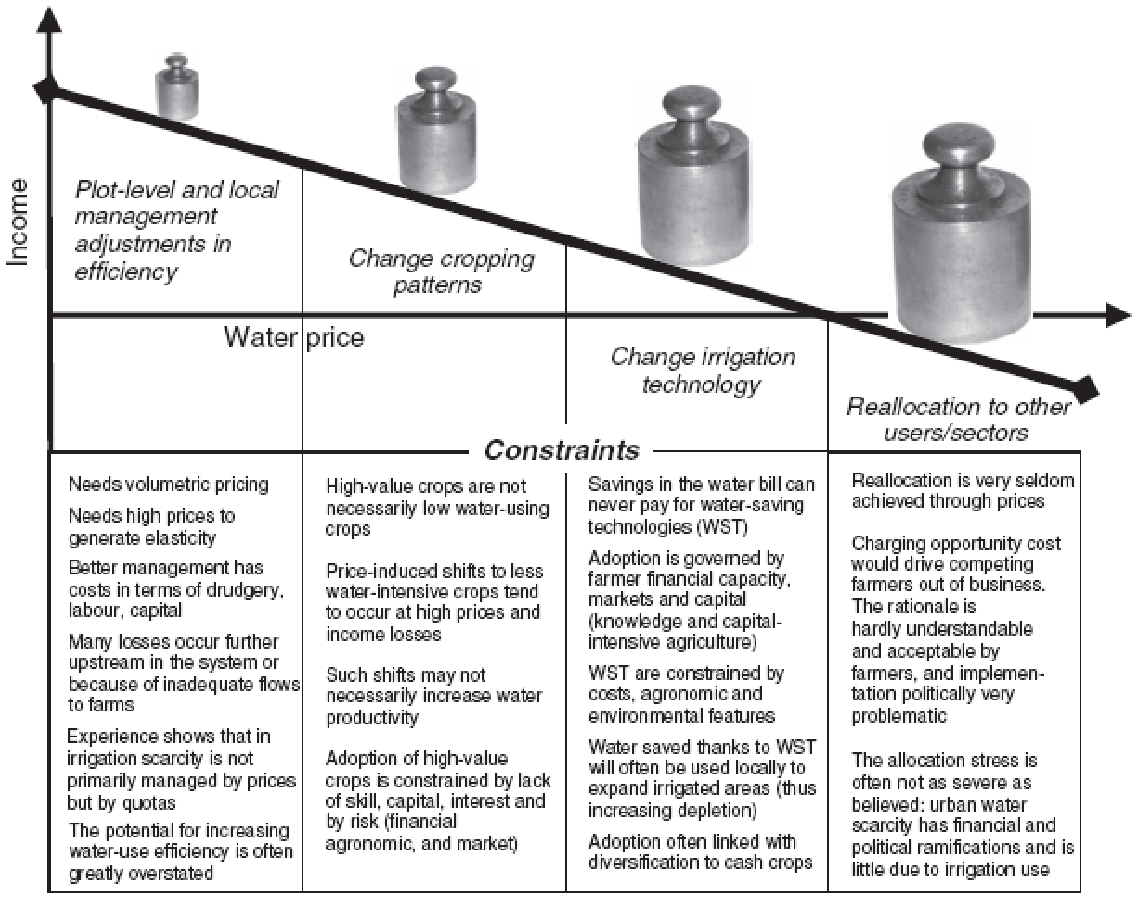
Figure 4.1. Changes in irrigation water use and price in Tunisia



Source : DGGR

Although it may be difficult to demonstrate rigorously, there can be impact on demand in agriculture at high total prices. It will not be a simple gradual response of reducing demand as prices increase. Instead there are likely to be a series of step changes as the price triggers major decisions by the farmers: whether to invest in irrigation technology (a long-term decision), which crops to grow (a seasonal decision), and how much water to apply to growing crops (a short-term decision). This illustrated by Molle and Berkhoff as follows (Figure 4.2), indicating the impact of prices on alternative farm strategy, showing a decline in income as prices increase.

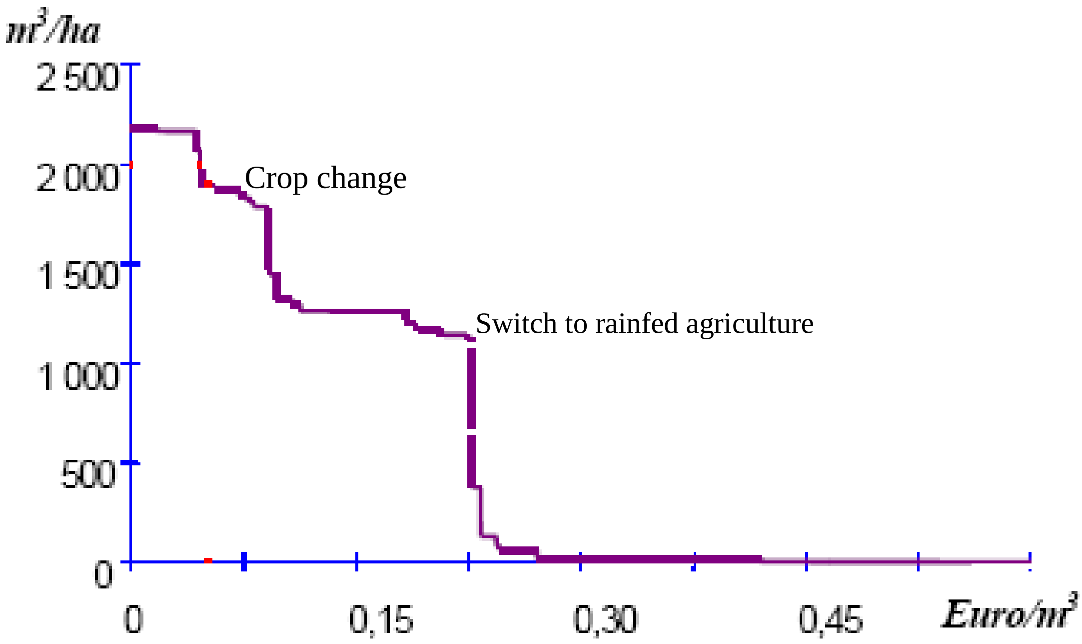
Figure 4.2 Impact of price on water demand in irrigation



At typical prices charged for irrigation, elasticity is low, but the following example from the Charente region in France indicates a significant drop in water use at a price of €0.05/m^3, (Y0.5/m^3), dropping to zero at a price at around €0.25/m^3 (Y0.25/m^3) – Figure 4.3. However, this had a substantial impact on farmer income, and was politically unacceptable and discontinued (Anne Chohin-Kuper *et al*, 2003).

In other more water-stressed regions, it may be necessary to raise prices to the extent needed to stimulate some of these step changes, but it will be necessary to provide alternative support to farmers so that they can cope with less water.

Figure 4.3. Price elasticity of water in Charente, France



4.3 Pricing of water and water services

Introduction

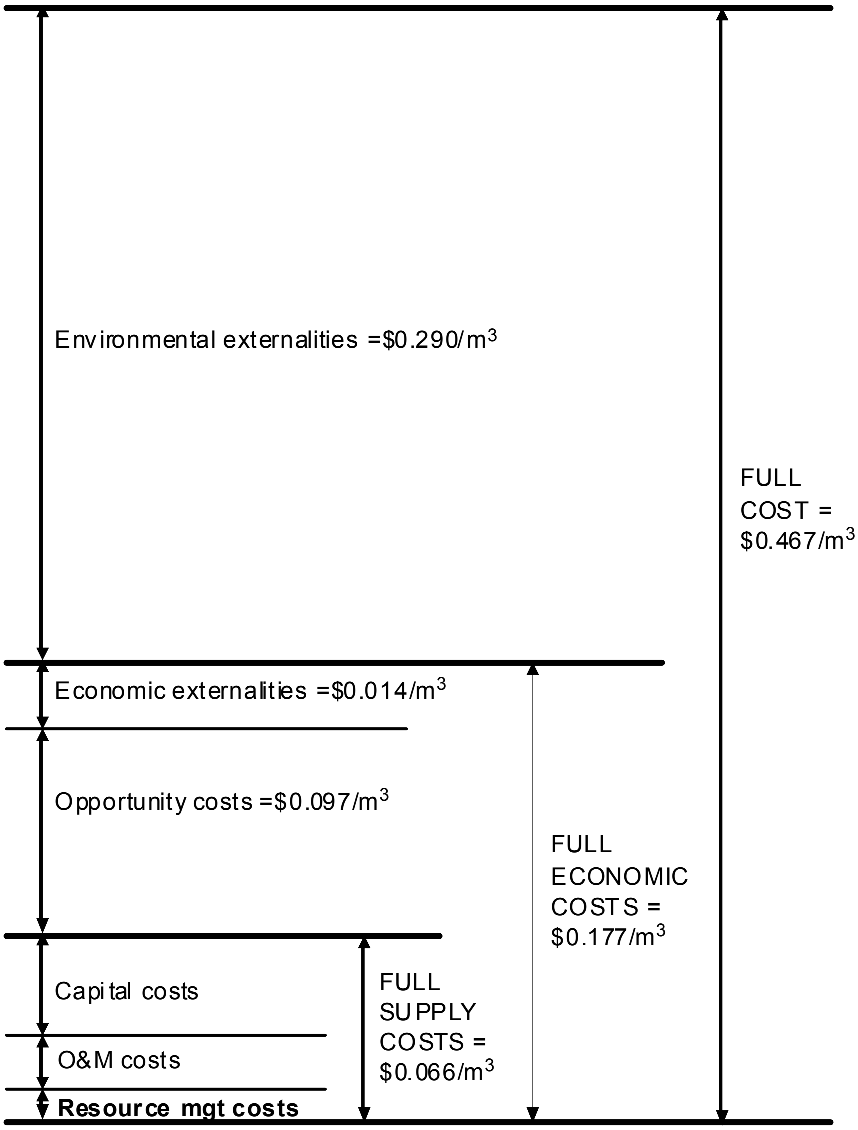
Water tariffs are an important part of any demand management plan, and considerable care needs to be taken in designing a system which:

- ensures adequate funds for operation and maintenance (the resulting improved quality of O&M should reduce demand),
- where possible, covers costs of system renewal and improvements
- provides the correct signals regarding the need to save water,
- is implementable, and
- is politically and socially acceptable.

Often the price is set at levels dictated by social and political acceptability rather than environmental sustainability, but this tendency needs to be reversed with other instruments used to meet social objectives without compromising environmental requirements. This could be by modifying the structure of agricultural subsidies: water supplied at less than cost price is in itself a subsidy encouraging excess use of water which should be avoided.

The cost of water is made up of several components: the resource cost; the engineering cost for the delivery system; and the environmental cost. The various components are illustrated below (Figure 4.4 gives estimates for an example in a predominantly urban area in India). Irrigation water charges are fixed for political reasons to cover just the O&M costs (including resource management costs) or often less. It is rare for capital costs to be included, and almost never are environmental or economic externalities, even in the case of urban uses. This means that the water charge is much less than the 'true' value of water. But increasing the price to cover these costs would mean that agriculture becomes uneconomic and would collapse.

Figure 4.4 Components of the full cost of water



Water resource fees

Water resource fees (WRFs) are often regarded as very important for reducing demand, but they are generally a small part of the total water cost. They are generally set at levels to cover the cost of water resource management, which is usually of the order of 1-2% of the full cost of water – see Figure 4.4). They are normally introduced to complement and reinforce, but not replace, administrative measures such as abstraction licensing. They are intimately linked with abstraction licensing because an effective WRF charging system can only be operated if there is a register of abstractors.

WRFs or environmental taxes can be charged to the license holder and added to the charges they make to the users. However, these are often very small compared to the delivery service charges received by the WSC. These can be effective in influencing demand but for reasons of political and social acceptability the increased charges should be **seen** to be used for environmental enhancement and not perceived to be simply augmenting the profits of the water supply company or going into general Government funds. WRFs are discussed in detail in TP5.3 (water resource fees).

Pricing as an irrigation demand management tool

Economic methods are often stressed in international and local literature for their role in demand management. Irrigation financing systems and water charges are undoubtedly a critical part of the equation, but economic methods of demand management for irrigation are far more complex than for urban water supplies and much less likely to have the effects hoped for. Expectations are often unrealistic. As Tropp *et al* (2006) note,

> "*many countries are introducing water supply pricing mechanisms for irrigated agriculture to come to terms with increasing water scarcities. The theory behind water pricing, either through public administrations or private markets, is that it can improve water allocations and distributions and impact positively on water conservation. The basic rationales are found in: 1) improved water use efficiency; 2) increased cost recovery; 3) water is allocated to sectors that provide high economic value-added; and 4) improved equitable use*".

However, it is difficult to find examples where these benefits are realised in practice. The greatest impact has been on improved cost recovery, which can contribute to reducing demand by improving standards of O&M. The direct influence on demand, equity and inter-sectoral transfers has been negligible except in a few special cases.

The various irrigation pricing regimes that can be applied differ with regard to their costs and benefits as well as between efficiency and equity. Johansson (2000) distinguishes between three main water pricing regimes: 1) volumetric; 2) non-volumetric (per output basis, per input basis, per area basis, crop choice, choice, based on land value); and 3) market-based methods, including tradable water rights.

Although the logic behind using price as a direct instrument for demand management is self-evident, the practicalities of applying it in irrigation systems undermine its role significantly. These include such problems as that:

- Flow cannot be measured accurately in an extensive network of open channels to a large numbers of small farmers;
- Farmers cannot make rational decisions about how much water they receive and pay for, since this is controlled by higher-level system operators;
- Sale of water to other users is generally not possible, because there is no means of delivering it to them and no easy method of physically making the transfer; and

- Reduction in water use may result in total loss of the crop, not just a marginal reduction in yield.

There are ways round some of these problems: this is possible in places with small numbers of large farms, as in Australia, but is very difficult if there are large numbers of small farmers. In that situation, the tendency is to rely on strong WUAs able to take decisions and manage irrigation on an equitable, collective basis. Such WUAs are able to manage water slightly more efficient than at present, so that demand for water is slightly price-elastic. However, once the supply has been reduced to a level close to the crop water requirement, any further reduction is likely to impact severely on yields. There is some scope for deficit irrigation and for changing crops to lower water consuming crops. As indicated above in Figure 4.3, price changes may stimulate such changes, but at the limit irrigated agriculture becomes unprofitable and is discontinued. This effectively sets an upper limit on price.

This is a topic which has been well-studied recently (eg by FAO, and by Molle & Berkhoff, 2008). Cornish *et al* report on the difficulties of meeting demand management objectives through irrigation charges:

> "*It is always instructive to estimate the value of water in relation to the likely price. For example, if a farmer's net income with irrigation is US$1,000 per hectare higher than without irrigation and the quantity of water used is 10,000 m^3/ha, then the productivity of water is in the order of 10¢/m^3. If the ISC to meet cost recovery objectives is US$100 / ha, then it is clear that a volumetric charge sufficient to meet cost recovery objectives (i.e. 1¢/m^3) will do little to limit demand. A volumetric charge will not serve the purpose of demand management to the point of balancing supply and demand but may encourage a degree of care in water use. Pricing may thus have a symbolic impact in emphasising the value of water – even if water charges are not fixed at a high enough level to limit demand as determined by classic economic theory.*

It is therefore not surprising that economic methods have not had much direct impact in the irrigation sector. Tropp *et al* (2006) note:

> "*The current application of water pricing regimes for irrigated agriculture in developing countries suggests that there in practice has been fairly little impact on improving efficiency and equity. … a major difficulty is to assess all the marginal costs and benefits, especially since they vary across the seasons as well as over the years. It has also been observed that volumetric pricing in combination with opportunity cost pricing can have detrimental effects on lower income groups. Water scarcities will consequently lead to higher marginal cost for water and that such pricing can lead to negative social effects. Due to the nature of surface and groundwater systems they are inherently difficult to monitor and police. It has been noted that transaction costs are high in fee collection and monitoring of use and to exclude those without the right to use. For example, Ostrom (1990) noted that keeping "free-riders" out of the irrigation system requires heavy transaction costs that may outweigh benefits*".

These observations may seem surprisingly strong, but there is indeed remarkably little evidence that pricing systems have had much impact on irrigation demand. This is apparently the case in Northern China, where Yang et al. (2003) - demonstrated that irrigation pricing has had little impact on water use.

> "*despite rapid increases in irrigation costs and thus higher water prices (based on per area) this had no effect on water conservation. On the contrary, the shift to more water intensive high-value added crops led to an intensification of overexploitation of groundwater. In this case, which is a rather typical case for many developing countries, the cost for using groundwater was equal to power supply costs for pumping and equipments. Due to current water governance systems, there were instead incentives to continue to increase water use, such as government agencies wanting to increase their budgets through intensified water use and very lax monitoring of groundwater regulations*."

This last point highlights the need for stricter administrative regulation of water use. Water use has decreased in some places at the same time as price has increased, but the fact there is *correlation* between higher prices and lower demand does not mean that the increase in prices *caused* the reduction in demand. Studies in WRDMAP have indicated lower water use in parts of Gansu where charges are higher, but the change in water use was governed by reductions in allocations which made at the same time as increasing the price. This is the same situation as in the example from Tunisia cited above, in Figure 4.1. Farmers or even villages are not able to respond to changes in irrigation water price since they have little means of deciding or controlling the amount delivered.

In some places, supply contracts between main system managers (the permit holders) and WUAs are creating a theoretical mechanism for WUAs to decide how much water they want to receive and pay for. This is the approach which is now widely recommended in China, although it has not been implemented in many areas yet. Such contracts need to specify the timing as well as the total volume of water, but these are difficult to use to enforce actual reductions in demand. Much of the observed water saving may be due to other improvements to the infrastructure done at the same time as the introduction of the water supply contract: the cost of water saved will be less than the cost of canal lining so there will be little incentive for the farmers or WUA to do this afterwards.

Even in Europe, irrigation water pricing is, in general, oriented towards cost recovery objectives and has contributed to the reduction of public financing at least with respect to operation and maintenance costs of irrigation schemes. However, these price increases did not contribute significantly to water demand reduction objectives and there is a need for complementary tools and policies in order to tackle the water resource issue (Chohin-Kuper *et al*, 2003).

Further information on the management of fees, and the incentives and disincentives which can result from them is presented in AN5.2 irrigation service charges and TP5.3 water resource fees.

Water pricing and irrigation in China

There is considerable literature and research on irrigation water pricing in China. Ehrensperger (2004) provides a summary of some of this literature and made the some observations that, in general, at that time:

- water charges should cover the full costs of water supply (O&M costs and the overhaul and replacement costs of water supply infrastructure).
- Water costs are recognized as a cost of production, and are not considered to be a part of the farmers' tax burden.
- Water charges for grain crops are lower than charges for cash crops.
- Water that is directly diverted from rivers or lakes by ID institutions or individual farmers is free of charge.
- In the case of groundwater that is extracted from privately owned wells, farmers pay only the costs of power and equipment, but nothing for the water itself. Some provinces, however, are considering the introduction of a groundwater resource levy in order to restrict groundwater use to sustainable levels.
- Setting actual price levels is a very bureaucratic procedure. Water management agencies have some discretion in setting water prices, price levels are not allowed to exceed certain limits.
- Water charges are based on the actual situation and are set according to economic and political factors, and local water supply and demand.
- Water charges are kept low because of broader social and political objectives, such as overall rural economic development, employment, and food security.
- The pricing system is generally area-based and a standardized volume of water is assigned per unit of irrigated land, to suit the crops cultivated.
- volumetric water charging was introduced in the 1970s but the method was not implemented due to difficulties in measuring the volumes of water supplied. It is now becoming more common with the introduction of a two-part tariff, consisting of a fixed area-based charge plus a quantity-based fee.

In addition to paying a fee to the WRB for irrigated land, farm households also contribute labour to maintain irrigation infrastructure. This is a carry-over from the collective period when most rural infrastructure was constructed using teams of collectively-managed labour under the communes which gave farmers a sense of ownership. Formal labour contribution requirements no longer exist, but local maintenance generally remains a local responsibility (by village or WUA).

Despite experience elsewhere in the world, higher prices are seen as essential for reducing demand as well as for improving cost recovery. Thus the impact of higher prices on rural livelihoods is a key topic and is seen as major constraint to reform. Studies by the Centre for Chinese Agricultural Policy[10], indicate that the impact on

[10] See Lohmar B, Huang Q, Lei B and Gao Z (2007) Water Pricing Policies and Recent Reforms in China: The Conflict between Conservation and Other Policy Goals, *in* Molle and Berkoff (*op cit*)

income should not be an overwhelming constraint to price rises. For example on average, the cost of groundwater applied to irrigated wheat is 24% of total production costs, while for cotton it is less than 10%. They concluded that doubling of water prices would result in only an 8% fall in crop income and that increases in water prices might cause farmers to grow less grain, and more cash crops. However, there are equity issues which need to be taken into consideration, and some households, generally the most poor, would be more adversely affected.

Economic instruments for urban and industrial demand management

The situation in urban and industrial settings is very different from rural water use; here pricing can play an important role in demand management. There is considerable evidence from around the world that heavily subsidised water supplies lead to excessive and wasteful consumption by those who have access to water and shortages for people at high points or at the end of the distribution network, as investment in new resources fails to keep up with demand.

Metering consumers and charging by the amount of water consumed and setting tariffs to meet the full cost of the supply is a key component of any urban demand management programme. Any significant subsidy sends the consumer a message that water has a low intrinsic value and that wastage of water is not important. Urban water supply differs from agricultural water supply in that the volumes used are much less and it is generally possible to charge the full cost without resulting in excessive charges to the consumer. The higher unit costs for urban water use have a greater impact on water demand, and thus tariffs can be an effective tool for demand management as well as for cost recovery.

Metering with volumetric charging gives customers a financial incentive to save water, and can therefore encourage water efficiency measures and water savings. Metering offers a number of benefits. It is fair in that customers pay for what they use and it can allow the WSC to introduce a range of tariff structures. Metering has also been shown to reduce average household demand in UK by about 10%. In addition to saving water, meters could also deliver carbon savings both in the home through reduction in hot water use and for the water industry through less need to treat and pump water.

Customer metering tends to have an impact on consumption only where it is undertaken in conjunction with a progressive volumetric tariff structure that penalises customers financially if their consumption is unduly high (see Box 4.1 for an example). Progressive volumetric tariffs provide an efficient pricing framework to encourage metered customers to use water wisely. The progressive volumetric tariff should ensure that low income households are able to comfortably pay for a minimum needs level of water consumption with customers who consume additional volumes being progressively penalised financially.

Box 4.1 Urban water tariffs in Zaragoza, Spain

For example, a 3-block tariff structure has been designed for Zaragoza, Spain to match the socioeconomic attributes and consumption habits of the population. Whereas consumption in the first two 'blocks' is subsidised, the upper tariff block is designed to curb excessive consumption and to cover full supply costs.

The WSC has been offering economic incentives to households that reduce their consumption rates. If households reduced their consumption by at least 40% in 2002, they were entitled to a 10% discount on the bill. In subsequent years, the target was reduced to 10% reduction in consumption rate per year. The scheme is being embraced by an increasing number of households, which has contributed to overall reduction in water consumption in Zaragoza.

It should be noted that, from a customer perspective, even if water demand management includes changes to prices to stimulate reductions in demand, this does not mean that there are reductions in total payments. This is because the water companies will still need to generate sufficient funds to maintain and upgrade water infrastructure and to remain profitable: the combination of the tariff structure and delivery volumes need to be planned to ensure adequate cost recovery. Equally, low-income and vulnerable households must not be made unfairly or disproportionately worse off through policy measures aimed at achieving better environmental outcomes. The regulator will need to ensure that the interests of both the consumers and water companies are protected. Demand management in this context entails protecting the wider interests of the consumers, rather than reducing their short-term costs. Further information on charges for urban water supply is presented in AN5.4 Urban water tariffs

4.4 Pollution and environmental charges

Discharge to surface water and risk of contamination to groundwater are covered by regulations in many countries, requiring discharge permits. In the same way that abstraction permits are required for use of water, discharge permits may be required to control volume, quality and location of discharge to water bodies, and there may be regulations to limit direct contamination of groundwater. Fees may be levied for issuance of these discharge permits, and penalties may be charged for breach of permits. Comparable observations regarding the impact of the fees and penalties on the extent of pollution or environmental damage can be made as for fees for abstracting water. Pollution is however a more complex issue, and more difficult to monitor. Charges need to be made to recover the cost of managing the system, and they may be set at significantly higher levels in order to act as direct disincentive to polluting activities. The complex issues around discharge permits and associated charges are discussed further in TP4.2: waste water permitting.

These are related to demand management indirectly, since requirements to control effluent can encourage waste water recycling and hence reduced demand.

4.5 Water markets

Water markets (Box 4.2) are a topic of considerable interest both internationally and in China. There are many examples of water trading, but this is generally informal exchange of water between adjacent irrigators or similar methods. Formal tradable water rights, facilitating inter-sectoral transfers of water are a new concept which are believed by many to have considerable potential, as outlined in Section 3.2 and Appendix C. Wang ZJ (2009) states that in the longer term such markets should enable economic efficiency to be achieved without compromising social equity. However, he recognises that this is not yet possible (see Section 3.2). The procedures followed and progress achieved in other countries is briefly outlined here, but it is not believed that this is a practicable approach in the short term in China

Box 4. 2 Water markets

"Water markets are an appealing option for an economically efficient allocation of water. They do occur spontaneously at the micro scale, where users may swap, borrow, and buy water allotments to better fit their needs. Likewise, groundwater markets in India, although they refer to the payment for a service (extracting water with mechanical means) rather than to the allocation of a scarce resource, provide flexible and price-sensitive water supply mechanisms.

This flexibility, however, is much harder to obtain at a larger scale. There, the allocation of water through markets is constrained, among other things, by the difficulty to control flows volumetrically and temporally, by the lack of infrastructure to move water from one point to the other, by the lack of definition of water rights, and by the greater probability of having a higher heterogeneity of users and, therefore, possible adverse impacts on poorer segments of the society. It is recognized that water markets are prone to market failures and externalities and demand a background of legal consistency, administrative accountability and law enforcement that are rarely found in developing countries, where, on the contrary, "the social and environmental risks of getting it wrong are considerable" (Morris 1996). Water markets in most of Asia have therefore little short-term potential to help managing water and, rather, remain a long-term objective that comes with mature economies and institutions".

http://www.agnet.org/library/eb/543/

The Murray-Darling basin in Australia probably has the most advanced system (World Bank, 2009 – Addressing China's water scarcity), although most transfers (over 90%) are local temporary measures. One well-development market is for temporary trading in the irrigation areas in the Goulburn-Broken Catchment. Here

> "*A set of rules has been instituted to clarify the trading environment. These involve placing limits on where water can be traded and the mechanisms for establishing the price. The trading zones … have been . . .designed to minimise adverse effects of trade on other water users and the environment" … Each week, if there are sufficient sellers and buyers with overlapping offer prices, a 'pool' price is established for each zone* (Zaman *et al*, 2005) " .

Sellers tend to be small farmers relatively dependent on off-farm income, and buyers to be larger mixed farms. The price and volume traded varies during the season: before the start of the season water trades are planned so that planting area can be optimised, but during the season water is traded to protect the actual crops grown. The water trade is managed by a facility known as *watermove* (www.watermove.com.au) – see box below. This applies to both groundwater and surface water but different rules apply for different situations, and are defined by *watermove*.

Box 4.3 Water trading in Australia

" Watermove" has been set up to facilitate water trading by establishing a fair, transparent process that will provide market information for people seeking to trade water… throughout Victoria and Southern New South Wales….It conducts water exchanges for all water trading zones in Victoria where trading rules have been defined…. A trading zone defines the physical boundaries to, from or within which water may trade. …Traders must submit original offer forms to Watermove. Offers must define the trading zone, volume for trade in megalitres, price per megalitre and the number of exchanges for which the offer is valid…. Eligible offers will be included in an exchange for the relevant trading zone. Watermove will conduct the exchange each Thursday… Watermove will calculate a pool price for all trading zones where trade can occur. All successful sellers and buyers within a trading zone will receive the same pool price….No human intervention occurs in the price determination process, adjustments to volumes or balloting. An independent party, the Water Exchange Controller, who is not permitted to be an owner or trader of water, supervises the integrity of the exchange…Where more than one seller or buyer have nominated the same price and there are insufficient volumes to satisfy all of those sellers or buyers, the system shall conduct a random, computerized ballot to determine the successful seller(s) or buyer(s) at that price

http://www.watermove.com.au/aboutwatertrading.asp

Examples of trading rules[11] for surface water are:

- All offers to buy Permanent or Temporary Water in this zone will be subject to the waterway's ability to supply, assessment of environmental impact and the Guidelines for Irrigation Development.
- Permanent and Temporary trades of Surface Water Licenses must be downsteam and the buyer will receive 80% of the volume transferred.
- Sellers whose use is not metered will not be able to sell in the current season if any water is used for irrigation in the current season.
- All trades are subject to *watermove* terms and conditions and approval by the relevant water authority.

And for groundwater:

- The buyer must have a groundwater licence and metered bore before purchasing Water Entitlement.
- If the sellers bore is equipped, it must be metered in order to trade whole or part of the unused licence volume.

[11] http://www.watermove.com.au/selectregion.asp?next=selecttradingzone.asp&jump=tradingzoneprofile

- Transfers can only occur between bores, in the same zone or between zones subject to the rules listed below.
- Transferred entitlement may be banned from use or be restricted, if adverse interference occurs to other authorised users and/or the environment. Eg. adjacent bores.
- Transferred entitlement is available for use from the date of approval of the trade until end of the same financial year (30 June).

An important feature of the water trade is that there is an independent regulator and the trade is independently audited. A party independent to *Watermove* supervises each exchange.

The market was stimulated by a water audit in 1990 which found that the Basin was overcommitted for extractive use, and trading reached 2.5% of annual entitlements (overall) after 15 years, although the percentage is much higher in some localities. The impact is wider than just on the individual farmer who trades water, since it also affects secondary industry and it is widely feared that the viability of some communities would be adversely affected.

Chile is often said to have a highly developed water market, although it is controversial. There have been substantial economic benefits in some areas – for example where large table-grape producers have bought rights, but there have been very few transactions in the large canal systems because of the high costs of modifying fixed infrastructure. There are many factors limiting the wider adoption of water trading.

These two examples both highlight the need for strong administrative regulation to ensure that the environment is protected when small 'inefficient' users sell their rights to more commercial users who are more efficient and consume a greater proportion of the abstracted volume. Economic instruments are this important to support administrative regulation, but they cannot replace it.

Water markets are thus a growing trend in several countries. They are not easy to administer and they may have adverse impacts, but in the right circumstances they can be beneficial for optimising water use. It will, however, be many years before they are widely adopted. They are relatively easy to use for local trading of ground water, but the constraints to larger-scale markets and markets relying on surface water are very greater – both institutional and physical.

4.6 Subsidies and incentives

There are often a wide range of subsidies which affect agricultural production and water demand. Ostensibly aimed at protecting the poor, they can have many impacts, some contradictory, which are difficult to unravel. Furthermore, it is politically very difficult to change an established regime of subsidies, however inefficient and inequitable they might be.

Irrigation water charges which are less than full cost price contain an implicit subsidy, other subsidies encourage a change in cropping to more profitable but more water-consuming crops (eg in Europe, from rain fed olives or citrus to irrigated cultivation of maize, sugar beet or olives). If modern efficient irrigation techniques are used and the saved water is used to expand irrigation as it often has been in Spain, then even more water will be used and consumed.

Subsidies in the EU used to be based on crop cultivation and thus encouraged water use in line with crop requirements, and thus increased water demand. These subsidies are now being changed to agro-environmental schemes (such as stewardship in the UK) which are environmentally benign. These encourage land users, through financial incentives, to undertake agricultural practices which will give the desired environmental results, rather than maximise agricultural production. These could be set in ways which will encourage a reduction in water demand. Farm subsidies have been de-linked from direct production payments under recent EU reforms in a major attempt to build on existing programmes that have ‘paid’ farmers to adopt environmentally sustainable practices. In Germany, revenue from water taxes is used to compensate farmers for restrictions on fertilizer use in vulnerable areas.

5 Direct Technical Interventions – An Overview

5.1 Introduction

Direct technical interventions are the most obvious form of demand management, and include such as measures as leakage control in pipe networks or canal lining in irrigation systems. These account for the vast majority of activities listed in NDRC Document 17 (which is included in Appendix A to this paper). These techniques are very important and in many cases are the actual method by which water is saved. Regulations, incentives and awareness are all used to encourage people to adopt them, but it is the application of the actual water-saving technique which is ultimately needed.

Like so many issues, however, such water savings are not straightforward. Although it is intuitively obvious that techniques which result in savings from loss reduction from pipe networks or canal systems should be beneficial and enable the saved to be used productively elsewhere, the reality is more complex: many of the ‘losses’ are likely already to have been reused somewhere else. This does not mean that such losses should not be avoided, as they can still be wasteful of, for example, expensively treated water, and it should be more efficient to deliver water where it is needed rather than to rely on recycling of losses through the vagaries of the natural system. Nevertheless it does mean that direct techniques need to be carefully assessed.

Urban water demand management has a fairly clear and direct impact – reduction in losses saves on the cost of treatment, the capacity of pipe networks, pumping costs and so on. This is a saving of water and energy, and thus reduces also the carbon footprint of the water services industry.

Agricultural water demand management is more controversial as so much of the loss is recycled and it is raw rather than treated water which is ‘lost’. If water is saved, it can be used locally to extend irrigation or transferred to other sectors (depending on the layout of the system). One option which is sometimes cited, is for an industry to line a canal, and then gain an entitlement to the water which would have seeped through the unlined canal banks.

The complexity of the losses, savings and use of saved water means that it is important that these are subject to the supervision of the regulator. SCD 460 allows transfer of water saved, but this depends on them being assessed accurately, and that there are effective institutional and physical arrangements for the transfer.

This chapter provides an overview to the techniques in the rural and urban sectors, but more detailed information is provided in later chapters as well as in supporting documents in this series, and in a number of standard reference works and textbooks.

Various other documents in this series provide further information on these topics, for example;

TP3.1 Water saving in irrigated agriculture

AN3.1 Practical techniques for agricultural water saving

TP3.2 Urban water demand management

TP3.3 Active leakage control

5.2 Efficiency of use – Agriculture

There are a range of direct approaches for demand management – these are the traditional methods such as canal lining, drip irrigation, land levelling - which are expected to increase irrigation efficiency. There has been a considerable amount of work done globally on improving irrigation efficiency. The International Commission on Irrigation and Drainage has instituted a programme of awards known as '*watsave*'. Of the 30 awards given since 2000, six have been to China a number not exceeded by any other country (http://www.icid.org/awards.html). These awards are for technological and management innovations which result in significant water savings – typically of the order of 50%. They are given to irrigation operators, and thus water saved is always used locally within the irrigation sector. The greater precision in which results delivering the required amount of water to the crop generally results in increased productivity. Although large local savings are achieved, the award does not consider the impact on water resources at river basin level. It can be expected that some 'real' water savings (as defined below) are achieved, albeit not of quite the same magnitude as at the level of the farmer who receives the award.

Irrigation efficiency is a widely used but misleading term, and some authorities recommend using the term fraction rather than efficiency. This is because losses from irrigation in one place are often used in another, so that increasing efficiency in one place can in fact reduce water availability in another. The term fraction, by contrast, simply identifies the destination of each fraction of the water supplied – consumptive by crops, non-productive evaporation, seepage to aquifers, return flows to rivers, and so on. Some of these fractions are available for other uses, others are not dependant on the process, location, timing and quality.

The perception that irrigation is inefficient has put pressure on the agricultural sector in much of the world. In California, for example, this perception combined with population growth and greater awareness of environmental water requirements has increased the pressure on agriculture to use water more efficiently and to make more water available for urban and environmental uses. This is however, very difficult. California agricultural water use when considered on a broad regional scale, for the most part, is very efficient. Individual fields and farms in some regions may have low efficiencies, but water that is not used on one farm or field is often used on a nearby farm or field.

Experience in Huantai County of Shandong Province has shown the potential to increase agriculture production while reducing the amount of consumptive water use by soil moisture management, agronomic measures and improved irrigation technologies (World Bank, 2000). This experience suggested that three sets of measures are needed: physical improvements to irrigation and drainage systems at the tertiary level and on-farm; agronomic measures; and management measures.

This section focuses on the use of water in irrigated agriculture, however improvements to rainfed agriculture and rainwater harvesting are also possible. Livestock are very important, and the significance of livestock farming is growing with urbanisation and increasing prosperity. Livestock require water both for direct consumption and more significantly for growing fodder. Typically the water required to produce 1 kg of beef (15 m^3 water) is 15 times greater than 1 kg of grain (1 m^3 water). In addition pollution from intensive livestock farms can be one of the main sources of water pollution: this was identified as a particular problem in the recent national pollution survey in China.

The concept of 'real' water savings

It is first necessary to clarify the meaning of water use efficiency. There may be high local losses on surface irrigation schemes, for example, due to seepage from canals, but this water may reach the aquifer to be recovered by downstream users. Reducing losses in the upper part of the catchment may have an impact on water resources available further downstream. For example, if local efficiency is improved by using of new techniques such as drip irrigation, without reducing the water allocation from the river, then consumptive use of water may increase and there will be less water available for downstream users. Some losses from inefficient irrigation systems return to the groundwater aquifers or downstream surface water systems and become available for other users, and are not true losses at the basin level.

This does not mean that water use efficiency should not be improved, but it does mean that the impact of measures to improve efficiency in terms of both their local impact and their impact on water resources in the basin as a whole are not the same. In some areas, overall basin 'efficiency' may be quite high, even where individual systems are 'inefficient'.

'Real' water savings will results from reduction of non-recoverable losses such as evapo-transpiration (ET) or losses to non-usable water bodies such as saline aquifers or the ocean. 'Real' water savings can also result form the reduction of crop ET per unit of production.

The World Bank Water Conservation Project have evaluated 'real water resource savings' at experimental field sites in various pilot areas in the Hai basin and considered that the introduction of such measures could reduce evapo-transpiration (ET) by 30-45 mm/yr (ie of the order of 10% of the crop requirement) whilst increasing farmers' income to above the national average. The actual savings at a larger scale are more difficult to quantify, but there is evidently scope for real saving of water.

Approaches for real irrigation water saving

There is scope for real agricultural water-savings through

- *Crop types and physiology.* There is considerable research ongoing into crop varieties which will use less water or cope with poorer-quality water
- *Agronomic measures*: these include activities such as crop choice and cultivation techniques such as those which have been proposed on other projects in China (World Bank 2000). These include land levelling, non-tillage

in the dry season, deep ploughing in the rainy season, soil fertility improvements, organic and plastic mulching, seed improvements and development of drought resistant varieties, balanced fertilization, improvements to planting and cultivation techniques, changes in cropping patterns, forestry shelterbelts to reduce wind velocity and hence evaporation.

- *Irrigation techniques*: these include replacing flood irrigation by furrow irrigation (with appropriate length, slope and flow rate, or more modern techniques such as drip and sprinkler; adjusting irrigation schedules to meet crop needs on the basis of soil moisture measurements, and thereby reduce unproductive evaporation;
- *Infrastructure type, condition and management:* measures include improvements to canal lining, control structures and other infrastructure, flow measurement facilities, and maintenance of the system, and management measures to improve irrigation forecasting and water scheduling.

These actions will have a range of impacts and they are not only required for WDM. Indeed improvements to irrigation technology may be more important for their impact on productivity than on water saving. Nevertheless these methods should result in some real water savings. Further information on all of these methods is presented in Chapter 7.

Methods for irrigation water savings promoted in China

A wide range of methods for agricultural water saving have been proposed and are being adopted in China. For example, the policy outline prepared by NDRC (NDRC 2005:17) recommends numerous options for irrigation water conservation in the following broad categories:

- Optimizing water conveyance for agriculture
- Improving field irrigation technology
- Using biological and agronomic water conservation techniques

In all cases, a considerable emphasis is placed on research to develop new or improved methods of achieving these aims.

- Optimizing water conveyance for agriculture
    - Canal lining in high-seepage areas (using a range of local, low cost and modern materials)
    - Optimise canal cross-sections, with standard designs and prefabrication where possible
    - Low-pressure pipeline to replace low volume canals
    - Self-pressure pipeline in high-lift irrigation areas
    - Real-time irrigation forecasting and drought forecasting technology
    - Low cost accurate and simple water measurement facilities
    - Develop techniques to prolong the life of structures (corrosion prevention, etc)

  - Unified management of surface and groundwater, with local storage
  - Quota management, with realistic norms for agricultural water consumption for different regions in different precipitation years, for different plants under different irrigation methods
- Field irrigation technology
  - Narrow border irrigation, tiny-stream furrow irrigation and wave irrigation, with precise specifications
  - High-accuracy (laser) levelling techniques, optimize field sizes
  - Optimise flow rates and durations into border strips and furrows for seepage control
  - Accurate timing of irrigation to suit crops, taking account of soil water content and other factors for each stage of growth
  - Deficit irrigation techniques at key growth stage of crops.
  - Alternate wet-dry irrigation for rice.
  - Sprinkler, micro- and drip irrigation techniques irrigation suited to local conditions for commercial crops
  - Combine micro-irrigation techniques with the agronomic techniques of film field cover, and synchronous supply of water and fertilizer.
  - Crop systems adapted to local water resource conditions (including hygrophilous planting technology).
- Biological and agronomic water conservation techniques
  - Coupling water and fertilizer application techniques to enhance utilization.
  - Water storage and soil moisture conservation techniques such as deep ploughing and loosening, and biological soil nourishment techniques.
  - Low-cost farm machinery, for deep-ploughing etc.
  - Low-tillage techniques
  - Use of film and furrow-sowing techniques to conserve and enhance soil moisture and temperature
  - Use transpiration and evaporation inhibition techniques (leaf anti-drought spray)
  - Grow drought-resistant, high-yield and quality crops (using molecular biology techniques for the breeding new varieties)
  - Encourage seed dressing with plant-coating and water-preservation agents.

This NDRC policy outline thus provides a fairly comprehensive list of potential interventions to improve water use efficiency in the irrigation sector. The key question is how to convey this information to farmers and others and encourage adoption. Considerable advice and support will be needed, and this must be targeted at areas which have greatest beneficial impact.

Work in WRDMAP indicated that great emphasis is given to quota management (ie administrative control, as described in Chapter 3), and this needs to be supported by advice on other measures to ensure that livelihoods can be protected even with this smaller amount of water. The direct interventions listed above are important for this.

Performance of technical approaches to demand management in irrigation

An overview of the most effective direct technical approaches to irrigation demand management is presented in Chapter 7. This section briefly summarises the overall impact that these have had elsewhere in the world, as reported in international literature. Tropp *et al* (2006) reviewed the technological approaches to demand management such as through drip irrigation and developing crops that require less water inputs, or minimize unaccounted for water, such as through seepages and "water theft" and reported that there is in general higher water use efficiency in countries where water availability is lower. In Latin America, for example, it is only 25 percent, compared with 40 percent in the Near East and North Africa and 44 percent in South Asia. Efficiency in water use often increases in parallel with development of high-yielding crop varieties.

Considering the individual techniques, Saleth[12] reported that irrigation technologies can raise water use efficiency to the level of 60 % (sprinkler) to 90 % (drip) and also provide additional savings in terms of energy and labour costs. "*Empirical studies in India establish that these irrigation technologies save 48 to 67 % of water, 44 to 67 % of energy costs, and 29 to 60 % of labour costs".* In India, these are largely restricted to vegetable and horticultural crops, and there is also a very low adoption of other water saving technologies related to the selection of water conserving crops and farm practices such as crop spacing, use of plastics and deficit irrigation. Saleth reported that the reason for this is the absence of incentives, and the inability to enforce restrictions on total water use.

Canal lining has been strongly promoted for many reasons, although ostensibly for improving the "efficiency" of the irrigation system. Canal lining is extremely popular with both lending agencies and recipient governments. A recent review by IWMI of a number of World Bank investments (totalling $500 million) found that none of the project documents included any form of water balance. The reduction in percolation and seepage loss may have been at the expense of farmers depending on groundwater. No assessment of the real water saving or changes water productivity were made (www.agnet.org/library/eb/543/). The reverse approach that can be used is to introduce systems of groundwater 'banking', where artificial recharge of aquifers can be induced at times of relatively abundant water supply and re-abstracted at times of shortage.

GW-Mate (2005) provide an interesting evaluation of the impact of demand management measures in North China where there is a critical need to reduce use of water as there is severe overdraft of the available water resources. They note that:

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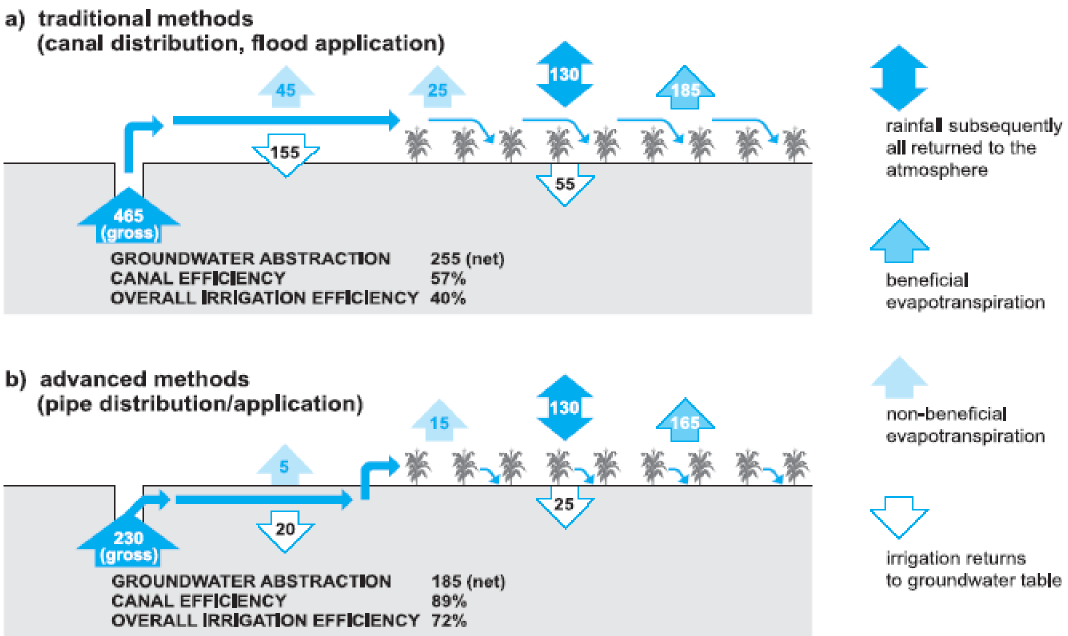
[12] Saleth nd www.iwmi.cgiar.org/.../NRLPProceeding-3Paper-1.pdf

“*There is considerable evidence that agricultural water-saving measures can substantially reduce non-beneficial evapo-transpiration and effect ‘real water savings’ of 50 to 80 mm/yr for areas under groundwater and surface water irrigation respectively. Such measures are considered capable of reducing the rate of decline in the deep confined aquifer and of making a contribution to stabilizing the shallow water-table. But since they depend heavily on water-user participation and require well discharge metering to confirm their effectiveness, they are likely to take some years to implement fully. Nevertheless it is considered that there is everywhere considerable scope for agricultural water-savings through*:

- *engineering measures: such as irrigation water-distribution through low-pressure pipes (instead of open earth canals) and irrigation application through drip and micro-sprinkler technology*
- *management measures: to improve irrigation forecasting and water scheduling*
- *agronomic measures: such as deep ploughing, straw and plastic mulching and the use of improved*
- *strains/seeds and drought-resistant agents*”.

They illustrate the potential savings with the following figure:

Figure 5.1: Water saving in groundwater irrigation



Impact of demand management on water use at basin-level

Demand management when applied to individual users or irrigation districts can have adverse impacts at a larger scale, since the losses from one area may be the source of water for another. Return flows from one irrigation district enter the river system and may be available for abstraction by a downstream district, or they may recharge an aquifer from where water can be pumped and reused. It may still be efficient to implement WDM and simultaneously reduce abstraction so that water is kept within the river system and is still available for downstream users without the need for pumping from aquifers – however, this depends on the layout of the infrastructure.

If demand is constrained by price or other measures, farmers will seek to maximise the productivity of that limited amount of water and hence they will minimise return flows. As Cornish *et al (op cit)* report

> *"An additional complexity in respect of demand management is the important distinction between water* ***diverted*** *to irrigation use, and water* ***consumed****. Irrigation efficiency, often computed as the ratio of diversion to consumption, is usually well below 50% in surface systems. But the "lost" water is sometimes still available for use, being either captured in drains and returned to the river or recharging aquifers for use through wells. Thus, increasing the efficiency of irrigation through charging mechanisms may not save much water. In the extreme case, when water is surplus in one season and scarce in the next season, "inefficient" irrigation to recharge aquifers may be positively beneficial. However, the reaction of a farmer to higher volumetric water charges may be to improve his technology so that more of the water he receives and pays for will be consumed. This in turn generally leads to higher water productivity, because more of that water is converted productively into crops. So, paradoxically, the result of an increase in volumetric price, inducing a shift in technology, is to increase the demand for water."*

Adoption of new technology and the use of financial and other incentives to influence adoption of new technologies may thus have the opposite effect to that desired in terms of overall water resources. It should be note that there still be significant other benefits, and the investments may still be worthwhile even if the impact on water saving is small or even negative. These issues do, however, need to be taken into account in the demand management plan so that sound methods of achieving the required real water savings can be designed.

Recycling and reuse, return flow management

Water reuse is already an integral part of water management in many water-scarce areas, particularly for small-scale vegetable cultivation in peri-urban areas. For example, it is common practice for farmers in Egypt and also in North China to place small pumps in drainage ditches to reuse water. This reuse strategy often requires blending drainage water with freshwater to improve the quality increase the useable supplies (nutrient pollution of irrigation losses can thus be beneficial).

In the Shiyang River Basin in Gansu, there are groundwater irrigation areas just down-slope from large surface irrigation areas. This is a less visible but equally important re-use process: the groundwater which is abstracted comes from deep infiltration of losses from the upstream surface water irrigation systems. Water saving in the surface water irrigation systems – whether by reduction in total irrigated area, or reduction in losses from the remaining area could impact on the sustainability of the downstream groundwater systems. The combination of 'inefficient' upstream surface irrigation and more precisely controlled downstream groundwater irrigation results in good total yields per unit of water abstracted from the river. Such an approach is not always possible – it depends on their being suitable downstream agricultural land, and aquifer characteristics which allow groundwater movement to these areas.

In all such situations careful water management has proven to be essential, both to minimise or eliminate damage to the soils, adverse impacts on the crops, impact on the health of farm workers or general environmental damage.

Grey water reuse and other forms waste water reuse for irrigation is of growing importance in peri-urban areas, which are themselves growing rapidly worldwide. This is a valuable form of water saving, but there are some health risks which do need to be taken into account. Some pollutants and pathogens are concentrated in some types of plants – particularly the vegetables which are widely grown in such areas.

Rainwater harvesting is traditionally very important for small-scale irrigation, but these techniques have sometimes been supplanted by modern irrigation. The use of small-scale local techniques should be reconsidered for augmenting supplies:

> "*More small-scale rainwater harvesting technologies have been used since ancient times and are still used in both urban and rural areas. Despite its long history, the technology remains greatly ignored and underutilized. Rainwater harvesting systems have been ignored in favour of modern and supposedly better alternatives. Still, many communities depend on a variety of rainwater harvesting technologies… Rural rainwater harvesting initiatives in places like Gansu, China, and Northeast Thailand have shown that rainwater harvesting technologies can be upgraded and scaled-up in order to provide affordable and sustainable supplies (Gould, 1999). Considering that hundred of millions of people harvest rainwater, it is surprising that so little attention has been paid to develop the technologies further. …*
>
> *Gansu province, located in a very dry part of northern China, has a population of 26.7 million. Here, rainwater harvesting has a thousand-year tradition, and several projects to scale up the investment in rainwater harvesting techniques are in place. The Rainwater Harvesting Irrigation Project is funded by the government and covers 2.9 million ha of cultivated land and 17 million people in the province. Farmers can receive funds or credits for investment in greenhouses, cement slabs and tanks. Water is collected from roads, courtyards, playgrounds, etc., and stored in underground tanks….*
>
> *Harvests have increased by 40 percent, and the use of greenhouses has made it possible to grow cash crops and fruit trees previously not grown in the region. The economic return for the farmers has sometimes improved by 100 percent. The investments made by the farmers, from funds or credits, are low, as much of the equipment and material can be shared by whole communities (SIWI, 2001).*"

Rainwater harvesting is mainly practiced for domestic use, but it has potential for small-scale cultivation of high value crops (such as fruits and vegetables) which can supplement household income or nutritional status.

Water saving in agriculture – an international example

The Murrumbidgee River Efficiency Project is a major programme in Australia which aims to:

- Improve water delivery service and efficiency to users within the Murrumbidgee River system;
- Generate water savings;
- Create increased farm productivity by more closely match irrigation delivery with crop water demand; and
- Improve the health of wetlands and the riparian environment of the river system.

It thus provides a useful international example for an agricultural water savings programme. It covers the regulated sections of the Murrumbidgee River down stream of Burrinjuck and Blowering Dams, with investigations likely to cost in the order of $5 million and implementation estimated at $50 million.

The project is being funded by Water for Rivers which is a company set up by the NSW, Victorian and Commonwealth Governments to recover environmental water for the Snowy and Murray Rivers. As part of the Snowy Hydro Corporatisation, there was a commitment given by these three governments to invest $375million in the recovery of 282GL of water by June 2012. The Commonwealth Government has since committed another $50 million to the company.

The project is a partnership between State Water and Water for Rivers. Other NSW Government Agencies including the Department of Energy and Water and the Department of Environment and Climate Change will also be involved. The Murrumbidgee Customer Service Committee and water user groups and organizations such as Murrumbidgee Private Irrigators, Murrumbidgee Irrigation and Coleambally Irrigation Cooperative Limited will be widely consulted as the project develops. It is thus a large and complex project, and a Project Steering Committee has been convened by State Water to oversee project investigations, development and implementation.

There is currently in the order of 300GL of losses which are not easily measured in the Murrumbidgee system. It is thought that a significant proportion of these losses could be reclaimed through improvements in the way the system is measured, operated and monitored. An improvement in river system operation will benefit the river environment and water users. State of the art metering, ordering and monitoring systems will give confidence that water is being used in an efficient, effective way.

Some of the options for water efficiency and savings include:

- Investigating where regulated flows are being lost to breakouts and wetlands and ways that these flows can be contained within the river system;
- Investigating how evaporative losses can be reduced;
- Identifying ways in which water flows and water use can be measured more accurately and in a more timely manner (real time gauging and metering);
- Automating the release of water from dams based on information gained from real time metering, real time gauging, improved gauging of tributary inflows and more accurate measurement of water demand;

- Introducing effective water ordering;
- Identifying operational system improvements (re-regulation and additional gauging); and
- Developing a robust decision support system (model) to assist the river operator State Water to efficiently regulate the river flows.

What is the scope for water saving in Murrumbidgee?

It is recognised that there is no "new water" to be created in the Murrumbidgee River system. All water is currently going to an end use, whether intended or not. Part of the project investigations will involve identifying where water "losses" are going, and in which of these areas can an intervention create a "saving". Some examples of water savings include reducing evaporative losses, reducing seepage and leakage to saline aquifers, and reducing unauthorized use and theft.

There are also examples where water losses are contributing to environmental damage, for example permanently flooding wetlands. In these cases, a more suitable wetting and drying regime can create both water savings and positive local environmental outcomes.

Who gets the water savings resulting from the project?

The water savings are primarily intended to increase environmental flows in the Snowy and Murray Rivers. This should not change the availability of water for licensed water users since the water savings generated by the project will come from a reduction in system losses – currently water that is unavailable for consumptive use or for the environment. The impact of any actions implemented as part of the project will however, be assessed, particularly any impacts on other water users.

Depending on the scale of the savings, there is potential to share some of the water savings generated with the environment of the Murrumbidgee River and also to improve security of water supply to consumptive users.

What measures will be used in the project?

New metering standards are being introduced nationally as part of the National Water initiative and most meters will need to be replaced with more accurate meters to meet these new standards. Real time metering and monitoring is an options being investigated to look at ways that improved metering can facilitate more timely delivery of water to users along the river system by delivering accurate information about water extraction in real time to the river operators.

An improved method of water ordering and billing is also being investigated as part of the project. The aim is to provide water users with a frequently updated record of water used and remaining balanced in their water accounts. It is also possible to provide remote operation of extraction points using modern telemetry.

Automated river operations using appropriate computer models to analyse storage levels, tributary inflows, real time gauging data, real time water usage data and times of travel will be used to match dam releases with water use demand and water orders more accurately.

The computerised operation model will also use information on levels of soil moisture, meteorological data and areas of crop established to better predict catchment runoff and water use demand. This will result in the delivery of the correct amount of irrigation water to the right place on time with minimal wastage. Less operational surpluses means more water held in the upper storages, less evaporative losses and more flexibility to manage end of system flows and environmental releases.

The Project is considering all available options to store and release water as efficiently as possible within the river system. The project will investigate options such as new on-route storages and reducing evaporative or seepage losses by partitioning or lining existing on-route storages.

Further details of this interesting project are available on *http://www.statewater.com.au/Current+Projects/Water+for+Rivers+Projects*

Lessons from this project

This project provides some valuable lessons for China. In particular, it highlights:

- The need for realistic assessment of what losses can be saved and reallocated in a river basin where all water is currently being used, on the basis of accurate data;.
- The Importance of reliable flow measurement – existing gauges are deemed to be insufficiently accurate and are being replaced;
- The value of using real-time monitoring data for management
- The importance of improvements to irrigation operation, including more responsive arrangements for scheduling or ordering deliveries which are considered essential
- The need for strong institutional arrangements set, with effective systems for involving key stakeholders.

5.3 Urban water supply systems

Approach to urban water demand management

The nature of demand management is very different in urban systems, where the cost of water services is much higher due to the cost of treatment and distribution – water saved has greater economic impact, and measures such as tariffs can be expected to have an impact on demand. These need to be accompanied by technological and behavioural changes so that people can cope safely with less water, and industry can continue to be productive.

The aims of urban water demand management are to:

- Prevent wasteful use of water, limiting consumption and hence minimising investments needs
- Ensure an equitable distribution of potable water supplies to all customers
- Ensure water supply systems are sustainable, providing customers with the level of service they want at a price they can afford while covering the total costs of providing water

- Ensure an efficient and equitable distribution of available water resources between municipal water supplies, industry, agriculture and the environment

At its simplest, urban water supply demand management comprises two components, customer-side demand (consumption) and supply-side demand (leakage, etc). Water utilities are responsible for supply-side demand management whilst the behaviour of the customer is the focus for the customer-side demand management (see Table 5.1 and Figure 5.2), although the distinction between the two can be slightly blurred (eg losses at property-level).

Demand management is not automatically to be preferred to supply-side investments in every case. However, taking demand management seriously does entail a systematic identification of all demand management options as part of water strategy, and a comparison of all options using a common methodology and criteria, e.g., the cost of a unit of water supplied or saved.

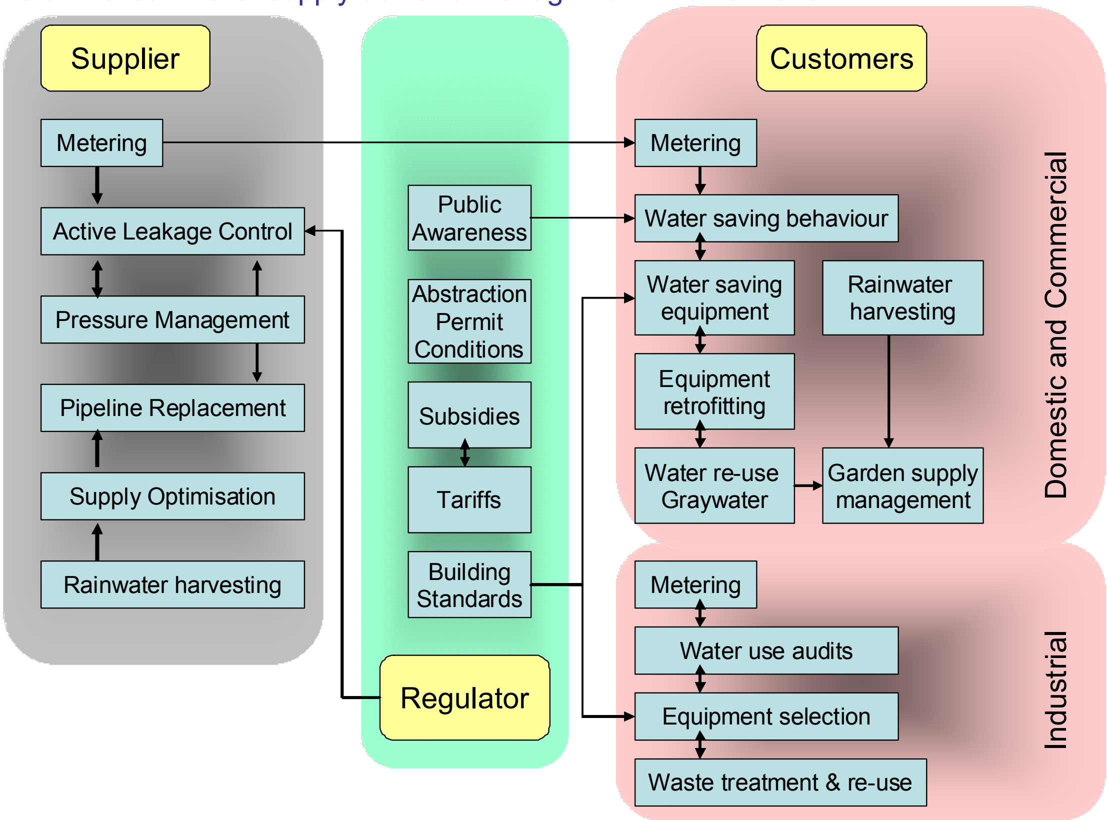
It is obvious that water supply companies (WSCs) must take the lead in managing supply-side demand by reducing water losses from their networks near to economic levels. However, WSCs should also take the lead in getting their customers to use water sparingly, either by enforcement or by encouraging voluntary action. A more detailed summary of the actions and typical responsibilities is presented in Table 5.1.

Table 5.1: Demand management practices

Demand management practice	Supply side	Customer side
WSC-led		
Active leakage control	Y	N
Pressure management – action by WSC	Y	Y(1)
Pipeline replacement	Y	N
Customer metering	N	Y
Tariff setting	N	Y
Free/subsidised repairs on customer supply	N	Y
Customer internal plumbing inspections	N	Y
Industrial customer water audits – by WSC	N	Y
‘Temporary’ restrictions	N	Y
Education campaigns	N	Y
Administrative regulation		
Abstraction permit conditions	Y	N
Performance targets	Y	Y(2)
Building standards-driven		
Rainwater harvesting	Y	Y
Water efficient sanitary fittings	N	Y
Grey-water recycling	Y	Y
Customer-led		
Retrofit water efficient sanitary fittings	N	Y
Choose water efficient appliances	N	Y
Repair leaks within the home	N	Y
Adopt water saving behaviours in home	N	Y
Adopt water saving behaviours in garden	N	Y
Adopt water saving behaviours in commercial premises	N	Y

(1) Reducing network pressures reduces “open tap” flow rates in customers’ fittings
(2) Some moves to set WSCs targets for reductions in customer demand

Figure 5.2: Urban water supply demand management interventions



Customer led demand management techniques can be implemented by the customer without assistance from the WSC, but they usually require encouragement and assistance from the WSC.

A number of the above activities are customer-friendly in that they will cost the WSC in providing additional customer services, and reducing customer consumption. This will potentially reduce revenue and hence the WSC may resist their introduction. This can be mitigated by an appropriate progressive tariff structure that reflects the expected reduction in customer consumption and ensures adequate revenue (and incentives to the WSC). In the wider context of water conservation these activities should be economically advantageous to society and should result in better service delivery, although their implementation will be difficult in the short-term.

These demand management activities should be supported by a public education programme to raise awareness of the benefits of minimising water consumption, as described in section 6.5.

Further details are presented in section 8, with more comprehensive details in a separate paper (TP3.2 – urban water demand management) which is aimed at Ministry of Construction and Water Supply Companies. This paper presents information primarily for the benefit of MWR personnel.

Industrial water use

In the industrial sector a combination of subsidies, higher water prices and environmental regulations have encouraged industries to improve processes and reduce withdrawals (see Chapter 7). It is hard to get a consolidated picture of how industries manage water worldwide, but there are global indications that the business community is devoting growing attention to water management, as a result of increased efforts to improve water management. Industries can realize major savings in natural and financial resources by raising awareness through environmental audits and by investing modest amounts. In agricultural and emerging market economies the scope for progress through clean processes is even greater, since production processes are generally well below world standards. Multi-national companies can play a key role in transferring knowledge and technologies between countries.

In many country including the USA and UK, power generation is the largest single abstractor of water, although most of this is non-consumptive. 40-50% of total withdrawals in the UK and US are for this purpose.

In some countries public intervention through subsidies or more stringent enforcement are necessary. The international competitiveness of companies in the global market is enhanced by a commitment to best environmental practices, which reduce pollution and improve the efficiency of water use.

At the national level a growing number of companies are introducing clean production processes – often for pollution reduction – that result in substantial water savings. These efforts are supported by various UN programmes (United Nations Environment Programme, United Nations Industrial Development Organization) through a network of cleaner production centres in 27 countries (Molle and Vallee, 2009).

Further information on approaches for industrial WDM is presented in Chapter 8.

Recycling and reuse, return flow management

Most water in industry is used not for the actual industrial processes, but for substantially non-consumptive uses such as non-contact cooling from (30% in the sugar industry to 91% in industrial organic chemical manufacture). This is encouraging, because under appropriate regulations or incentives, it is possible in many cases to have closed-cycle systems for cooling. The remainder of the water is usually used for process-related items which are very sensitive to the process technologies employed. Major industrial processes which use a lot of water include pulp and paper and petro-chemical industries, and, to a lesser extent, fertilizer, sugar and the iron and steel industries. In both the UK and USA, the largest single category of use for which water is abstracted is power generation (either for hydro-electric generation, or for cooling of thermal power stations), but this is almost entirely non-consumptive.

The implications for changing water use are radically different. There are many easy technical options for non-contact cooling which are very price sensitive, hence, pricing on the input side in these industries could lead to large water savings at relatively low costs. If the bulk of the water goes for process related activities, the policy options are less clear. For example, it will be necessary to change the process technology to achieve significant savings. These are likely to be expensive and are less input price responsive that cooling water options. In this case, both input and output pricing may be indicated as well as some form of product environmental charge.

Curiously, even in the USA where most industrial water is recycled, it is still difficult to determine accurately the recycling rate in industry (defined as a share of the gross water use contributed by recycled water). While the actual consumptive use in industry is small (15% overall in the USA) its diversions exceed that of domestic water supplies. Much of the water which is currently discharged does have the potential to be recycled, and is increasingly being used as such for additional supplies where water is scarce, as in Israel. Between 1985 and 1990 there was a 30% increase of in the amounts of wastewater recycled in the U.S. However, due to the often poor water quality of the effluent from water used in contact processes, it is easier to recycle domestic sewage than industrial water.

Recycling rates vary considerably – some such as synthetic rubber, petroleum and pulp and paper have high recycling percentages, but others such as cane sugar and industrial organics have considerable potential for improvement.

Similar conclusions can be drawn from the situation in China, and preliminary findings of the national pollution census[13]: "*most of the industrial pollution comes from a small number of industries and are mainly concentrated in economically well-off areas, with over percent of industrial emissions of COD come from seven industries such as paper-making, textile, agricultural processing and chemicals".* An important finding, however, was that agricultural pollution has a notable influence on the country's water environment, which means the prevention and control of agricultural wastes must be strengthened. This includes the impacts of livestock farming as well as the excessive use of fertilizer and pesticides.

Grey water recycling

A recent development in urban demand management is grey-water recycling which is increasingly being considered as an alternative to treated water for non-potable use (this has long been used in rural situations, but with negligible volumes of water). Grey-water is the term used for wash water from baths, showers and hand basins which is reused elsewhere in the same property, typically for toilet flushing or garden watering. The grey-water needs to be collected and routed around the property in a separate system from the incoming supply to avoid contamination. It is imperative that the risk of cross contamination of potable water is eliminated, both during initial installation and during future works to the building. In many countries where grey water reuse has been adopted, such as Japan, the reclaimed water is coloured blue or green by a dye added to the water at distribution. This has the benefit of making it immediately obvious that the water is not potable (highlighting any cross contamination', plus making it appear 'cleaner'). Grey water systems should always fail safe i.e. if any disruption of the system occurs, the supply defaults to mains water supply. Grey water systems require much smaller storage tanks than rainwater systems, as the water is generated constantly throughout the year and used almost immediately. The treatment processes required depend upon how the recycled water will be used within the building or garden. The design must provide for safe storage of water to avoid bacterial growth such as Legionellae. Maintenance is absolutely essential if the systems are to operate correctly and safely.

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[13] China Daily, 10th February, 2010

Grey water systems are generally best incorporated into new-build. Modifying existing buildings can be difficult and expensive, but not impossible and can be considered in severely resource-constrained situations.

Rainwater harvesting

Rainwater harvesting is extensively used in rural areas by individual property owners but is not often formally used in urban areas with piped water supply systems. With increasing concern about water scarcity in many parts of the world rainwater harvesting is attracting more interest. There are certain issues related to water quality but simple filtration is often sufficient. The key issue for rainwater harvesting prospects is the local rainfall pattern and the available collection area. Rainwater is usually collected from roof areas so is more suited to houses and factories rather than apartment blocks where the number of users relative to roof area is very high. However office premises may be suitable because the amount of water used by the workforce during the day is much less per capita than domestic use. If rainfall is highly seasonal with a long dry season the approach may not be cost effective because of the volume of storage that would need to be provided.

Rainwater harvesting is particularly important in remote rural situations, where costs of piped distribution systems are very high. Rainwater storage in such situations is relatively cost, and it is often the most cost-effective solution.

6 Non-market Based Instruments – Supporting Instruments

6.1 Introduction

The main non-market based instrument for demand management is the use of administrative regulation such as abstraction permits, as described in Section 3. However, these administrative instruments and the economic instruments and direct techniques (discussed in chapters 4 and 5) need to be supported by a range of other non-market-based instruments and incentives. These were categorised in Figure 1.1 in the following way:

- Assessment of resources and needs
- IWRM plans
- Social change
- Conflict resolution
- Information management

These should, however, not be regarded as optional 'extras' to be used, or not used according to individual interest or preference, but they are an integral part of WDM. Climate change is influencing resources and demands in may ways, not all of them clearly understood yet. This is an important influence on WDM, and in some places is an important driver for it

These are generally covered in more detail in supporting documents, as listed below and in the references at the end of this document. In the case of conflict management, this supporting information is provided in an appendix to this report. The most relevant supporting documents are:

TP1.2: Groundwater resource quantity assessment

TP1.8: Demand forecasting

AN2.1: Developing an IWRM plan

TP2.2: Sector coordination and user participation in IWRM planning

AN2.3 Water resource scenario development and modelling

AN6.1 Role of WUAs in water saving in groundwater

AN6.2/3 Village level planning of WUAs

AN6.2/4 Promoting and training WUAs

TP6.3/1 Social issues in IWRM

AN8.1 Data sharing and management

6.2 Assessment of water resources and needs

Introduction

Demand management must start from a clear understanding of the available water resources and water needs, and anticipated trends in these. This understanding does not directly lead to a reduction in demand, but it is a prerequisite for demand management. It provides a basis for both planning and monitoring demand management. From the resource manager's point of view, they can only calculate appropriate permit volumes on a basis of knowledge of the available resource. Indeed it is usually knowledge of the limits to the resource which drives the introduction of WDM.

Equally, demand management depends on changing the attitudes of users and other stakeholders. This can only be achieved effectively if they understand the resources and the conflicting demands and pressures on the resource. It is unrealistic to expect anyone or any organisation to reduce their use of water unless they understand clearly and consistently the limitations to the availability of the resource.

In the context of WDM, water resource assessments are needed:

- To determine safe values for entitlements and allocations, with appropriate levels of headroom (or contingency)
- To provide information to stakeholders on resources
- To monitor the impact of water use and management on the river and groundwater

Water resource assessment

Water quantity assessments can be complex because of the variable nature of runoff, groundwater conditions and the combination of climatic and human factors. Lack of water in a river may be due to a drought or to excessive abstraction, and thus the assessment should be based on several years of monitoring. In the case of groundwater, the key issue is groundwater levels in relation to aquifer characteristics. Aspects include the recharge characteristics, lateral groundwater movements, connectivity with the river systems and abstraction volumes.

Detailed guidance on water resource assessment is available in standard textbooks with key features summarised in documents this series under the heading water resources and demand assessment (particularly TP1.6 Data preparation for water resources assessment modelling). Key aspects are:

- hydrological and hydrological data (rainfall and other climatic data, river flows, river levels, water qualities, groundwater levels and qualities, reservoir levels and releases etc);
- information for understanding patterns of water use, and changes in natural flow systems and groundwater bodies caused by human intervention;

Water Quality and Ecological Assessment

Demand management in the European Union is driven by the need to maintain or improve river water quality and ecological conditions, which is achieved by (among other measures) ensuring that water abstractions are limited so that sufficient water is left for environmental purposes.

Water quality assessment is normally based on a range of physical, chemical and biological parameters. The assessment of the ecological status of a water body will usually involve detailed study of the biology of the water and bed sediment – phytoplankton, phytobenthos / macrophytes, benthic invertebrates and fish. Although, this is the best way of determining the health of the water body, there are not yet well-established techniques for interpreting data.

Other assessments

There are a number of other water management issues which need to be assessed in order to inform water demand management. These include:

- Flood risk (relating to probability of floods of different magnitudes and durations, and linked to hazard analyses).
- Agricultural impacts of waterlogging or salinisation

6.3 Demand forecasts

Introduction

Successful demand management depends also on a good understanding not only of the water resources but also of the various uses of water and future trends in demands for water for various uses. This, too, can only be achieved if there is accurate data available, if it is analysed systematically, and presented clearly and succinctly. This knowledge and analysis is required by the water administration, other related technical bureaus and government at all relevant levels so that it can be made available to users and other stakeholders.

Future needs can be estimated on the basis of current demands, taking account of relevant trends such as population growth, urbanisation and industrialization and environmental consciousness. However, they cannot simply be extrapolated from current uses without consideration of the impact of future demand management. This is an iterative process, as the future demands need to take into account the impact of demand management activities, and need to be updated on the basis of actual performance. The process of forecasting future demands under various scenarios of demand management are outlined in AN 1.8/2 Agricultural water use norms and TP1.8 Demand forecasting and AN2.3 Water resource scenario development.

Demand management must be supported by accurate demand forecasts, preferably those that are built up from micro-scale multi-component demands as these can provide better information on which optimal decisions about water allocation can be made. Demand forecasting must also take into account many aspects that relate to the impact of demand management interventions. In the past, when demand management was little considered, demand forecasting was much simpler and could be based on trend analysis and relatively simple population projections. Demand forecasting is now much more complex and probably uncertain owing to the need to predict the effectiveness of demand management and the impacts of climate change.

It should be pointed out that water demand forecasting and associated sensitivity analyses (see later) is an approach that should be used to help design demand management programmes that meet specified policy related targets. These forecasts should be based on user and water supply company response criteria to demand management interventions.

However, good demand forecasting in itself is not sufficient to promote the sustainable use of water resources. The implications of demand, and strategies to manage that demand, must also be considered, notably in the equitable allocation of supplies between future and current users, between current social groups, and the needs of the environment. Accurate forecasts can help identify areas and sectors to be targeted for demand management programmes.

Principles for demand forecasting

There are some basic principles that can be applied. These are as follows:

- The accuracy of the forecast should be in relation to the cost of the errors that may result from an inaccurate forecast e.g. such as construction of a large piece of infrastructure that is not needed because demand has been overestimated;
- The forecast of a demand component that represents a small proportion of the total demand can be relatively inaccurate without causing too much concern. For example if un-metered households only made up 5% of the total urban domestic demand of a city a forecast of this component that was in error by 50% would not cause a major inaccuracy in the overall forecast of urban domestic water demand.
- The most important water demand sectors and sectors and components should receive the most attention. This does not mean that the sector or component with the largest water demand should have the most resources allocated to it.

There are many different demand forecasting methods, of varying degrees of sophistication. In the United Kingdom the water industry has now largely abandoned the extrapolation of trends in measured water consumption as a means of forecasting future water demands in favour of the component method.

This was noted in recently research paper in Australia[14]

> *"Approaches based on historical trends have an important role but should not be the sole way of forecasting demand. If we do not know how much water consumers use for different purposes and which uses we might be able to influence, it is very hard to design relevant and effective demand management and efficiency programs. End use analysis allows us to focus on what is*

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[14] Water Services Association of Australia - Occasional Paper No. 9 - Urban Water Demand Forecasting & Demand Management, 2003

important. This End use analysis (EUA) provides a mechanism for understanding how and where water is used, for choosing the most effective demand management measures and estimating the water savings they will yield. End use analysis focuses on the factors and technologies that affect water use, including emerging trends, relying less on historic trends. End use analysis involves disaggregating demand into the 'services' for which people use water. This perspective is consistent with the principle of a utility providing a service (e.g. clean clothes) rather than a commodity (water) and it assumes that providing the same service with less water provides the same amenity to the consumer".

The methods currently applicable in China are outlined in SL429-2008 – "*Technical specification for the analysis of supply and demand balance of water resources*", with more details given in a national project-level document "*National integrated water resources planning – technical details of water demand prediction*", issued by the Ministry of Water Resources (MWR) in 2004. These methods use on extrapolations of populations and norms. These are simple and easy to apply approaches but do have some limitations. These include gaps in knowledge or understanding of the:

- assumptions inherent in the water use norms;
- water use efficiency values and their relationship to the condition of a water supply delivery system;
- current water use levels in different parts of a supply area;
- direct information from major water users to clarify any uncertainties and anticipated future changes; and
- operating performance of flow measurement equipment and the accuracy of the data.

Whichever method is used, forecasts are needed for

- **Domestic water demands**
- **Other municipal demands**
- **Industrial Water Demands** (whether from municipal supplies, or from independent sources)
- **Agricultural Water Demands** (sometimes referred to as primary industry) this is likely to be the dominant user of water in many places, but it is also the demand which is most likely not to be met at times of shortage.

Demand forecasts should be internally consistent and should normally be broken down into components in the supply system:

- From the raw water source to the distribution system;
- Within the distribution system; and
- Within the water system to the user level.

Return flows

A large part of the water demand – whether from domestic, municipal, industrial or agricultural uses - is not actually ***consumed*** but is returned to the river system or aquifer and may be available for reuse (or may be used in-stream). Forecasts should also include estimates of these return flows This applies in varying degrees to all categories of water demand. Typically surface irrigation will result in about 50% of the water and power generation will result in close to 100% return flow (dependant on the process). As these are the two main uses in most countries (together accounting for almost 80% of withdrawals in the USA) so the importance of return flow forecasts should be self-evident.

Although water may be allocated for environmental purposes, the requirement is usually that there should be a minimum flow or minimum depth of water in the river. This may be achieved in some locations without a specific allocation, but in other places water may be allocated so that the residual flow or depth meets this target. Water quality targets may also limit the amount which can be abstracted or discharged into the rivers, depending on the quality of the wastewater. Other more subtle requirements, such as oxygenation from riffles may be needed.

Forecasts based on component analysis

The component analysis technique allows estimates of water use to be based upon an individual component, e.g. household appliances, industrial machinery, crop and the extent of usage or production of that individual component.

The component method of water use forecasting has the following advantages:

- It can be useful in determining the effect of changing uses and production technologies on overall water use;
- It can be used to identify key areas of use, predict areas of use which may increase or decrease and how these may effect the total water use.

This is a more useful approach for demand management purposes than the simpler techniques often used. Water demands and use are disaggregated into major components so that the water demand of an individual component, be it household appliance or crop, can be estimated or measured. This makes it possible to predict future changes in each component taking demand management options into account.

Water use norms

Norms are used for all sectors of water use in China, and they can be a useful part of demand forecasting, but they need to be clearly understood, transparently calculated

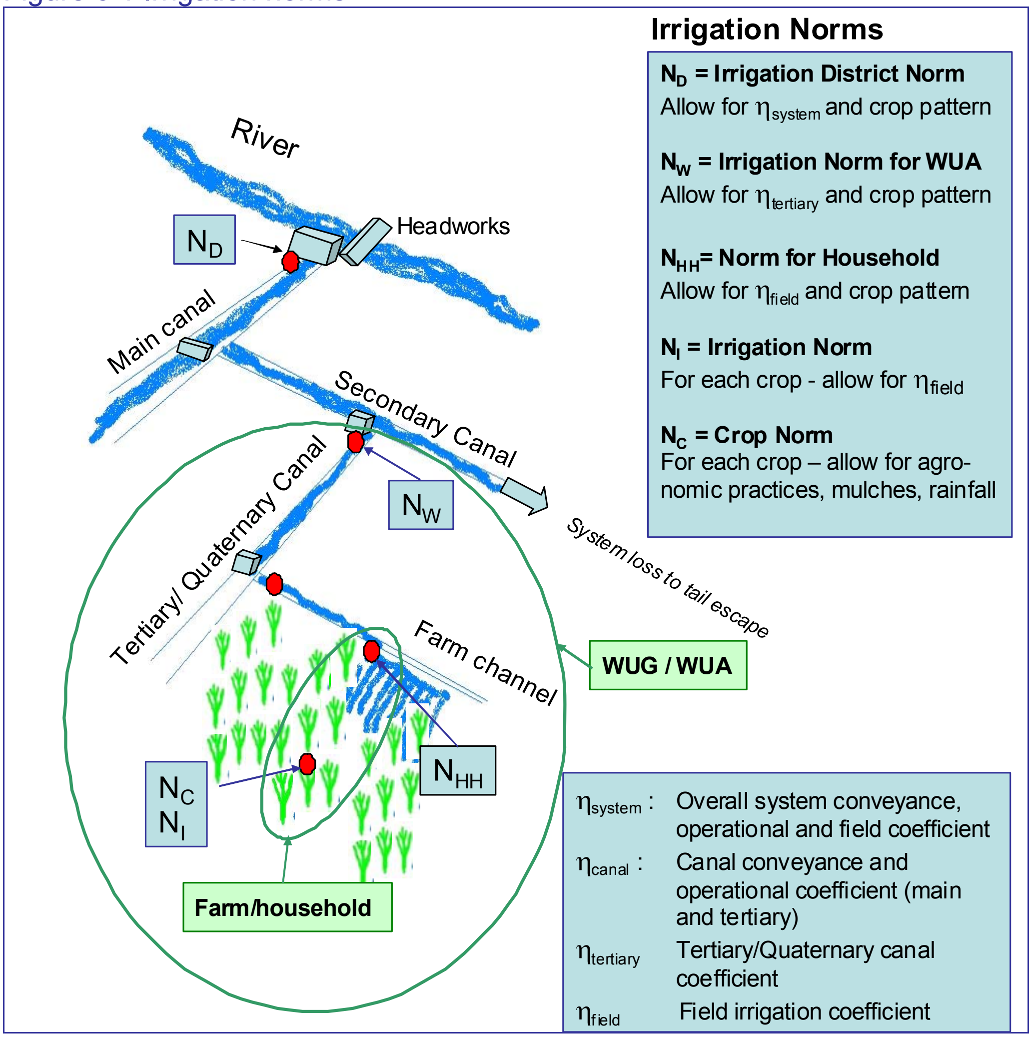
Norms are a key part of demand forecasting in China, but several different types of norms are used and they are not always interpreted or used in the same way if different places. Consistent and accurate use of norms is important to ensure that water resources are managed in a rational, sustainable and equitable way. It is important to understand the link betweens the use of a norm, the numerical value of the norm, and the assumptions inherent in the norm. Those calculating norms need to be aware of these assumptions, and to be able to relate them to the actual situation. They should periodically verify and update norms on the basis of actual uses and updated. They are used for all sectors – domestic, industrial and agricultural.

If crop norms are to be cut back gradually as part of a demand management plan, this needs to be done on a rational basis (such as by deficit irrigation or improvements to field techniques) Simple reductions in crop norms to meet arbitrary targets, without reference to crops or cultivation techniques are not recommended. Such methods may meet short term water use targets, but they are unlikely to be equitable and they are unlikely to maximise the productivity of water.

The main factors which influence the norms include: natural and geographical conditions, irrigation practices, types of water sources, the size of irrigated area, types of irrigation, distance from the water intake, water saving standard, full or deficit irrigation, crop types, crop cultivation methods, crop varieties, management practices, agronomic measures, and irrigation practices.

Norms can be expressed at different places in the system, and the magnitude of the norm will differ significantly between them because there are various losses in delivery and application of water. The definitions of the main types of norms are presented in Figure 6.1

Figure 6.1 Irrigation norms



Industrial demand can be estimated on the basis of audits of actual industries, or on the basis of statistical data according to the type of industry. Table 3 shows some typical water usage figures based on real situation water audits, indicating average, maximum, minimum and upper and lower quartiles of demand. As can be seen from the data, there is a wide variation in usage rates. This shows the uncertainty surrounding the overall process of demand estimation.

Table 6.1: Typical industrial water usage in UK

Sector	Water Use Units	Water Use Estimates (Annual)					Nr of Samples
		Minimum (Good)	Average	Maximum (Poor)	Lower Quartile	Upper Quartile	
Automobiles	m^3/employee	1	99	409	17	162	13
	m^3/vehicle	2.2	29	159	4.5	28	11
Ceramics	m^3/tonne	0.04	12	77	0.35	12	18
	m^3/employee	22	166	474	17	162	20
	Litres/ brick	0.1	0.3	0.6	0.2	0.4	6
Glass	m^3/tonne	0.01	11.3	27.5	3.1	20	13
Foundries	m^3/tonne	0.01	17	129	1.1	19.3	34
	m^3/employee	8.3	161	648	41	251	14
Chemicals	m^3/tonne	0.02	28	198	1.8	24	35
	m^3/employee	4.5	33	77	8.1	48.6	6
Printing	m^3/employee	3.5	37	143	18.4	34.9	9
Leather	m^3/employee	172.5	1462	6042	543	1967	21
	Litres/skin	60	100	170	70	120	4
Furniture	m^3/employee	4.1	125	882	7.9	63	15
Brewery	m^3/m^3	2.6	7.3	21	5.1	8.4	30
Soft drinks	m^3/m^3	1	3.1	9	1.6	4.3	24
	m^3/employee	88	260	486	133	359	4
Fruit & veg	m^3/tonne	0.1	7.8	39	1	8	14
Meat process.	m^3/tonne	1.2	4	16.5	2	6	15
Poultry farms	Litres/ bird	10	20	60	20	20	14

Source: Envirowise (Environment and Energy), UK

In places where water is scarce, demand management measures are likely to be put in place to encourage each industry to move towards the 'minimum use' over a period of a few years. The demand forecast needs to take account of the current use, and the impact of these demand management policies which will take time to have full effect.

This is allowed for implicitly in the approach used in China, where norms are updated and reduced periodically – at any particular time there will be a single figure for the norm for each industry. Norms cannot necessarily be transferred from one country to another because of differences in context (particularly where norms are presented as m^3/employee, since staffing levels vary so much, or m3/unit value, since local pricing may differ). In other cases norms are relatively transferable. The norm for breweries in Wuwei, for example is 14 m^3 water per m^3 beer, compared to an actual consumption in 2006 of10 m^3/m^3 (and a future target of 5 m^3/m^3)[15]. The average water use by breweries in the UK is 7 m^3/m^3 and maximum is 21 m^3/m^3 beer.

Domestic water use norms in China tend to show an increasing water use, reflecting growing standards of living and socio-economic conditions. However, this trend

[15] Data reported by Xiliang brewery in July 2006

should partly be offset by increasing adoption of water savings appliances and so on. However, the variation in actual use between cities can be surprisingly great and not easy to explain. Norms must therefore be used with great caution. This can be seen from the two examples in Box 6.1.

Box 6.1: Local variations in urban water use – examples from China and UK

Growth in per capita water demand – Beijing and Tianjin compared

As the nation's capital, Beijing has a much higher daily per capita domestic water use than that of Tianjin. However, the trends in the two cities over the past 30 years are not consistent with each other. 1978, the daily use in Tianjin per capita was less than 50% of Beijing's (66 vs. 139 L/p/c/d), rising to 86% in 1988 (136.1 vs. Beijing's 158 L/p/c/d). The gap opened up again by 1998, with use in Tianjin' being just 60% of Beijing's (145 vs. Beijing's 238 L/p/c/d).

Source: 'Understanding urban residential water use in Beijing and Tianjin, China'; H H Zhang and D F Brown, Habitat International 29, (2005)

Water use in Tendring and Three Valleys, South-east region, UK

These two locations in the same region of the UK have very different water uses. Three Valleys Water estimates that each individual uses 177 litres of water per day, while nearby Tendring Hundred estimates the corresponding figure as 124. Ofwat, the water supply regulator, cannot fully explain this variation but believes that 60% of the difference is due to socio-economic factors.

Source: Ofwat

6.4 IWRM planning: options and interactions

The data and information outlined above is important, but it needs to be analysed and interpreted in order to understand the options and interactions between competing demands. It is only possible to manage demand once these options and interactions are understood, which is generally achieved through identifying and modelling alternative scenarios.

The drivers for WDM are discussed in more detail later (Chapter 9) and will vary according to the local situation; they will be identified in an IWRM planning process. The nature of these will guide the scenarios to be investigated and optimised. These will include varying degrees of

- concern over water resource availability,
- mismatch between supply and demand
- Desire to delay or avoid capital investments in supply-side options
- Need to reallocate water to other users, new users, or the environment
- Economic or financial constraints to the water management system
- Desire to improve equity between users.

This is optimisation is part of the process of IWRM planning, and will result in WDM interventions becoming an inherent part of the plan to implemented. This covers the following IWRM management instruments:

- Modelling scenarios
- Developing management plans
- Undertaking social, environmental and economic assessments
- Risk assessment and management.

These are discussed briefly below, focusing on their importance for WDM

Modelling scenarios for water resources planning and management

Mathematical simulation models in water resources assessment can greatly assist in the evaluation of alternative resource management and development scenarios, taking account of all features which influence the availability and utilisation of the water resources. These models can also be used to identify issues and constraints, and present these clearly in ways that are easily understood by a wide range of stakeholders.

Models should enable alternative demand management scenarios to be assessed and evaluated on the basis of a sound knowledge of both the resources and uses, in order to determine the most effective and sustainable scenario. This will enable their overall impact on the water resources system to be determined under the recommended management system. This is of critical importance, given the high degree of reuse of return flows which means that local estimates of losses can be highly misleading.

Water resources simulation models can also assist in identifying areas in which there are critical gaps in knowledge or understanding and hence where additional monitoring would be advantageous. They can be used to test the sensitivity of results to uncertainty in model inputs or assumptions. This will inform the assessment of the robustness of particular management or development strategies.

Management plans

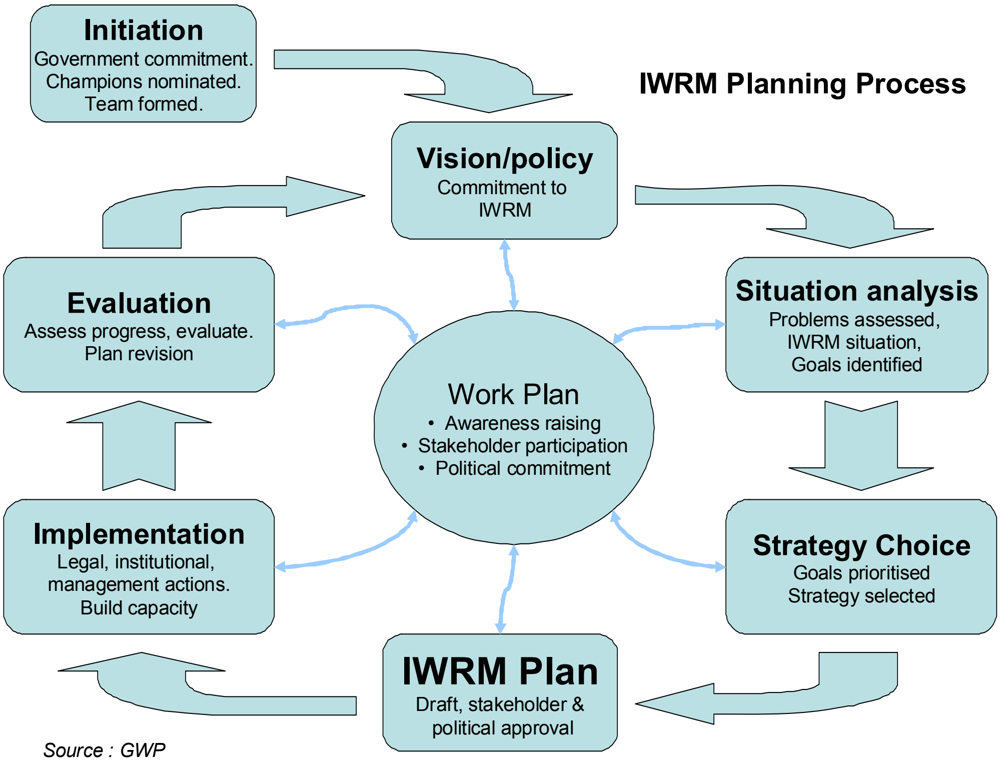
Management plans need to be prepared and implemented on the basis of:

- knowledge of water resources and needs (see above),
- knowledge of economic, social and ecological issues related to water resources development and management,
- Strategic planning for water resource management, on the basis of the above and through multi-stakeholder workshops,
- Review and ratification through stakeholder workshops,
- Plan implementation, monitoring and evaluation, and feedback to stakeholders.

Demand management can be a key element of IWRM planning, requiring a process of matching resources and demands (taking account of social and environmental requirements), and managing demand so that it does not exceed the sustainable resource.

This is a cyclical and iterative process as illustrated below (Figure 6.2):

Figure 6.2: IWRM planning cycle



Source : GWP

The box below gives an example of how the IWRM process has developed over a 40 year period in the Netherlands, indicating the change from a supply-dominated approach to one aimed at sustainability. Further international examples and experiences with IWRM planning are given in OV1: IWRM best practice.

IWRM is of course a much larger concept that WDM, including issues such as water quality management or flood management as well, but for WDM to be effective it needs to be undertaken within an overarching framework such as that provided by IWRM. Attempts to make small-scale piecemeal water savings are unlikely to succeed or to be effective.

Box 6.2: IWRM planning in the Netherlands

The Netherlands is preparing its fifth integrated water management plan, with the possible consequences of climate change high on the agenda.

Its first plan, prepared in 1968, was supply-driven and addressed only quantity issues. Deteriorating water quality, and the very dry summer of 1976, led to fundamental changes in the country's approach to water management. The second plan had to be completely different, so the Policy Analysis of Water Management for the Netherlands was carried out before drafting the second plan.

For the second plan, despite a thousand years of experience in water management, the government enlisted the assistance of the RAND Corporation, a U.S.-based think tank with extensive experience in complex policy processes. The company had been involved in an earlier integrated water project in the Netherlands – the storm surge barrier, a multibillion dollar project to protect the southern part of the country – helping them secure close cooperation of other ministries and governmental levels involved.

The plan was expected to achieve three primary ends: develop and apply a methodology for producing alternative water management policies, assess and compare their consequences and help create domestic capability to conduct similar analyses by the related Dutch entities.

Using more than 50 models, the project resulted in a much better operational understanding of the water system. Multiple cost-benefit analyses of options to improve water management led to the identification of implementable local projects and helped avoid large, expensive infrastructure works that proved not to be cost-effective. An important conclusion was that water quality problems cannot be solved at the national level – for example, reallocating water could inflict large losses on some sectors. Tight restrictions on groundwater abstractions were needed to meet desired environmental standards, which would impose large losses on some users. The second plan, published in 1984, reflected this complete change in thinking about how to develop and manage the water system.

Subsequent water management plans continued to develop integrated water resources management. The third plan (1989) added in-depth analysis of the role of ecology in water management, and the fourth plan (1998) focused on specific water systems and themes, facilitating implementation of needed actions and clarifying institutional roles.

The evolution of these five water plans, each building on its predecessor and responding to changing circumstances, facilitated significant shifts in thinking and engendered new approaches to water management. From its origins in a technical, supply-oriented, model-based decision process, the planning process is now multifaceted, with a main pillar being stakeholder involvement (other ministries, local authorities, public and the like) with a focus on sustainability and climate proofing related to anticipated changes.

The lessons learned from developing the five water management plans in an integrated manner are that implementing complete integrated water resources management takes time (more than 30 years in the Netherlands), that external input can facilitate implementation of new concepts and that full involvement of all stakeholders is needed. While cooperation may not always be possible, involvement is essential. By helping stakeholders understand the difficult trade-offs, the participatory practices made it easier to accept the importance of change for the greater good of society.

Source: E. van Beek, H. Engel and G. C. de Gooijer.

Risk assessment and management

There are some risks associated with demand management; these are discussed in general in section 11.4. This section covers specific risks which need to be taken into account when allowing for WDM in IWRM plans. It should be recognised that risks and hazards are not the same[16]: Risk reduction is not the same as hazard reduction; risk mitigation has to consider the reduction of vulnerability. This can include measures such as insurance to cope with the impacts of drought.

Risk is a complex topic which is often misunderstood and responses to risks may not be rational. Issues include, for example

- Uncertainty in water resources (natural variation, extreme events, long term climate change etc) and in developments which affect the use of these resources (population growth, urbanisation, environmental awareness etc)
- Uncertainty in the ability of water service providers and regulatory agencies to undertake their functions and implement WDM.

[16] A hazard is a source of potential harm or damage, whereas a risk is the probability of a harm if exposed to a hazard

- Uncertainty in the understandings of the complexity of the water environment and the impact of WDM actions on it
- Varying perceptions and priorities in relation to different risks and appropriate responses to these risks by Government organisations, civil society and other stakeholder agencies, and the wider public.

There are procedures for quantifying risks and incorporating them into planning processes (eg through the use of Monte Carlo methods), but there are some general features which need to be recognised:

- Risks need to be considered as a whole - analysing them by sector may be inefficient or inequitable. However, institutional arrangements for analysing and coping with risk are complex and difficult.
- There are a wide range of mitigation strategies from complete hazard avoidance, through to vulnerability reductions and post-event harm alleviation.
- Stakeholder preferences must play a role in establishing risk mitigation priorities and practices.
- Risk mitigation has economic impacts – the costs of reducing or mitigating risks need to be quantified.
- Decisions about what risks are to be addressed and how they can have impacts on equity – the process of decision-making and the design of mitigation measures is important.

As an example, irrigation is designed with a certain probability of rainfall – typically a 80% probability. If there is less rain the demand for irrigation water will be higher. If this is not met, yields and hence farm income will be reduced. Strategies for coping with this situation could range of transferring water from elsewhere or pumping extra groundwater to completely offset the shortfall through to accepting that crop damage will occur and encouraging farmers to take out insurance to compensate for the loss. Such issues need to be considered when designing demand management options and including them in the plan.

Social, environmental and economic assessment

Demand management is partly driven by social, environmental and economic factors, but equally it has impacts on these issues. Often these impacts will be positive, but there may be some adverse impacts. Demand management planning needs to assess these impacts. The scale and nature of environmental impact, social impact and economic assessments are covered in other documents in this series (see document reference list) and if implemented correctly should result in an optimum demand management plan with broad stakeholder understanding and acceptance.

Application of a demand management instrument as described in this report – for example an economic instrument such as tariff levels for irrigation management has a social impact because of the effect it has on rural incomes. This is distinct from use of a social *instrument* for demand management as described in the next section.

The social and economic assessments described in this section relate to a plan as a whole. It is important to assess the impact that all the WDM management instruments will have. All instruments – whether it is, for example, leakage detection, introduction of water resource fees, or establishment of a WUA - will have impacts which needs to be assessed. Any adverse impacts will need to be identified and mitigated. Sometimes the impacts are conflicting – beneficial in some respects, and adverse in others – in this case they need to be combined in some objective way to develop the best compromise: a multi-criterion decision analysis is the best way to achieve this (see AN7.1: Multi-criterion decision analysis)

Economic assessment is best done through a cost-effectiveness analysis which enables selection of the economically optimal way of achieving certain specified objectives. If the benefits of alternative interventions are different, then the alternatives can be compared by using a cost-benefit analysis. These are described in AN2.8: Economic analysis for IWRM planning

Implications for water demand management

The comprehensive approach outlined in this document should ensure that water demand management:

- focuses on the key issues of water management in the region;
- optimises uses and resources, ensuring that demands for each sector and use are met fairly, and that demand is managed on a consistent, equitable and sustainable basis;
- reallocation between sectors and users from the current situation to a future more sustainable usage pattern is done in a rational manner, accepted by stakeholders;
- is monitored systematically, objectively and rapidly, with standard methods of measurement which are relatively easy to use and analyse
- is easily understood by stakeholders (both organisations and water users), with information made freely available to them.
- Is integrated into wider aspects of water resource management (including particularly drought management, but also water quality management and flood management

6.5 Social and participatory instruments

Introduction

There are a range of instruments loosely grouped under the term "social change instruments" in the GWP toolbox. These include many topics and are closely linked to concepts of public participation but with the specific objectives of improving water resource management and, in the case of WDM, of reducing demand for water. This is a broad subject, and it needs to be analysed carefully. There are many different groups who need to be involved, and many aspects of behavioural change may be needed. Broadly speaking, water users need to change aspects of their behaviour and they may need to influence other individuals and organisations. It is thus important, in each case, to consider the incentives to be involved, and to act in response to such participation.

For example, it is commonly believed that WDM requires social change in terms of improvements in:

- Communication [with the public – communication with other stakeholder organisations is covered separately – section 6.7]
- Awareness raising
- Education curricula

This is fairly narrow definition, which makes it relatively easy to implement and it avoids contentious issues of empowerment or participation in decision-making. In practice, however, many programmes related to social aspects of demand management often attempt to address these more difficult processes. This is because effective demand management (particularly in irrigation) usually requires a more extensive programme.

In addition to being informed through communications programmes and becoming aware of the need for water savings, there is a need for the users to be involved through:

- capacity building in how to achieve water savings, and
- active participation (rather than just receiving information) in managing water, with a focus on water saving or more effective use of water.

Social change is not easy to achieve, and despite considerable research on water conservation behaviour by social psychologists, means for promoting changes in practices and behaviour at larger scales and across sectors remain elusive. The theory of *cognitive dissonance* has been used to stimulate change at a small scale, but these are not easily translated to a larger scale. This approach is based on emphasizing the inconsistencies between two simultaneously held beliefs (the state of cognitive dissonance – eg between knowledge of the need to save water, and the desire to continue with existing wasteful practices). Because the experience of dissonance is unpleasant, the person will strive to reduce it by changing their beliefs. Programmes can be designed to provoke the dissonance and thereby change behaviour, but it is difficult to do this on a large scale.

In the long run, much can be achieved through incorporation of key concepts in school curricula but other activities are need in the short term. Education also has a short-term as well as long-term benefit (see below) but this is not sufficient.

The need for active participation in irrigated agriculture accounts for the huge emphasis in the literature on the importance of Water Users' Associations (WUAs), and is reflected in many policies and programmes in China. Much progress has been achieved with WUAs, but it is important to be realistic and not expect more from them than they are capable of achieving. WUAs are, however, only one aspect of public participation. Participation in general is described first below, before consideration of WUAs in detail. This is then followed by wider discussion of issues related to communications and general awareness raising, and finally environmental education.

Box 6.3 Participation in water management in China

The importance of participation in water management and in building a harmonious society is recognised at the highest level in China. Hu Jintao said at the 17th National Congress of CPC, October 15, 2007 that we should: "*Expand socialist democracy and better safeguard the people's rights and interests as well as social equity and justice… ensure that all power of the state belongs to the people, expand the citizens' orderly participation in political affairs at each level and in every field, and mobilize and organize the people as extensively as possible to manage state and social affairs as well as economic and cultural programs in accordance with the law… people's democracy is the lifeblood of socialism*"

Public participation

Public Participation can defined as *direct participation* by *non-governmental actors* in decision-making (Mostert, 2003). *Direct participation* includes many different activities: the opportunity to send written comments, referenda, water users' associations, mass demonstrations, legal action, etc. This may be spontaneous or fostered by the government. *Non-governmental actors* include individual citizens, individual companies, public interest groups and economic interest groups. It is recommended that women, or women's groups are specifically identified, given their direct responsibilities in relation to water and food production (see TP6.3: social issues in IWRM for further details of this topic).

Public participation has several benefits and should lead to more sustainable water management in all senses: economic, environmental and social. More specifically, it can result in water demand management through several processes, such as:

- Better-informed and more creative decision-making, on the basis of better knowledge of local conditions.
- Greater public acceptance of decisions, fewer delays and more effective implementation since the public has had an opportunity to have its say, even if this does not change the decision.
- Social learning and 'water awareness,' so that the public, government and experts can manage a complex river basin and deal with conflicting views and interests.
- More open and outward-looking government and enhanced democracy.

The value of participation is well-recognised now, but there is a tendency to underestimate the difficulties of achieving it. Effective participation is not easy:

- It may be started too late (ie after key decisions on water management have already been taken); the results may be ignored (resulting in even less public acceptance than before); or the costs may be deemed to great.
- Public response may be limited and unrepresentative, and dominated by small interest groups. Vulnerable groups may be reluctant or feel their views will be ignored; many groups lack the resources to participate; and many may simply feel that they should not be expected to take on responsibilities from the Government.

- Quality of the response may be low or inconsistent, although this should be mitigated by providing good information and stimulating social learning.
- There is a cost to participation, even if the costs are offset by longer term benefits. It is reasonable that the public should be financially supported to cover the costs of specific participation efforts of the public. A stakeholder analysis can be used to discover which stakeholder groups lack the financial resources to participate (Mostert, 2003).

Effective participation in water demand management depends on the government and non-government actors having knowledge of participatory approaches and methods. "*It requires an open, transparent and outward-looking government that recognises that it cannot solve current water management problems on its own and has sufficient confidence to enter into direct discussion with its citizens. This is the real challenge of public participation*".

It is important to consider who the actors are in the various aspects of WDM, what their roles are, and what the scope of the participation is. It is then possible to ensure effective participation and achieve the objectives of sustainable water management. The nature of participation should vary greatly to suit the local cultural context and political system. Different approaches apply in situations where there is:

- ***Representative democracy***, where decisions are taken by politicians who are selected by and accountable to the public through regular elections – thus combining professionalism with popular control. There is traditionally little participation apart from in elections, although powerful interest groups can influence decision-making, and the direct role of the public could be strengthened
- ***Direct democracy***, where individual citizens participate directly in government, giving the public more control over public affairs and counterbalancing the power of government bureaucracies and sectoral interest groups.
- ***Subsidiarity***, which emphasises the role of intermediary organisations between government and individual citizens. Government recognise these organisations and only responsibility only for those tasks that they cannot perform satisfactorily. Water users' associations are an important example of such intermediary organisations.

Further discussion of the nature of participation is outside the scope of this document, but there is a very extensive international literature on the subject.

Water User Associations

Water user associations are an important form of public participation for irrigation management, following the subsidiarity principle. Analogous organisations are commonly adopted for rural domestic water supply and, less often, for urban water supply. These are widely expected to result in water savings, although they will only achieve this indirectly as a result of improved management: they are rarely, if ever, set up specifically to use less water.

At first, WUAs were often set up to facilitate participation in management at low levels in systems largely managed by others (participatory irrigation management - PIM), but increasingly they are promoted for irrigation management transfer (IMT) where responsibility for large parts of the system are taken over by the users. This is anticipated to improve management, make it more responsive to needs, and reduce costs (particularly to governments). It is also expected to reduce water consumption – this can be achieved by reducing the 'management losses' which can occur when there is weak management which delivers the right amount of water but to the wrong places or at the wrong times.

Areas where participation is particularly valuable are:

- Participation in management of canals and infrastructure
- Participation in abstraction and flow monitoring
- Awareness of water resources, water savings, permits, etc.

Numerous documents have been written on procedures for establishing and supporting WUAs, and a range of national-level documents and training materials have been prepared by the China Irrigation and Drainage Development Centre (CIDDC). It is not intended to repeat these here, but just to stress the need for a comprehensive approach and for adequate support. Without the right institutional environment and adequate technical support, WUAs will not be effective and will soon lapse to become 'paper organisations' or worse. As noted earlier, failed attempts at participation are often even more demoralising than no participation at all.

Brooks, for example, stated that governments give Participatory Irrigation Management (PIM) nominal support, but do not provide incentives, mechanisms and regulations to allow local management to flourish. Clearly, some governments are less enthusiastic about local water management than they claim. It should be noted that the increase in water delivery and use efficiency does not necessarily imply a reduction in water use; more commonly, it means that tail-enders on the water system now get water regularly – greater equity and efficiency, but not less water use. Other, less well documented, benefits include reduction in conflict and a sense of empowerment that is said to improve family health and well-being (Brooks, 2002).

The Pro-Poor Rural Water Reform Project in China, supported by DFID and the World Bank, has promoted the development of democratic and inclusive Water User Associations to manage, operate and maintain small-scale irrigation schemes. Nearly 500 water user associations that promote more equitable sharing of water resources between communities have been set up, resulting in the reduction of conflict, water savings, increased transparency and revenue collection, and the empowerment of women.

Five principles have been found to be crucial for establishing and sustaining a WUA in China:

- A WUA is the farmers' own organization - its management body is democratically elected, and it is a registered legal entity;

- A WUA is formed in accordance with hydrological rather than administrative boundaries;
- There should be a water measurement device at intake, where the WUA takes over responsibility, so that the WUA pays water on volumetric basis;
- A WUA collects water fees from farmers and pays directly to the irrigation company based on a contract, symbolizing a clear commercial relationship between water provider and buyer;
- There should be a functional irrigation system, supplying water to the WUA.

If any of these five principles is not met, it is unlikely that the WUA would sustain itself in the long run. Financial transparency is another critical factor in building farmers' trust and a sustainable WUA.

Participation in management of canals and wells

Management of **groundwater irrigation** is traditionally done by production groups on an independent basis, however there is an emerging recognition that there is a need for some overall control of this otherwise farmers can simply pump excessive and unsustainable amounts of water. A key part of any WDM programme will be to restrict such excess abstraction. Control by the WMD is one option for this – either using technology such as IC cards, or by simpler methods - but it is generally recognised that it will be difficult to enforce this control unless there is some local involvement in management. The WUA and perhaps an overall aquifer-based organisation will play a key role in this. This will include:

- Involvement in decisions on entitlements
- Management of permits and related tasks
- Monitoring water use and groundwater level
- Assistance with maintenance, ensuring efficiencies of scale (eg by employing a technician to be responsible for groups of wells
- Financial management
- Coordination with higher level organisations and ensure farmer interests are recognised
- Ensuring fair access to training, information and technical support
- Coordination with adjacent villages and WUAs

Local participation in **surface irrigation** is better understood and easier to achieve, as there is much more experience with WUAs in China and overseas. Not all WUAs are very effective, and the weaker ones need to be strengthened. WUAs are rarely established with the specific objective of WDM, but they should improve local management and the equity of distribution, and reduce conflict over water. This should reduce demand for water. Support to strengthen WUAs will include measures to:

- Identify the functions and activities of existing WUAs, and

- Assess the skills and resources available for water management, and
- Identify areas where WUAs and subordinate water user groups are able to improve management,
- Increase awareness of water resources and demands, and hence ways to reduce the mismatch between them, and
- Undertake capacity building as needed for WUAs to undertake these activities, and ensure that the WMD/WMS provide a reliable water supply to the WUA and the technical support required.

WUAs are required to assist in wider aspects water resources management, and to take a more significant role than the village has done in the past. They will need to work with WMD, and it is reasonable for them to be paid a portion of the water resources fees collected in order to compensate them for their activities.

Several documents in this series cover many aspects of establishing and supporting WUAs to be effective and sustainable. This is an issue which needs careful attention. WUAs can be highly effective, but only if they are properly established. Attempts to economise on support and capacity-building will be counterproductive. TP3.1 and the four advisory notes in AN6.2 should be referred to for an in-depth analysis. In addition, documents prepared for the Pro-poor rural water reform project are invaluable (see CAAS, 2009).

Participation in abstraction and flow monitoring

A key area where there is a need for community participation is in monitoring flows and (in the case of groundwater) water levels. This is essential for stimulating an understanding of water management, and for providing the community with the information they need so that they can improve standards of management (see section 6.2). This is required both for day-to-day management and as a part of a wider environmental education programme to build an understanding of water resources and uses (see below).

The WUA needs to liaise with the WMS in order to monitors flows into the branch canal (or wherever water is delivered into the WUA area of responsibility). This can be a complex task: there may be several different channels which need to be monitored (and there may be flows out of the WUA as well). The WMS and WUA need to monitor not only the flow rate (m^3/sec) but also the duration so that the total volume can be calculated. If flows are variable this can become a very difficult task.

WUAs need training in use of flow measurement structures, or alternative techniques such as current metering, and they need to be aware of the accuracy of these methods.

There is often a temptation to simplify the process, make fewer measurements than necessary, or assume that actual deliveries are the same as the norms. This undermines the whole process of water management. It is important that measurements are made in appropriate times and places, and that they are done well and as accurately as possibly. Furthermore, unless the WUA and its members are confident in this process, they are unlikely to manage water well within the WUA and thus they would be unlikely to implement water savings techniques.

The WUA also needs to manage and monitor volumes to individual users – this may not be done by explicit flow measurement techniques, but they will need to devise simple water distribution rules and monitor compliance with these. Use of traditional techniques, such as time to reach a specified depth in each corner of a field may be sufficient.

Awareness of water resources, permits and other management tools

Construction of a water saving society depends very heavily on building an awareness of water. This requires actions to:

- Stimulate wide public understanding of issues, through information campaigns and involvement in relevant management activities
- Ensure that expectations are realistic
- Ensure wide knowledge of methods for water saving
- Ensure information on water use and water saving is widely and freely available
- Monitor changes in behaviour, knowledge and provide feedback so that the water saving society plan can be improvement.

It is only if people understand the availability of water and the constraints to its use that they will appreciate the need to manage it economically. Facilitation participation in monitoring water resources and uses is an important way of encouraging people to use less (van Steenbergen, 2006).

Environmental education

The problems of water management are long-standing and will continue long into the future. It makes sense, then, to include these issues into the school curricula for those who will have to grapple with these problems in the future – whether as users or as future water managers. Moreover, the understanding gained at school through such an educational programme can be quite profound even in the short term, since children can influence their parents. Such approaches have been tested and found effective in many countries.

For example, in the Brazilian Northeast a recent programme (Mott MacDonald, 2006) aimed to improve on the present low levels of community organisation and limited experience with communal management of water resources. Although, in the past, there had been good local knowledge of traditional methods of land management, this had faded after introduction of modern irrigation technology and this led to overuse of the limited groundwater resource.

The project was based on the principle that improved rural community understanding of their water and land resources is fundamental to improved livelihoods and long-term community stability (including a reduction in out-migration). The approach was a participative environmental education programme, targeted at younger as well as older community members and with a major focus on water and land in three municipalities in Pernambuco region. Although implemented through the existing school systems, it involved local farmers, who worked with the teachers in the dissemination of knowledge to the students. Such participation not only empowered the farmers, but it acknowledged the importance of local knowledge.

In the context of demand management, key features were that the programme demonstrated a replicable approach to environmental education and

- Established monitoring facilities, managed and maintained by the community.
- Developed an appreciation of the value of environmental education and monitoring.
- Encourage active involvement in water resource monitoring, data analysis and dissemination.

Another programme, in South Africa, took a similarly long term view, and also targeted children. It was felt that this was the only approach for successfully stimulating a change in human attitudes and behaviour:

> *"One outstanding feature of the WDM approach is the fact that it is designed to achieve sustainability. This involves changing people's attitudes to water and water consumption over time. In this regard the Hermanus case offers some unique and insightful aspects. In the short-term, attitude changes are ensured through the provision of information that simply empowers consumers to make decisions that impact on their own pockets. Over the long-term, children are being targeted as the basis for the needed fundamental attitude shift".*

Rural demand management: education, awareness and behaviour

Water demand management needs broad public support and understanding, and creating water awareness is increasingly seen as important. Information is a powerful tool for raising awareness and empowerment through engaging the public. People are unlikely to be willing to save water unless they believe that others are facing the same restrictions.

Water campaigns can use a number of communication methods such as

- Direct use of conventional media (printed media, TV, radio, brochures, slogans)
- non-conventional media (messages on water bills, games, comic books, etc)
- Organization of large events and specific awareness programmes.
- Use of street theatre, local festivals etc
- Use of existing networks (religious networks, social movements, NGO networks, business associations)

It should be remembered, however, that information and awareness is not sufficient – people must have the knowledge, skills and incentives to act on the information. This usually requires specific technical support and training. Awareness without follow-up is unlikely to yield significant benefit.

Such programmes need to be extensive and do require funding. Such funds are very small in comparison with other water management activities, but this is a new category of activity and governments often find it difficult to allocate resources for this purpose. There is scope for reducing costs – through careful use of existing media and possibly with support of the private sector (suppliers of water-saving equipment) – but the campaigns do need to be carefully designed to ensure that the both the content and the delivery method are sound.

Urban demand management: education, awareness and behaviour

Domestic customers

The water sector must target its communications effectively to ensure the best take up of the demand management messages. Clearly initiatives aimed at influencing industrial or commercial users need to be framed differently from mass public education campaigns. Similarly emergency measures required during a drought need to be promoted with a distinct sense of urgency.

All urban water supply demand management measures should be accompanied by a long-term public education programme to generate and sustain consumer awareness of the need for sensible water use to achieve national objectives on water conservation. A public education programme can use various communication channels, such as leaflets distributed with water bills, WSC and other web sites, TV and radio messages, posters or public notices in newspapers.

Actually reaching the target audience and successfully influencing their behaviour is a difficult task when most urban water users are in an environment where they are constantly bombarded with advertising and information. To catch and hold their attention requires a professional approach to communications, including a thorough evaluation of the success, or otherwise, of all dissemination activities.

In the UK, for example, the Environment Agency stress the

> "*need for people and businesses to value and hence use water more efficiently, and have a greater understanding of how managing water resources effectively will benefit society and the economy".*

They recognise that this is not easy to achieve. Financial methods are perceived to be very effective, and highlighting the connection between water and energy is now regarded as a promising approach – a large part of energy bills in the UK cover the cost of heating water. Thus a combined approach is now being promoted:

> *"There should be a co-ordinated communications campaign to ensure that water efficiency and water conservation messages are more effectively targeted. The expanded remit of the Energy Saving Trust to cover energy and*

water will help provide consistent messages and should be much more effective in reaching consumers and changing behaviours"[17].

Communication between a WSC and its customers is central to encouraging water saving. Metering saves water and also makes customers more likely to engage in demand management activity. Therefore directing information on demand management opportunities to metered customers with their billing is particularly effective. Smart metering is particularly useful for improving awareness of water use (and hence costs), and relating this to payments for water. Such meters can provide detailed information about patterns of water use in the household. These can have a direct impact on water use, by stimulating an understanding of how water is used and where it can be saved. These will help in preparing water audits as described in Chapter 8.

The internet is a powerful tool in awareness-raising because of the ease with which anyone seeking information can move from site to site via directed links. A WSC customer may access the WSC's web site and from there be directed to the national standards organisation or to firms selling water efficient appliances or to the water resources agency for drought status reports etc.

Women are the main water users in the home and often have responsibilities for managing household finance: water saving publicity campaigns should focus on this target audience. Messages used in the UK may include

- A humorous poster campaign featuring a well known television personality to get people to take quicker showers (maximum of 5 minutes) to save water.
- Only use your washing machine when you have a full load, to make the most efficient use of the machine and save money.
- Wash food items under a running tap and collect the water into a basin to be recycled as grey-water.

Assuming that they are reached by the publicity campaigns many people are quite ready to take up water saving in the home including:

- Using displacement devices in large toilet cisterns
- Taking short showers
- Using their washing machine only when full
- Not preparing food under a running tap
- Collecting greywater for recycling in the garden

These same activities are usually promoted more strongly by WSCs during droughts. Experience in some drought-affected areas such as mid-western USA and Australia, has shown people respond well to appeals to save water provided they are kept well informed of the situation and appreciate the need to conserve water. However, such appeals must be used for limited periods (a few months at most) and water supply companies must be open and honest with their customers. Water demand

[17] UK water demand management bulletin Issue 94, April 2009:

management must be clearly distinguished from the extreme measures required short term in droughts

As a minimum, consumers should:

- Be able to obtain advice on:
  - the sensible use of water in the home and industrial and commercial premises
  - how to conduct an audit of their own consumption
- And to be aware of:
  - the availability of water saving devices
  - the availability of free customer supply leak detection and repair, and a leak-line telephone number
  - how to get further information.

Box 6.4 Sydney - the benefits of an informed community

Outdoor water conservation:

- 93% of Sydney Water customers are aware of the 'Go Slow on the H_2O' campaign
- Water conservation website had 348,000 visitors in 2004-05
- 100 billion litres reduction in use each year under restrictions

Indoor retrofits:

- 75% of Sydney Water customers aware of the programme
- 310,000 homes have participated
- 6.5 billion litres saved each year
- A$30-$100 in utility bills saved for each participating household

Every Drop Counts Business

- over 7.3 billion litres saved each year
- 304 participating partners

Source: 2006 Metropolitan Water Plan

Education and publicity are two key components of a demand management policy. School children, who are effective at taking the message of the importance of saving water home to their parents, are a key target audience. However, it is also important to explain to adults why it is necessary to save water, how they can contribute to savings and how using water carefully can help reduce their water and wastewater bills. This is effective when combined with increases in tariffs and the imposition of new tariff structures that penalise unduly high consumption.

Education campaigns can cover:

- The importance of not wasting water, including replacing washers on leaking taps, not leaving taps running, not washing-up under running taps, etc.
- Advice on purchasing water saving washing machines
- Advice on plants with a low water consumption for the garden

- The implications of excessive water use for the environment and levels of service that can be provided to all customers.
- Specialist advice for business users

Persuading people to invest in devices for the home that use less water will have a long term beneficial effect. The tariff is also an important influence here, since if people are paying the full cost of water and are penalised for unduly high consumption, they will be more likely to recoup the cost of their investments in water saving devices from reductions in their water bills.

The WSC engages with its customers through the billing process. Information on demand management opportunities that customers could take up can be sent out with bills. The WSC can also use this mechanism to promote meter use, to advertise services that it offers to assist customers with leaks or water audits, and to provide details on how to report leaks and other problems.

WSCs have a key role in raising awareness of the need for water efficiency among their customers. In this they can contribute to public education measures implemented by governments and water resources agencies to promote sustainable use in river basins.

Non-domestic consumers

It is usually easier to motivate people to use less water at home than in the workplace. Employees spend up to a third of their day at work, and thus many of their domestic needs such as toilet flushing and hand washing will be partially met at work rather than at home. Workplaces offer a further opportunity to design in water efficiency. Measures to encourage economical use of water amongst staff include:

- Make sure staff are fully aware of the importance of water minimisation
- Appoint a water monitor within the organisation to undertake periodic site walk-overs to identify water minimisation opportunities
- Train employees how to use water efficiently and establish a recognition and reward programme for employees and teams who do an outstanding job
- Where the firm operates several sites encourage the sharing of best practice

Initiatives aimed at influencing commercial users need to be framed differently from mass public education campaigns. These require a different approach that aligns with the financial ambitions of the management and recognises the pressures under which they are operating.

Businesses need to be persuaded that while water costs may appear trivial in comparison with turnover, in terms of absolute cost they often represent significant amounts of money; and that considerable reductions in costs can be achieved without requiring large investment. In fact many actions to reduce water-use have short payback periods.

Potential opportunities for water efficiency savings depend on the business sector. There is usually a range from new installations where the latest technology has been employed to older plant, both across the industry and between factories within the same firm. Many industries have a members' organisation that provides an avenue to spread best practice within their industry.

Government programmes to help foster business success are also common. More recently government programmes focusing on environmental improvements have been introduced. Water is usually one of the focus areas, especially in countries where resources are scarce.

Large industry is guided more by financial than social incentives. Water resource or other fees can give a significant signal to use less water and to adopt water-saving techniques such as improved processes or waste-water recycling. However, public pressure can have a powerful impact in some settings. Environmental pressure groups can be influential over industry in several ways:

- Ensuring the regulator is aware of breaches of abstraction or discharge permit conditions
- Persuading the public not to buy produce from a water-wasteful company
- Influencing employees to press internally to improve water saving and other environmental practices
- Naming and shaming companies that breach their legal or moral obligations with regard to water saving

6.6 Conflict resolution

Background

Rising urbanization, denser populations, diversifying economies, multiplying uses of water, global climate change, rising competition for water, and rising water scarcity are all making water conflicts become increasingly pervasive, frequent and intense. The greater the scarcity of water and the severity and frequency of conflicts, the more important it becomes to resolve conflicts quickly. Whenever there is a conflict over any resource, the parties in the conflict are unlikely to be willing to relinquish any of the resource which they have – even if it exceeds their current requirements.

Whether international "water wars" or local disputes between farmers, conflicts can erupt from disturbances caused by rising competition for ever scarcer supplies of water. Such conflicts can develop into much more extensive conflicts, far beyond 'simple' disputes over water.

Conflicts or fear of conflict can in turn lead to considerable waste of water and other resources. These conflicts can occur at every level from international down to individual users, within sectors and between sectors. For this reason, conflict resolution is identified as a specific management instrument within the IWRM toolbox.

Despite awareness of the problem, there is still little evidence of improved dispute resolution procedures, and problems continue to occur. Conflicts can be expected to increase as pressure on resources increases. There is a close link between conflicts and demand management: two aspects of this relationship are evident:

- Conflicts can arise over the implementation of some measures in a WDM programme
- Resolution of existing conflicts may reduce demand directly, and this is in itself a demand management instrument

Conflict resolution and demand management

Use of demand management as a conflict resolution technique is recognised as a topic which needs further investigation[18]. Improved management systems can reduce conflicts over water in two ways:

- Conflict avoidance – better management can ensure that water is delivered in a planned, timely and predictable manner to users, and that water users accept the need to comply with rules over the water is distributed
- Conflict resolution – an effective management organisation can provide a basis for resolving conflicts, with agreed rules and penalties for those who break the rules, and effective systems for enforcing these rules

In the context of water demand management, the converse situation – the role that conflict resolution can play in reducing demand also deserves more study. Resolving conflicts can reduce demand for water if, for example, they enable to receive water in a predictable and timely manner, thereby avoiding the need to take water through illicit methods.

Water can play different roles in conflicts. In "real" water conflicts, water is the *object* of the conflict; water can also be an *instrument* in a conflict (which occurs over some other issue); or water can be a *catalyst* for conflict and can create internal political instability.

The causes of conflicts can generally be divided in three interlinked categories:

- Factual disagreements (or different perceptions of relevant facts),
- Conflicting goals (often in regard to environmental or other externalities),
- Relational aspects (distrust or battle for power) (Mostert, 1998).

It should be noted that the potential for cooperation can be approached from the positive side – the potential for benefits (enhanced access to water, better environmental conditions), or the negative side – the avoidance of the costs of conflict, or the foregone benefits of cooperation in other sectors.

Conflicts can however, be difficult, costly and time-consuming to resolve. It is always better to prevent dispute arising than to face lengthy resolution procedures. Even if conflicts arise, local methods of resolution, through negotiation between adversaries possibly with mediation by a third party are likely to be more effective than going to courts. Adjudication by courts, however, remains the mechanism of last resort

[18] http://www.idrc.ca/en/ev-31803-201-1-DO_TOPIC.html

6.7 Information management

Introduction

Public participation and communications with non-state actors was described in section 6.5. This section covers information management within the government system – a distinct topic but equally important for demand management. A stakeholder analysis can indicate the interests of all the various stakeholders in managing water and more specifically in water demand management (TP2.2 – Stakeholder Participation). This should be used as the basis for establishing a communication strategy in order to ensure effective and timely exchange of information – both for improving management and for ensuring that all those with an interest in water are aware of how it is managed.

There are two parts to these aspects of information and communications:

- Information management systems within organisations (data collection, processing, storage and publication)
- Data sharing between organisations (of which international data sharing is a specific case).

Although there have been dramatic improvements in communications and data management in recent decades, with far-reaching developments in electronic devices which can facilitate data collection, analysis, management and communication, these are still not as widely used in the water sector as they could be – particularly for rural water use. This is surprising, since mobile phones have had profound impacts on improving access to information on agricultural markets, but negligible impact on improving water management. This is an area where there is large scope for improvement.

Effective WDM does depend on a much better knowledge of existing resources and uses, and future changes in requirements than is generally available at present. The data requirements for this are outlined in sections 6.2 and 6.3. This section covers the arrangements for managing this and sharing with other organisations and the public.

Water resource management requires vast amounts of data comes from several agencies and can take a long time to collate and check. In some situations elements of the data can be simplified or approximated without significant impact during early stages of the studies with a view to their being replaced as the data collection progresses. Efforts must concentrate on collecting detailed data on the fundamental components of the water balance but perhaps certain socio-economic data can be approximated without substantial impact on the outcome. The primary focus of data collection and preparation should be on the fundamental data for the analysis.

Poor quality data will compromise the reliability of anything based on the use of the data. Suspect accuracy is to be avoided; it is better to be approximately right rather than precisely wrong. It is important to establish a good system for ensuring the quality of data, with appropriate storage systems. Databases and GIS are invaluable tools.

Information management systems within organisations

Demand management cannot be introduced with collection, processing and dissemination of information concerning water demands, water resources, water management and the impact of water management actions, etc. Many practices relating to information management around the world are based on manual procedures, but these can be improved substantially by use of computers and communication between computers through the World Wide Web.

In the arid south west of USA, they have introduced high-technology solutions for ensuring reliable information is available to the managers, thereby removing the guesswork from management. "*The U.S. Interior Department's Bureau of Reclamation has worked with the water users to install more than 20 solar-powered monitors that constantly measure water levels and the rate of flow at reservoirs, diversion dams, canals and key points along the river itself*.

All this information is relayed by radio to a "data hut" built with assistance from the Technology Opportunities Program near Richfield, Utah. There, it is amassed on a website that gives a round-the-clock snapshot of what is happening at every key point on the Sevier River's journey from a high plateau in southern Utah to a dry lake bed in the middle of a broad expanse of desert 225 miles north and west of the river's headwaters." (Sevier River WUA). Such approaches have been introduced in some places in China, albeit mainly on pilot projects. It is likely that they will be extended in the future although they will need considerable simplification before they become much more common.

Information needs to be managed efficiently to ensure reliable and timely information on resources and uses, in a form suited to the uses it will be put. This depends on

- Data collection – effective and affordable systems, involving relevant stakeholders
- Data integrity – quality assurance
- Storage, processing and publication
- Knowledge management

As mentioned above, modern technology should make these tasks much easier than in the recent past but effective systems still need to be developed. Part of the problem is in willingness to cooperate, the view that 'knowledge is power' and the fear of loss of control if information is shared. However, the potential benefits of better cooperation and communication far outweigh these perceived risks.

Data sharing between organisations

Sharing water resources data is an indispensable component of effective water resources management. However, this is a difficult task because of the technical complexity and variety of the data and, more critically, non-technical factors, such as data policy, standards, and sharing circumstances. Most effective data sharing systems are web-based. These can offer free access to information, or have access to information restricted to "registered" users, or those who make necessary payments for information. All these are relatively easily set up and once established dissemination of information is very effective and prompt.

The United States, employing the principle that tax-payers had already made payment for all services of data collection, made access to basic hydrological information and reports freely available through the web. This has made the involvement of stakeholders in the water management processes much better informed, and produced very positive results. Other countries have much less free access to information, indicating a clear potential for improvement.

Key points to recognise when considering data sharing arrangements are:

- The need for sharing – what information is needed by whom, when and for what purpose, what is the best form for presenting this information
- Who are the stakeholders, what are their interests, openness, full picture
- What is the nature/complexity of the data
- What are the constraints to sharing – security, reliability, cost

Where data needs to be collected from several agencies it may be advantageous to formalise data sharing arrangements. Advisory Note 8.4 'Use of Inter-agency Agreements for Collaborative Water Quality Management' (see bibliography) provides useful guidance on how to set up tools such as Memorandum of Understanding to facilitate data sharing *(note the use of such tools is not restricted to water quality management)*. Stakeholder participation in the activities which use the data can yield substantial benefits

To make processed data available and useful to the stakeholders it is important that clarity in presentation is achieved. The use of advanced database and spreadsheet systems allows for rapid interrogation of data and for production of graphs and simple mapping. GIS is used for visualisation of spatial data and is a very powerful medium for results processing and presentation as well as data management. Thematic papers on groundwater studies (TP1.1 and TP1.2) further address this issue.

Box 6.5 Benefits of improved data sharing for demand management (Australia)

Drought and climate variability severely affect Australia's stressed water supplies, making access to reliable water data a critical requirement for effective and sustainable water management.

Over 600 agencies hold water resources information and there is no mechanism exists to distribute and merge this data. The new national water initiative aims link individual data management systems, and this will provide benefits to river managers and facilitate a clearer understanding of system losses due to theft or leakage.

At the local level, users would have access to real-time data so that they can schedule irrigation better and use more efficient irrigation procedures. With broader access to data, quality would improve, and productivity and efficiency could be more precisely monitored by local users.

http://www.nwc.gov.au/resources/documents/4._Benefits_of_improved_water_data_sharing_-_PS1.pdf

7 Irrigation Water-saving and Demand Management Techniques

7.1 Introduction

A recent statement made by IWMI (International Water Management Institute) provides the context in which all irrigation demand management options need to be considered (Box 7.1). All irrigation demand management measures need to be evaluated in the context of their impact on the water resources system as a whole

The main pathways for enhancing water use or achieving water saving in irrigated agriculture are to increase the output per unit of water (engineering and agronomic management aspects), reduce losses of water to unusable sinks, and reduce water degradation (environmental aspects). Recent work in China has highlighted the importance of "ET management" as being the most promising approach. This is described in more detail in Section 7.7.

Box 7.1 Limitations to demand management in irrigation

"Most of the water saving options identified and promoted to overcome the growing scarcity of the resource, do not save much of it. Very often, they divert water from one place or use to another and open the possibility for more productive use of the same volume of water.

Unless freshwater is 'lost' irretrievably to the ocean or a saline aquifer, it is often reused somewhere in the river basin. Water running into a drain is reused downstream; when water seeps into shallow groundwater it is pumped by another farmer; water released for irrigation of rice is used by coconut trees downstream of the irrigation. Seepage from canals and fields is often a major source of domestic water supply, particularly in developing countries. Accordingly, the common practice of increasing the efficiency of water at farm and irrigation system levels, overlooking the basin perspective, has several negative impacts.

Essentially, the function of water savings should be freeing up of water from non-beneficial use and providing it to another more productive use. In agriculture, it is often possible and also advisable to identify means that decrease non-productive uses of water, and release the resource for other uses. Reducing flows to sinks or non-beneficial evaporation, for example, to water logged areas, would lead to some water savings."

7.2 Crop types and physiology

Water shortage is probably the single most significant challenge that will confront the world's farmers in the coming years. Droughts are increasingly common, and research funded by the National Science Foundation in the US recently found that drought areas have more than doubled in the last 30 years, with climate change implicated as at least part of the cause. Drought tolerance is a feature of some crop plants, and for many years farmers and, more recently, plant breeders have taken advantage of these tolerant varieties in traditional breeding.

Internationally, crop breeding over the last century has increased the productivity of water by increasing yields without increasing crop water demand. The focus has primarily been on getting more yield per unit of land. It is only in the past decade that attention has turned to producing crops that can yield more with less water, withstand water-scarce conditions, and thrive on low-quality (saline/alkaline) water. Scientists have already identified traits and genes for drought-and salt-tolerance in a number of crops. For some crops, conventional and molecular breeding techniques are expected to yield results by 2010 (see Table 7.1).

Table 7.1: Genetic approaches to increasing crop water productivity

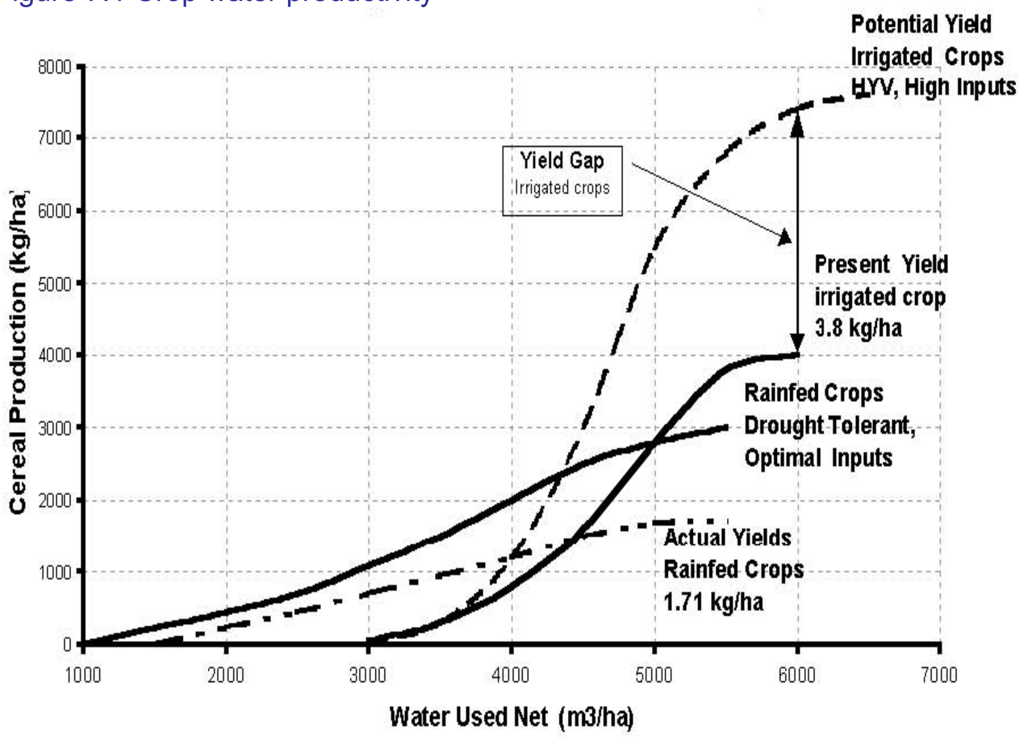
Water productivity factor	Genetic approach	Probability of major progress by 2010
Minimise non-transpirational uses of water	Herbicide resistant crop.	Low
	Weed competitiveness.	Low
	Heat and cold tolerance at flowering.	Medium
	More efficient cooling via evapo-transpiration	Medium
	Nitrogen-use efficiency.	Medium
	Nitrogen fixation	Low
Reduce water consumption without reducing production	Waxy cuticle production	Medium
	Rapid stomatal closure	High
	Cooling mechanisms for leaves	High
	Rapid canopy closure	Low
	Thicker more intact casparian strip	High
	Sustainable production of aerobic rice	Medium
Increase production without increasing water consumption	Short duration seedling vigour	High
	Higher harvest index	Medium
	C4 photosynthesis per unit area transpired	Medium
	More photosynthesis per unit water transpired	Low
	More dry matter allocated to grain after stress	Medium
	Stay green flag leaf	Medium
Use lower quality water	Tolerance to salinity	High
Less water management	Tolerance to water-logging	Medium
	Tolerance to submergence	High

Source: Bennett – 'Water Productivity in Agriculture', 2003.

The Future Harvest Centres of the CGIAR have already released drought-tolerant varieties of several crops for evaluation by collaborating institutes and farmers, including rice, maize, wheat, barley, cowpea, groundnut, lentil, and sweet potato. There are, for example, varieties of maize which can yield up to 50 per cent more than traditional varieties. Short-duration varieties of some crops, such as chickpeas can avoid the drought period by maturing early. Comparable research is currently underway in China.

Water stress affects crop growth and productivity in many ways. Most of the responses have a negative effect on production but crops have different and often complex responses to shortages of water. Crops or varieties which have the highest productivity under optimal water supply and soil fertility conditions may be highly sensitive to water stress. Different varieties may give better yields under sub-optimal water conditions, as can be seen from Figure 7.1. This indicates that high yield varieties of cereals will under-perform other varieties if the total water supply (from irrigation and rainfall) of less than about 4,400 m^3/ ha (300 m^3/mu), even though under optimal conditions 6,000 m^3/ ha (400 m^3/mu) they will yield double. The precise figures will vary according to location and type of crop, but this conclusion is generally valid.

Figure 7.1 Crop water productivity



If large water resource savings are needed, then major changes in crop type or land use may be needed. There is significant potential to substitute irrigated cereal crops with higher-value crops, possibly in greenhouses. The water implications of washing and other post-harvest activities and also need to be considered – some water may be needed for this on-farm, as well as there being a need for suitable local processing facilities

Horticultural crops (fruit and vegetables) are very valuable and can be a productive use of water when expressed as value per unit water consumed (RMB/m^3). However, they are water-intensive per unit area, there are limitations to demand, and many deteriorate rapidly in storage. They form an important part of a demand management strategy, but they are only part of it – other crops will be needed as well. These crops are sensitive to method of irrigation which can influence yield and quality, and hence price and marketability. For example:

- tomatoes may have lower solids content when grown with drip irrigation compared with furrow irrigation, but they are susceptible to root phytophthora, and hence waterlogging should be avoided.
- onion crops under sprinkler irrigation are at risk of downy mildew,
- lettuce crops are extremely sensitive to water stress.

It should be evident from the above, that any plan for reducing water demand by changing crop patterns to focus more on water-saving high-value crops will need careful specialist investigation of alternative crops and livestock, taking account of, *inter alia:*

- the crops grown at present,
- knowledge of alternative crops,
- implications for water management,
- soil conditions and water quality
- other factors influencing crop choice (costs, markets, labour requirements, access to inputs, skills/knowledge, sources of information, etc).

7.3 Agronomic techniques

There are many agronomic measures which have been widely proposed to keep water in the field, distribute water more efficiently across the field, or encourage the retention of soil moisture. These measures include land levelling, non-tillage in the dry season, deep ploughing in the rainy season, soil fertility improvements, organic and plastic mulching, balanced fertilization, improvements to planting and cultivation techniques, changes in cropping patterns, breaking up of extremely compacted soils, and furrow bunding to prevent runoff. Typically, field practices are not very costly although the local impact can be significant – even a small increase in labour requirements can make cultivation a less attractive proposition that off-farm employment.

One of the watsave awards, referred to earlier was for an improved method of pre-season cultivation for winter wheat in Turkmenistan which was found to save about 20% of the crop irrigation requirement. Another was for a simple form of mechanisation (see photo on right) to create raised beds for wheat cultivation in Pakistan, saving 50% of water and increasing yields by 25%. The same methods can also be used for maize and cotton, with similar results

Some of these techniques need more sophisticated equipment – especially for laser levelling – which needs to be used on a cooperative or commercial basis, and thus requires a change from traditional farm management practices, but often simpler variants are possible and still beneficial. Some simple mechanisation is valuable and may be possible with relatively simple locally produced equipment. Uptake of these techniques may be improved if cooperative management systems are introduced (eg, by a WUA – see section 6.5). These are described further in TP3.1 (water saving in irrigated agriculture) and AN6.1 (Role of WUAs in water saving in groundwater irrigation).

In addition, forestry shelterbelts around fields will slow wind velocity and help reduce evaporation. Experiments and practice has shown in China and elsewhere that substantial increases in agricultural production (and value) per unit of ET can be achieved through these types of measures. These are "real" water savings, although the water consumption of the shelterbelt itself must be taken into account.

Table 7.2 Summary of agronomic practices linked to water saving category

Item	Comments	Constraints to adoption
Water Related		
Alternate row irrigation	Suitable for row crops but depends on irrigation system	Requires more labour and management than conventional furrow irrigation
Minimise pre-planting irrigation		Requires control over the irrigation supply
Minimise time between pre- planting irrigation and planting		Requires control over timing of irrigation; availability of labour and farm machinery.
Soil related		
Reduced or conservation tillage		Cost, availability & maintenance of machinery
Zero tillage	Placing seed on saturated soil without tillage	Reduced yields unless fields are level
Raised beds or broad beds and furrows		Requires tools, also labour requirement if beds have to be remade each season.
Row spacing and orientation	Affects interception of radiation and if planting is on contours, reduces runoff	Requires flexible seed drill; may be more labour intensive
Land Levelling	Prevents ponding and unequal application of water	Requires skilled labour and machinery; to be repeated every 2 to 3 years
Mulching and residue management	Lowers evaporation from soil surface and reduces runoff	Gravel mulches etc are expensive.
Application of organic matter	Increases water holding capacity of the soil	Organic matter is scarce and often used for other purposes. Can decompose quickly.
Plant related		
Timely planting	Timely sowing, weed control, fertiliser application, nutrient management and best crop rotation raise yields	Requires good farming skills and extension services; labour intensive.

Source: Kijne in 'Water Productivity in Agriculture' 2003.

Deficit irrigation is a promising approach for severely water-short areas - studies in Syria have shown that applying 50 percent of the irrigation requirement at the correct time only reduces yields by 15 percent. This requires a good understanding of the relationship between yield and water deficit, arrangements for support and incentives so that farmers adopt the practice, and infrastructure which can deliver carefully targeted volumes and timing of deliveries. FAO Technical Paper No 33 "Yield Response to Water" provides considerable body of technical information on this subject and much more work has been done subsequently. In China much experimental work on deficit irrigation in central Hebei as well as other parts of the North China Plain. However, it remains a difficult to concept to implement systematically. Prof Kang Shaozhong was given a Watsave award for his work on regulated deficit irrigation in the Shiyang River Basin in Gansu (Box 7.2).

Box 7.2 Regulated deficit irrigation in Gansu and Shaanxi

Prof Kang studied regulated deficit irrigation technique for maize, wheat, cotton and other crops in Shanxi, Gansu, Shaanxi and Xinjiang of Northwest China from 1995-2002. The degree of water deficit can reach 45%-50% of field capacity without a serious effect on crop yield. He derived that the feasible regulation deficit indicator of winter wheat for each crop stage and soil horizon: for example, the soil moisture content should not be below 60% of field capacity in 0-50 cm soil layer before winter, but should be higher than 60% of field capacity in 0-100 cm soil layer in tassel to milking phase. There should then be no obvious reduction of yield.

For maize, moderate or light water deficit is feasible, with the soil moisture above 50% of field capacity in seedling season, above 60% of field capacity in jointing season, and sufficient irrigation for other periods.

For cotton, bad effect of soil moisture as low as 48% of field capacity on cotton alimentation growth can be recovered by irrigation in budding season.

The optimal techniques of regulated deficit irrigation were applied on 10,000 mu in Hongdong of Shanxi Province, and irrigation water use was reduced by 34% and crop yield increased by 19%.

Further details are given in his book "*Principle and Practice of Deficit Irrigation*" which was published by China Water Resources and Hydro-power Press in 1995 and his paper "*Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China*" Agricultural Water Management, v55 n3, p.203-216, 2002

Irrigation is traditionally designed to avoid crop water stress and to meet maximum ET needs, for a specified cropping pattern (with a specified reliability, typically 80%). Surface irrigation infrastructure and management procedures may lack the flexibility to deliver water to do other than meet design requirements.

More flexible irrigation management is often needed to make best use of limited water supplies. This has already been provided in some places, but it should be note that where precise control of deliveries is possible, water applications may already be adjusted in order to meet quality or other requirements. See for example Box 7.3 which indicates how deficit irrigation is used in California for quality control rather than water saving purposes.

Alternate partial root-zone irrigation (CAPRI) is another technique to improve crop water use efficiency by exploiting the plant physiological responses to partial soil drying in their rootzone. This exposes approximately half of the root system to soil drying while the remaining root system is fully irrigated.

Box 7.3 Regulated deficit irrigation in California

This is standard practice for many crops, to achieve the required quality. The potential to save additional water through deficit irrigation is less than often perceived. For example, it is already practice on:

- Grapes for wine to control sugar content
- Tomatoes to control solids content
- Cotton to maintain a balance between boll and vegetative growth
- Almonds to avoid hull rot

Source CM Burt, Irrigation Training and Research Centre, California (2010)

The wet and dry sides of the root system are alternated on a time cycle according to crop water requirements and soil drying rate. The method is based on four theoretical considerations. Firstly, fully irrigated plants usually have widely opened stomata. A small narrowing of the stomatal opening may reduce water loss substantially with little effect on the photosynthesis. Secondly, part of the root system in drying soil can respond to the drying by sending a root-sourced signal to the shoots where stomata may be inhibited so that water loss is reduced. Thirdly, controlled partial root-zone wetting and drying alternately can stimulate the root uptake ability for soil water and nutrients. Fourthly, partial root-zone watering can enhance soil water movement from the wetted part to the dried part, and reduce the depth of water infiltration.

7.4 Field irrigation techniques

Introduction – the need for better field techniques

Although for most crops, production and yield is directly related to crop water use, so that a decrease in applied water will often directly decrease yield, there are management strategies that can improve water use efficiency without decreasing yield. These include improved irrigation scheduling and crop specific irrigation management which often not only conserves water, but also saves energy and decrease farmers' costs.

Traditional flood irrigation, whereby water is received 3-4 times per year to a depth of perhaps 20 cm is a simple method of irrigation commonly used in parts of Chian– it requires little labour to manage and is well known, but it and leads to considerable local losses and wastage – due to field bunds breaching; erratic land level within fields; disputes and struggles during irrigation (which requires coping with high volume flows for short durations under difficult circumstances, including at night); etc Furrow irrigation is in common use, but it can be optimised through better selection of furrow length and slope, and of flow rates and durations.

The need to improve irrigation techniques and to increase the productivity of water is a prime concern of farmers throughout much of the world, particularly in countries such as Australia and Israel where pressures on the resources are extreme and farmers seek actively to increase their incomes in face of declining global prices for many agricultural commodities. Much of this information is readily available in standard textbooks and on the internet. More recent research is available in academic journals, both in China and internationally. It is not intended to repeat this here, but just to highlight certain key topics in relation to WDM.

Some of this is available for example on www.npsi.gov.au (National Program for Sustainable Irrigation) and www.irrigation.org.au in the case of Australia. Useful freely available information includes publications such as *Irrigation Insights Nr 5: Water Use Efficiency* and *Irrigation Essentials: Research and innovation for Australian irrigators.*

Israel has made huge progress in productive use of water: agricultural output has increased sevenfold over the past 25 years with hardly any increase in the amount of water used. "*Growing vegetables has become an art in Israel - based on choosing the right hybrid varieties, fertilizers and irrigation methods, selecting greenhouse covers designed for specific crops and employing innovative growing tools, harvest equipment and post-harvest treatments, and profitable market niches such as organic produce, as well as specialties like herbs and selected mushrooms".* The area of greenhouses for vegetable cultivation tripled in the 10 years to 2000, and tomato yields have reached an average of 200-300 tons under controlled climatic conditions in greenhouses. Some crops, notably tomatoes and melons, have been adapted for growth in the desert with saline water irrigation Almost the entire cotton crop is drip irrigated, using mainly treated sewage.

The key to this success lies in the two-way flow of information between researchers and farmers. Through a network of extension services (and active farmers' involvement in all R&D stages), problems in the field are brought directly to the researcher for solutions, and scientific results are quickly transmitted to the field for trial adaptation and implementation[19].

California is another region which has made considerable progress in maximising the agricultural productivity of water (see Box 7.4)

Box 7.4 California – the future of agriculture

- More irrigated land will be abandoned, particularly in water-short or saline areas
- Yields will increase: tomato yields have increased from 40-70T/ha over 10 years, almonds from 2-4T/ha – to a combination of due to irrigation design and management, improvement varieties, pest management and better agronomic practices
- More reliable water transfers between basins (north to south)
- More urbanisation of agricultural land, and better management of urban environment

Burt (2009) Water conservation's role in California water transfers, ITRC paper P10-006

[19] www.mfa.gov.il/MFA/Facts+About+Israel/Economy/Focus+on+Israel-+Israel-s+Agriculture+in+the+21st.htm

Farm level water audits

Audits at farm level are a useful technique for farmers to determine where the most water is used on the farm, and help identify leaks and losses (evaporation or seepage), and thus where they can save water. It is only then that it is possible to develop a strategy to save water in the easiest, most cost effective and least work intensive way.

Such an audit needs to consider:

- Are irrigation bays/furrows lengths and bay widths appropriate for the crop type?
- Are channel openings and water supply appropriate?
- Are watering times the correct duration?
- Does the irrigation layout meet agronomic needs?
- Given current water reform policies what changes are needed to ensure farm sustainability?

A more detailed set of questions are presented in Box 7.5. These were developed for Australia and are not directly applicable to the situation in China, but thaey can be used as a basis.

Runoff from fields and furrows can be surprisingly high: Runoff from contour and border check systems has been reported as high as 20% of water applied; and for furrow systems, it can exceed 30%. On-farm storage and recycling of surface drainage from irrigation and rainfall thus provides an alternative water supply and reduces the flow of nutrients and chemical residues into waterways. On a typical farm in Murrambidgee in Australia, this can potentially save between 250-1000 m^3/ha (15 – 70 m^3/mu) (although some of this may be available for reuse downstream, or via groundwater).

Seepage from farm channels is much less significant - perhaps 75-300m^3/ha/yr (5-20 m^3/mu), which is very small compared to the cost of channel works. In Australia farmers are reluctant to invest in this as it is usually uneconomic. Where adopted, low cost methods such as bentonite, water sludge or rice hull ash lining can save 50-80% of losses. This is comparable to the situation in China.

Farm-level audits in Australia have that the greatest potential for water saving is generally found in:

- Better scheduling and monitoring flow rates
- Land levelling (preferably using laser control);
- Matching crop to soil type and water table depth.

Box 7.5 Check list for irrigators: New South Wales, Australia

WATERWISE ON THE FARM

key checks for efficient irrigation

SERIES 3: IRRIGATION MANAGEMENT

Planning

Do you have a current whole farm irrigation plan?
Has your irrigation system been designed to suit different soil types?
Have your irrigation works been professionally designed?
Do you know where the different soil types are on your farm?
Have you investigated the soil types under proposed storages and channels for suitability?
Do you laser level all of your fields on construction, and re-laser (polish) at regular intervals?
Do you undertake a seasonal water balance or budget and update it during the season?
Do you know how much water your crops need at different times of the season?
Do you know the active root-zone for each of your crops, using backhoe pits?
Do you know the minimum amount of water required by your crops for each irrigation event?
Do you know throughout the season when your crops require their next irrigation?
Do you know the readily available water capacity of each of your soil types?
Do you time the application of the last irrigation for the season to maximum effect?
Can you recycle all excess surface water back to 100% of the irrigated area?
Do you capture surface run-off for reuse?
Do you use the crop's root-zone to store rainfall during the season?
Is the drainage capacity adequate?

Implementing

Do you contain all irrigation water on-farm outside severe storm events?
Do you control weed growth in channels and drains?
Do you empty channels after or between use?
Do you irrigate to avoid accessions past the root-zone in excess of leaching fractions?
Are the irrigation works professionally installed and commissioned?
Do you undertake seasonal and preventative maintenance to prevent algae, silt or mineral build-up in mains and laterals?

Monitoring

Do you have a soil moisture monitoring sensor below the root-zone to monitor excess irrigation?
Do you monitor, record and interpret soil moisture levels at various depths for each of your crops?
Do you know if your pump is operating at its optimum performance?
Do you measure your recycled water?
Do you have a water meter that is calibrated, correctly installed and accurate?
Do you manage on-farm storages for inflows, outflows, evaporation and seepage losses?
Do you regularly check your system's flow rates?
Do you check sprinkler heads for wear or drip lines for blockages?
Do you regularly check the differential pressure across any filtration system?
Do you regularly check your system's distribution uniformity?
Do you regularly check your system's operating pressures?

Evaluation

Are your operators and staff qualified and informed on optimised system performance?
Do you calculate $ returned per megalitre and yield per megalitre?
Do you have a supply system designed to minimise losses and energy inputs?
Do you irrigate to get water on and off the field as quickly as possible (in areas of suitable infiltration)?

Do you irrigate your crops with the minimum amount of water they need plus a leaching fraction?
Do you undertake evaluation of infield irrigation performance?
Do you know how your irrigation enterprise's performance compares at a local and industry level?
Do you revise your whole farm irrigation plan on a regular basis?
Is your system automated?

If you answer yes to all of these key checks, you are very efficient with your water use.

If there are areas where you answered no it would be worthwhile to look at these areas to improve water use efficiency.

Soil moisture monitoring

One of the most important aspects of efficient irrigation management is monitoring soil and water conditions and collecting information on water use and efficiency. The information helps in making decisions about scheduling applications or improving the efficiency of the irrigation system. The methods include measuring rainfall, determining soil moisture, checking irrigation delivery system and/or pumping plant efficiency, and scheduling irrigation. Soil moisture monitoring can involve high-tech equipment, or simple observation by farmers, but it is a key aspect of optimising the timing of irrigation. Applications of fertiliser can also be adapted to suit irrigation will further increase productivity of water.

Maintaining optimal soil moisture conditions can decrease labour needs and reduce annual costs – saving on energy and water use. Techniques for soil moisture monitoring can range from the most basic 'feel' approach to the use of meters and sensors. Simple metal probes are an intermediate approach which can be used to provide a consistent estimate of soil moisture within a irrigation scheme - the depth to which the probe can be inserted by light manual pressure gives an indication of whether irrigation is complete. A range of more sophisticated meters are also available. One of the Watsave awards, referred to earlier, was for a simple wetting front detector which could be made locally with no special skills and was designed for use in small-holder irrigation in South Africa

The cost of soil moisture meters is decreasing, making these modern techniques much more readily available. The system can be linked to data loggers to show the water moisture in different parts of the soil profile for the whole irrigation season. Advanced technologies can be used to evaluate soil type and salinity levels. These can differentiate between soils with good moisture holding capacity and leaky soils - ie those prone to deep drainage. Knowledge of soil type is useful as matching crops or crop varieties to suitable soils can increase production and decrease water use (with better irrigation strategies).

Automatic irrigation allows farmers to apply water at an appropriate rate for the soils and property conditions with minimal labour, reducing excessive water and nutrient build-up, minimising waterlogging of soils and controlling the run-off of excess irrigation water.

Such systems can be highly efficient but are still prohibitively expensive in the economic setting in many parts of rural China. They also need to be linked to a reliable and flexible irrigation system able to deliver water as required. This is a major constraint in large scale surface water irrigation but less so in groundwater irrigation.

Irrigation practices to reduce water use at farm level

The farm-level water audit should indicate where most losses occur, and hence where changes to on-farm practices will be most effective in maximise applied water use efficiency. As noted earlier, these practices typically include:

- Better scheduling and monitoring flow rates
- Laser levelling;
- Matching crop to soil type and water table depth.

Once these relatively cheap and easy savings have been made, it might be time to consider upgrading the irrigation system. Irrigation supply and drainage layout can have a large impact on water use efficiency, and traditional irrigation techniques (flood and furrow) can lead to over-watering as compared to drip, trickle or sprinkler irrigation. Inefficient surface irrigation decreases productivity, wastes water, and can lead to increased groundwater levels, exacerbating salinity and nutrient pollution. Reducing water use can also decrease labour and energy costs.

Experience in Europe suggests that communication of better public real-time information on crop water requirements to suit actual climatic conditions, and technical and financial assistance (loans) to improve equipment can both be valuable for saving water (see Box 7.6).

Box 7.6: Irrigation demand management in the Charente region in France

There are two categories of action: (i) those for the piloting of irrigation, aimed at helping the farmer define the quantity of water to bring to the crops and the corresponding period and (ii) those involving equipment for optimizing each supply of water.

- Several advisory actions for piloting exist; but the most noteworthy is the development and diffusion of an irrigation warning. During the course of a corn irrigation season, a weekly bulletin is sent free of charge to all the Charente irrigators. This bulletin, "Irrig'Info" provides data relating to local climatology, but also to potential evapo-transpiration of the plant, as well as start and stop orders for irrigation, the irrigation doses to be done during the week in progress. The information presented comes from around thirty agricultural parcels chosen to represent the diversity of soils and situations in the slope basins. This bulletin also informs farmers on the condition of water resources and restrictions that have been made.
- Actions for equipment are varied. The farmers can take advantage of financial aid for acquired equipment in order to improve the functioning of irrigation equipment. This involves electronic regulation, slow-return spouts, automated supply systems and "jet-disturbers". The second action involves equipment diagnostics (hose reels and swivels) to improve the distribution of water to the parcel and reduce overdosing. These first two actions are all the more important since the equipment fleet is relatively old and the hose reels are the most heavily-used equipment even though they are not as accurate for supply. The last action is aimed at providing financial, administrative and technical support to farmers wishing to create substitute reservoirs, with priority given to collective

actions.

- The other actions surveyed are not limited to the Charente region. They are really more like service delivery and involve technical support for irrigation provided either by the technical services department of the chamber of agriculture or by equipment suppliers.

Source: How to deal with irrigation demand in a context of water scarcity and water uncertainty: an example of combining tools in the Charente river basin in France, by S Loubier, N Aubry, F Christin, E Giry, P Garin, P-O Malaterre,Cemagref, Montpellier France

Irrigation scheduling

Careful water management and irrigation scheduling, (ie providing the correct amount of water to crops at key stages of growth) is often the most cost effective way of improving production per unit of water used and can increase local water use efficiency by up to 30%. Measures include irrigation at night, adjusting schedules for each crop, decreasing the frequency but increasing the volume, and taking full account of rainfall.

Whether it is possible for an individual farmer to adjust irrigation in this way depends on the local infrastructure and management system. It is difficult in China, where there are large numbers of small farm holdings, but the approaches for decentralised management outlined in Section 6.5 of this report (including establishment of WUAs) should help.

Scientific approaches to scheduling (often using soil, plant or atmosphere-based measurements) have generally shown decreases in the amount of water applied while improving yield. Significant water savings can be made in flood or furrow irrigation by manipulating the rate of water flow across the soil surface according to soil type, infiltration rates, and furrow or field length and slope. Such systems can apply water very uniformly if the system is properly designed and operated.

Models to determine the optimum flow rate at a field level have shown a saving of between 0.1 and 0.25 ML/ha (5-15 m^3/mu) for cotton. The flow *rate* needs to be increased so that water has less time to percolate beyond the rootzone. This can be achieved by putting two siphons in the same furrow or by increasing the head in the supply channel.

To provide adequate water to the low end of the field, surface irrigation requires that a certain amount of water be spilled or drained off as tailwater. Tailwater return systems catch this runoff and pump the water back to the top of the field for reuse, or it may more simply be used by gravity in fields further downstream.

Laser levelling

Laser levelling results in accurate land forming of flood irrigation bays, and hence:

- Reduces waterlogging and the time it takes to irrigate and drain a bay; and
- Increases the evenness of water application.

Land forming has been widely adopted as benefits are well recognised. It is not feasible in areas where the cut will expose the subsoil or volumes of soil to be moved are too great. Laser levelling is likely to lead to saving between 100 and 400 m3/ha (7-25 m^3/mu), as compared to conventional land levelling as part of routine land preparation.

Land levelling can also be done without use of laser controls; this is cheaper but less precise and does not save quite so much water but it may be more appropriate in some situations

Conversion to pressurised irrigation

Although modern irrigation techniques are becoming more common, traditional methods still predominate - even in the Murrambidgee irrigation district in Australia where surface irrigation (flood or furrow) accounted for approximately 91% of total irrigation in 1998. However, there is a trend for both horticultural and large area farms, with conversion to pressurised irrigation systems which can result in substantial water savings, with drip providing greater savings than sprinkler irrigation. There have been many technological advances in pressurised irrigation, which can result in much greater application efficiency.

Similarly in California, there has been a trend towards to irrigation system improvement. For example improved furrows, combination of furrow and sprinkler, and changing from surface irrigation (flood, furrow and border check) to pressurized systems. Changing from surface irrigation to pressurized systems (sprinkler, drip, micro-irrigation) generally increases irrigation distribution uniformity and decreases the volume of water applied. The ideal is to apply a uniform depth of water but this rarely achieved because a mismatch between the system and the infiltration characteristics of the soil. Nevertheless, pressurised systems such as sprinklers and drip irrigation can be managed to provide more uniform application, resulting in better control of deep percolation, than is possible with surface systems.

One-third of the Murrumbidgee Irrigation Area is planted to horticultural crops such as citrus, vineyards and stone fruits. An increasing proportion of these crops are grown under drip irrigation. This can have significant side benefits, which include:

- improved fruit quantity and quality;
- easier farm management; and
- substantial saving in labour.

This has been evaluated by CSIRO used the SWAP (soil water atmosphere plants) crop model to calculate potential water savings between different types of systems. Crop water use and water use efficiency was found to be highly dependent on depth to water table, soil type, crop type and irrigation time.

- With shallow water tables, plants can obtain some of the water they need directly from the soil, greatly reducing the need for irrigation water compared to areas with deep water tables. This is true for both surface and sprinkler irrigation.

- Depth to water table has more of an impact on water use than does soil type, especially under surface irrigation.
- The irrigation time of 'depletion of readily available water' and 'depletion of total available water' are promising and practical ways of determining the next irrigation time.
- Converting to pressurised irrigation can potentially save water when growing wheat, maize, barley, sunflower, faba bean and soybean.

Pressurised irrigation is capital intensive: indicative costs for lateral move systems cost around $1,500/ha (700 Y/mu), centre pivot $2,000/ha (1,000 Y/mu) and subsurface drip irrigation $4,500 /ha (2,000Y/mu).

Apart from cost, there are some disadvantages with sprinkler and drip irrigation, as described in Figure 7.1, also from Australia. In the WRDMAP project area, the impact of wind is a particularly important limiting factor for sprinkler irrigation.

The application rate should be controlled so that the infiltration rate of the soil is not exceeded, and thus surface run-off minimised. In sprinkler systems, application uniformity is affected by pressure variations in the system (which can be avoided by good design), and wind speed and direction (which can be mitigated by selection of sprinkler spacing and operating when wind velocities are low). Although drip systems are non-uniform on the surface, this is smoothed out and becomes quite uniform after water has infiltrated, but poor hydraulic design can lead to poor distribution uniformity in drip systems and ultimately excessive deep percolation losses. Box 7.7 indicates the important of precise irrigation management for optimising horticultural crop production.

Careful operation of pressurised systems can have valuable benefits in terms of WDM. Operation several times a week, or even per day makes it possible to set the total water application equal to estimated crop evapo-transpiration between the irrigation intervals. If the soil water content in the root zone had been lowered prior to beginning irrigation, then there should be some soil water storage available to reduce the deep percolation resulting from non-uniformity. This results in much less deep percolation due to non-uniform application than is the case with less frequent high volume irrigation.

Figure 7.1: Advantages and disadvantages of sprinkler and drip irrigation in Australia

Overhead sprinklers

Advantages	Disadvantages
Low labour and maintenance required.	Relatively more prone to poor distribution uniformity (DU). If fertigation is used, the results of poor DU will be further exacerbated.
Can be used for frost control.	Wind reduces efficiency and DU.
Allows easy establishment and maintenance of cover crops.	Relatively high pumping costs.
	Can damage fruit close to harvest.
	Can create a greater threat of disease. Overhead irrigated vineyards often require more fungicide sprays.
	Wetting of foliage leads to salt uptake in leaves (especially in citrus). River salinity is predicted to increase in the future, increasing potential damage.
	High evaporation losses on hot, windy days.
	Run-off and erosion will occur with sandy soils on steep slopes.
	Not suited to heavy clay soils due to surface sealing.
	High sprinkler output and slow infiltration may lead to run-off.
	Least suited to high precision management such as regulated deficit irrigation (RDI).

Low level sprinklers

Advantages	Disadvantages
Wind effects minimised.	Checking sprinkler operation is labour-intensive.
Minimal wetting of fruit and foliage.	Good canopy management and under-vine weed control is necessary for good distribution.
Suited to most soil types.	More susceptible to physical damage from pickers and machinery than overheads.
Lower pumping costs than overhead sprinklers.	
Well suited to fertigation.	

Drip irrigation

Advantages	Disadvantages
Highly suited to fertigation.	High frequency of irrigation means a flexible and frequent water supply system is required.
Low pumping costs.	High degreee of filtration necessary.
No wearing parts.	Unsuited to frost and heat control.
Reduces need for fungicide sprays.	Establishment of cover crops reliant on autumn rain.
Potentially the most water-efficient system.	Little margin for error. Plants stress quickly if the system fails or watering is delayed.
Allows access to orchard at all times.	
Large water savings in young plantings due to accurate and even water placement.	
Highly suited to RDI and precise irrigation scheduling.	

Box 7.7 Irrigation of horticultural crops

Horticultural crops are an important part of an agricultural water demand management strategy, but they are very sensitive to irrigation practices. Vegetables are 80 to 95 percent water, and because they contain so much water, their yield and quality suffer very quickly from drought: water shortages early in the crop's growth may delay maturity and reduce yields; shortages later in the season may affect quality. Most vegetables are rather shallow rooted and even short periods of two to three days of stress can hurt marketable yield.

Irrigation is likely to increase size and weight of individual fruit and to prevent defects such as toughness, strong flavour, poor tip fill and pod fill, cracking, blossom-end rot and misshapen fruit. On the other hand, it reduces soluble solids in muskmelons and capsaicin in hot peppers if applied during fruit development.

Soil moisture requirements differ with the crop and stage of crop development. Soil type is very important in planning for and using an irrigation system. In the case of sprinkler irrigation, droplet size and irrigation rate are also very important in vegetable crops. Large droplets resulting from low pressure at the sprinkler head can cause damage to young vegetable plants and contribute to crusting when soil dries.

Irrigation rate will depend on soil type but application rates should not exceed about 10 mm per hour for sandy soils, about 7 mm per hour for loamy soils or about 5 mm per hour for clay soils. High application rates will result in irrigation water running off the field, contributing to erosion and fertiliser run-off. Good irrigation practices can have significant impacts on yield and quality, even without changing the irrigation volume: precise timing of irrigation at the time of planting can have a large impact.

Fluctuations in soil moisture injure the fruit crops of vegetables like tomatoes and peppers. These fruits contain large amounts of water and depend on this water for expansion and growth. When soil moisture is allowed to drop below the correct level, the fruit does not expand to its maximum possible size before it ripens, thus reducing yield. If moisture is allowed to fluctuate too much, blossom end rot can occur, and the fruit will no longer be useable. If moisture fluctuation occurs during the fruit expansion stage, fruit cracking will occur. Fruit cracking usually occurs when inadequate water has been applied and then heavy rains bring too much water. The best way to prevent fruit cracking is a steady moisture supply.

Summary of recommendations

There are a range of measures which can be used to maximise the productivity of water at farm level. These include:

- Review of area-based entitlements to better reflect best irrigation practice in terms of soil type, water table depth and hydraulics
- Ensure all water in the soil profile is used through water efficient rotations
- Conversion of horticultural farms to pressurised irrigation systems
- Adoption of soil moisture monitoring and irrigation scheduling technologies and practices
- Improve water productivity by bringing water application rates closer to net crop water requirements

- Opportunities for use of regulated deficit irrigation to maximise productivity of water and quality of produce
- Monitor on-farm seepage rates from channels as a key input to on-farm water use efficiency decisions

The challenge is to ensure that water is used for crop transpiration and is not lost by excess evaporation from soil or unproductive transpiration from weed growth. The quality and hence value of many high-value cash crops is strongly influenced by water management practices – even with the same amount of water

7.5 Engineering techniques

Overview

There can be high losses from irrigation systems and control systems may be insufficiently precise to deliver water as required, and this may result in wastage or inability to use water in an optimal manner. There is therefore scope to improve the infrastructure (and the management of this infrastructure) to reduce losses. However, this needs to be planned on the basis of an audit to identify where the losses are, which losses are non-beneficial, and which can be saved – see Box 7.8 for two contrasting situations in California.

Box 7.8 Water saving in California

In the downstream of the Imperial Valley in California, for example, water losses go to the sea or saline sinks and is thus a true loss. In this, area irrigation districts can improve their system and sell the water to higher value (urban) uses without impacting on agriculture. For example, they have recently lined canals and improved other infrastructure (tail water return systems, canal automation) so that they can sell water to San Diego at a cost of 0.2$/m^3. This is a win-win situation – the urban area gets water and the farmers get an improved irrigation system.

In other areas, however, the losses can be used by others and thus canal lining would have a negative impact on them. In this case, it is necessary to reduce consumption. Further north on the Colorado river in California, for example, there is a system whereby farmers are paid to keep land fallow ($4,000/ha or 275/mu) on a voluntary basis on up to 15% of land

System audits

Water audits are equally important at system level as there many potential areas of wastage of water. This depends in turn on a system of measurement – proxy indicators can sometimes be used, but measurement at key locations is essential. This is a technical issue, but it will only be possible if there are clear regulations for water measurement, institutional arrangements and responsibilities and clearly defined and realistic, water auditing requirements have been identified, and that there is clear understanding as to how water measurements will be used.

The audit needs to cover such issues as:

- Diversions from the source, and at intermediate points in the system
- Accuracy of measurements
- Climate and rainfall
- Use of water - Crops grown
- Equity of distribution

Losses in conveyance systems

Irrigation delivery between the source and the farm level is often seen as the most 'wasteful' element in the system. Such conveyance losses are also always seen as easy to address – line the open channel with concrete or similar or put the water in a pipe. But it is important to remember that these seepage losses often feed into drains, rivers and aquifers which are sources of water for downstream irrigation. Inter-sectoral transfers of water further complicate the picture and it should be noted that diverting water from upstream irrigation to downstream urban uses may affect irrigation in both upstream and downstream areas.

Box 7.9 Conveyance losses in the Murrambidgee system in Australia

Some 42Mm^3/yr is lost from 500 km of channels through seepage. Typical capital costs to save water vary from less than $0.5 / m^3 to over $4 / m^3 depending on losses per unit length and the seepage reduction method used. it was also found that seepage is highly non-uniform, with up to 10 Mm^3 of losses occur in one channel reach of 36 km, ie 25% of losses occurred in 7% of the canal length

Evaporative losses are less than one third of seepage losses and total 12.5 Mm^3/yr over the same length. Although the potential to save water lost through evaporation is considerable, at current water rates it may not be economic to do so

Measurement of losses from irrigation canals is not easy. Traditional techniques include measuring the flow in and out of a channel reach by current meter, or ponding water in a closed-off section of canal and measuring the rate of change of level. However, the accuracy of these measurements means that the estimate of losses can be very approximate. Furthermore, losses can be very variable – local problems with condition or maintenance of canals can cause large variations in seepage rates. In one study in Murrambidgee (Box 7.8), losses were found to be very variable – even within a single district,. Canal lining thus needs to be very precisely targeted to avoid being very expensive in terms of water actually saved.

Modern more sophisticated techniques: are now available, but these are not widely used in normal operational practice. These include EM 31 meters to measure electrical conductivity of the soil; doppler flow meters to measure inflow and outflow from canal reaches; and Idaho seepage meters to measure actual seepage flows. Such methods can, however, be used in research studies to provide a basis for improving estimates of losses from operational canals in comparable conditions.

Improved control systems

A typical irrigation system diverts water from a river via a network of canals to farms . Excess water, sometimes termed "administrative spill" is also diverted and conveyed through the canal system to assure that all of the farms receive their share of the water. The excess flow eventually returns to the river system. More efficient control can ensure that canal flows match requirements more closely and have the potential to yield both agricultural benefits and environmental benefits (since more water remains in the river). Increased delivery flexibility and dependability will benefit farmers and canal operators while better system management reduces water waste, maintenance costs, and environmental impacts. Crops will receive the correct amount of water at the correct time to optimize production.

Many improvements are now feasible because of recent advancements in data collection, communication, and control technologies. This technology is readily applied on new projects, but there is considerable potential for applying this retrospectively on older projects.

If comprehensive Supervisory Control and Data Acquisition (SCADA) system is prohibitively expensive on older projects, there is still scope to implement telemetry and control along the canal on an incremental basis. Canal operators usually have a good understanding gain from years of operational experience, and this can be combined with technical assistance and training on modern methods and new computer operated systems.

Principles of new irrigation design

Water saving in agriculture generally requires improving existing irrigation systems, which is usually more difficult than building a new system. However, sometimes new systems are needed. FAO (http://www.fao.org/docrep/004/ac799e/ac799e03.htm) give guidance on key considerations for design, noting that modern irrigation schemes should be regarded as several subsystems or levels with clearly defined interface, where water is measured and controlled. These are that:

- *“Each level is as financially autonomous and hydraulically independent as possible.*
- *Each level is technically able to provide reliable and timely water delivery to the next lower level. At each level there are the proper types, number and configurations of gated turnouts, measuring devices, communications systems and other means to control flow rates and/or water levels as desired.*
- *Each level is responsive to the needs of its clients. Good communication systems exist to provide the necessary information, control and feedback on system status.*
- *Each level of delivery has confidence, based on enforceable rights, in the reliability, timeliness and equity of the water which will be supplied from the next higher level. Effective mechanisms for conflict resolution are in place.*
- *The hydraulic design of the water delivery system is created with a well-defined operational plan in mind. The operational plan is established with a clear understanding of the needs of the end users.*

- *The hydraulic design is robust, in the sense that it will function despite changing dimensions, siltation, and communication breakdowns. Automatic devices are used where appropriate to stabilize water levels in unsteady flow conditions.*
- *Motivated and trained operators are present at all levels of the system. They are not necessarily the farmers themselves but preferably hired staff. Instructions for individual operators are well understood and easy to implement.*
- *Maintenance is the obligation of each level. Maintenance plans are defined during design and are adequately funded and implemented.*
- *There is a clear recognition of the importance and requirements of agriculture and of the existing farming systems. Engineers do not dictate terms of water delivery; rather agricultural and social requirements are understood at all levels and in all stages of the design and operation process".*

These principles should be applied as far as possible when improving existing systems

Irrigation modernization

Much of the recent effort in improving irrigation has concentrated on management and institutional issues. Where infrastructure is at fault, it is often assumed that it needs little more than completion or rehabilitation. Much less attention has been given to the type of infrastructure. Most irrigation systems were designed when the agricultural requirements were very different from now, and were aimed more at protective irrigation – to protect the livelihoods of farmers growing subsistence crops – than at maximising the productivity of water in the context of diverse livelihoods.

This situation is beginning to change, but most recent developments have been in relatively well-developed countries. It has proved difficult to transfer these modern technologies to developing countries. FAO have developed a systematic methodology for evaluating irrigation systems (FAO, Irrigation and Drainage Paper No 63, 2007) presents a step-by-step methodology for water engineering professionals, managers and practitioners involved in the modernization of medium-scale to large-scale canal irrigation systems

Modernization is usually attempted through a process of incremental changes to the infrastructure needed for water control and water scheduling. This should help ensure coordinated development of both institutional capacity and technology. Canal control systems should be designed so that it fits the needs and understanding of operators. As the US Bureau of Reclamation report there have been many problems in the past, where *Control systems were designed and installed without adequate instructions to the operators, and the systems did not perform well because operators did not understand how to use them. On these projects, managers may view automatic controls as a waste of time and money, and they will be hesitant to allow any future automation development".*

There has been a major initiative in recent years to upgrade water delivery systems in Australia, particularly the open channel systems that dominate much of the irrigated areas. Accurate metering, monitoring and flow control have been a major focus of this upgrade for obvious reasons, for this provides the knowledge, as well as the ability, to optimise channel systems. However, a recent stakeholder consultation by NPSI found numerous challenges being faced by this programme:

- "*Data and understanding. Whole-of-system water balances can be problematic, due variously to:*
    - *insufficient understanding of the system (e.g. surface water and groundwater interactions);*
    - *lack of confidence regarding current losses and water budgets; and*
    - *difficulties in defining, estimating and valuing savings (including benefits such as improved supply options and reliability for irrigators).*
- *Social engagement and rationalisation. The pace of planning and change threatens to leave people behind unless there is an emphasis on engaging people and sharing information and ideas. Insufficient involvement in the process can result in sub-optimal planning and decision making regarding rationalisation. Whole modernisation programs may be jeopardised as a result.*
- *Uncertainty and investment horizons. Water supply companies, irrigators and communities face numerous uncertainties, e.g. the real quantum of likely water savings and their 'value', the likely quantum and location of water trades or government buy-backs, and commodity markets and production costs. Consequently, flexible, short-term, low-cost solutions are required; but infrastructure planning usually seeks long-term and long-lived solutions.*
- *On-farm change. If irrigation practices remain the same it can undermine the efficiency of enhanced supply systems – and mean that potential improvements in water use efficiency or operational enhancements (e.g. timeliness of applications, options to adopt more manageable irrigation systems etc) are not capitalised on by irrigators*".

One example is the Total Channel Control system developed by Rubicon (Box 7.10)

Box 7.10Total Channel Control®- A breakthrough in irrigation network automation.

A breakthrough in both irrigation control and flow measurement, the system is based on the control of large networks of solar-powered canal regulators and gates, which are linked through radio telemetry and advanced computer software to enable the whole canal network to operate automatically and remotely.

A fundamental component of Total Channel Control® is Rubicon's unique FlumeGate™, which provides exceptional control and accuracy of water flow. The FlumeGate™ is complemented by Rubicon's wide range of gate products and flow meters, enabling us to tailor a solution to suit the unique configurations of a wide variety of irrigation districts.

Total Channel Control's modular design means that components of the system can be implemented separately, giving you the flexibility to phase in the technology over time - eventually building towards an end-to-end Total Channel Control® solution.

Automated irrigation network operation eliminates the significant limitations that come with manually operated networks and assists in the detection of leaks and provides an alert for repair.

Accurate measurement and control

Total Channel Control's® gate technology reliably measures and controls flow throughout the entire system while eliminating manual operation of water control gates.

Identification of losses

Total Channel Control® allows you to measure and locate leakage, seepage and theft losses by pinpointing losses to individual pools. The comprehensive information supplied by Total Channel Control® enables you to address those areas where the greatest losses are occurring, allowing you to efficiently and cost-effectively target your maintenance spend.

Water savings

More accurate control of open canals and flow measurement generates significant water savings that can be retained by the irrigation authority or diverted to urban uses or distressed river networks. Additionally, the reduction of outfalls afforded by Total Channel Control® has the added benefit of minimising the entry of pollutants into wetlands and river systems.

Ideally, this should be linked to improved management systems at farm level. Some of the general approaches for improving farm-level practices were outlined in Section 0, but automated systems such Total Channel Control® require linked farm-level approaches if they are to achieve their full benefit (Box 7.11). These are applicable to large-scale farms, such as are to be found in Australia and USA. Applications to smallholder farms have not yet been effectively developed and will need to work through WUAs.

Box 7.11 FarmConnect™ - A revolution for irrigation farming

Rubicon leads the world in irrigation efficiency with its unique water control gates and Total Channel Control® - Rubicon's completely automated irrigation canal management system. Now FarmConnect™ brings the same advanced industrial-grade technology to the farm, providing farmers with an integrated solution for:

- water ordering/metering
- irrigation scheduling
- on-farm automation

iβee™ Wireless Network

FarmConnect's™ iβee™ wireless network links field devices including high-flow bay gates and soil moisture sensors to allow you to wirelessly monitor and control your irrigation. The iβee™ network gives you the flexibility to easily add numerous field devices over time, allowing you to build a highly efficient automated farm operation.

- Dedicated on-farm wireless network based on the ZigBee protocol for easy connectivity and reliability

- Excellent all-terrain coverage and GPS positioning
- Wireless monitoring and control of a wide range of field devices including soil moisture sensors, weather stations, gates, valves and pumps

Benefits of Precision Surface Irrigation

It is now being demonstrated that high flows/faster irrigations lead to more efficient irrigation.

When precision and high flow surface irrigation are combined, the water efficiency savings are sizeable. The science behind precision surface irrigation also becomes necessary with high flow irrigation, because of the difficulty in operating high flows manually.

Additional benefits come when integrated with an automated supply point meter operating under Total Channel Control®, giving the ability to adjust flows to the real time needs of the irrigation system.

http://www.rubicon.com.au/EN/solutions/canal_automation.html

7.6 Management of irrigation systems

Appraisal and benchmarking of systems

Modern management methods place considerable emphasis on understanding and benchmarking current levels of performance. This is essential for identifying weaknesses and enabling the impacts of any changes to be monitored. A Rapid Appraisal Process (RAP) has been developed which allows qualified personnel to systematically and quickly determine key indicators of irrigation projects. Key performance indicators from RAP help to organize perceptions and facts, thereby facilitating informed decisions regarding:

- The potential for water conservation within a project
- Specific weakness in project operation, management, resources, and hardware
- Specific modernization actions that can be taken to improve project performance.

A parallel activity to the RAP is called Benchmarking. This is a systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards. The overall aim of benchmarking is to improve the performance of an organization as measured against its mission and objectives. Benchmarking implies comparison - either internally with previous performance and desired future targets, or externally against similar organizations, or organizations performing similar functions.

The Rapid Appraisal Process (RAP) of irrigation projects was introduced in a joint FAO/IPTRID/World Bank publication entitled Water Reports 19 (FAO) - Modern Water Control and Management Practices in Irrigation - Impact on Performance (Burt and Styles, 1999). That publication provides an explanation of the RAP and also gives RAP results from 16 international irrigation projects. A document that discusses philosophy of operation and design of irrigation projects is World Bank Technical Paper No. 246- Modern Water Control in Irrigation (Plusquellec, Burt, and Wolter, 1994)

Operation

Operation of irrigation system can leas to significant operational losses - these can be difficult to pinpoint but result from operation of control structures in a manner which lead to flows that do not comply exactly with the crop water requirements. This can result in excess irrigation in some areas, shortages in others, and unnecessary losses to drains and aquifers. Irrigation systems are never sufficiently sensitive that it is possible to meet precise requirements in all locations and at all times, but they are often not even operated in accordance with the design or the irrigation schedule. Some losses are thus unavoidable (because of the nature of the system, until it is modernised), but others can be reduced by better management.

These losses are often manifest in tailwater flows – monitoring these flows can provide a useful indicator of system performance, but it should be noted that these are often diffuse, with many small channels. Vegetation conditions (weed growth) at irrigation boundaries can provide an approximate indicator of surface management losses. Losses to groundwater are less easy to observe and almost impossible to measure directly, but are still important and need to be assessed indirectly.

Adequate information on actual water delivery is important for effective management and can help reduce losses to unproductive areas or disputes over access to water. Measurement is required at various levels in the system. The infrastructure in the main canal and at the outlets to branch canals is generally sufficient for this purpose, but measurement of flows between villages and from branch canals to WUAs or production groups is more difficult and unreliable.

Internationally, systems for Remote Monitoring and Control of irrigation are being encouraged. In California, Many irrigation districts are installing remote monitoring and in some cases remote control systems such as Supervisory Control and Data Acquisition Systems (SCADA). Remote control systems allow district to measure flow or water depth and allows the district to remotely operate hydraulic structures or devices. Remote monitoring and control systems allow districts to improve water management and control.

Traditional management systems are well understood by local water managers, and it can be difficult to introduce new systems – but these are required for new types of infrastructure (such as the Total Canal Control system described above. The required skills in Australia include, for example[20]:

- Control device generally in the form of a gate, valve or pump – traditional skills in mechanical, electrical and civil engineering required.
- Instrumentation to measure levels, flows and other quantities necessary for successful control – an active market is available to support this requirement available from early adopter markets.
- Communications systems – a rapidly evolving market place with niche skills required in the low power high performance space.
- Software engineering – significant diversity required from low level microprocessor programming to enterprise class data management systems.
- Dynamic hydraulic engineering – specialist knowledge and techniques required to solve these technical challenging issues.
- Control engineering – niche control engineering knowledge, techniques and software.
- Civil construction/installation – relatively simple and standard construction practice with high focus required on project management and standardisation.
- Electrical technicians – standard skills with specialist training on unique products.
- Water System Operators – experienced and progressive operators that are supported in the challenge of continuous improvement.

There has been an active programme for several years now, so many of these skills are being developed in Australia (Oakes and Luscombe, 2008), but much of the technology is new to other countries and thus they will need to develop these skills rapidly. For this reason, such high technology control solutions may take time to be introduced and much will depend on the outcome of the current trials in the Qingtongxia ID in Ningxia Hui Autonomous Region (Box 7.12).and in Shaanxi

Perhaps the most challenging issue for water distribution operators is the complete reversal of the traditional manually operating systems, from an upstream control to a demand or “downstream” based control paradigm - where all upstream regulating devices are operated to meet downstream needs. Although this might appear to increase flows to meet downstream consumptive and non consumptive needs, in fact it should avoid much of the wastage associated with traditional upstream control which was not responsive to demands and was limited by the nature of the control

[20] Oakes and Luscombe (2008) Channel Automation and People. Irrigation Australian Conference and Exhibition was held in Melbourne from Tuesday 20th May to Thursday 22nd May 2008

and measurement system. However, managing this transition is not easy and there are critical human issues to address.

Box 7.12. First FlumeGates™ Installed in China 21 July 2009

Rubicon Systems entered the Chinese irrigation market this week with the installation of its first FlumeGates™ in the Yellow River basin as part of a trial of Total Channel Control® - Rubicon's end-to-end solution for modernising open canal irrigation systems.

The installation in the Qingtongxia irrigation district of the Ningxia province, along with a second installation to follow in the Yangtze River basin, will revolutionize irrigation practices in the areas, while showcasing Rubicon's irrigation network modernisation technology in a new market.

In terms of scale, there are currently about 10,000 water regulator gates in Victoria's Goulburn-Murray Irrigation District - one of the largest irrigation districts in Australia - whereas there are approximately one million regulator gates in China. Like Australia, China is facing the increasingly serious challenge of water scarcity in many regions and is looking for ways to increase the efficiency of irrigation practices.

Farmers in the Qingtongxia irrigation district currently irrigate on a roster basis, receiving their schedule up to 12 months in advance, with no choice but to take water in accordance with the predetermined schedule. With the system now operational, Total Channel Control's® accurate measurement and control capabilities will not only provide irrigators with near on-demand water delivery and high flows, but also provide precise location of leakage and seepage losses.

The expectation is that the new system will facilitate, over time, a change in the type and value of agricultural production as well as freeing up valuable water resources for new applications.

http://www.rubicon.com.au/EN/news/news_item_2.html

Maintenance of irrigation systems

The importance of good maintenance for ensuring effective water management is well-recognised. This is a joint responsibility of the Irrigation District (for the main canals) and WUAs for the smaller channels. Maintenance is often neglected, sometimes because responsibilities are not clearly defined, and often because of inadequate funds. Improved cost recovery, as described earlier (Chapter 4) is important for this reason. Equally important is the need to plan maintenance carefully.

It is evident that maintenance of irrigation is often neglected, or planned unsystematically – leading to poor performance, misuse of funds or both. Concepts of asset management (where the term ‘asset’ refers to the irrigation infrastructure), developed for the urban water supply sector have recently started to be used for irrigation systems in many countries. This can help ensure that irrigation systems are maintained in a functional condition. If maintenance is planned without reference to the functionality of the assets, it may result in excessive investment in easy-to-identify but inappropriate works such as canal lining in places where the performance is not adversely affected at present.

Canals may be lined to reduce losses as part of a WDM strategy, but this also has an impact on maintenance arrangements and requirements. New canal lining reduces the maintenance needs for the first few years, but effective systems for maintenance do need to be put into place to prevent future deterioration which later becomes very expensive. Optimising maintenance on a financial and economic basis, which is the normal approach, may mean that losses are not minimised. WDM would require more intensive system maintenance and upgrading than can be justified on economic grounds. This is one reason why it is often subsidised by governments.

Canal lining and condition are key areas which influence conveyance losses. Maintenance or improvement is requested by different stakeholders for various reasons

- To reduce losses, so that more water is available locally by the same users
- To reduce short-term maintenance, for the first few years whilst lining remains in 'as-built' condition
- To reduce losses, so that water saved can be transferred to other areas or users

The existing procedures for planning, financing and implementing maintenance should be evaluated in order to identify measures to improve this process on a sustainable basis.

Canal lining is widely seen as fundamental for WDM as it reduces seepage from the canal. But as mentioned earlier, this may not result in a real saving since such losses are often reused. Canal lining also needs to be well-targeted since most of the losses may occur in a few locations.

There are many different materials used for lining, with varying costs and degrees of effectiveness. This is a topic well-understood in China since many canals are lined in very extreme environments where they are liable to severe frost damage. However, experience in other countries (such as the programmes in Australia referred to earlier) may also be very useful.

7.7 ET management – where to improve the system

It should be apparent from the above that there is potential for improving irrigation management in order to improve access to water and productivity of water. This will make much better use of water applied, but it will not necessarily result in water saving. In fact it may even encourage greater water use since farmers will be better able to increase their income, and by reducing waste they will reduce return flows.

The key is to identify the part of total losses which are non-beneficial losses of water and try to minimise these. Many of the other losses can be reused elsewhere, and thus reducing these losses has only a local benefit, and possibly has adverse impacts elsewhere. For this reason, irrigation entitlements need to be based on water consumed rather than water diverted. Evapo-transpiration (ET) is the water needed by for crop growth, so ET management refers to a system for reducing non-beneficial ET (this non-beneficial ET includes weed growth and evaporation from bare soil).

Water consumption is not nearly so easy to measure: the simplest is on the basis of crop areas, climate and crop coefficients which can be used to calculate consumption, but modern techniques, using remote sensing are likely to become increasingly common. If diversions are measured and water consumption calculated, then losses can be deduced by doing a water balance.

Two cases where modern approaches to measuring and reducing non-beneficial losses have bee made are the Tarim Basin and the Hai basin.

> "*The Tarim basin is a river basin under stress in a desert area of northwest China. The objectives of the Tarim Basin II Project were to increase farmers' incomes sustainably while reducing water allocations, and to restore environmental flows to the "green corridor," an area of natural beauty and lakes that had dried up three decades before, because of massive irrigation development upstream.*
>
> *Satellite imagery gave a clear picture of the pattern of beneficial and non-beneficial ET in the basin and was used along with other methods to assign reduced water quotas to water user groups and to the riverine environment. The knowledge of ET also allowed the project to identify the most productive investments that would save water to achieve optimal basin-level water efficiency, including engineering, agricultural, and management investments. Canals were selected for lining if their leakage was mainly going to non-beneficial ET. This was often the case because the leakage was contributing to high water tables and salinity, and water was being lost to capillary flux and ET from the ground surface in areas around the canals. Canals where losses were mainly returning to the river or groundwater systems were not lined. Under the project, geo-membrane lining along with concrete was used and nearly zero seepage was achieved. The differentiation of ET at the crop and farm level allowed the project to draw up land and water management plans and inventory the ET requirement of each crop, and even to give advice to individual farmers on ways to improve ET management".* (World Bank, 2006)

Similarly in the Hai basin,

> "*The Project will introduce a new practical approach to water savings in irrigated agriculture using remote sensing and ET management rather than only focusing on irrigation systems efficiency improvements, which has been the approach in China in the past. Improving irrigation system efficiencies does not necessarily save water and in fact can often increase the amount of consumptive use (ET) of irrigated agriculture by eliminating leakages which were returning to the surface or groundwater systems and utilizing that water for more crop production. "Real" water savings focuses on reduction in ET which can be accomplished through a combination of irrigation technology, agriculture and management measures.*
>
> *The objective is to reduce the ET at the county level to target levels and then maximize the production and value of production per unit of ET. There is a wide range of water productivities (Yield/ET) for each crop type depending on irrigation, agriculture and management practices*".

These remote sensing techniques make it possible to quantify the components of the water balance quite simply. Non-beneficial losses can then easily be derived. In the short term, these pilot methods can be used to derive generic recommendations for the sort of improvements that are needed to maximise the productivity of water. Such recommendations can then be adopted more widely.

In the future, remote sensing methods are likely to become far more common, but in the short term simple crop coefficient methods will remain in use for estimate actual crop ET. Thoresen et al (2009) compare three methods - remote sensing, water balance and crop coefficient methods for calculating crop consumptive use. These methods resulted in differences in estimates of consumptive use of up to 15%, and the remote sensing method was estimated to be accurate to within 5% on a seasonal basis. Given the magnitude of savings that are envisaged in through improved irrigation management these estimates of accuracy highlight the problems in quantifying savings.

This approach should, however, highlight areas where infrastructure or management needs to be improved so that output value per unit of water *consumed* can be maximised.

These methods are still at the pilot stage of implementation, but they are being strongly promoted in certain areas in China so that knowledge of the techniques and the capacity to implement them elsewhere is being developed. For example, this approach was used by Wang et al (2009) in assessment of water management in the Yellow River Basin. They classified each sub-process as productive (or efficient) or non- productive consumption. Productive consumption is further categorized into high efficiency and low efficiency consumptions "*High efficiency consumption usually refers to the transpiration contributed to the production, while the rest refers to low efficiency consumption (i.e. luxurious transpiration, soil evaporation among plants used to adjust the farm micro-climate)*". However these can be difficult to distinguish so all transpiration is considered as highly efficient consumption. "*Low efficiency consumption from soil evaporation changes with the vegetation closing degree. Usually, the higher the vegetation closing degree, the lower the total evaporation efficient consumption. Non-productive consumption is composed of the part of the evaporation amount among plants and unusable land (i.e. bare land, desert and salinization land)".*

However, they conclude that "*an ET-based modern water resources management strategy is still primarily in the concept phase, and many difficulties still exist in both monitoring and calculation of regional/basin-scale water resources consumption*"

Experience from these and other projects where ET management is being practiced will allow some generic recommendations to be made, for example only lining canals where seepage losses go to saline aquifers or the sea, or where they contribute to non-beneficial ET from water-logging and weed growth, or evaporative loss from bare soil.

It is however recommended that water managers from other areas should visit the pilot projects to gain a better understanding of the approach. This will make the lessons much easier to understand and apply than either a brief summary, or a technical description of the process

8 Urban Water Demand Management

8.1 Introduction

China is a rapidly urbanizing country, with several mega-cities as well numerous smaller cities and peri-urban areas. This has advantages in that new water supply systems are being built in many areas, but also there are many places where existing supply systems are being put under extreme pressure and where pipes are old or small and water resources limited. There is thus a huge variation in conditions in urban areas in China, and the water supply requirements are likely to change rapidly in the future.

Water conservation is strongly promoted in China, through a combination of engineering and non-engineering measures, advanced and conventional techniques and mandatory requirements (permits etc). It is clearly expressed in the 2002 Water Law.

A more comprehensive description of urban water demand management is presented in TP3.2 (Urban water demand management), which is primarily aimed at Construction bureaus, water supply companies and related organisations. This section provides a briefer overview for the benefit of water resource departments and bureaus.

At its simplest, urban demand management comprises two components, customer-side demand (consumption) and supply-side demand (leakage). WSCs are responsible for supply-side demand management whilst the customer is responsible for the customer-side demand management. WSCs should also encourage their customers to use water sparingly, and adopt supply-side demand management measurements. WSCs may have a perverse incentive to do this, as the less metered water their customers consume, the less revenue the WSC will receive. This problem must be addressed through the regulatory system and tariff structure. Information on the magnitude and location of losses should be made freely available.

For any WSC, the incentive to undertake an active leakage control programme may be low, and they may well favour the traditional approach to resolve this by supply augmentation: the trouble and cost of reducing leakage significantly is an impediment to action. In many countries, this situation can best be resolved by the intervention and control of a regulator. A regulator can set leakage reduction targets. This issue is addressed in another document in this series: 'Regulation of Small and Medium Size Water Supply Companies', Thematic Paper 4.3.

As a further development the regulator may also set targets for customer-side demand reductions. For example, the 23 private WSCs in England and Wales have a statutory duty to promote water efficiency; from 2010 the water sector regulator, Ofwat, will set mandatory water efficiency targets in addition to mandatory targets for reducing burst water mains and distribution system and overall leakage.

From a water resources management perspective a key issue is how to assess the effectiveness of demand management measures. The involvement of a regulator in target setting places a strong emphasis on ways of demonstrating efficiency savings through scientific measurement.

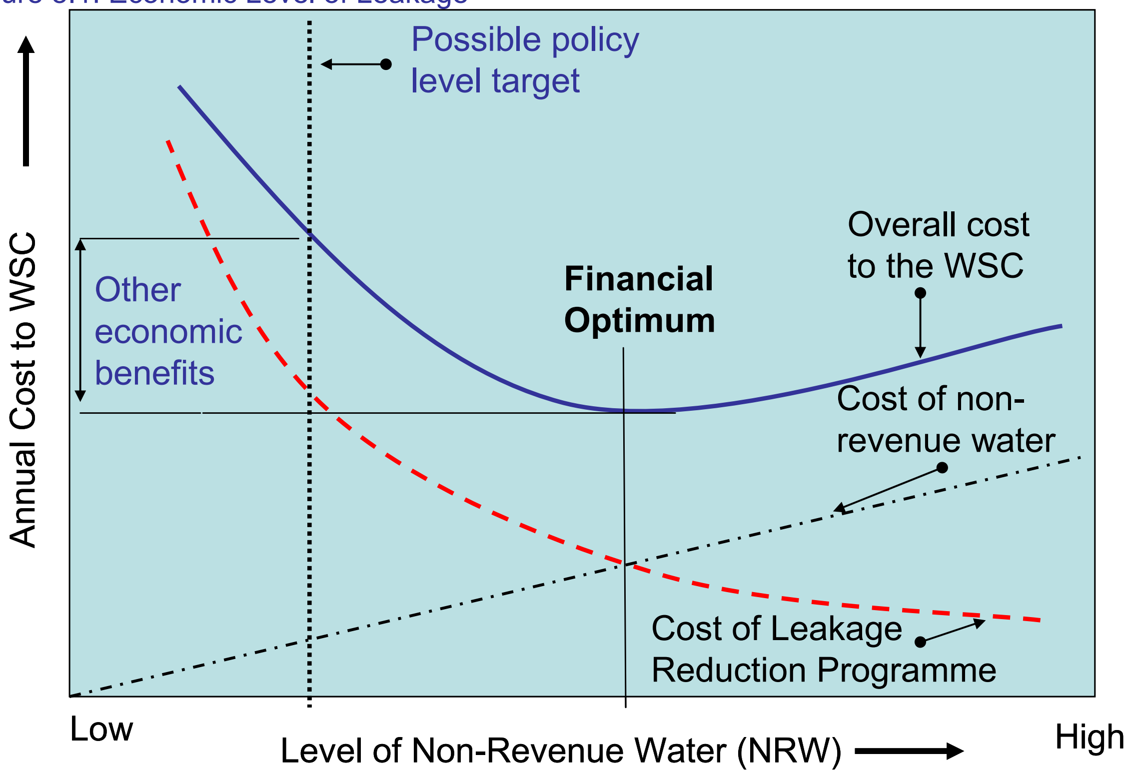
Accurate measurement of all the components of the WSC water balance is required in order to make a reliable assessment of the effectiveness of demand management measures. This clearly must include the volume of water delivered to customers in their properties, and would imply universal metering – however, even where, as in China, domestic metering is compulsory some users will always be un-metered (broken meters, illegal connections, etc) or there may be single meters for large apartment blocks.

8.2 Supply-side measures

Many aspects of WDM relate to the condition and performance of water infrastructure – these are referred to as 'physical assets'. Sustainable asset management is a key business driver in the water sector with asset owners establishing an effective and holistic approach to asset management. Understanding how an asset performs in its environment is essential to delivering service to customers in a cost-effective and sustainable manner. Within the regulated environment of a water supply utility, asset-intensive businesses require clear, auditable, investment plans for maintaining assets and ensuring customer service levels. Internationally, water and waste water companies are increasingly being expected to operate their assets in the most efficient and safe manner possible. Leakage target are often set by regulators.

Supply-side demand management measures mainly relate to reduction of leakage between the source and the user, and are implemented by the WSC. There are various ways of reducing leakage. The decision on whether and how these should be implemented will depend on the relative costs of the measures and the potential benefits to be obtained. The intensity of leakage control activities should be increased until the marginal cost of leakage control exceeds the marginal value of water saved. – the 'economic level of leakage' (ELL).

Figure 8.1: Economic Level of Leakage



The means of reducing water delivery system leakage in urban areas are broadly the following:

- Pressure management
- District metering, followed by active leak detection and repair
- Replacement of old pipework that is in poor condition

These are likely to be implemented in order of increasing cost. Pressure management, where appropriate, will usually offer the greatest benefit cost ratio, but it may require greater technical skills and information. Targeted replacement of distribution pipes in poor condition can be a cost-effective solution, but large-scale replacement will be expensive and only adopted where large sections of pipe are in poor structural condition or badly laid.

Pressure management

Reducing pressures in the pipe network will reduce leakage levels both by reducing flow rates from existing leaks and bursts, and also the reduced frequency with which leaks and bursts occur. In addition, any “open-tap” use in the customer’s supply is reduced. Proactive pressure management can thus play an important part in a demand management strategy, and can provide some or all of these practical benefits:

- Ensure minimum standards of service for pressure are achieved
- Identify and minimise surge:
  - Reduces new leak frequencies
  - Extends infrastructure working life
- Reduces excess pressures:
  - Reduces flow rates from existing leaks
  - Reduces some components of consumption
  - Reduces new leak frequencies and natural rate of rise of leakage
  - Extends infrastructure working life

However, pressure management requires

- Good knowledge of the pipe network
- Ability to survey pressures within the network
- Provision of pressure reducing valves at strategic locations

Pressure reduction programmes also benefit from a good network simulation model. Specialist software is available to analyse pressure reduction options

Active leakage control

Active leakage control is a technique for measuring and monitoring leakage levels in the pipe network, and reducing leakage by detecting and repairing leaks. There are a number of techniques for detecting leaks from sounding every fitting to the use of noise loggers. Active leakage control is an ongoing activity that maintains leakage levels at the appropriate level to prevent natural rise, ie once leakage has been reduced to the target level, regular active leakage control is required to prevent the leakage level from slowly increasing over time.

Research suggests that up to 65% leakage reduction can be achieved through district metering compared with a passive leakage control policy (ie just repairing leaks as they are observed or reported). However, in practice the reduction achieved will depend on a variety of factors including:

- The existing level of leakage in the distribution system
- The pressures in the system
- The type of pipe in the system. It is more difficult to detect leaks on non-metallic mains than on metallic mains.

Further details of leakage reduction target setting and ELL are given in the accompanying Thematic Paper 3.3 'Active Leakage Control as a Key Component in Increasing Efficiency in Urban Water Supplies' and Advisory Note 3.3/1 (see bibliography) provides guidance on implementing an active leakage control policy in small and medium size WSCs.

Pipeline replacement

Replacement of the mains pipelines in parts of the network where the mains pipes are in very poor condition will normally reduce leakage levels significantly. Renewal of customer connections and supply pipes to the meter is normally undertaken at the same time if the leakage reduction benefits are to be achieved in full.

Pipeline replacement is normally a more expensive option than active leakage control. It is often undertaken for other investment reasons, such as insufficient hydraulic capacity or poor water quality (pollutants can be sucked into leaky pipes if operating pressures are variable). In these cases the additional benefit from reduced leakage should be included in the investment evaluation.

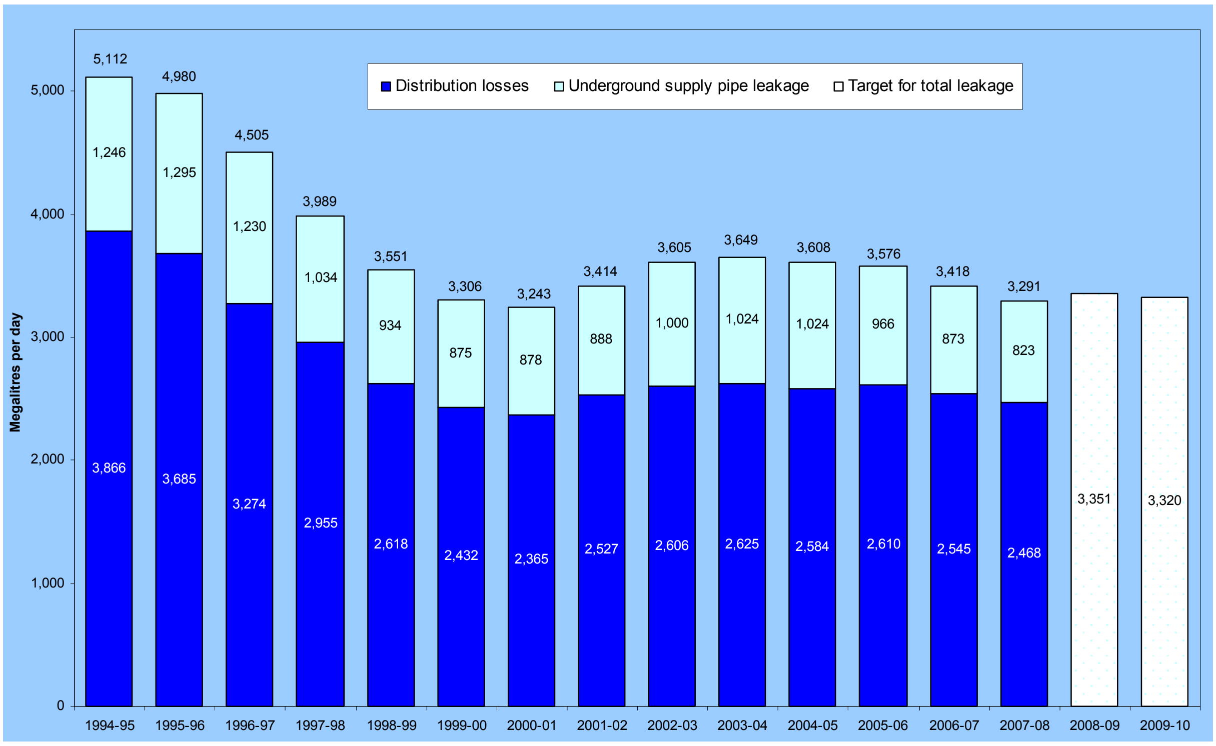
International experience - reducing unaccounted for water

Each year more than 32 billion m^3 of treated water are lost globally through leakage from distribution networks. An additional 16 billion m^3 per year are delivered to customers but not invoiced because of theft, poor metering or corruption (source: World Bank Discussion Paper no 8 – December 2006). In some low-income countries this loss represents 50-60% of water supplied, with a global average estimated at 35%.

Leakage within a distribution system is inevitable. The initial integrity of distribution systems is dependent on good design, quality of materials and standard of installation but even the best system will suffer some losses. Then these will increase over time: joints tend to leak over time, pipes corrode, ground movement disturbs pipes and there is always the possibility of accidental damage.

A typical pattern of reduction in losses after introduction of an active leakage control policy is shown in Figure 8.2. This indicates a rapid initial reduction followed by a period of near steady losses maintained at the economically justified level. The total leakage was reduced by 35% over a period of five years to 2000 and has remained essentially unchanged since then.

Figure 8.2 Trend in UK leakage showing economically justifiable leakage level



An active leakage control programme must be continued in perpetuity, although the optimum level of leakage may reduce over time as the value of water increases through competition for scarce resources. The saved water from leakage control can be used to extend coverage or to improve the reliability of supplies to existing customers.

8.3 WSC-led customer-side measures

Changing behaviours

In the UK rising living standards, and social trends towards smaller households, have led to rising household demand despite many homeowners diligently choosing water efficient appliances and fittings. With the pressure to take action on carbon emissions the momentum for water and energy efficiency savings may come to outweigh the negative potential of rising living standards on water demand. Similar trends can be anticipated in China

Climate change has brought environmental issues to the forefront of media attention. In terms of altering behaviour towards more sustainable lifestyles the enhanced media interest should help to get messages about the need to use water wisely across – linking messages about water to messages about energy efficiency has considerable potential.

Assisting customers to reduce their water use

Free/subsidised repairs on customer supply: A significant proportion of network leakage can be related to the customer-side supply (this was observed in studies under this project in Liaoning Province). By offering free or subsidised repairs, reductions in leakage levels can be made. However, applying an appropriate tariff will encourage customers to carry out the repairs themselves in order to avoid high water bills. A combination of incentives and regulation is needed to ensure that these measures are actually undertaken.

Industrial customer water audits: Water audits can be undertaken by the WSC staff to aid industrial and commercial customers to suggest ways of using water more efficiently (as proposed in NDRC 2005:17). This should reduce the customer's demand for water, or at least highlight which elements have the greatest demand. However, to provide this service the WSC needs suitably experienced staff who are knowledgeable about assessing the condition of existing installations and water-using equipment and practices.

Restrictions on use

Most WSCs aim to provide all their customers with a continuous supply - this is a statutory obligation in many countries. However, there will be exceptional circumstances where the WSC is unable to meet this target and the supply will be restricted – for example during short term emergencies (eg pollution incident, burst main) or longer term problems associated with a shortage of resources (eg drought, under capacity of delivery systems). WSCs should have specific plans in place for dealing with emergencies and for droughts – such plans are often a statutory requirement to ensure that vital services (hospitals etc) will receive adequate water in emergencies.

Restrictions should only be introduced to overcome shortages created by extreme droughts or major unanticipated failure in the supply system. This should not be regarded as part of WDM, but as drought management – these are extreme measures which cannot (or should not) be sustained, as they may result in a significantly lower standard of service or other problems. These measures include shutting parts of the distribution system down for a few hours in turn, providing an alternative temporary supply options (eg bowsers)

Further discussion of possible actions during a drought is given in Advisory Note 2.5 'Developing a Drought Management Plan' (see bibliography).

Sustainable buildings are one area where research has been strongly influenced by the concerns about climate change. While much of the focus is on energy, water is also a central issue. The research is focused on rainwater harvesting, grey water recycling, new water treatment processes including using vegetation, more efficient appliances and sanitary fittings, and reuse of storm drainage.

There is also research into the effectiveness of water saving devices in the home in actual domestic situations – to establish if the hoped for savings are realised. In Australia research on new BASIX homes (see Section 5) has shown that the expected savings are achieved on average, with some households doing better than the target but others using far more water than expected.

Similarly research is being carried out in the UK on means of introducing efficient fittings and appliances in existing housing stock. This is very important because of the very large amount of old housing – effective demand management must achieve significant reductions in water usage in such properties. Some research indicates that it can be difficult to get strong uptake if the approach is not very carefully targeted.

8.4 Customer-led actions

Domestic customers

Water audit: Customers can carry out their own water audit to find out where efficiency savings can be made. In the UK a government sponsored organisation to promote demand management, Waterwise (www.waterwise.org.uk/), provides an easy to use checklist so that households can do a water audit. This audit checklist is also linked to the individual web sites of the water utilities and sent out with bills to give it maximum exposure.

Sanitary refitting: Where the residence is not of recent construction the householder can choose to replace sanitary and washroom fittings with more efficient modern equivalents. For most householders such a decision will be largely determined by a personal cost-benefit assessment. If the benefits of more efficient fittings in terms of lower water bills will not cover the cost of the purchase and installation of new fittings within a reasonable pay-back period the householder is unlikely to make any replacement. In some places, subsidies may be available to encourage uptake. In any case, customers should have access to information on the most efficient fittings, likely cost, payback periods, and availability of grants etc. Product labelling such as that used in Australia is useful for highlighting the water-efficiency of appliances.

Figure 8.3 Australian water efficiency label

Design standards for toilets, taps and showers can drive water efficiency in the home and business premises. Local preferences will dictate the most popular design but kite-marking schemes can identify the most efficient options on the market, and the water consumption may be regulated – as it is in the case of toilet cistern capacity in the UK. Different types of shower can have very different water consumptions – with power showers using much more water.

The volume used is obviously a function of how long the shower is on which is in the control of the user. The introduction of efficient shower fittings should be accompanied by a campaign to get users to take less time in the shower to save water. In some properties it can take a long time for water to run hot, because of the length of pipes between the boiler and the tap. This water can be collected and used for other purposes.

These observations are based on experience in UK, but are equally applicable to China; indeed many of the appliances used in the UK are actually manufactured on China. Many Chinese are well-aware of these simple systems for domestic WDM, although they make lack access to the more sophisticated equipment (whether because of cost or local availability).

Impacts of customer-side measures

The impacts of demand management measures in the urban and industrial sectors will vary according to the particular circumstances in the country, or even the district, where they are applied. They will depend on climate, the income levels of consumers, local customs, attitudes to conservation and present water consumption practices. In the case of industry, economic performance of the industry is likely to be the factor

Demography is a fundamental driver in urban water supply and urban populations are generally growing at a faster rate than national populations. The number of households is key, as is the local preference for housing density. The household occupying a suburban house with garden, strongly associated with affluence in such countries as the USA, Canada, Australia, and UK, is a higher water user than a high rise apartment dweller in the same country, largely because of garden water use.

Without any constraint to supplies there is a strong relationship between income levels and *per capita* water usage - the more affluent the lifestyle the greater water use. In UK average *household* demand has increased by around 55% over the last 25 years and continues to increase at 1% per annum. Average consumption of water *per person* in England and Wales in 2005/06 was around 150 l/c/d (litres/capita/day). This compares to an average consumption per person of around 140 l/c/d in 1992/93. This growth in the use of water has been largely attributed to an increase in the number and range of appliances in households and increases in the frequency of their use, and to changes in numbers of households and household size.

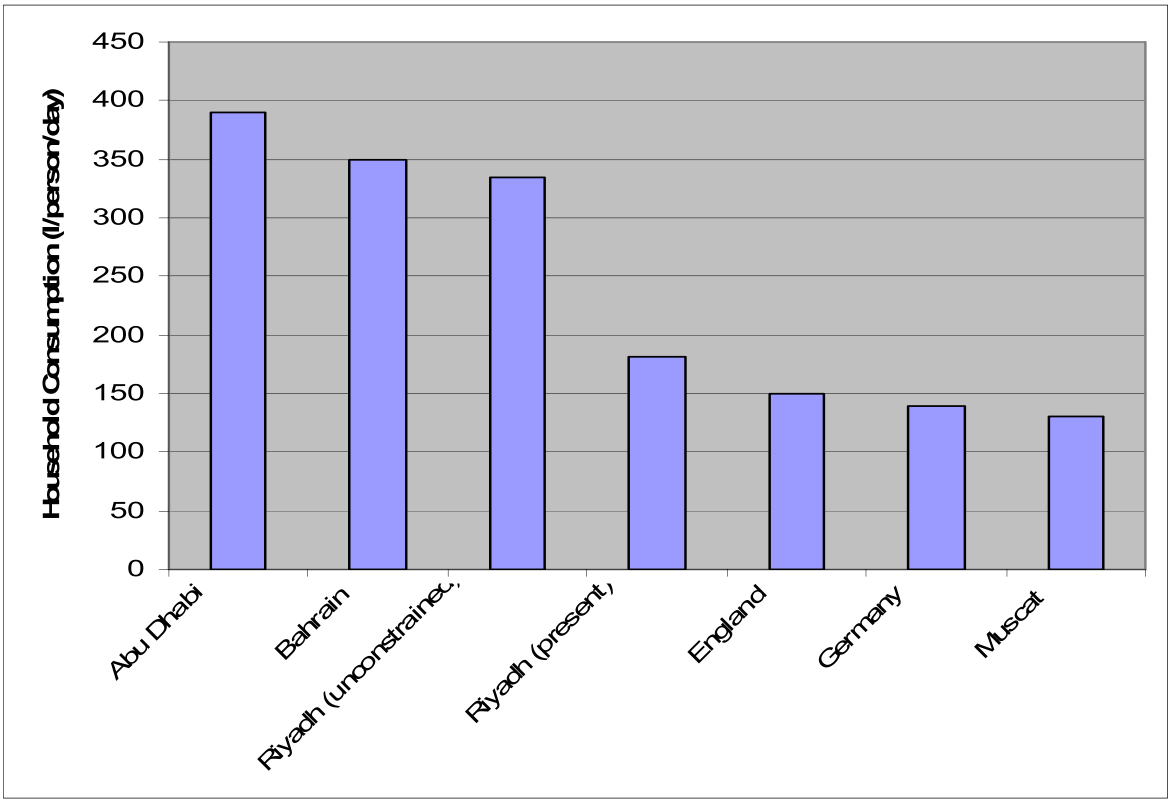
Against this background trend towards increasing water use, some countries have managed to hold the line and a few to reduce per capita demand. They have done so by exerting considerable pressure to restrain demand using a number of management tools – particularly tariffs.

This can be seen from the comparison of per capita consumption levels in various countries in the Middle East and Europe (Figure 8.4).

The Middle East is hot and arid, highly urbanised, and with high GDP, yet large differences can be seen in domestic water usage. Demand is much higher in Abu Dhabi and Bahrain, where tariffs are low than in Muscat (Oman) where tariffs cover over 50% of the supply costs. Consumption rates in England and Germany, which have a temperate climate and where tariffs meet the full cost of supply, are much lower than in Dubai and Bahrain. Muscat and Riyadh serve as an indicator of the possible magnitude of reductions in demand that might be expected in the region from metering of supplies and increased tariffs combined with other demand management measures. These are all countries with good infrastructure.

Even in the temperate climate and relatively homogeneous economic area of the EU there is significant variation in present water use (Figure 8.5); with some countries where per capita consumption is increasing, although most are having some success in maintaining or further reducing demand.

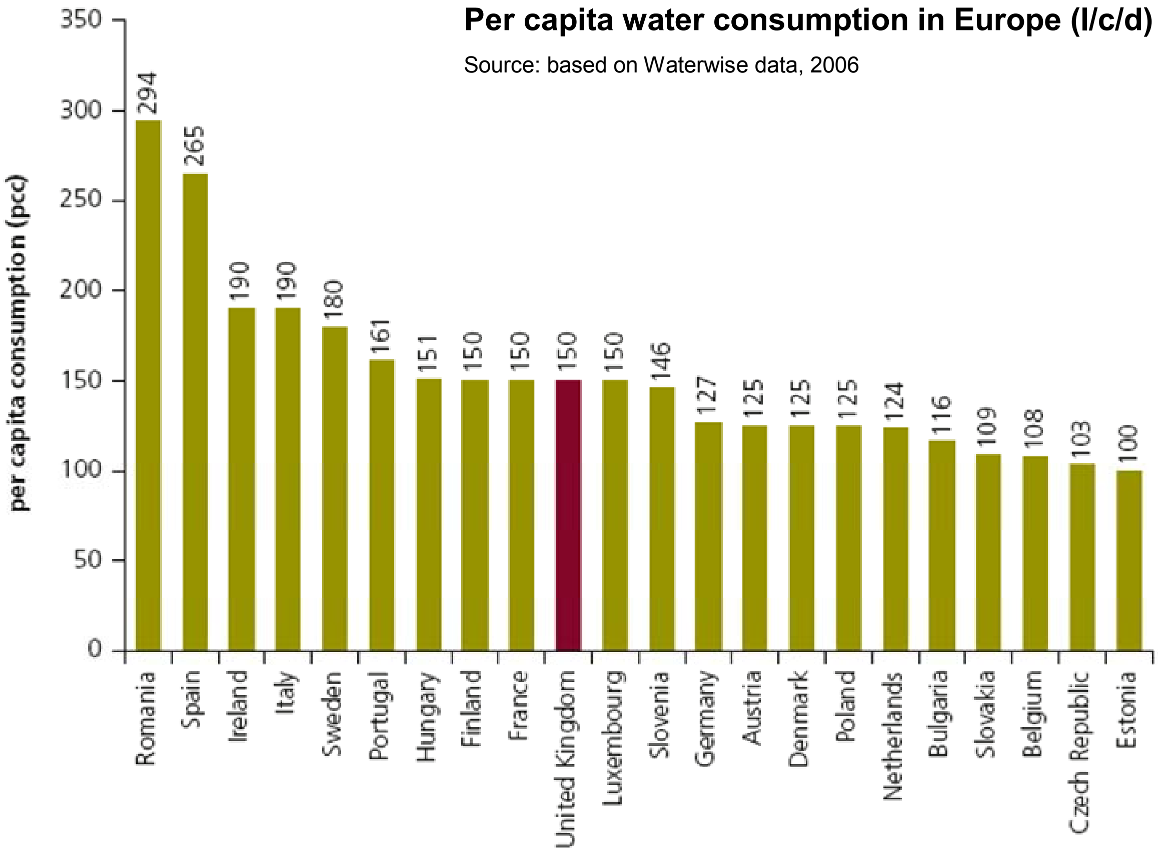
Figure 8.4 Household consumption (l/c/d)



The impacts of more widespread metering and higher tariffs in Eastern Europe have had a dramatic impact on water consumption, which has fallen by over 50% where individual flats have been metered and tariffs raised to cover some new investment costs as well as operating and maintenance expenses.

In England, on the other hand, the introduction of metering for household supplies has had a relatively small impact on demand. Prior to 1990, very few household customers in UK were metered. Trials were introduced to assess the impact of metering in the early 1990s. The outcome of these trials indicated that there would be an immediate fall in demand of about 20% on the introduction of metering and charging for water by volume. However, over a period of about a year there was also a recovery in the level of demand, so the long term savings appear to be about 10%.

Figure 8.5 Domestic water consumption in Europe



Growth in the use of water has been largely attributed to an increase in the number and range of appliances in households and increases in the frequency of their use, and to changes in household size. The proportion of households with washing machines and dishwashers has increased with ownership now at 95% and 33% respectively.

There have also been important demographic changes. The population is growing and ageing and the number of households has increased.

Similar trends can be anticipated in China

Institutional customers

A variety of public services fall into this category some of which are office based and therefore low water use, but others such as hospitals or residential homes may have significant water use. In general residential institutional water use can be viewed as similar to that of domestic users and non-residential as similar to commercial customers.

Government and public services should seek to demonstrate best practice. Schools in particular with their role in raising awareness of all forms of water saving should demonstrate high standards of practice themselves. Procurement requirements need to be designed to ensure that agencies preferentially purchase water efficient appliances, fittings and other water using equipment.

The same sort of measures can be applied as in the case of domestic users, but institutional users may have slightly different facilities. For example, urinals can be fitted with passive infrared controls which only flush the urinals only when they have been used: one UK water company reported water savings of up to 65% when these devices were fitted in their office premises. These type of facilities are increasingly used in China.

Push-top taps which deliver a small flow (typically 0.1 l/sec) and switch off automatically after a few seconds (typically 6 seconds) can save a considerable amount of water. UK trials suggest that these taps can save approximately 2 m3/person/year if set up correctly.

Another useful device is a tap flow reducers which, when fitted to existing taps, allows the flow to be modified according to use. With half a turn of the tap the device offers a spray and when the tap is opened further the flow changes to full flow. One UK water company reports that the average water saving per hand wash was around 50%.

Commercial customers

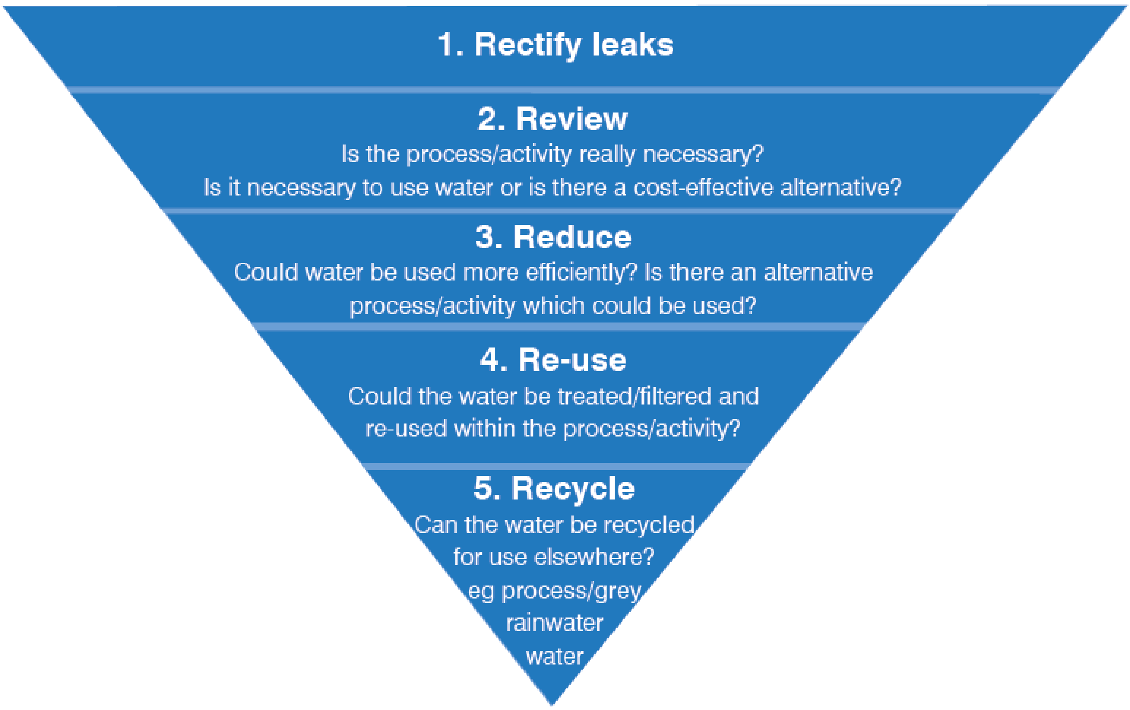
Water audit: Businesses can carry out self-auditing so that they know how much water is being used within their premises and where. Water use by commercial customers depends on the nature of their operations. Offices and shops are generally low volume users with use only required for staff washrooms, cleaning, and possibly canteen facilities. Car washes, laundries, communal bath houses etc are very significant water users. Restaurants would generally use more water than shops.

Water use by commercial customers depends on the nature of their operations. Audits of office buildings in Australia and overseas indicate that over 95% of water use in modern office buildings is accounted for by amenities (toilets, showers etc) [37%], cooling towers (air conditioning) [31%] and leakage [26%]. The figures in brackets are typical figures from Australia

The NABERS (National Australian Built Environment Rating System) is a voluntary benchmarking scheme covering office buildings and public institutions. It is anticipated that 50% of office space in Sydney will have obtained accredited NABERS OFFICE Water ratings by 2009-10 (www.nabers.com.au).

Following the audit the next step should be to draft a water management plan (WMP) to identify all the necessary actions and resources – these may include new or improved equipment, different processes, changes in behaviour and attitude, and of course, money and staff time. Such a plan need not be overly complicated and can be enhanced and improved over time as feedback is received and data improves. If the business already has an environmental management system (ISO 14001) then the water management plan would constitute a component of the system. This should identify target areas for improved – probably ranked by return on investment (as in Figure 8.6).

Figure 8.6 Hierarchy of water saving measures for a Water Management Plan



This information on Figure 8.6 indicates that repairing leaks should be the first target – as they typically account for 25% of use. These should be completed before any efficiency measures are undertaken so that a true baseline of consumption can be established against which to check the savings from other measures.

Cooling

Many commercial and public buildings, and in particular larger buildings particularly in hot and arid climates need a lot of water for cooling: this can account for up to 30-40% of such a building's water use. Evaporation is an essential and unavoidable part of the cooling process, but the controls and plant configuration should be reviewed to make sure that only the minimum needed is in operation at any time – saving water and energy. This is especially important in multi-tenanted premises which may not always be fully occupied.

Refit premises

For most businesses the possible options are similar to those described earlier for domestic premises. Refitting staff facilities can achieve significant water savings:

- Where the urinals operate without flush control install passive infrared sensors, or waterless urinal systems
- Spray taps can reduce water use by 60 - 70% compared with conventional taps
- Install tap aerators and flow restrictors

In some cases, such as for car wash business recycling might be the most cost effective measure for water saving. A car wash with significant recycling could be exempt from initial bans during a drought.

Industrial customers

The business case for water saving can be summarised as follows:

- To save the company money
- Compliance with current and future environmental legislation
- To improve the company's environmental performance and benefit from positive public relations
- Better relationships with stakeholders

In the UK a government sponsored organisation, Envirowise (www.envirowise.gov.uk), promotes environmental best practice focusing on the industrial sector. This organisation provides advice on industrial process design, the latest energy efficient and water saving technologies, opportunities for recycling on site, etc. To help businesses benchmark their water use, Envirowise has developed a free web service called 'water account'. This enables a business to enter in its annual water use, which is shown in a graphical format compared to other businesses within the sector, or for food and drink, within the sub sector. Such benchmarking can be a strong incentive to take action because, if competitor firms use less water, their utility bills are lower providing them with a competitive edge.

Water audit: Managers can carry out a water audit to find out where efficiency savings can be made. Industrial premises can be complex, and have a number of high water using components such as boilers and cooling systems. If there is only a water meter for total water use then purchasing or hiring sub-meters and/or flow-meters would provide the information needed to calculate consumption or flow data for key equipment or process lines. A regular monitoring system should be established and the data recorded. The advantage of recording the data in this way is that any changes in water usage will be identified earlier than the next bill and any issues, such as leaks, could therefore be rectified, saving the business money. Water use can be compared against production output for manufacturing companies or against staff numbers for service sectors.

Changes in processes: Having completed a water audit and identified high water use processes (such as cleaning, boiler feed, cooling, etc) it is possible to consider whether there are any technically feasible and financially viable opportunities for water saving and/or water recycling. Measures that require only moderate investment and can deliver significant savings include:

- Cleaning in place
- Membrane technologies (small scale process treatment)
- Flow controllers
- Meters and monitoring equipment

- Rainwater harvesting systems

There may also be scope for effluent recycling either for low grade water usage applications or, with on-site treatment technologies, reuse for higher quality applications.

All these water savings measures cost money, and industries will evaluate them in terms of their impact on financial performance of the industry. In some industries, the long term financial gains which should result from greater water efficiency may be sufficiently attractive, but others may be more concerned by short-term financial impact and thus reluctant to invest in new technology which has a long pay-back period. Changes to water abstraction permits and tariffs are likely be needed to influence corporate behaviour. Public pressure may also have an impact as society becomes increasingly environmentally aware.

8.5 Demand Management Initiatives in China

Practical details related to the demand management policy (as stated in the 2002 Water Law) are provided China Water Conservation Technology Policy Outline (NDRC Announcement 2005 No.17) which provides guidance on the development and application of water conservation technology and promoting its use to improve water use efficiency.

The Outline is intended to guide the research and industrial development of water conservation technology, key technological investment trends for water conservation projects, promote the wide application of water conservation technology, restrict and eliminate outdated and high water-consuming technologies, techniques and equipment, and provide technological support to water resource planning and water conservation development. It aims to be practical and effective, and suited to the actual situation in China

Water conservation measures in industry and urban domestic water supply are addressed. They focus on both supply-side and customer-side demand management using the techniques and measures described earlier. Supply-side measures focus on minimising network losses through active leakage control including improvements in network mapping through the use of GIS. Customer-side measures focus on demand management through appropriate increasing volumetric tariff structures supported by the use of water fittings and appliances that are more efficient in their use of water.

Thus for example national targets have been set for leakage minimisation. These represent a major challenge to WSCs, especially those with aging or poorly maintained distribution systems and those in weak financial circumstances. The standards for urban networks have set the allowable leakage rate at no greater than 12%, with an adjustment of -2% to +3% depending on the length of network and water quantity supplied, although the precise details of timeline for achieving this, funding and responsibilities are not entirely clear.

8.6 Climate change – a driver of change for demand management

As countries try to reduce emissions of the greenhouse gases that are driving climate change, all aspects of national life are being scrutinised and new approaches sought – the water sector is no exception. New trends in thinking and a new urgency to find sustainable solutions are apparent everywhere, even in places historically viewed as well endowed with water resources.

The way water is pumped, treated, cleaned and heated has profound implications for energy use. The water industry and domestic hot water are major energy users, with a significant carbon impact. The type of water-energy analysis now being undertaken by the water supply industry is illustrated in Box 8.1 for by the UK, and indicates that 5% of total carbon emissions in the UK are from domestic water use (including heating)

Water efficiency measures are a real win-win solution: they reduce water use as well as energy use, and therefore greenhouse gas emissions. They reduce tariffs for both energy and water. It is interesting to note that the financial incentive for reducing domestic water use in UK is its impact in reducing household energy bills than water bills

Box 8.1 Carbon emissions in the UK water sector

During 2006/07 the UK water supply industry used almost 7,900 GWh of energy in its total operations, and emitted over 5 million tonnes of greenhouse gases, as carbon dioxide equivalents (CO_2e). Around 56% of the water industry's emissions came from wastewater treatment, 39% from clean water supply and treatment, and 5% from administrative and transport emissions.

Domestic water use (including water heating) contributes roughly another 35 million tonnes of greenhouses gases (CO_2e) per year. This is seven times as much as that emitted by the industry itself, and amounts to over 5% of total UK greenhouse gas emissions.

9 Drivers, Incentives and Constraints

9.1 Drivers of change

Introduction

A “driver” of change is a factor that has the potential to bring about change. In the context of WDM in a water resource-constrained situation, the environment is an important driver. It is, however, not just the mismatch between demand and supply that is important, but also the rules adopted for allocate water and balance supply and demand, and the organisations who manage water. Influential users may try to bring pressures to bear on management organisations in order to distort the rules in their favour and obtain an unfair share of the water.

Drivers are considered in this section in four categories.

- Environmental: resolving the mismatch between supply and demand, and the need to allocate water to reverse environmental decline
- Social: improving equity of access to water, whilst protecting livelihoods
- Financial: the need to avoid or delay major capital investments; and to improve cost recovery for O&M
- Economic: the need to maximise the productivity of water

These need to be viewed in their wider context, including national and local objectives for food security, economic growth, poverty reduction, avoidance of local or regional conflict and so on. The key players in political debates on these broader topics are not always fully aware of specific water-related issues, and particularly of their complex inter-relationships.

Strong political leadership is always important for implementing difficult decisions – of which there are many in water demand management. If sound management of the water sector is seen to be important for the wider political objectives, then the synergy can be very powerful.

Water management actions need to be framed in ways which correspond to political targets. This is not always easy. For example, the decision to make electricity free in Andhra Pradesh for pumping groundwater for agriculture, and the refusal to charge for agricultural water in Sri Lanka specifically contradicted the recommendations of water sector studies and the need for water demand management. Both of these were campaign issues for state or national elections.

Environmental drivers

The scarcity and uneven distribution of water resources (both in time and space) are obvious for all to see. Despite the extensive development of large-scale infrastructure in recent decades, it is evident that this approach cannot resolve all the problems of access to water. In addition the quality of surface and groundwater has been deteriorating. These two features are powerful drivers for a new approach to water resources management, as embodied in Minister Chen Lei's speech in February 2009.

These pressures on the resources will become even more critical in most places as a result of the anticipated impacts of climate change, which may well affect both average and extreme events. Whilst the precise details at local level may still be uncertain, a general trend towards more unreliable and more unpredictable water resources is anticipated. The water industry as a whole (including agriculture) is an important direct and indirect source of carbon emissions. Demand management can thus also reduce the carbon footprint.

Supply management alternatives sometimes exist and may still be needed, but these are increasingly complex, expensive and environmentally sensitive – requiring, for example, resettlement from areas flooded by reservoirs, avoidance of ecological impacts due to transfer between catchments, compensation for water quality problems, and so on.

Key environmental features which will drive change are:

- Deteriorating river quality (and growing awareness of the importance of this issue), as a result of both over-abstraction and wastewater disposal
- Declining groundwater levels, and groundwater quality
- Reallocation of resources between productive uses and environmental uses
- Avoidance of adverse impacts from the construction of new water supply infrastructure
- Climate change, which will lead to the need to adapt to changes in water resource availability, and to the need to reduce the carbon footprint of water use

Social drivers

Water is fundamental for livelihoods as well as for economic development, but access is uneven. Rural livelihoods are reliant on water for agriculture, but also on off-farm employment in industry which uses water more productively (in terms of GDP per unit water).

Demand management implies both reducing total demands so that it does not exceed environmental sustainability limits and allocating this water to meet specified developmental objectives (see TP 2.7: Water allocation). This may result in increases in supplies to some sectors in some locations (eg urban poor domestic water users), but will still require demand management measures to meet these requirements.

Changes in livelihood strategies may be needed to cope with environmental limitations on water. Wider economic and regional development policies will be needed to support these. Small changes to livelihoods can be achieved as a result of local water demand management programmes, but incentives to develop industry and hence alternative livelihoods will need a wider economic development programme (which will extend beyond the water sector).

Health can also be related to access to water in several ways – negative impacts can arise due to water-related diseases, or poor nutrition as a result of inadequate agricultural production or reduced income. Improved access can benefit health in many ways, but the impact is generally indirect. Demand management programmes which help ensure equitable access to water will thus indirectly benefit health.

Key social features which will drive change are:

- Insufficient water to maintain livelihoods
- Inadequate water for health
- Inequity in access to water

Financial drivers

Supply management options – dams, inter-basin transfers, or other infrastructure - are sometimes available as an alternative to demand management. These are generally expensive, and may have other adverse impacts. Although the costs of demand management should not be underestimated, they are generally less than construction of major infrastructure.

Supply augmentation may be needed in the longer term, but demand management can delay the need for such investment

Key financial features which will drive change are:

- Cost of augmenting supply and the desire to delay or avoid this investment
- Need to improve cost recovery for water management

Economic drivers

Water is a fundamental resource for many economic activities. Most is used for agriculture which, although a low value use, is essential for rural livelihoods and national food security. Maximising the productivity of water (GDP/m^3) is the key economic driver. WDM will contribute towards this, by helping ensure that water is allocated and used efficiently, but wider programmes will be needed to promote economic development as a whole and hence diversify the economy into more productive uses of water.

Summary of drivers

Although environmental pressures may be severe and obvious, it is usually economic factors which drive WDM in developing countries. More efficient use of water and more rational allocation of water between sectors can increase GDP, and at the level of individual users or organisations WDM can reduce the cost of water. The reverse is true in higher income countries, where the environment may be valued sufficiently highly that short term economic benefits are regarded as less important.

However, in all cases the drivers interact with each other, with potential conflicts between social equity, economic growth and environmental sustainability which need to be resolved. These need to be reconciled through a programme of IWRM, which bring together all the actors and defines the institutional arrangements through which water will be managed. WDM is an important element of this process.

9.2 Incentives

Water demand management is not easy to introduce, and traditional supply augmentation is conceptually much simpler. It is also much easier to ensure that it is successful and to demonstrate success: a supply from a new source is directly measurable; demand management is invisible, and difficult to observe or quantify.

Any demand management programme needs to consider the incentives for all actors in the programme – creating or encouraging positive incentives, and avoiding perverse incentives. These incentives need to be reviewed for a wide range of stakeholders, including:

- Political leadership
- Water sector administration
- Other government sectors and organisations
- Private sector
- Water users

Water users – individuals and organisation

The key incentives for individual water users are:

- Confidence they will receive more water (by reallocation from others),
- Simplified and improved management, better access to managers, and the more predictable and reliable supplies which will result
- Reduced costs (unless it is accompanied by an even greater reduction in access to water)
- Direct assistance in coping with less water if less water is inevitable.

Indirect benefits such as increased off-farm employment in industry dependent on more water, changes in subsidy structure to offset increase in fees, long term sustainability of the resource are less likely to provide an incentive to water users to change their practice in the short term. Advocacy and environmental education is needed to turn these from hidden benefits into incentives for change

Irrigation water users have a strong incentive to participate in demand management in the sense that participatory irrigation management is by definition, a form of demand management. But this is different from an interest in saving water - they have little direct incentive to save water There is some evidence, however, that this form of improved, and more accountable, management may result indirectly in water saving or in greater productivity of water. Progress has been reported in many countries[21] where farmers gained significantly in terms of transparency, more reliable information about future irrigation timing, better service, reduced conflict, etc.

Urban domestic water users can be given effective incentives through the fee structure and improved water metering. These will, however, remain weak incentives and have limited overall impact until the supply is reliable and adequate

Industrial water users

The incentives for industrial users to save water are usually dominated by financial considerations – to reduce costs, maximise profits and increase returns to shareholders, often with a very short term view.

These incentives can be moved towards promoting demand management by introducing and ensuring compliance with regulations. These regulations need to be devised so that industries gain financially by implementing WDM measures such as more water-efficient processes or water reuse. This can be achieved by ensuring that the amount saved from cost of the reduced abstraction permit volume is greater than the cost of recycling water.

Public image or reputation can also influence industries. In some countries, there can be a public backlash against companies which are seen to abuse the environment which affect their sales. This approach can be used to encourage industry to be more efficient in their use of water.

Water supply companies

Generally, water supply countries benefit mainly from the sale of water and have little direct incentive to reduce water supply. However, reduced water supplies do save them some costs – for example for water treatment. Tariffs should also be designed to ensure that the WSCs still achieve cost recovery – the opposite of demand management.

In the UK, for example, the Environment Agency recognises that the structure of the public water supply industry will need to change to provide an incentive to ensure a sustainable water industry in the medium to long term. This is because '*the established water industry model has rewarded companies for selling as much product as possible to customers'*. A 'water **service** company' approach would put the provision of sustainable water services at the centre of the companies' delivery and their reward structure[22].

This is easy to state, but less easy to implement as there are conflicting pressures to:

- maintain WSC income (and, in some countries, profits);
- minimise prices for consumers; and

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[21] Vermillion, 1997 and Shah, 2002

[22] Environment Agency water demand management bulletin Issue 94, April 2009

- protect the environment by abstracting less water and improving the quality of waste water.

For the WSC, the financial incentive is normally dominant. The regulator needs to ensure that they comply with other targets/objectives and are then able to maximise their financial returns legitimately.

Water resource departments

Water resource departments at all levels will be faced by significant change to implement WDM – there will be a change in tasks, loss of some traditional activities, and addition of new and unfamiliar activities. Even if the overall staff requirements remain the same or even increase, there will be a change in its nature and possibly changes in relative importance or status of activities: there will be fear and possibly resentment. Many staff will have been attracted to the profession in the first place because of their interest in the traditional approaches (eg in design and construction), and this will have been supported through their training and professional development.

These negative incentives need to be recognised and tackled, through awareness and skill development programmes. New potentially perverse incentives should be identified and avoided. For example, charging water users according to the amount of water they use may give them a strong incentive to use less, but if it reduces the funds available to the department managing the resource it will give them a negative incentive. Such fees need to be structured in a way which gives incentives to both – for example by giving matching funds from central budgets on a progressive basis.

There should be longer term incentives in the form of satisfying work, reduced conflict with users and other stakeholders, a more stable resource base and so on, but these will need to be encouraged with an active capacity-building programme.

Government departments are often believed to be the losers when programmes such as participatory irrigation management (PIM) transfer authority from the agency to the farmers, making the agency accountable to the farmers for delivering water on schedule, making repairs to the main system, etc. While there are also some benefits that agencies can derive from PIM (such as less political interference), some of those benefits - such as reduced opportunities for rent seeking - are actually costs.

However, irrigation and water resource departments should benefit directly - Shah et al (2004) point out that there is a large amount of work still to be done by the irrigation agencies. The nature of the work will change, but there is a need for "*the role of the state to grow – not shrink – as the stress on water resources grows further. … for, leave alone direct regulation, even indirect instruments of water management require a bureaucracy to implement*". Thus that government staff should not feel threatened by the reforms – rather they should see them as an opportunity. Shah believes that this particularly true in China, where their new role is explicitly recognised by the Government, and there is less pressure to reduce staff numbers than in other countries such as India. The process of reform has already begun in China, with the establishment of water savings offices.

Environmental and other departments

Many Government departments are involved in water in various ways, and they will need to become more involved in order for WDM to be effective. For example, agricultural departments will need to be active in giving advice on water-efficient crops and cultivation methods. These other departments already have an incentive to participate, but this is often resisted by water departments.

High level inter-departmental working groups or commissions may be needed to reconcile the competing interests, and ensure positive incentives for all.

9.3 Constraints

The sections on drivers and incentives above indicate a number of factors which will constrain implementation of demand management. These constraints are summarised below under various headings:

- Institutional
  - Difficulties of effective co-operation and data sharing between departments
  - Knowledge management in general
  - Human resources - lack of skills for new activities, and lack of opportunities for established skills
  - Willingness (at all levels) to accept DM as a valid approach
- Financial
  - Sufficiency of resources for DM actions
- Technical
  - Data collection on water use, water use efficiency, water savings etc
  - Complexity/interrelationships of measures (perverse impacts)
  - Difficulty in quantifying impacts, designing measures to meet targets

Demand management is usually required in combination with some elements of supply augmentation. Supply management generally entails discrete, high-profile projects which attract much public attention, whereas demand management is diffuse involving a large number of small activities which are low-profile and individually of little apparent impact. The public profile of demand management is much lower, but this situation will change as environmental awareness grows.

10 Water Demand Management Plans

10.1 Overview

The earlier chapters of this document have described the various instruments, methods and requirements for t water demand management. This final section of this document outlines how these might be brought together into a coherent demand management (or water saving) strategy and plan and implemented. It is important to note that the measures individually may have small impacts, but they should have a substantial impact when implemented together over a large area

Understanding the value and impact of alternative WDM measures and the likelihood of their success is an important consideration when developing a water demand management strategy and plan. These will include an estimate of the direct impacts on water demand as well as the wider environmental, economic, social and financial impacts of a measure. Comparisons of the value and impact of alternative individual measures and the likelihood of their success are important considerations, but these will need to be developed into a coherent and comprehensive approach, as a combination of *ad hoc* measures are unlikely to meet the overall goal.

Such plans can be prepared at different scales, for example a river basin, a municipality, or an individual entity such as a water supply company. This chapter focuses on preparation of an overall plan at municipality/river basin level.

The overall approach for preparation of a WDM plan includes actions to:

- Undertake analysis of water resources and uses to Identify critical water issues, constraints and opportunities,
- Assess institutional setting and capacity
- Undertake water system audit – both for system as a whole and for representative sub-systems
- Formulate targets
- Develop WDM options and costs, and consult with stakeholders on these
- Evaluate anticipated impacts of measures (effectiveness, ease of implementation, stakeholder compliance, sustainability)
- Select and prioritize options (including institutional arrangements), taking account of financial, economic, social and environmental criteria
- Assess staff and capacity building needs
- Identify funding needs and sources
- Develop the WDM plan and optimize to meet targets, including timing or phasing of components of the plan, with involvement and agreement of stakeholders
- Design arrangements for implementation, monitoring and evaluation

An example of this is presented in Figure 10.1, which relates to urban settings in Queensland, Australia. As this is a plan of relatively confined scope for an urban area, the scale of institutional assessments and stakeholder involvement is less than is normally required.

10.2 Development of the WDM plan

Overall objectives of the demand management plan

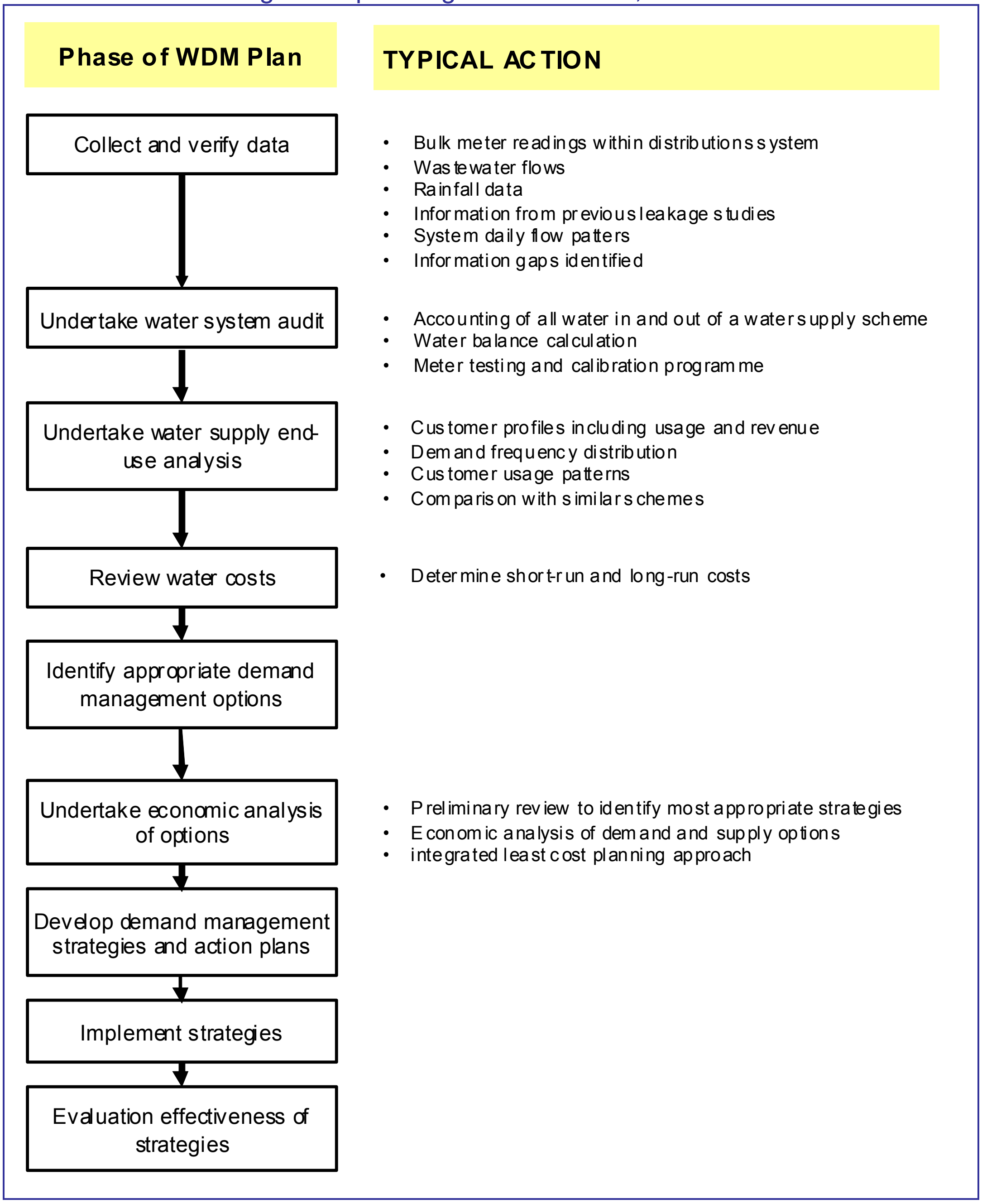
There are many potential objectives for WDM. The purpose is generally to reduce water consumption, either to restore sustainability of a resource or to make water available for other consumers.

The plan should commence with a statement of the desired outcomes of the water demand management strategy, which might include[23]:

- reduced water usage (both average and peak demands);
- reduced water leakage or loss;
- reduced wastewater flows;
- improved financial performance, through:
    - deferment of infrastructure investments, and
    - reduced operational costs;
- greater awareness by consumers of the financial and environmental value of water;
- increased agricultural production through the increased water availability arising from greater water use efficiency;
- improved viability of industry; and
- reduced run-off of pesticides and nutrients into rivers and streams.

[23] This is taken from an example in Queensland, Australia – details will vary according to the location

Figure 10.1 Demand management planning in Queensland, Australia



A specific set of objectives should be drawn up for the plan area (county, municipality, river basin, or other unit as appropriate). In the case of Jinchang in Gansu Province, for example, the Water Savings Office has set up objectives related to the:

- Proportion of water use by sector, with a target productivity of water (volume of water abstracted per unit GDP)
- Volume of total abstraction for agricultural irrigation water use
- Environmental protection – desertification control, urban green coverage, water shed protection, source water quality protection zones, and river water quality

- Industrial waste water recycling rate of 75% and treatment rate of 95%. 80% utilisation of urban water-saving appliances, 8% urban water leakage, 100% urban sewage treatment rate
- Clearly-defined water resource management system

These general objectives need to be translated into specific targets which can be monitored. These objectives should not be decided arbitrarily but should be based on a good understanding on the existing situation and what can actually be achieved.

Current status of water resources and uses

A sound demand management plan can only be prepared on the basis of knowledge of the existing situation – it is not possible to make a rational plan for change without knowledge of what exactly is to be changed. The need for data to understand the present situation and to provide a baseline for evaluating future change is fundamental to WDM planning. Without this, the plan will just be an aspiration and it will not be possible to know whether it is a success.

This assessment of the current situation should include all sources of water and all categories of water use, including environmental uses. This will include estimates of current losses, and indications of where these losses are used.

This status report should be based on a water audit, including a water balance calculation based on a thorough review of all actual flows into and out of a system. The audit must be based on actual data, rather than norms which may differ from actual usage.

Where information is incomplete or of uncertain accuracy, both the reliability of the estimate and the sensitivity of the water audit to the accuracy of the estimate should be assessed. If necessary, actions should be identified and taken to improve data availability and reliability.

Water use targets

Water use targets should be based on the existing water use situation, and on realistic estimates of what can be achieved through the measures available to be used. Targets should not simply be arbitrary or percentage reductions from the current situation, but it should be possible to define precisely how they could be achieved through specific water savings or demand management activities – whilst still complying with the overall objectives of social, environmental and economic sustainability

Changes to water use patterns will take time - to build awareness of the need and skills to implement new methods, to implement specific activities, and so on. Long term and short term targets need to be set for this, with assessments of the impact of achieving these targets and the progress towards sustainability, environmental quality and social equity anticipated at each stage.

In the UK, the Environment Agency has recommended that targets for water efficiency should be set based on an appropriate indicator of water availability such as Catchment Abstraction Management Strategies (CAMS), water stress or similar, to focus efforts in areas with greatest needs.

These targets should be specific and measurable. There is a risk that objectives will be set in general terms and a set of activities defined which should lead towards these objectives – but within assessing their anticipated specific impact. In this situation the measures may be implemented but neither the specific targets nor the achievements in reaching these targets are quantified.

For this reason it is important to be as precise as possible in setting targets which will be met through the demand management plan.

Demand management options – categories and impacts

The range of potential options for achieving these targets can be classified in a matrix to facilitate presentation and evaluation. An international example, derived from another DFID-funded project Water demand management in areas of groundwater over-exploitation (Black & Veatch, 2006), provides an example on the basis of case studies in India and Jordan. (Figure 10.2): this is simply an example, and should not be applied directly in other areas.

For each option a simple proforma for evaluating key indicators was developed (Figure 10.4). It is not expected that this proforma will be applied directly in other situations, but it is indicative of the methods which could be used for summarising anticipated impacts of WDM actions and the other actions which need to be implemented simultaneously.

In this example, key indicators for anticipated impacts are classified under the following headings:

- Potential amount of water per year saved or made available;
- Unit cost of water saved or made available (including subsidy and tax issues);
- Groups and number of persons affected;
- Impact of measure on groups and sub-groups (including the poor and vulnerable)

Figure 10.2 Summary of demand management options in India, Jordan, Oman

	WATER DEMAND MANAGEMENT			
	Domestic/municipal		**Agriculture**	
Developmental and technical measures	DT1	Reduce water losses	AT1	Reduce losses from surface irrigation systems
	DT2	Water saving devices and fittings	AT2	Introduce sprinkler/drip systems a) with subsidy b) without subsidy
	DT3	Recycling of industrial water		
	DT4	Use of "grey" water		
Distributive, financial and market based measures	DA1	Inter-sectoral water quotas and allocations	AA1	Inter-sectoral water quotas and allocations
	DA2	Intra-sectoral water quotas and allocations	AA2	Intra-sectoral water quotas and allocations
	DA3	Land development control	AA3	Change land use by: a) land purchase b) re-zoning/classification c) well buy-out (transfer of water rights)
			AA4	Crop area prohibition
			AA5	Change cropping patterns by: a) extension b) tax c) market support
			AA6	Introduce water markets
	DA4	Water tariff: a) progressive b) differential	AA7	Water tariffs: a) volumetric b) on power to pumps c) area based
Other socio-economic measures	DS1	Community level management	AS1	Water users associations
	DS2	Population distribution	AS2	Population distribution
	DS3	Migration	AS3	Migration

This is an example where the objective of WDM is primarily to improve equity of access to water – to reduce wastage of water and excess use by some groups of people, so that more water can be made available to disadvantaged groups. This is a different – and simpler - situation to that in China where the objective of WDM is to optimise water uses from economic, social and environmental points of view. Here the impacts of each option can be grouped, for example as follows:

- Water demand
  - Amount of water saved and used to increase productivity for that user
  - Amount of water saved and made available to other users
  - Amount of water saved and made available to other sectors
- Social
  - Changes in water access, prices and household budgets, labour requirements, likelihood of conflict etc, (livelihood assets);
  - Changes in one use on users in other sectors;
  - Impact of changes in water access on livelihoods – livelihood strategies, vulnerabilities and outcomes; and
  - Impact of changes in water environment and quality on livelihoods.
- Environment
  - Enhanced river flows and quality
  - Stable groundwater level and quality
- Financial
  - Cost of measure and recovery of costs
- Economic
  - Productivity of water in each use
  - Increase in average productivity of water

Figure 10.3 Datasheet for summarising WDM options and impacts

Ref No. DT1 Reduce Water Loss (Leakage control)

1. Description of measure

The measure comprises control of leakage from the piped system to reduce water losses or "unaccounted for water" (UFW). UFW in municipal systems is the difference between the total amount of water produced and amount of water delivered to the users. It consists of (i) transmission losses; (ii) meter under-registration; (iii) public uses; (iv) leakage and illegal use. The measure is implemented through repairing leaks, pressure control, pipe replacement and rehabilitation. Leak detection surveys are required to locate the sites of leakage.

2. The measure is normally implemented by one or more of the following agencies:

Government	National	
	Regional or State	
	Municipal	X
	Local	X
Water supplier	Public utility	X
	Private	X
	Public-private-partnership	X
	Public-private-community partnership	X
	Community	X
Water consumer	Municipal	
	Community	
	Family/individual	
	Agricultural	
	Industrial	

3. Supporting measures may be required through:

Domestic/municipal/industrial		Agriculture	
Public awareness campaign	X	Public awareness campaign	
Legislation and regulation		Legislation and regulation	
Advice to industry		Agricultural extension services	
Metered water supplies	X	Metered agricultural wells or supply	
Public-private-community participation	X	Water rights/licensing/registration	
Community mobilization	X	Monitoring and enforcement	
		Subsidy introduction	

4. Example of the amount and unit cost of water saved or made available

Jordan

The overall Unaccounted for Water (UFW) in Jordan is high, about 54% in the Ma'an Governorate. The large proportion of UFW is reported to be leakage and illegal use (36%). The potential water saving is large, of the order of 30%, by improving and rehabilitating the existing distribution network and household connections.

Water supplied in Ma'an Governorate was 15.8 MCM/year and the potential for saving water through leakage control would be 4.7 MCM/year. Preliminary estimates of the cost of projects and potential water saving in different Governorates showed that projects implemented during 1993-1997 at a total cost of 51.7 JD Million could save a total water of 20.1 MCM/year and proposed projects implemented during 2005-2010 at a total cost of 23.1 JD Million could save 10.3 MCM/year. The cost of water saved by these measures would be 0.216 – 0.248 JD/m^3 (0.31-0.35 US$/$m^3$)

Oman

In Muscat and Salalah, transmission and distribution pipelines are relatively new and in good condition. It is estimated that further savings could be made of 5% of current supplies.

Items	India (USD/m^3)	Ma'an, Jordan (USD/m^3)	Muscat, Oman (USD/m^3)
Cost of water saved or made available	NA	0.31-0.35	0.98

5. Subsidy and tax issues

Not applicable

6. **Potential impact on community**

6.1 Groups directly affected

Population of project area (including those affected and those not affected by the measure): ....

Type of group affected	**Population in group**	**Number ranked poor in group**	**Group as % of total population**	**Poor as % of total population**
Urban domestic water consumers				
Rural domestic water consumers				
Farmers and farm labour				
Industry and industrial workers				
Government and commercial				
Other (to be described)				

6.2 Impact of measure (Social)

Group: .... (Population ....); *Sub-group:* (e.g. Poor/vulnerable)..... (Population.....); *Location:* Ref. ......

Social indicator	**Potential impact on group**				
	Very positive	**Slightly positive**	**No change**	**Slightly negative**	**Very negative**
Access to water					
Quality of water					
Effect on livelihood					
Affordability					
Sense of empowerment					
Health					

6.3 Impact of measure (Financial)

- Net financial benefit (or loss) arising from implementation of measure per individual, family or enterprise

7. **Implementation**

7.1 Preconditions to implementation

- Will of and financial resources for water supplier to undertake measures required.
- Leak detection studies undertaken

7.2 Likelihood of success

Viability	1 - 5	Mean score
Ease of implementation	1 - 5	

Planning process

The selection of options and development of them into a coherent plan should always take four key points into account:

- Individual isolated WDM measures have a limited impact on overall water demand. Complementary and integrated measures are preferable.
- Awareness raising, training and information campaigns are vital to any WDM programme. Competency or the capacity to implement a measure is important.
- WDM interventions cannot solve all problems – they need to be evaluated together with traditional supply-augmentation interventions.
- The choice of intervention(s) needs to be informed by financial, social and environmental concerns and criteria.

There is a cost to introducing any water demand management measure. The unit cost may be high where new infrastructure or equipment is required (e.g. treating and recycling industrial water) or small where the measure relies principally on a public information campaign (e.g. water saving within a household).

Selection of components of the plan is best done through a multi-criterion approach based on economic, financial, social, environmental and institutional analyses and linkages to other activities, and other criteria. In this approach the benefits are assessed against each criterion and then weighted and aggregated to give an overall score (see AN7.1).

Economic and financial analyses are important part of the process (TP5.1, and section 4 of this document), but only part as other criteria may be equally or more important. The process of selection of criteria, and the scoring and weighting system should itself be developed in a participatory manner, as this is important for ensuring its acceptability and that it addresses all issues.

Simple pragmatic rules such the 80:20 rule are also useful: this rule gives priority to WDM interventions that yield 80% of the desired results (eg. water savings), with 20% of the effort. This will ensure a focus on measures which will yield:

- The largest results with the lowest current efforts and capacity burden
- Tangible, immediate results

10.3 The demand management plan

An example structure of a Water Demand Management Plan for Queensland is presented below (Figure 10.4). This is an urban area, and thus the scope of the plan is slightly limited, but the general structure is widely applicable.

Figure 10.4 Example of a demand management plan (Queensland)

Sub-plan features	Water Demand Management Plan content
Issues covered in sub-plan	▪ Supply metering. ▪ Water pricing. ▪ Customer education. ▪ Water-efficient hardware. ▪ Irrigation efficiency. ▪ Water restrictions (consumption regulation). ▪ Supply reduction.
Purpose of plan	▪ To provide an overview of the WSP's current water demand management practices. ▪ To outline the WSP's future objectives and initiatives in managing water demand.
Policies that may be required	▪ Pricing. ▪ Customer metering. ▪ Water use restrictions. ▪ Effluent reuse. ▪ Trade waste minimisation. ▪ Infrastructure service standards (re supply rates and pressures).
Other Total Management Plan elements that are linked intimately to this sub-plan	▪ Service Standards Plan: considers supply-side service parameters (e.g. supply rates and pressures) that influence demands. ▪ Financial Management Plan: considers implications of consumption-based pricing and falling demands. ▪ Infrastructure Plan: takes account of deferring future headworks consequent on falling demands. ▪ Water Loss Management Plan: provides for water audits which utilise demand data, and may incorporate common strategy(ies), e.g. pressure reduction, leak detection, etc.
External issues contributing to the current operating environment that need to be considered	▪ New developments in government such as WaterWise. ▪ *Local Government Act 1993* requirements for two-part tariffs for certain urban supplies. ▪ Increasing encouragement of WSPs by governments to develop formal water demand management programs, with some offering financial assistance on preparation and/or implementation. ▪ Progressive implementation of COAG pricing principles for irrigation water pricing. ▪ Requirements of EPP (Water) for preparation of local government environmental plans on water conservation. (This sub-plan and the Water Loss Management Plan should jointly be formulated so as also to meet these requirements.) ▪ Consumption data from other WSPs for benchmarking current demands. ▪ Efficiency improvements in irrigation practices. ▪ Advances in efficiency of water appliances, irrigation equipment and other hardware.
Issues that need to be considered in summarising the status of current operations	▪ Scope of WSP's water demand management program. ▪ Progress on environmental plan for water conservation under EPP (Water), for local government WSPs. ▪ Status of customer education programs, e.g. WaterWise. ▪ Extent of customer metering. ▪ Water consumption trends and benchmarking results. ▪ Current and planned pricing practices, and effects on consumption trends. ▪ Promotion of water-efficient hardware, improved irrigation practices, trade waste minimisation recycling and reuse, etc. ▪ Broad SWOT analysis of relevant operations.

Sub-plan features	Water Demand Management Plan content
Strategic basis of the plan	The strategic elements forming the basis of the plan should include: ▪ goal for asset management; ▪ objective(s) for water demand management; ▪ adopted KPIs; and ▪ management strategies and performance targets. The management strategies developed will be based on the identified key strategic issues and SWOT findings, including risk assessment, in respect of water demand management, and on the required TMP development level. Many WSPs are likely to require strategies for enhancing their customer educational and promotional programs; optimising water-pricing policies in terms of water demand and projected revenue; and minimising consumption on all WSP-owned properties. The strategies should be supported by detailed action plans covering a period of up to 3 years.
Suggested performance measures	**Outcome**: Ratio of infrastructure investment cost (new works) to base year cost. **Output**: ▪ Average water demand/customer. ▪ Maximum day: average day demand ratio. ▪ Peak hour: average day demand ratio.
Supporting documentation	This will depend on the WSP, but typically would include: ▪ current WaterWise (or similar) water conservation program; ▪ strategic water demand management reports; and ▪ water consumption analysis/benchmarking reports.

In addition to this Water Demand Management Plan, the Queensland authorities require detailed supporting documents, including for example:

- Business plans for public campaigns – awareness of water savings, measures to achieve savings;
- Water demand management reports dealing with specific issues;
- Water consumption analysis / benchmarking reports;
- Water audit reports; and
- Meter calibration reports

This is a valuable approach and one which is readily applicable to China. Key points to note are the emphasis on data and water audits, including a specific assessment of the accuracy of data. Water is notoriously difficult to measure accurately. It is difficult even in urban areas, but the complexity and difficulty is vastly greater in rural areas and when environmental uses of water need to be assessed and monitored.

10.4 Programme for implementation

The components of the plan need to be developed into a programme for implementation, including

- **Short term**, quick win activities for immediate implementation which can be expected to have visible impact and few constraints to implementation
- **Longer term** activities, which are more difficult to implement and where the impact will take longer to be seen
- **Enabling activities** – establish regulations, enabling environment etc, and adapt as needed. It is necessary to set up everything in advance – this can be done incrementally as new features are needed. It is almost impossible to identify everything that would be required and to design it correctly in advance. It is better to have a system of adaptive management
- **Parallel activities** – there may need to be other related policies for economic development which are not strictly part of water demand management, but which impact on it. For example, policies for industrialization, incentives for setting up new industries may be required.

The details of this will vary from country to country. For example there is strong high level commitment in China to WDM, but the difficulties arise with implementation issues at local level. In other countries, local implementation is simpler, but there is less political commitment to the process.

11 Implementation of Water Demand Management

11.1 Introduction

The difficulties in overcoming the constraints to implementation of water demand management are underlined by a project in the southern African region implemented by the IUCN (The World Conservation Union) (Hazelton, 2002). This study has shown that, despite the potential savings that would accrue from implementation of WDM, the water sector across the southern African region continues to focus on water supply augmentation.

In addition to the overarching problem that plans tend to be aspirational and unrealistic, and are not based on sound data or knowledge of the existing situation, the main specific reasons for failure of WDM appear to be:

- inadequate financial and human resources for rehabilitation, operation and maintenance of water conveyance systems to reduce system leaks;
- lack of commitment to implementing WDM, even though guidelines exist for catchment management institutions and water supply institutions
- the effectiveness of instruments has not been evaluated in most countries.
- a lack of clarity about responsibility for WDM implementation, and especially for monitoring implementation, and taking action in case of non-performance

Thus, the strategies to overcome constraints to implementing WDM should include high-level advocacy to increase awareness among the stakeholders at different levels on the needs and benefits of WDM; and capacity-building that targets those planning and implementing WDM. It is not sufficient to know how to implement WDM, one needs to know what requires implementation, when to implement it, how to select and motivate the appropriate parties to implement it and how to audit the results.

It should be recognised that success depends on strong leadership – there must a credible champion for WDM from the outset of the programme. The high-level commitment to WDM in China is very important, and creates a strong basis for the enabling environment for WDM. This needs to be translated into strong local-level leadership and commitment to WDM at Provincial, Municipality and County levels.

The need for sound data has been stressed throughout this document. In Australia, there is a saying ‘if you cannot measure it, you cannot manage it’ – this is fundamental to implementation of WDM. The plan must be based on reliable data, there should be an accurate baseline for monitoring, the plan should be monitored systematically and updated on the basis of this monitoring. This will involve various different organisations, who will need to be well-coordinated and to share data and other information. Knowledge management is critical.

11.2 Responsibilities, and coordination

One of the key tasks in WDM is to ensure that there is clarity as to who is responsible for WDM implementation, for facilitating and monitoring implementation, and taking appropriate action when a serious case of non-performance occurs. Thus, one of the main strategies to overcome constraints to implementing WDM in the region is through high-level advocacy to increase awareness among the stakeholders at different levels on the needs and benefits of WDM.

There is also need for capacity building that target the private and public sector planners responsible for development of proposals, as well as at scheme managers and operators who have to implement WDM. It is not sufficient to know how to implement WDM. One needs to know what requires implementation, when to implement it, how to select and motivate the most appropriate parties to implement it and how to audit the results.

Management information systems and other aspects of knowledge management are critical effective implementation and monitoring of Water Demand Management (WDM) in urban centres of Southern Africa. WDM has been much more successful in places with a comprehensive MIS strategy have a sustained long term successful WDM programme.

Many new skills are needed to implement WDM. Training and wider capacity-building programmes are an important part of the programme and are outlined in the next section.

11.3 Training

Introduction

At present there is limited capacity to implement WDM programmes in most countries, and there is no doubt that delivery of education and training is essential for increasing awareness and equipping stakeholders with the necessary skills and tools to implement Water Demand Management (WDM). As the IUCN found in South Africa:

> "*One of the identified major constraints to the adoption of Water Demand Management (WDM) measures is the absence of well structured educational and training programmes or courses suitably targeted to all stakeholders in the water management chain*".

Of course, this raises some key questions:

> "*What form of education and training in required? How does it fit in broader programmes like IWRM? Who should be educated or trained and what are the target figures? And, importantly, who funds the exercise? As much as WDM awareness has been given due attention, education and training to move beyond the barriers to implementation have been lacking*".

This will need to be based on relevant training needs surveys, to identify skills needs in the context of current local human development

Demand management is a relatively new concept, and requires different skills to traditional supply management. Institutional arrangements may need strengthening or reform to suit the change, but equally individual skills will need to be developed accordingly. This requires both different emphasis by water engineers who are traditionally the dominant professional group, and the involvement of other professionals – economists, social development specialists, governance experts, and so on.

There will need to be training both at universities for the next generation of water professionals and training within the Government for existing professionals who will need to adapt their skills or learn new ones.

Academic and professional

Traditional academic training will need to be augmented to ensure that sufficient new graduates are trained in the new concepts. This will require more diverse skills, possibly more co-operation between academic departments to establish inter-disciplinary courses. There will still be a need for training in traditional water management activities, and hence the new courses will need to include a range of options, since it will not be possible or necessary for all to cover each topic equally.

In addition to teaching, Universities can be expected to undertake research into demand management, including evaluation of ongoing implementation programmes. This may lead onto further modification of curricula.

Professions from other disciplines (such as economics, politics, law, psychology or sociology) will need to become involved in future water management. Courses in these subjects should also be adapted to include modules in the relevant water-related aspects of these disciplines. Professional accreditation – membership of the respective professional body – will need to recognise these new skills, including cross-cutting skills.

Finally continuing professional development will be needed to ensure that professionals retain or develop the required depth and breadths of skills and keep up to date with new developments.

Government

There is always a risk within government departments that professional staff do not diversify their skills sufficiently through contact with other related departments, and there can often be professional rivalry between them. A range of measures may be needed to ensure sufficient capacity-building. These could include:

- Multidisciplinary recruitment, and sharing skills and ideas within the department
- On-the-job training and study tours
- Periodic reviews of human resource capacity and needs
- Encouraging analytical thought, and appraisal of on-going activities

- Improving communications between departments, and encouraging training bodies to develop courses which are attended by members of several departments
- Specific skills trainings, either in-house or at an external body.

Such training will need to continue into the future – it is not a one-off activity – and so it will need a continuous funding arrangement

11.4 Risks

Potential risks associated with implementation of the water demand management strategies include:

- Strategies based on inaccurate data (e.g. consumption, financial);
- Over-optimistic consumption reduction targets;
- Unsustainable consumption reduction;
- Inadequate community education or consultation;
- Customer backlash;
- Inadequate revenue due to inappropriate tariff levels; and
- Implementation of sub-optimal strategies[24].

The effectiveness of the water demand management strategies should be evaluated at regular intervals.

11.5 Monitoring

Overview

The purpose of monitoring is to assess the progress with demand reduction and achieving sustainability with respect to water resources. If the activities are not implemented as planned, or if they are not achieving the desired impacts, then the plan may need adjustment. Both the institutional arrangements and the characteristics of the water resource system are complex, with many potential interactions or conflicts which will make the outcome initially different from that hope for. It is to be expected than iterative approach will be needed, with activities adjusted as the programme is implemented.

Sometimes this complexity will result in better than expected outcomes, but in other cases the impacts will be reducing by conflicting factors (eg water saving lead to reduction in return flows which are reused, and thus less scope for water saving downstream).

Secondly, impacts may be observed which are not actually caused by the action taken but occur simultaneously for other reasons – there is a difference between

[24] Derived from Queensland DMP

causation and correlation which will need to be understood when planning further activities.

Monitoring needs to cover two aspects: compliance with the plan, and achievement of the plan in managing demand and reducing water use. Appropriate indicators need to be developed for these two aspects. As with all monitoring indicators they should be SMART (ie specific, measurable, achievable, realistic and time-bound]. Further information is presented in AN3.4: auditing a water saving society

Criteria and indicators for monitoring

As part of the plan development key criteria for evaluating the plan should be developed (see Chapter 10). These may include, for example:

- Overall water-saving targets
  - GDP per unit of water
  - utilization of water resources: the volume of water actually used as a proportion of available resources, expressed as a percentage
  - Percentage of total water abstracted which is metered
  - Total water abstracted expressed as percentage of abstraction permit volume
  - Overall water use (aggregate for all uses and sectors) per permanent resident
- Agricultural water-saving targets and indicators
  - utilization coefficient of irrigation water: the net water requirement of crop as a percentage of the total amount supplied at the headworks;
  - field water use coefficient: crop water requirement as a percentage of amount of water to enter the field;
  - irrigation water norm: the standard amount of water for a crop in a certain location and stage of socio-economic development which is used as a basis for determining irrigation quotas or entitlements (and which in aggregate will match the abstraction permit volume);
  - irrigation water productivity: productivity of water expressed as crop yield (kg dry matter) per unit water supplied, and the net value of production (RMB) per unit water supplied.
- Industrial water-saving targets and indicators
  - industrial output value per unit of water used.
  - reuse of water as proportion of total industrial water consumption.
  - proportion of industrial wastewater which is treated to meet wastewater discharge standards.
  - Industrial waste water reuse as a proportion of the total sewage treatment and water reuse.
  - industrial unit output per unit water (according on the specific product)

- Urban water-saving targets and indicators
  - leakage rate for urban water supply networks, expressed as percentage of total water not charged for
  - the use of water saving devices as a proportion of the total number of devices.
  - number of users of the public water supply with meters as a proportion of the total number of users.
  - waste water treatment rate in cities and towns, expressed as a proportion of the total volume of waste water
  - reclaimed water use rate, expressed as a proportion of urban waste water which meets water quality standards for the purposes specified for reuse.
  - The average daily water quota per person calculated as total consumption divide by the number of permanent residents.
- Regional indicators of water saving. Local water saving may not result in overall water saving, and may lead to a change in use rather than a reduction in consumption, so it is also necessary to identify regional targets.
  - River flows
  - Depth to groundwater
  - Surface water quality
  - Ground water quality
- Implementation indicators for the WDM plan or water savings society. There are also a wide number of factors for successful establishment of water saving societies which cannot easily be quantified. Qualitative targets and indicators need to be defined for these, which include issues such as:
  - Regulations, policies and incentive systems: do these exist, do they support water saving sufficiently, are they easy to comply, do they stimulate the formation and implementation of comprehensive procedures;
  - Coordination with other departments related to water management and water conservation: is this smooth and efficient;
  - Extent of stakeholder participation in the development of the plan, consultations and refinement of the plan, monitoring and updating plan targets and methods;
  - Public awareness, including the establishment of water-saving education and training system, publicity, water users association (formation and strengthening), culture of water-saving, etc.

Data collection methods

Most of the data required is or should be collected as a matter of normal irrigation management practice, and can then be analysed to provide an assessment of WSS progress. It is important that ‘actual’ data is collected accurately and not assumed to be the same as the norm.

Reliability of data is critical: it is important to assess the accuracy of the data, and the sensitivity of the conclusions to uncertainty in the data. Even with good infrastructure accurate measurement of water is difficult. Flow volumes depend on measurements of flow rate (which usually vary) and durations. Integrating meters are common in pipe networks, but very rare in open channels.

Use of monitoring outputs

China's water conservation planning and water-saving social construction planning has been carried out thoroughly, but the assessment of achievements in water-saving has not yet been done in such detail. Continuous assessment of demand management plans is needed, so that they can be revised to be flexible and, appropriate to the changing situation and to improved understanding of the situation.

11.6 Conclusions

It is relatively easy to develop a WDM plan and estimate theoretical benefits and impacts. It is quite another task to implement it successfully. Numerous activities are required: they may not all be as successful as each other or as easy to implement; some may be implemented in full by everyone, others only partially; some may be implemented successfully but not achieve their anticipated impact; and many other problems may be encountered.

Key issues highlighted in this section include the importance of

- Defining institutional arrangements, responsibilities, leadership and coordination
- Sound technical basis for implementation, based on accurate data and knowledge of the water resource and demand system
- Training and wider capacity building, both in government and in academic and professional circles
- Careful analysis and management of risks
- Thorough monitoring, based on rational criteria and indicators, with accurate data collection for monitoring
- Adaptive management, based on analysis and use of monitoring outputs

Water is a critical input for livelihoods, the economy and the environment, but it is under severe stress. Water demand management is not easy, but it is essential for sustainable use of water resources. The approaches outlined in this document will help achieve this goal.

APPENDIX A Water Conservation Technology Policy Outline

National Development and Reform Commission of the People's Republic of China
Ministry of Science and Technology of the People's Republic of China
Ministry of Water Resources of the People's Republic of China
Ministry of Construction of the People's Republic of China
Ministry of Agriculture of the People's Republic of China

Announcement

2005 No.17

The National Development and Reform Commission, Ministry of Science and Technology, Ministry of Water Resources, Ministry of Construction and Ministry of Agriculture have jointly worked out the China Water Conservation Technology Policy Outline to provide guidance to the development and application of water conservation technology, push forward the progress of water conservation technology, enhance the efficiency of water use and its benefits, and promote the sustainable utilization of water resources. It is now released and implemented as of the date of issue.

April 21,2005

China Water Conservation Technology Policy Outline

The China Water Conservation Technology Policy Outline (hereafter Outline) is worked out to provide guidance to the development and application of water conservation technology, push forward the progress of water conservation technology, enhance the efficiency of water use and its benefits, and promote the sustainable utilization of water resources. The Outline mainly focuses on the popularization of water conservation technology, techniques and equipment before 2010, and gives relative considerations to medium and long-term water conservation technology.

1. General situation

1. 1 China is a country scarce in water resources. Its per capita water resource is about 2,200 m^3, accounting for one fourth of the world average level. Because various regions are situated in different hydrologic belts and affected by the monsoon climate, China has an extreme imbalance in the distribution of precipitation over time and space. The distribution of water, land and mineral resources is not adapted to the structure of industrial and agricultural water consumption. With serious water pollution, the lack of quality water has exacerbated water supply shortages.

1.2 The tension between the supply of and demand for water resources is obvious. In normal years, the national water deficit is about 40 billion m^3.The water crisis has seriously impeded socioeconomic development in China. Due to water scarcity, tension has grown from struggles over water between industries and urban life, agricultural production and the ecological environment. In some parts of the country, rivers have dried up, the underground water level continues to decline and the environment deteriorates day by day. In recent years, urban water scarcity is also severe. The nature of water scarcity is shifting from engineering-oriented water scarcity to resource-oriented and quality-oriented scarcity. Urban water scarcity shows a tendency of evolving from a regional to a national problem. In some cities, water scarcity has seriously affected living conditions. Urban development faces a challenge.

1.3 With economic and social development, the demand for water continues to grow. The consumption structure is continuously adjusting. In 2003, the proportion of agricultural water consumption (including forestry and wetland) of the total dropped to 66 percent from 88 percent in 1980, while the proportion of industrial water consumption and urban domestic water consumption increased to 22.1 percent and 11.9 percent from 10 percent and 2 percent respectively. Because of differences in China's local socioeconomic development and water resource conditions, the difference in the structure of water consumption is distinctive. With increasing urban, rural and industrial water consumption, the water-consumption structure will undergo further adjustments. Therefore, requirements for quality water and guaranteed supply rate are getting high.

1.4 Water conservation and high efficiency in using water is the fundamental path to release the tension between the supply and demand of water resources. The core of water conservation is to enhance the efficiency of and benefits drawn from water consumption. Currently, China's water consumption for every 10,000 yuan of industrial value-added is 5 to 10 times that of developed countries. The utilization rate of irrigation water in China is only between 40 and 45 percent, leaving a relatively large gap when compared with the advanced levels in the world. There is a great potential for water conservation.

1.5 The government advocates water conservation. It insists on a scientific outlook by placing water conservation in a prominent position. The government encourages the research, development and application of new technologies, new techniques and key facilities for water conservation. It impels measures for water conservation, develops water conserving industry, agriculture and services and constructs water conserving cities and societies.

1.6 Adopt practical comprehensive legal, economic, technological and engineering measures to push forward overall water conservation. Water conservation work should realize "three combinations", namely, the combination of engineering measures with non-engineering measures, the combination of advanced technologies with conventional technologies and the combination of mandatory water conservation with efficiency guidance.

1.7 This Outline stresses the selection principles, implementation paths, development trends, promotion means and encouraging policies for water conservation technology. It is used to guide the research and industrial development of water conservation technology, key technological investment trends for water conservation projects, promote the wide application of water conservation technology, restrict and eliminate outdated and high water-consuming technologies, techniques and equipment and provide technological support to water resource planning and water conservation development.

1.8 This Outline follows the "practical" principle. Measures such as "research", "development", "promotion", "restriction", "elimination" and "prohibition" will be taken to guide the development of water conservation technology based on the actual situation in China, and in accordance with the maturity of water conservation technologies, applicable natural conditions, the socioeconomic level of development, and the costs and potential of water conservation. It stresses the research and development and popularization of those advanced and applicable water conservation technologies that are highly efficient, beneficial and have widespread influence.

1.9 The water conservation technologies referred to in the Outline are technologies that can help enhance water utilization efficiency and benefits, reduce water loss and replace conventional

water resources. They include direct water conservation technology and indirect water conservation technology. Some of them are energy-saving technology, clean production technology and environmental protection technology.

1.10 This Outline provides technological policy support in order to realize water conservation goals. With the guidance of the Outline, China will strive to achieve "micro-growth" in industrial water consumption, "zero-growth" in agricultural water consumption and a gradual reduction in overall per capita water consumption in urban cities between 2005 and 2010.

2. Agricultural water conservation

Ninety percent of agricultural water consumption is used for irrigation and the rest is used for forestry, animal husbandry, fishery and drinking water for rural people and domestic animals. Although the proportion of rural water consumption was decreased significantly in recent years, agriculture is still the No.1 consumer of water in China. Developing highly efficient water conserving agriculture is a fundamental strategy of the country.

2.1 Optimizing water dispatch technology for agriculture

Water resources for agricultural consumption consists of precipitation, surface water, underground water, soil water and return water, briny water and regenerated water that has been treated to bring it up to the water quality standard. By means of engineering measures and non-engineering measures, optimizing various water resources is the basic requirement for realizing planned water consumption, water conservation and enhancing the efficiency of agricultural water consumption.

2.1.1 Actively develop technology to unify dispatching of water from multiple resources. Greatly popularize various agricultural water-consuming projects control and dispatching methods, use surface water with high efficiency, reasonably exploit underground water, reasonably dispatch and use water resources across time and space, develop "long-vine melon" irrigation systems and irrigation water management technology, realize the unified dispatching of water and enhance dispatching-storage and anti-dispatching abilities within the irrigation area.

2.1.2 Gradually push forward the controls over the total amount and quota management of agricultural water consumption. Speed up setting the total amount indicators for agricultural water consumption for different regions in different precipitation years, setting irrigation water consumption quotas for different plants under different irrigation methods and conditions. Reasonably adjust the water consumption proportion for farming, forestry, animal husbandry, sideline production and fishery.

2.1.3 Set up water-saving high efficiency crop systems that adapt to water resource conditions. Advocate the development and application of hygrophilous plant planting technology. Based on the conditions of local water, soil, sunshine and heat resources, and based on the high efficiency and water conservation principle, crops should be decided by water conditions. Reasonably arrange the crop planting structure and irrigation scales. Restrict and reduce the plant area of high water-consuming and low output crops.

2.1.4 Develop the combined irrigation technology of wells and ditches. Popularize and apply unified adjustment and control technology for surface water and underground water. Advocate dual-irrigation from wells and ditches. Use well water, supplemented by ditch water, to irrigate. Pay attention to research on technologies regarding the balance between underground water exploitation and replenishment.

2.1.5 Develop soil moisture and drought supervision and forecasting technology. Strengthen research on the changing rules of large-scale soil moisture and research on soil moisture and drought index systems across time and space. Actively research and develop soil moisture, drought supervision instruments and facilities.

2.2 Highly efficient water transfer and dispatching technology

Agriculture-use water loss during the process of transfer and dispatching occupies a great proportion of water used. It is the main focus of agricultural water conservation to enhance the efficiency of water transfer.

2.2.1 Suit applications of ditch anti-leakage technology to local conditions. Give priority in taking anti-leakage measures to ditches and branch ditches that cause great loss and low-efficiency in water transfer. Advocate overall anti-leakage to fix ditches that are not required to supplement the irrigation water from wells. Popularize anti-leakage to ditches in the pumping irrigation areas.

2.2.2 Develop pipeline water transfer technology. When renovating relatively small volume ditches, low-pressure pipeline water transfer and dispatch technology should be given priority. In high-lift pumping irrigation areas and areas suited for self-pressure pipeline water transfer, self-pressure pipeline water transfer systems should be given priority in development.

2.2.3 Popularize the adoption of low-cost anti-seepage materials. Advocate the use of spodosol, cement, stones and other local materials. Popularize common materials for mature ditch anti-seepage projects such as concrete, bituminous concrete and plastic film. Encourage the use of geotechnic film such as compound geotechnic film, modified bituminous water-proof materials and anti-seepage materials of polymer fiber concrete, soil solidifying substance and geotechnic synthetic bentonite cushion on the basis of the experimental research. Strengthen research into the new ditch anti-seepage materials, techniques and construction facilities under different climate and soil quality conditions. Strengthen research into product development of anti-seepage, anti-freezing and anti-expansion ditch technologies.

2.2.4 Develop anti-seepage ditch cross sectional scale and structure optimization design technology. Large and medium-sized anti-seepage ditches should adopt non-standard cross sections with sloped or arced bottoms. Small ditches should use the U-shaped cross section. Medium and small-scale ditches should use concrete anti-seepage stone laying. Advocate the use of standardized design technology and the on-the-spot assembly of factory prefabricated materials.

2.2.5 Actively develop ditch system dynamic water dispatching technology. Develop and apply real-time irrigation forecasting technology. Strengthen the research and application of irrigation area water use management technology. Advocate dynamic planned water use management.

2.2.6 Speed up water measuring and survey technology in irrigation areas. Encourage the research, development and popularization of small water measuring facilities that are highly accurate, low in cost, strong in application, easy of operation, and convenient for managing and maintaining.

2.2.7 Develop ageing prevention technology for water transfer projects. Actively research technologies of ageing prevention for water transfer constructions, disease diagnosis and corrosion prevention, restoration and leakage-blocking technologies. Speed up the development of consolidating technology and the product development of water-transfer constructions.

2.3 Field irrigation technology

Field irrigation is the last sector for enhancing the utilization rate of irrigation water. It is also the basis for water diversion, transfer and dispatch. It is the key part of agricultural water conservation for improving field irrigation technology.

2.3.1 Improve field irrigation technology. Popularize narrow border irrigation, tiny-stream furrow irrigation and wave irrigation. Reasonably set furrow and strip specifications and field natural slope and shrunk field. Popularize high-accuracy field leveling techniques, encourage the use of laser field leveling. Scientifically control the irrigation factors affecting water volume into the strips (furrows), water intake and irrigation quotas, and the proportion of water volume changes. Eliminate no-border wild-flooding irrigation.

2.3.2 Greatly popularize water management technology that is based on rice-field dry-wet alternate irrigation. Advocate square fields in rice irrigation areas and adopt rice shallow-wet control irrigation techniques. Advocate the combined technique of rice soaking and tilling. Develop the technique of rice "three-drought" tillage, drought breeding and rarefaction plant and seedlings tossing. Eliminate long-term wild-flooding rice irrigation. Prohibit continuous irrigation and draining techniques for rice fields. Actively research suitable rice field water standards, soil water control indexes, rice field drying techniques and related irrigation systems.

2.3.3 Suit the development and applications of sprinkler irrigation technique to local conditions. Actively encourage the application of sprinkler irrigation techniques in commercial crop planting areas, suburban agriculture areas and concentrated scaled management areas. Give priority to the popularization of light and small-type complete sprinkler irrigation techniques and equipment. In hilly areas or areas with self-pressure conditions, encourage the development of self-pressure sprinkler irrigation techniques. Actively research and develop low-cost, low energy-consumption, easy-to-use sprinkler irrigation equipment.

2.3.4 Encourage the development of micro-irrigation techniques. Widely popularize micro-sprinkler irrigation and drip irrigation techniques in fruit tree planting areas and in areas where agriculture requires facility support, offers quick returns and earns foreign exchange. Advocate the combination of micro-irrigation techniques with the agronomic techniques of field film cover, and synchronous supply of water and fertilizer. Encourage the development of self-pressure micro-sprinkler irrigation, drip irrigation, tiny-stream irrigation in hilly areas where the ground has natural slopes. Encourage the use of rainwater cache storage projects to develop and apply low-water gravity micro-irrigation techniques. Actively research and develop low-cost, low energy-consumption and multi-purpose micro-irrigation equipment.

2.3.5 In the areas where the spring drought is serious but late natural precipitation can basically meet the needs of crop growth, widely popularize sitting-water planting techniques. Advocate the research and development of low-cost, good-performance, high-efficiency dual unified water-supplement planting machine tools.

2.3.6 Encourage the application of accurate control irrigation techniques. Advocate timely and proper irrigation. Strengthen research on the physiological features and water demand of crops. Actively research the relations between the crop growth and soil water content, nutrition, air moisture, atmosphere temperature and other environmental factors.

2.3.7 In water-scarce areas, greatly develop various insufficient irrigation techniques. Advocate the technique of "key water irrigation" at the water-demanding critical stage and key growth stage of crops. Encourage experimental research into crop water content production functions. Research crop economic irrigation quotas and optimized irrigation systems. Strengthen research into insufficient irrigation and water-lacking adjustment water conservation production-growth mechanisms. Research and apply controlled root-division alternate irrigation techniques.

2.4 Biological water conservation and agronomic water conservation techniques

Biological measures and agronomic measures can help enhance the utilization rate and production rate of water content so as to save on the volume of irrigation. It is a main water conservation measure for agriculture.

2.4.1 Encourage research into the application of water/fertilizer coupling techniques. Advocate the reasonable application of a combination of irrigation and manure in terms of times, amounts and methods to adjust the fertilizer with water and apply water and mature together so as to enhance the utilization rate of water and fertilizer.

2.4.2 Advocate water storage and soil moisture preservation techniques such as deep ploughing and loosening, and biological soil nourishment techniques. Improve the soil structure and enhance the water-storage, water-preserving and water-supplying ability of soil. Enhance the utilization rate of natural precipitation and reduce the water volume of irrigation. Pay attention to the research, development and industrialization of deep-ploughing machine tools.

2.4.3 In the areas where the soil is light, the ground has a big slope or the amount of precipitation is not great, actively popularize protective ploughing techniques. Strengthen research into the three key techniques of straw mulching treatment, mechanical biological tillage and chemical herbicide use in protective ploughing. Strengthen the research and industrialization of protective ploughing machine tools that are applicable to different areas.

2.4.4 Popularize field water-increasing techniques. Develop film and furrow-sowing techniques. Strengthen research into low-cost and completely degradable film. Strengthen research into the development of techniques of soil surface water-preservation and thermal enhancement.

2.4.5 Develop and apply transpiration and evaporation inhibition techniques. Advocate the application of leaf anti-drought spray during the high water-demanding period of crops. Encourage research into the industrialization of drought-resistant water conservation products that have functions of metabolism, filming and reflection.

2.4.6 Popularize varieties of drought-resistant, high-yield and quality crops. Speed up the development of molecular biology techniques for the breeding of drought-resistant, water conservation crop species. Select and breed new species of drought-resistant, drought-enduring and high-efficient water-utilizing crops.

2.4.7 Encourage seed dressing with plant-coating and water-preservation agents. Strengthen research into the development of low-cost, multi-functional water-preserving seed dressing agents and water-preserving products and equipment specialized for economic crops and grasslands.

2.5 Precipitation and return water utilization techniques

Enhancing the utilization rate of precipitation and the repeated utilization rate of return water can directly reduce the water volume of irrigation. It is the most basic content of the agricultural water conservation program.

2.5.1 Popularize the utilization technique of precipitation storage. Actively develop field management techniques for different crops and different precipitation conditions. Popularize irrigation systems and techniques that co-ordinate crop water-consumption with natural precipitation. In drought-resistant crop zones, popularize field leveling techniques and improved ploughing techniques that aim to restore natural precipitation. In rice planting zones, actively popularize rice shallow-irrigation and deep-storage techniques. In drought and semi-drought zones and hilly areas that have poor water conservation capacities, popularize rain-collection water-preservation techniques with rhegmalypts and level furrows.

2.5.2 Popularize techniques of utilizing return water for irrigation. Actively develop irrigation-drainage unified management techniques. In areas that have no saline and alkaline threat, prohibit ineffective water receding and low-effective drainage irrigation water management techniques. In areas where the quality of irrigation return water is not up to the standard of irrigation water, actively develop the simple "mixed watering of salty and fresh water" irrigation return water safe utilization technique.

2.5.3 Greatly develop rain-storage utilization techniques. Popularize facility agriculture and courtyard rain-collection techniques. Popularize engineering facility standardization. Research and apply water quality protection techniques in the use of stored rain. Actively develop environmentally friendly, highly effective, low-cost new materials for rain-collection, preservation and anti-seepage.

2.6 Unconventional water utilization techniques

Based on experimental research, Increase agricultural water-resources by safely using such unconventional as part of the resurgent water, brackish water and desalted seawater or through unconventional means such as artificial rain-increasing techniques.

2.6.1 Develop techniques for unconventional water resources. Develop techniques for the multiple use of water and use waters according to their different qualities. Develop the technique of the mixed use or alternate use of unconventional water and fresh water. Set up sewage water irrigation volume quota systems and salty water irrigation control quota systems. Develop supervision and appraisal techniques for determining ground water and surface water quality, crop output and quality, and the physical and chemical features of soil while using unconventional water. Strengthen research into the drainage and treatment of daily-life sewage and brackish water. Actively research and develop economically effective unconventional water treatment equipment and water quality supervision instruments.

2.6.2 Pay attention to the development of artificial rain-increasing techniques. Artificial rain stimulation should follow the principle of government leadership, coordinated planning and reasonable distribution. In the artificial rain potential area of bedded cold clouds and convective clouds, adopt artificial rain-increasing catalysis techniques. Set up artificial rain-increasing comprehensive decision-making technological systems.

2.6.3 Properly develop techniques of seawater utilization. Encourage the reasonable use of seawater resources in the breeding sector or other agricultural and by-product sectors. Strengthen research into techniques of watering salt-enduring crops with seawater diluted with natural fresh water.

2.7 Breeding sector water conservation techniques

Developing breeding sector water conservation techniques, enhancing water consumption efficiency in the breeding sector for forage grass irrigation, animal and domestic fowl drinking water, washing water at animal and domestic fowl breeding sites, temperature reduction water and aquatic products breeding water are all important aspects of agricultural water conservation.

2.7.1 Speed up the development of drought-resistant (drought-enduring) water conservation quality forage grass species selection and breeding techniques. Select and breed wild forage grasses that adapt to local natural conditions or artificially cultivate quality forage grass varieties. Select and breed deep-root, straight small-sized leaf quality drought-enduring grasses that have relatively strong adaptability and resistance in water-scarce environments.

2.7.2 Develop and popularize cultivation techniques for water conservation, drought-resistant quality grasses that adapt to natural grasslands and artificial grasslands. Set up plantation structures and plantation systems that adapt to sunshine resources, water resources and precipitation resources. Reasonably assort different forage grasses of different species such as the fabaceous and gramineous species. Develop and popularize gramineous-fabaceous, forage grass-fodder dynamic plantation or grassland-planting field alternative techniques.

2.7.3 Greatly popularize artificial grassland water conservation irrigation techniques. Popularize grassland water conservation irrigation systems. Adapt the development of grassland irrigation ditch anti-seepage liner and pipeline water-transfer irrigation techniques to local conditions. Encourage grassland sprinkler irrigation techniques under proper conditions. Improve grassland surface irrigation techniques. Develop grassland irrigation water management techniques. Strengthen research into forage grass water-demanding rules, irrigation systems and means of irrigation, and technical experiments. Eliminate grassland no-border wild-flooding irrigation techniques.

2.7.4 Develop grassland water conservation tillage techniques. Advocate grassland ploughless direct seeding techniques. Develop labor added seeding and plantation techniques. Pay attention to enhancing the ability of grassland soil water storage and fertilizer preservation. Greatly develop pastoral area irrigation fodder production bases.

2.7.5 Develop intensive water conservation breeding techniques. Advocate domestic fowl centralized water supply and comprehensive utilization. Advocate "new-type" environmentally friendly animal and domestic fowl, water conservation temperature reduction techniques and drinking water equipment. Reasonably set up animal drinking water spots and effectively protect water sources and water-supply spots. For grasslands that face water-scarcity and extreme drinking-water difficulties, water pipelines can be built to supply water. Popularize rain-collection techniques and facilities built with concrete structures and brick-stone structures that have anti-seepage and purification functions. Encourage research into automatic water-supply equipment that is water conserving, multiple-powered, simple structure, convenient in use and has a high guarantee rate of water supply. Promote the research and application of water saving, highly efficient factory-style aquatic product breeding facilities. Gradually eliminate water slab long water-supply techniques.

2.7.6 Popularize breeding wastewater treatment and repeated utilization techniques. Popularize breeding wastewater re-use technique after anaerobic treatment and the recycling utilization technique after deep treatment and disinfection for washing sties. Advocate water supply according to different water quality and multi-level utilization. Change the traditional way of water washing manure and soaking manure to dry-cleaning. Research and develop low energy-consumption, highly efficient breeding wastewater treatment facilities.

2.7.7 Develop animal products, aquatic product processing water conservation techniques. Encourage the research and development of multifunctional, low-cost, water conserving and environmentally friendly processing techniques and technological equipment.

2.8 Village and township water conservation techniques

Develop village and township water conservation techniques focusing on the scattered water consumption of village and township residents, the simple nature of their agricultural product processing, the low water-consumption efficiency in villages and townships, the simple facilities for water supply in villages and townships, and the insufficiency of safe drinking water sources.

2.8.1 Develop and promote village and township centralized water-supply techniques. Actively pursue planned water-consumption and develop drinking water source development and utilization and protection techniques. The exploitation of underground water should seal the unhealthy water layers. Prevent and control bad quality water such as bitter and salty water, sewage and wastewater from getting into water sources. Encourage water source protective forest and grassland construction. Push forward a centralized water supply and actively develop village and township water-supply pipeline network optimized design techniques.

2.8.2 Encourage the research, development and popularization of village and township home-use water meters and water conservation facilities. In water-scarce areas, village and township water consumption should gradually be calculated on the basis of household size.

2.8.3 Develop village and township drinking water treatment and water quality supervision techniques. In areas where the water quality is not up to standard, drinking water sources should be treated on a concentrated basis. Set up water quality supervision systems. Encourage the development and popularization of simple supervision equipment and portable supervision equipment that conforms to village and township management conditions.

3. Industrial water conservation

Industrial water consumption mainly includes cooling water, water for heating power and craftwork and washing water. Among them, industrial cooling water consumption accounts for about 80 percent of total industrial water consumption. Its volume of fetched water accounts for 30-40 percent of total industrial fetched water. The volume of fetched water in eight industries including thermal power generation, iron and steel, oil, petrochemical, chemical, paper mills, textiles, non-ferrous metals, food and fermentation accounts for 60 percent of the national industrial fetched water (including direct cooling water for thermal power generation.)

3.1 Industrial water consumption repeated utilization techniques

Greatly developing and popularizing industrial water consumption repeated utilization techniques and enhancing the repeated utilization rate of water is a prime path for industrial water conservation. 3.1.1 Greatly develop circulated water systems, tandem water-consuming systems and water-returning and water-consuming systems. Push forward the development and application of enterprise water consumption network integration techniques. Optimize enterprise water consumption network systems. Encourage water exploitation and consumption network integration techniques in newly constructed, expanded and renovated projects.

3.1.2 Develop and popularize vapor condensation recovering and re-use techniques. Optimize enterprise vapor condensation recovering networks and develop closed recovering systems. Popularize the use of vapor condensation recovering equipment and devices. Popularize the water conservation steam trap that has a small blowing rate but big backpressure. Optimize the dust and oil removal techniques of vapor condensation.

3.1.3 Develop exterior wastewater drainage re-use and "zero-discharge" techniques. Encourage and support enterprise exterior wastewater (sewage) re-use after treatment. Greatly push forward the technique that re-uses exteriorly treated wastewater (sewage) in the recycling cooling water system. In areas that lack water and have a high ecological environment requirement, encourage enterprises to apply "zero-discharge" wastewater techniques.

3.2 Cooling water conservation techniques

Developing highly efficient cooling water conservation techniques is a key point of industrial water conservation.

3.2.1 Develop highly efficient heat exchange techniques and equipment. Popularize matter heat exchange water conservation techniques. Optimize heat exchange processes and the combination of heat exchangers. Develop new-type highly efficient heat exchangers.

3.2.2 Encourage the development of highly efficient environmentally friendly water conservation cooling towers and other cooling structures. Optimize recycling cooling water systems and speed up the elimination of cooling structures such as cooling pools and water-spraying pools that have low cooling efficiency and consume a lot of water. Popularize highly efficient new-type side-filters and eliminate inefficient counter-washing side-filter facilities that consume a lot of water.

3.2.3 Develop highly efficient cycling cooling water treatment techniques. In the open cycling indirect cooling water system, popularize water treatment operating techniques that have a concentration of more than four times. Eliminate water treatment operating techniques that have a concentration of less than three times. Restrict the use of hyper-phosphoric zinc water treatment techniques. Develop and apply environmentally friendly water treatment medicaments and prescriptions. 3.2.4 Develop air-cooling techniques. In areas that lack water and have proper climate conditions, popularize air-cooling techniques. Encourage research and development into highly effective, economic air-cooling techniques and equipment.

3.2.5 Popularize and apply vapor-cooling techniques for high-temperature equipment such as reheating furnaces. Make full use of the vapor separated from water.

3.3 Heating power and technology system water conservation techniques

Water consumed in the heating power and technology systems used in industrial production is divided into boiler water-supply, vapor, hot water, purified water, softened water, desalinated water and deionized water. Its volume of water consumption takes second place in industrial water consumption, next only to cooling water. Saving heating power and technological systems' water consumption is a key part of industrial water conservation.

3.3.1 Popularize heat-unifying techniques for production technology (within and between devices, within and between working procedures).

3.3.2 Popularize the use of desalinated water for medium-pressure vapor equipment and the use of softened water for low-pressure vapor equipments. Popularize the use of closed cycle water-vapor sampling devices. Research and develop hot water boiler and vapor boiler water treatment techniques that can realize "zero-discharge", boiler vapor ash ejecting techniques and "zero-discharge" non-block wet desulfurization techniques.

3.3.3 Develop dry-style distillation, dry-style steam stripping, non-vapor de-oxygen techniques that use little or no vapor. Optimize vapor automatic adjustment systems.

3.3.4 Optimize the preparation technologies of boiler water supplies and technology water consumption. Encourage the adoption of up-stream recycling, bunk bed, washing water recovering techniques to reduce the volume of water consumption. Research and develop boiler water supplies, technology water consumption and the preparation of new technology and equipment and gradually popularize deionized water purification techniques.

3.4 Washing water conservation technique

In the process of industrial production, washing water is divided into product washing, equipment washing and environment washing water.

3.4.1 Popularize water conservation techniques and equipment of up-stream rinsing, sprinkler washing, vapor washing, aerial fog sprinkler washing, high pressure water washing, oscillation water washing, and highly efficient revolving panels.

3.4.2 Develop equipment-using water conserving washing techniques. Popularize recyclable detergents or all-in-one detergents and washing techniques. Popularize the technique of carbon dioxide ice washing, microorganism washing, sprinkler washing, water vapor pulse washing and non-stop in-service washing.

3.4.3 Develop environment water conservation washing techniques. Popularize the use of recycling water and self-cleaning coating techniques that have the function of photocatalysis and air catalysis.

3.4.4 Popularize various water washing auxiliaries and related chemicals that help reduce water consumption. Develop various highly effective environmentally friendly detergents, microorganism detergents and highly effective water washing machines. Develop and research non-water washing techniques and equipment such as environmentally friendly dissolvents, dry-cleaning machines and ionophore washing.

3.5 Industrial water-supply and sewage treatment water conservation technique

3.5.1 Popularize the use of new-type filter material high-precision filtration techniques and automobile backwash techniques to reduce water consumption. Popularize the recycled use of backwash drained water and sedimentation tank mud water draining techniques

3.5.2 Encourage the application of ozone, ultraviolet light and other second pollution-free disinfection techniques during wastewater treatment. Develop and popularize the application of techniques such as supercritical water treatment, photochemical treatment, new-type biology, absorbent carbon adsorption, and membrane methods in industrial sewage treatment.

3.6 Unconventional water resource utilization techniques

3.6.1 Develop techniques for the direct utilization of seawater. Among industrial enterprises along the coastal area, greatly popularize seawater direct cooling and seawater recycling cooling techniques. 3.6.2 Actively develop seawater and bitter and salty water desalination treatment techniques. Implement industrial chain techniques that are mainly based on seawater desalination, as well as making salt out of bittern and extracting of other useful compositions. Enhance the comprehensive efficiency of seawater desalination. By expanding the scale of seawater desalination devices and implementing energy-recovering techniques reduce the costs of seawater desalination. Develop complete, serial and standard production techniques for seawater desalination equipment.

3.6.3 Develop mining well water resource utilization techniques during coal, oil and mineral extraction. Popularize the application of techniques for substituting water resources that turn mining well water into mining area industrial water, domestic water and agricultural field water.

3.7 Industrial water transfer pipeline network, equipment anti-seepage and rapid seepage-blocking techniques.

Reducing the water seepage rate of water transfer pipeline networks, water-using pipeline networks, and water-using equipment (appliances) is a main path towards industrial water conservation.

3.7.1 Develop new-type water transfer materials. Restrict and gradually eliminate traditional cast iron and galvanizing pipelines and speed up the development of water pipelines that have strong mechanical strength, rigidity and are convenient for installation. Develop valves and pipeline components that are non-leaking, convenient for operation and supervision and have a long service life.

3.7.2 Optimize techniques for industrial water supply pressure, liquid surface and water volume control. Develop swift, practical industrial water pipeline networks and equipment (appliances), leakage examination equipment, and instruments and technology.

3.7.3 Research and develop rapid leakage-blocking techniques for pipeline networks and equipment (appliances).

3.8 Industrial water consumption quantitative management techniques

Industrial water consumption quantity and control is foundational work for progress in water consumption measuring, management and water conservation techniques.

3.8.1 Key water consumption systems and equipment should have water meters and control instruments installed. Perfect and revise related various design specifications. Affirm the design and installation of water quantity measuring and supervision instruments and their precise requirements. Key water consumption systems and equipment should gradually have improved computer and auto-supervision systems.

3.8.2 Encourage and popularize the establishment of enterprise water consumption and water conservation computer management systems and databases.

3.8.3 Encourage the development and production of control instruments such as new-type industrial water quantity measuring instruments, volume-limited water meters and time-restricted controls, water-pressure controls, water-level controls and water-level sensor controls.

3.9 Key water conservation technology

Water conservation technology refers to the technology that uses less water or does not use water by changing production raw materials, techniques and equipment or the ways of water consumption. It is the highest level (water conservation, energy-saving and product quality enhancement) of all source water conservation techniques.

3.9.1 Greatly develop and popularize water conservation techniques and equipment such as industrial dry dusting and dry dust (slag) transfer, high-density dust/slag transmission, dust-washing water recycled in the industries of thermal power generation, iron and steel and calcium carbide, and the dry dust-collection purification techniques in smelters.

3.9.2 Popularize gas-vapor unified recycling power generation, clean-coal burning power generation techniques. Research and develop power-generation technology and techniques that consume less water such as the use of petrochemical fuel including natural gas for power generation.

3.9.3 Popularize non-blast furnace iron-smelting techniques using melted reduce in the iron and steel industries. Develop thin-belt continuous casting techniques. Popularize dry coke-extinction or low-water coke-extinction techniques in the process of coking.

3.9.4 Encourage hydrogen-adding refining technique and eliminate acid-base washing techniques in the process of refining oil products.

3.9.5 Develop water conservation techniques in the production of synthetic ammonia. Use low energy-consuming decarbonization techniques to replace water-washing de-carbon dioxide and use low-heat consuming Benfiledtechniques and MDEA decarbonization techniques. Popularize complete low-changing techniques, NHD de-sulfur, decarbonization gas purification techniques. Develop ammonia-production which uses natural gas as a raw material. Popularize alcohol hydrocarbon refineries and low-pressure low-energy-consuming ammonia combination systems. Produce synthetic ammonia with heavy oil as raw materials and use dry-retrieving druses.

3.9.6 Develop urea production water conservation techniques. In newly-built plants, popularize CO2 and NH3 stream stripping techniques. Popularize water solution complete recycling urea energy-saving and water conservation techniques. In medium and small-sized urea plants, popularize urea waste liquid deep hydrolyzation desorption techniques.

3.9.7 Popularize methanol production low-pressure synthetic techniques.

3.9.8 Develop caustic soda production water conservation techniques. Popularize ion-membrane caustic soda and use three-effect up-stream evaporation to renovate traditional down-stream evaporation. Popularize 10,000-ton three-effect up-stream evaporation plants and highly effective natural imperious recycling evaporators.

3.9.9 Develop sodium carbonate production water conservation techniques. In ammonia-soda plant, popularize vacuum distillation and dry dust-adding techniques.

3.9.10 Develop the acid-washing purification technique in the production of sulphuric acid and new-type heat-exchange equipment. Gradually eliminate water-washing purification techniques and traditional cast iron cooling pipelines.

3.9.11 Develop textile production water conservation techniques. Popularize the use of highly effective water conservation auxiliaries. Popularize the use of biological enzyme treatment techniques, highly efficient short-range pre-treatment techniques, cold rolling pre-treatment techniques, dye-bath new techniques, low-water up-stream rinsing techniques and high-temperature high-pressure small bath-ratio liquor-stream dye-bath technology and equipment. Research and develop high-temperature high-pressure stream dyeing, micro-suspension particle dyeing and low-temperature plasma processing technology and equipment. Encourage textile dyeing processing enterprises to use natural color cotton water conservation production raw materials and popularize natural color cotton new-type manufacturing techniques.

3.9.12 Develop paper industry chemical slurrying water conservation techniques. Popularize fiber raw material washing water recycling technique systems. Popularize lowKappa value stewing, pre-rinsing oxysome de-lignin treatment, closed washing and screening systems. Develop non-element chlorine or complete non-chlorine bleaching. Research and develop low-chlorine bleaching and complete non-chlorine bleaching that suits the character of straw pulp. Reasonably organize the up-stream use of bleaching wash filtered liquid. Popularize medium and thick techniques and the process intelligent control technique. Develop and enhance soda recycled black liquid multi-effective evaporation stations and secondary vapor cooling water recycling rate techniques. Develop the pulp-making water recycling use technique for mechanic pulp, secondary fiber pulp. Popularize highly effective precipitation filtration equipment "saveall" recycling techniques. Strengthen "saveall" closed circular technique research. Develop re-use technique and equipment for "saveall" recycle and mid-wastewater after second-grade biochemical treatment.

3.9.13 Develop food and fermentation industry water conservation techniques. Develop dry, semi-wet and wet preparation starch water extraction closed circular flow techniques according to different products and different technologies. Popularize water extraction closed circular flow techniques for the production of alcohol with mould adobe blocks corn powder, the production of gourmet powder and lemon acid with starch. Popularize high-density sweetwort fermentation (alcohol, beer, gourmet powder, yeast and lemon acid) and high-density mother liquor (gourmet powder) extraction techniques. Popularize concentration techniques by using double-plus effect evaporator. Eliminate the technique for starch raw material of high-temperature stewing and pasting, low-density sugar liquid fermentation, low-density mother liquid extraction. Research and develop beer wheat juice cooling, and alcohol differential pressure distillation devices.

3.9.14 Develop oilfield water conservation techniques. Popularize optimized water injection techniques and reduce ineffective water injection. For extremely high water-content stage oilfields, technical measures of thin-layer water injection and thin-layer water blocking should be taken to control the volume of water injected. Popularize advanced and suitable oilfield water treatment re-injection techniques. For water from those especially low and penetrated oilfields, popularize refined treatment techniques. For thick-oilfields that need to inject stream, popularize thick oil sewage deep treatment re-use stream injection boiler techniques. Research and develop treatment and re-use techniques for water extracted from the third exploration of oilfield. Popularize oil and gas field construction and under-well work water conservation techniques.

3.9.15 Develop coal production water conservation techniques. Popularize effective water-preservation measures in the process of coal exploration and prevent mine pit leakage or oozing. Develop and apply advanced exploration technology and equipment that cause less damage to surrounding rocks and water loss. Develop and apply water conserving coal selection equipment. Develop and apply dry coal selection techniques and equipment. Research and develop large-scale advanced dehydration and coal earth water treatment equipment.

3.9.16 Popularize new-type dry production technique of decomposition outside cement kilns. Gradually eliminate wet production techniques.

4. Urban domestic water conservation

Urban domestic water consumption includes water used by urban residents, commercial and trade firms, institutions, colleges and universities, tourism, social services, gardening and afforestation. At present, urban domestic water consumption accounts for about 55% of urban water consumption. Along with the development of the cities, urban domestic water consumption will further increase; urban domestic water consumption is closely linked to the daily life of common people, with a per capita water consumption 212 liter/per day (Of which, 228 liter/per day in municipal cities. Urban domestic water conservation is of significant important for the promotion of building water-conserving cities.

4.1 Water conservation appliances

The popularization and application of water conservation water-consumption utilities is a key technical guarantee of domestic water conservation.

4.1.1 Popularize water-conserving taps. Popularize water-conserving taps such as the non-contact auto-control, prolong time automatic close, water cut-off automatic close, foot-treading, ceramic-chip-sealed taps. Eliminate iron cast spiral water taps, iron cast spiral valves in construction.

4.1.2 Popularize water-conserving toilet systems. Popularize the use of two-level toilets. The toilet water volume in the new buildings should be less than 6 liters. In public construction areas, two-level toilets with a water volume of 6 liters are preferred. Urinals with non-contact control devices need to be popularized. Eliminate sanitary ware with water infusion on the tank lower than the water level, with water pumped up and flashed down, or with a water-flashing volume of more than 9 liters.

4.1.3 Popularize water conservation bathing facilities. Bathrooms commonly use bathing facilities with hot- and cold-water mixing taps. Popularize the use of intelligent card non-contact auto-control, prolong time automatic close, foot-treading showering devices. For hotels, restaurants and hospitals which consumer great amounts of water, popularize the use of bathing devices with restricted water flows.

4.1.4 Research and produce new-type water conservation appliances. Research and develop highly intelligent water appliances, water appliances with ideal water consumption volumes and household-use water taps with different functions.

4.2 Urban recycled water utilization techniques

Urban recycled water utilization techniques include urban sewage treatment recycled water use techniques, construction water treatment recycled water use techniques and living sewage treatment recycled water use techniques.

4.2.1 Set up and perfect urban recycled water use technique systems. Urban sewage recycled water use should follow the principle of local use for the area where the treatment is handled according to the source and scale of urban sewage while using reasonable recycled water treatment technology and transfer technology. Encourage the research and enactment of urban water system plans, recycled water use planning and technology standards. Gradually optimize urban water supply systems and water pipeline distribution networks. Set up urban recycled water use pipeline networks coordinated with urban water systems and centralize the recycled water use system for water from treatment plants, single construction sites and residential zones. Stipulate and perfect sewage recycled utilization standards.

4.2.2 Develop sewage concentration treatment recycled use techniques. Encourage cities that are lacking water resources to concentrate on sewage treatment plants and adopt recycled water use techniques. Recycled water can be used for agriculture, Industry, urban grasslands, rivers and lake landscapes, car-washing, underground water supplementing and be used in public construction covered by the urban sewage concentration treatment re-use pipeline network.

4.2.3 Popularize and apply urban residential zone recycled water use techniques. Water-scarce areas, residential zones, should adopt construction water treatment re-use techniques if the construction scale, population and water consumption reach a certain level. Recycled water can be used for toilet flushing, cleaning, car-washing, green land, environmental and ecological uses.

4.2.4 Popularize and apply middle water treatment re-use techniques. For water-scarce areas and areas outside the coverage of urban sewage concentrated treatment re-use pipeline networks, if construction water consumption reaches a certain level, construction middle water treatment re-use techniques should be actively adopted. Middle water can be used as domestic water.

4.2.5 Actively research and develop highly efficient and low energy-consuming sewage treatment and recycled water re-use techniques. Encourage the research and development of new treatment techniques and recycled water use techniques that take small space, are highly automated, easy to operate and maintain and low in energy consumption.

4.3 Urban rainwater, seawater, bitter and salty water use techniques

4.3.1 Popularize urban rainwater direct use techniques. In urban grasslands and residential areas, popularize urban grassland water-storage direct use technique. Rainwater can be directly used for grassland watering. In water-scarce areas, popularize road rainwater collection direct use technology. The rainwater collected by the roadside can mainly be used for urban use. Encourage dry area cities to adopt micro water conservancy project techniques to make use of the rainwater resource that is in small intensity widely distributed in accordance with their own conditions such as roof rainwater collection technique.

4.3.2 Popularize urban rain environment ecological use techniques. Combine rain use with protection and restoration of wetland such as natural low-lying land, lakes and rivers in parks.

4.3.3 Promote urban rainwater collection and pumping-back technology. Priorities should be given to the promotion of urban rainwater collection and pumping-back technology in areas short of water. Make full use of rain flood and flood-period water release from reservoirs to have underground water pumped back and reutilized through the grassland, urban water system, water-penetrating roads in urban transportation networks, roadside drainage, urban community rainwater storage and utilization systems and water collection penetration and replenishment and utilization systems in public buildings. Improve urban drainage systems and launch rainwater runoff collection systems and water quality supervision systems. Encourage areas that lack water to use urban water collection and pumping-back systems on the basis of systems that divide rainwater from sewage. Research and develop rainwater quality monitoring systems in urban areas.

4.3.4 Promote seawater utilization technologies. In northeastern, northern and eastern coastal cities where water is scarce, actively develop seawater desalination and transportation and dispatching technology. Speed up in developing low cost seawater desalination technology. Encourage these cities to develop seawater direct utilization techniques and actively develop processing technologies for salty daily-life sewage water. Develop technologies for the disposal of salty sewage water into the sea (ocean).

4.3.5 Promote systems utilizing bitter and salty waters. In water-scarce cities in north and northwestern and coastal regions, we should actively promote electro-dialysis disposal processing technology and anti-permeation processing technology and apply them to the disposal of urban varied water use and daily life varied water use and part of the drinking water use.

4.4 Leak-hunting and anti-seepage technologies in the urban water-supply pipeline network.

Water leakages in the urban water-supply pipeline network have become a problem in the current urban water supply. Actively adopting leak-hunting and anti-seepage technologies is not only an important technical measure in saving urban water resources, but will also play a significant role in improving the service quality of the urban water-supply and ensuring the safety of the supplied waters quality.

4.4.1 Promote pre-locating leak-hunting and precise leak-hunting locating technologies. Promote and apply pre-locating leak-hunting and precise leak-hunting locating technologies, optimize leak-hunting methods in line with the different building conditions of the water-supply pipeline networks. For networks buried under the earth, adopt passive leak-hunting method mainly, and use active leak-hunting method as a supplement. For networks covered with urban roads, active leak-hunting method and adopt passive leak-hunting method as a supplement. Encourage the adoption of area leak census system technology and precise-locating leak-hunting technology, on the basis of the construction of the GIS and GPS systems for the urban water-supply pipeline networks.

4.4.2 Promote the use of new tubular products. For big-caliber tubular (DN>1200),give priority to pre-stressed concrete cylinder pipes; for middle-caliber tubular (DN=300-1200),give priority to plastic or ductile iron pipe, and gradually discard ferro-steel pipes. For small-caliber tubular (DN<300), give priority to plastic pipe, gradually discard galvanized iron pipe.

4.4.3 Promote and apply advanced techniques in water-supply pipe linkage and antisepsis. Under normal condition, socket joints should adopt rubber-ring sealed flexible linkage technology. The inside wall of metal pipes should adopt the antisepsis technique of applying cement plaster or resin. As for welded or glued pipes, adopt relative construction technologies such as proper distance installing flexible interfaces, expansion pipes or U-typed pipes in consideration of pipe harmomegathus.

4.4.4 Encourage the development and use of piping leak-hunting determination and supporting information systems. Encourage the launch of the determination and supporting systems with the functions of artis-searching, condition emulation, incident analysis decision-making and dispatching, on the basis of the GIS system of pipeline network construction. These will provide technical support for determining the location of pipeline network leaks.

4.5 Water conservation techniques for public water-supply enterprises.

Water conservation of the public water-supply enterprises should mainly be focused on the recycling of backwashing waters. The recycle of backwashing waters should meet both urban water conservation and water environment protection targets.

4.5.1 For newly-built or expanded water-supply projects which uses surface water as primary water, actively promote backwashing recycling techniques. Choose new filtering technologies with strong waster entrapment capacities, build backwashing desilters, and adopt air-driven backwashing technologies, which are more effective with a low backwashing volume.

4.5.2 In the renovation of water-supply projects, actively adopt advanced backwashing technologies. Reform and strengthen the structural organs of the backwashing system, adopt adequate backwashing methods, and improve the backwashing recycling functions of the desilters. Discard high-intensity timing backwashing techniques by 2008.

4.6 Water conservation techniques for public buildings

With the fast development of urbanization and the service sector, water demands in public buildings will rise sharply. Water conservation in air-conditioners should be regarded as one focus of water conservation in these buildings.

4.6.1 Promote circular chilling techniques for air-conditioners in public buildings. The air-conditioners in public buildings should adopt circular water-chilling systems, the recycling rate of the chilled water should be above 98%.The concentration of the chilled water in open-form systems should be no less than three times. Circular water-chilling systems should be in open or closed form in line with actual conditions.

4.6.2 Promote and apply antiseptic, anti-fouling and anti-microbe techniques in air-conditioner circular water-chilling systems.

4.6.3 Encourage the adoption of air-chilling techniques

4.6.4 Promote and apply boiler condensation recycling techniques. Promote and apply close-end condensation recycling systems, hot-pump condensation recycling system, compressor wastewater recycling system, fixed-climate pressure water returning machine, the recycling rate of directly using condensation water no less than 85%.Develop antiseptic and water-quality monitoring systems for recycled machinery.

4.7 Water conservation techniques in municipal environment

The water usage in municipal environment accounts for an increasing part of urban water demand. Encourage biotech water conservation techniques, and adopt comprehensive techniques combining biotech water conservation and management, to better promote water conservation in municipal environment.

4.7.1 Develop afforestation water conservation techniques. Actively develop biotech water conservation, promote the planting of drought-enduring forests, and use non-sufficiency irrigation method in irrigation. Use recycled water in afforestation. For those who use non-recycled water, adopt water conservation techniques such as sprinkling irrigation, micro sprinkling and dipping irrigation. Select earth buried rise-fall sprinkling irrigation facilities, dipping irrigation pipes, micro sprinkling irrigation head and dipping irrigation belt in afforestation efforts.

4.7.2 Develop water-recycling techniques in scenic spots.

4.7.3 Promote water-recycling techniques in swimming pools.

4.7.4 Develop water conservation techniques for car washing. Promote and apply water conservation techniques for car washing, promote the usage of high-pressure gun-jet for washing vehicles, computerized car-washing and micro-water washing. Research and develop environmentally friendly water-free washing techniques.

4.7.5 Actively push forward non-flushing toilet facilities and other water conservation toilets

4.8 Information on techniques for urban water conservation

Water conservation information technology, which could realize water conservation information sharing and enhance scientific decision-making concerning water conservation matters, is of great significance in strengthening water-conservation management.

4.8.1 Develop the applied technology of geographic information systems (GIS).Encourage researches on GIS-based water conservation information systems so as to provide a solid foundation for urban water conservation information management.

4.8.2 Develop water conservation information-gathering and transmitting technology and specialized database technology. Develop internet-based water-conservation information technology and water conservation management systems and specialized database technologies in order to enhance and regulate water conservation management and guide the development of urban water conservation techniques.

5 Guarantee measures to develop water conservation technology

Improve laws and regulations and set up incentive and constraining mechanisms and perfect a well-functioning technology service system in order to push forward the development and application of water conservation technology.

5.1 Strengthen legislation work and administrative management on water conservation.

5.11 In accordance with the Water Law of the People's Republic of China and the Law on Clean Production of the People's Republic of China and other legislation, laws and regulations concerning the promotion of water conservation technology development should be enacted.

5.1.2 The progress of water conservation technology should be placed in an important position when central or local governments are drafting their "11th Five Year" Development Plan or other specific socioeconomic plans.

5.1.3 Research and development (R&D) into major water-conservation technologies should be incorporated into the country's medium and long-term science and technology development planning and into national science and technology development plans as well.

5.1.4 The central government will regularly issue "categories of outdated high-water consumption techniques and equipment that are to be abandoned" and "categories of water conservation production techniques and equipment to be promoted".

5.2 Establish incentive and constraining mechanisms for developing water-conservation technology.

5.2.1 Both the central and local governments should attach importance to the development, showcasing and promotion of these vital water conservation technologies, and offer the necessary financial backing.

5.2.2 Products made from wastewater (liquid) and conforming to 2003 Versions of Lists of Resources for Comprehensive Utilization could enjoy reduced income tax rates according to national policies.

5.2.3 Encourage industries that make good use of alternative water resources such as recycled water, seawater and minimum salty water. Enterprises that produce water from recycled water or enterprises that produce fresh water from seawater are entitled to enjoy preferential policies.

5.2.4 Water conservation technology and equipment encouraged by national policy are entitled to enjoy preferential taxes as permitted by national policies.

5.2.5 Water conservation projects, whether undertaken by the State, local governments or enterprises, should first choose their water conservation techniques and equipments as recommended by the Outline. For some important projects, the State and the local governments should provide fund subsidies support.

5.2.6 Guide social investment to water conservation projects, with special emphasis on leading financial institutions to grant loans to some key projects. Encourage diversified financing formula so as to provide sufficient funds for the technological renovation of water conservation projects and the funding for water conservation projects.

5.2.7 Building water pricing mechanisms that fully reflect China's scarcity in water resources. Its emphasis lies on water conservation, the allocation of water resources, efficiency in water usage and the sustainable use of water resources. Under the revised pricing mechanism, the number of people who should pay for water consumption is enlarged and the amount they are paying will see a moderate hike. The price of water used in water conservancy programs will also meet a steady increase. The price hike priority should be given to urban sewage treatment and water recycling. Promote laddering water price to make the pricing mechanism more scientific and reasonable, people should be more heavily charged if water consumption exceeds the prescribed quota.

5.2.8 Water conservation technologies recommended in the Outline should be actively adopted in all projects that are newly built, or being extended, or being rebuilt. In this regard, all water conserving facilities should be designed, built and operated at the same time as those of the main building construction. All water consuming entities should make sure that their water consumption plan, water conservation target, water conservation measures and water management system are all in place.

5.2.9 Establish and improve water consumption control and quota management systems. Establish evaluation and appraisal systems for fetched water quotas in combination with characteristics of industries and regions.

5.2.10 Strengthen the inspection and supervision of key water consuming companies, so that they will carefully observe the water quota, adopt water conservation technologies and products and discard outdated and highly water-consuming manufacturing techniques and equipment. All newly built water-consuming projects are not allowed to use the outdated techniques and equipments listed in the Outline.

5.2.11 Speed up the establishment of a water conservation products warrant system and water product market regulations.

5.3 Establish and complete a research development and service promotion system on water conservation technologies.

5.3.1 Reinforce the system of water conservation technology renovation through the establishment of more laboratories and research centers with expertise in developing water conservation technologies.

5.3.2 Strengthen the popularization of services and systems that conserve water. Organize a variety of related activities, such as technology exchanges, promotions, consultations, information releases, advertisements and training courses.

5.3.3 Strengthen the systemization of water conservation standards. Establish and improve various standards on water quotas, water conservation basis, water conservation evaluation, and water-conservation-related equipment, products standards and technology specifications.

5.3.4 Promote international exchange and cooperation on water conservation technology on more regular basis. Exchange and cooperation activities include the introduction and adoption of leading foreign technologies concerning water conservation and the research and development of such technologies and products with our own intellectual property.

5.3.5 Launch education campaigns that aim to promote water-conservation related issues, such as science popularization and promotion programs on water-conservation technologies in a varied and effective form.

(All information published in this website is authentic in Chinese. English is provided for reference only.)

APPENDIX B The Role of the Regulator in Water Services

B.1 Introduction

A strong regulatory system is needed to ensure sound management of water. Water is not a commodity which can be managed purely by market forces, and there is a need for a regulatory system to cover the processes of resource allocation, environmental protection, service delivery performance, and financial charges. Access to water in most countries has been managed by organisations within the government. This has changed in recent years, with a much greater diversity of roles and interests amongst stakeholders.

Regulation is needed because water supply is often a natural monopoly – enabling supply organisations to exploit their control with high tariffs and inequitable service delivery, or governments to keep water charges low for political reasons. High charges lead to high profits, but social unrest, whereas low charges do not even cover basic operations and maintenance, let alone expansion of services to marginal areas where the poor are concentrated. The need for a regulator is widely recognised in the urban water supply sector, but less commonly in the rural sector. The regulator also needs to cover more than just pricing – for example, they also need to act as a watchdog to ensure good service delivery.

Regulation should include:

- Resource Regulation - allocation of water resources, and water quality,
- Performance Regulation – service delivery, and
- Economic Regulation - water charges.

In both rural and urban situations, regulation should ensure that the sector is well-managed by:

- Protecting consumers against monopolistic abuse
- Protecting operators against government intervention (or intervention by other parts of government)
- Benchmarking performance
- Promoting efficiency through service targets

B.2 Governance requirements for the regulator

Regulators became common with the advent of private sector participation in water, but they are equally necessary for public sector management. However, they do face many problems which need to be guarded against with good governance arrangements (ADB[25]). These requirements apply equally for regulators for irrigation and for urban or industrial supply:

[25] http://www.adb.org/water/actions/REG/regulatory-bodies.asp

- **Clarity of roles and objectives.** The regulator should have a clear mandate of its functions and objectives. It should likewise have a clear role vis-à-vis the other government agencies involved in the sector.
- **Autonomy/Credibility.** A regulator should be free from political influence and commercial intervention, be well-funded and have fixed tenure for the regulatory board members.
- **Participation.** Key stakeholders should be consulted and involved.
- **Transparency.** The regulator should follow clear rules and guidelines, and explain to stakeholders how and why decisions were made. Those decisions should also be published and open to public scrutiny.
- **Accountability.** Decisions should be written and accessible to the public and the government. Regulators should be open to appeals courts and international arbitration to resolve disputes, and be subject to independent audits.
- **Predictability.** Operators need to be able to invest confidently, assured that "rules of the game" will not suddenly change, putting their investments and serviceability at risk. Decisions should be targeted and proportional to the scale of the problem
- **Capability.** Regulators should be staffed by competent and well-trained professionals, who receive continuous training and human resource development.

External regulators are commonly acknowledged in urban contexts, but current trends in rural water governance place considerable emphasis on self-regulation by WUAs. Their combination of local knowledge, locally defined norms, common interests and incentives places them in a good position for this. However, these self-regulated organizations do need to be externally accountable, since there is no separation between the regulated and the regulator. This is of particular concern when there are substantial externalities and social costs – where the performance of the organisations has significant impacts on people outside them (Ogus, 1998[26]). If the externalities are very great, public regulation, and strict compliance with externally imposed rules may be essential.

Although such externalities are commonly found in the water sector in China, Ostrom (2000[27]) does suggest that self-governance is indeed possible, and has identified characteristics for this. She has found evidence that self-regulation can lead, through direct participation and self-regulation, to a strong democracy where water users participate not to defend their individual interests but to ensure the fairness of decisions and fair process. This reduces conflict and tendencies to take water out of turn and can lead to significant reduction in water use.

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[26] Ogus A (1998) Rethinking self-regulation. In: Baldwin R, Scott C, Hood C (eds) A reader on regulation. Oxford University Press, Oxford, pp 374–388

[27] Ostrom E (2000) Collective action and the evolution of social norms. J Econom. Perspect. 14(3):137–158

B.3 Responsibilities and risks for the regulator

Regulators should be given powers which enable them to:

- **Set standards** for water quality, environmental conditions, customer service levels
- **Set tariffs** to allow for cost recovery or with a rational subsidy policy (to benefit the poor and maintain service sustainability
- **Gather information** to monitor the operator's performance.
- **Enforce rules** by imposing penalties for non-compliance.
- **Arbitrate** to settle disputes between consumers and operators and between the operators and government.

A regulator should operate within a framework that is structured around:

- **Regulatory rules:** The body of laws, regulations, guidelines, licenses and contracts that define expectations and acceptable conduct; consistent with a basic standard of living, with an emphasis on protecting the interests the poor.
- **Regulatory bodies:** Those institutions responsible for administering these rules.
- **Regulatory processes:** The procedures a regulator body must follow when carrying out the rules and their responsibilities.

There are some risks[28] to be aware of – notably the risk of

- Regulatory capture (either high level, during policy formulation, or low level, during operation), where the service organisation effectively controls the way the regulator functions– which it can do because it may have a virtual monopoly on key information;
- Over-complex monitoring the performance of private utilities, in order to avoid regulatory capture - resulting in excessive control, which could erode autonomy of the organisation;
- Political interference with the regulator; and
- Unwillingness to challenge regulatory decisions, which undermines their accountability – there is a balance between accountability and independence of the regulator.

[28] van den Berg (1997) "Water Privatization and Regulation in England and Wales" Public policy for the Private sector, World Bank No 15 1997

Box B.1 The regulatory system in the UK

The **water regulator** in the UK, Ofwat is a non-ministerial department of the government, audited by the national audit office (NAO), and financed by corporate operating fees from water supply and sewerage companies, (although to avoid conflict of interest, it is not paid directly by the companies). As a non-ministerial government department it is not subject to direction from Ministers, but is accountable to Parliament and regularly provides evidence to Parliamentary select committees

Ofwat aims to ensure that water companies provide a good service:

- making sure that the companies provide customers with a good quality, efficient service at a fair price;
- monitoring the companies' performance and taking action, including enforcement, to protect consumers' interests; and
- setting the companies challenging efficiency targets.

http://www.ofwat.gov.uk/

The **environmental regulator** in the UK, the Environment Agency, works to meet ever-higher environmental standards which are increasingly expected by society and required by legislation. The approach is based on the relative risks posed by different activities: this ensures society and the environment are protected in an efficient way, and the burden of regulation on businesses is minimised.

The EA follow five principles of better regulation:

- transparent – with clear rules and processes
- accountable – we explain our performance
- consistent – the same approach is applied within and across sectors
- proportionate – our actions are governed by the environmental risk
- targeted – we focus on the most important environmental outcomes

http://www.environment-agency.gov.uk/business/regulation/31993.aspx

There has been a recent trend in many countries towards more reliance on private markets to supply goods and services, including services traditionally supplied by the state, such as telecommunications, water and electricity. This has led to a vast amount of research and practice on the role of the regulator and the development of regulatory governance to avoid these problems. The Centre for Regulation and Competition (CRC), for example, is a partnership between internationally recognised institutions in the UK, Africa and Asia to provide research, advisory services and capacity building relating to regulation and competition (*http://www.competition-regulation.org.uk*)

Key issues include incentives and access to information: ensuring that the regulator is independent of the regulated, has equal access to relevant information, has an appropriate incentive to regulate, and that regulation is separated from political interests. This is not always easy to achieve and even actions to improve regulation, such as consultation (which is essential for improving flow of information, transparency and accountability) can increase the opportunity for corrupt transactions. This is avoided in the USA, by ensuring that all private meetings and communications between officials and third parties are placed on the official record.

There can be considerable conflict between the regulator and the regulated: for example, in the USA regulation is often appealed to the courts, leading to acrimonious arguments. And in the UK, regulation based on price caps has produced animosity between industry and the regulator (because of low price ceilings being imposed) at the same time as consumer complaints about high profits and 'fat cat' management salaries.

Criticism of the regulator is always possible over particular decisions, but legitimacy will be achieved when the regulatory institutions are generally accepted within society as they are by now in the water sector in UK. Achieving this public acceptance occurs over time and as public confidence in the regulators is built. This acceptance can be encouraged by adopting good regulatory practices and governance arrangements as described earlier.

In the UK, further organizations promote the interests of the consumers and water utilities, respectively. These are the:

- Consumer council for water[29]: a non-departmental organisation representing water and sewerage consumers which is ultimately responsible to Parliament. It acts an influential and effective consumer champion to make sure the consumers' collective voice is heard in the water debate.
- Water UK[30]: a private organisation representing all UK water and wastewater service suppliers at national and European level, providing a framework for the water industry to engage with government, regulators, stakeholder organisations and the public. Water UK aims provide a high quality service, to influence regulatory powers to ensure that any extension of choice or competition benefits all our customers, and to develop policies which help people on low incomes.

Although strong regulatory regimes have been developed in some countries, it is not easy to transfer these to others.[31] The temptation to transfer 'best practice' models of regulation rooted in the different economic, social and political conditions should be resisted, but such models should provide guidance on developing locally appropriate solutions. In particular, technical capacity is often limited with most skilled people working in the regulated industry rather than in the regulator. This can be mitigated by internal institutional assessment and capacity-building aimed at strengthening the autonomy of the regulator (both from the industry and political pressures), but takes time to resolve.

[29] www.ccwater.org.uk/
[30] http://www.water.org.uk
[31] Minogue, M. and Carino, L. 2006. Regulatory Governance In Developing Countries, Edward Elgar. UK

B.4 Options for a regulatory system for the urban sector in China

The existing system for regulation of the water sector in China is very 'light touch', and is best regarded as supervision rather than regulation: the supervisory agencies rarely set challenging targets for the water companies. This is reviewed in TP4.3: Regulation of Small and Medium Sized Water Supply Companies, which goes on to make some suggestions for alternative appropriate regulatory regimes in China, which are briefly summarised below.

Water companies are supervised by a parent bureau, often the Construction Bureau but also commonly the Water Resources Bureau (in some areas, the Water Affairs Bureau – which has a wider scope than the WRB). The role of the supervisor is generally considered as being to coordinate the activities of the water company with other government agencies and bureaux rather then to 'regulate' them in the sense of ensuring quality service delivery and encouraging efficiency.

Regulation is most effective in areas such as water quality where standards are clearly defined at national level and the consequences of a failure to comply could have an impact on public health. In other areas where performance or quality targets are set they are usually negotiated between the water company and the regulating agency. They are rarely challenging and do little to encourage efficiency or service improvements. Three alternative models for urban water supply which might be applicable in China can be considered, as described in TP4.3.

Model 1 – Strengthen Existing Agencies: In this model the existing local government agencies continue to carry out their present supervisory functions but are assisted by developing their capacity to operate as effective regulators.

Model 2 – Create Local Level Multi-Sector Agency. In this model a new Agency is created at local government level to act as a Utility Regulator to oversee the performance of all public utilities, i.e. water, wastewater, heating, gas, bus transport, etc. The principal function of the Regulator will be to ensure efficient management of the utilities so that the monopoly status of the utilities is not abused. The appointment of a Utility Regulator will not absolve the utilities from complying with national standards and several existing local agencies will continue to supervise compliance with national standards. These local agencies will provide the Regulator with information on the performance of the utility.

Model 3 – Create Provincial Level Water Regulatory Agency. In this model a new Agency is created at Provincial government level to act as a Regulator for all water utility providers in the province/ prefecture. The principal function of the Regulator would be to ensure efficient management of the water companies so that the monopolistic status of the utilities is not abused. The appointment of a Utility Regulator will not absolve the companies from complying with national standards and existing local agencies will continue to supervise compliance with national standards. These local agencies will provide the Regulator with information on the performance of the water companies.

Experience in other countries indicates that it can take 5 to 10 years for the Regulator to develop sufficient capacity and experience to establish a regime that is effective in promoting economic efficiency while at the same time protecting the interests of consumers and the financial viability of efficient suppliers. It is anticipated that the office of the Regulator would begin as a small unit, initially supervising a few water companies, and adding staff and expertise over a period of time as additional companies are brought under the supervision of the Regulator.

One of the roles of the Regulator is to represent the interests of consumers. As noted earlier, this is achieved in UK through the formation of a Consumer Consultative Council. In the initial years the Regulator could gather customer views and opinions through the local Consumer Protection Associations but, in later years as customer expectations rise, it may be appropriate for the Regulator to support the creation of local or regional Water Consumer Consultative Councils.

APPENDIX C Water markets

C.1 Introduction

Water markets are a topic of considerable interest both internationally and in China. There are many examples of water trading, but this is generally informal exchange of water between adjacent irrigators or similar methods. Formal tradable water rights, facilitating inter-sectoral transfers of water are a new concept that is believed to have considerable potential, as outlined in Section 3.2 and Appendix C.

Box C.1 Water markets

"Water markets are an appealing option for an economically efficient allocation of water. They do occur spontaneously at the micro scale, where users may swap, borrow, and buy water allotments to better fit their needs. Likewise, groundwater markets in India, although they refer to the payment for a service (extracting water with mechanical means) rather than to the allocation of a scarce resource, provide flexible and price-sensitive water supply mechanisms.

This flexibility, however, is much harder to obtain at a larger scale. There, the allocation of water through markets is constrained, among other things, by the difficulty to control flows volumetrically and temporally, by the lack of infrastructure to move water from one point to the other, by the lack of definition of water rights, and by the greater probability of having a higher heterogeneity of users and, therefore, possible adverse impacts on poorer segments of the society. It is recognized that water markets are prone to market failures and externalities and demand a background of legal consistency, administrative accountability and law enforcement that are rarely found in developing countries, where, on the contrary, "the social and environmental risks of getting it wrong are considerable" (Morris 1996). Water markets in most of Asia have therefore little short-term potential to help managing water and, rather, remain a long-term objective that comes with mature economies and institutions".

http://www.agnet.org/library/eb/543/

Chile is an oft-cited example of water markets, but the Murray-Darling basin in Australia probably has the most advanced system (World Bank, 2009 – Addressing China's water scarcity).

C.2 Structure of Water markets in Australia

Most transfers (over 90%) are local temporary measures. One well-development market is for temporary trading in the irrigation areas in the Goulburn-Broken Catchment. Here

> *"A set of rules has been instituted to clarify the trading environment. These involve placing limits on where water can be traded and the mechanisms for establishing the price. The trading zones … have been . . .designed to minimise adverse effects of trade on other water users and the environment"*

> *… Each week, if there are sufficient sellers and buyers with overlapping offer prices, a 'pool' price is established for each zone*[32]" .

Sellers tend to be small farmers relatively dependent on off-farm income, and buyers to be larger mixed farms. The amount traded did not change much in the first five years since establishment of the market, and remained at about 12% of total entitlement (although when expressed as a percentage of actual deliveries it was as much as 23% in drought years). The price and volume traded varies during the season: before the start of the season water trades are planned so that planting area can be optimised, but during the season water is traded to protect the actual crops grown. The water trade is managed by a facility known as *watermove* (www.watermove.com.au) – see box below.

Local trading of groundwater can be easier to manage than trading surface water as it avoids problems of delivery of water from the seller to the buyer, which is constrained by both the physical system and the canal management arrangements. In the case of the Goulburn-Broken Catchment, both surface and groundwater are available, but the salinity of groundwater in some areas requires mixing with surface water. Different rules apply for different situations, and are defined by *watermove*.

Examples of trading rules[33] for surface water are:

- All offers to buy Permanent or Temporary Water in this zone will be subject to the waterway's ability to supply, assessment of environmental impact and the Guidelines for Irrigation Development.
- Permanent and Temporary trades of Surface Water Licenses must be downsteam and the buyer will receive 80% of the volume transferred.
- Sellers whose use is not metered will not be able to sell in the current season if any water is used for irrigation in the current season.
- All trades are subject to *watermove* terms and conditions and approval by the relevant water authority.

And for groundwater:

- The buyer must have a groundwater licence and metered bore before purchasing Water Entitlement.
- If the sellers bore is equipped, it must be metered in order to trade whole or part of the unused licence volume.
- Transfers can only occur between bores, in the same zone or between zones subject to the rules listed below.
- Transferred entitlement may be banned from use or be restricted, if adverse interference occurs to other authorised users and/or the environment. Eg. adjacent bores.

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[32] A. M. Zaman, B. Davidson and H. M. Malano. Water Policy 7 (2005) 429–442.

[33] http://www.watermove.com.au/selectregion.asp?next=selecttradingzone.asp&jump=tradingzoneprofile

- Transferred entitlement is available for use from the date of approval of the trade until end of the same financial year (30 June).

BoxC.2 Water trading in Australia

" Watermove" has been set up to facilitate water trading by establishing a fair, transparent process that will provide market information for people seeking to trade water… throughout Victoria and Southern New South Wales….It conducts water exchanges for all water trading zones in Victoria where trading rules have been defined…. A trading zone defines the physical boundaries to, from or within which water may trade. …Traders must submit original offer forms to Watermove. Offers must define the trading zone, volume for trade in megalitres, price per megalitre and the number of exchanges for which the offer is valid…. Eligible offers will be included in an exchange for the relevant trading zone. Watermove will conduct the exchange each Thursday… Watermove will calculate a pool price for all trading zones where trade can occur. All successful sellers and buyers within a trading zone will receive the same pool price….No human intervention occurs in the price determination process, adjustments to volumes or balloting. An independent party, the Water Exchange Controller, who is not permitted to be an owner or trader of water, supervises the integrity of the exchange…Where more than one seller or buyer have nominated the same price and there are insufficient volumes to satisfy all of those sellers or buyers, the system shall conduct a random, computerized ballot to determine the successful seller(s) or buyer(s) at that price

http://www.watermove.com.au/aboutwatertrading.asp

An important feature of the water trade is that there is an independent regulator and the trade is independently audited. A party independent to *Watermove* supervises each exchange. The Water Exchange Controller is selected by tender and cannot be an owner or trader of water. The Water Exchange Controller checks and confirms that:

- Pool prices are properly calculated.
- Volumes determined and any adjustments to volumes are correct.
- Exchanges are conducted in accordance with Watermove's operating rules.
- All traders had equal and fair access.
- Offers listed on the exchange are genuine.

The Water Exchange Controller is required to sign a declaration that each exchange has been conducted in accordance with the operating rules for Watermove.

It is important that the potential environmental impacts of trades are assessed and trade only permitted in locations where the impact is acceptable, since an earlier study in Queensland indicated that trade in water entitlements is likely to increase the differential between extractive demand and historical flow regimes as extractive water-use concentrates on the most profitable crops, and that water markets are likely to limit the effectiveness of water policies aimed at restoring natural flow regimes[34].

C.3 Performance of water markets

It can be seen that the markets area sophisticated and complex process - and this is just for local temporary transfers between irrigation users in one locality. Water markets for inter-sectoral transfer will be much more elaborate. Overall, Turral *et al*[35] (2005) conclude that despite the relatively low rate of reallocation, the market performs well in Australia against most criteria but that further evolution of institutional arrangements is critical for sustained and improved success.

Bjornlund (2006)[36] has also reviewed the Australian Water Markets since their inception in 2002, and found that they have had an increasing impact on how water is used and that they do move water from less efficient and lower value- producing to more efficient and higher value-producing farms. At first the market was mainly for activating unused water, but as the market matured more actively-used water started to be sold with an impact on local farming communities. The dominant trend appears to have been from dairy farms to sheep and latterly horticulture and grapes for wine. Many have sellers have reduced their irrigated area during the last five years, in response to prices in the seasonal market for water allocations, before eventually selling their entitlement.

The market was stimulated by a water audit in 1990 which found that the Basin was overcommitted for extractive use. As the drought and increased need for environmental water reduced the annual allocation, the market especially for seasonal allocations, increased as irrigators with permanent crops were struggling to secure adequate water. Secondly a new water policy framework in 1994 led to separation of water entitlements from land, so that water can be used to maximize its contribution to national income and welfare within social, physical and ecological constraints of catchments. 2.5% annual entitlements (overall) are now traded, and the percentage is much higher in some localities.

The impact is wider than just on the individual farmer who trades water, since it also affects secondary industry and it is widely feared that the viability of some communities would be adversely affected – downstream communities growing value crops have grown at the expense of upstream traditional agricultural activity, such as dairying or mixed farming.

Water markets have thus weakened the link between land and water and more recently the National Water Initiative has formally severed this link and has removed the barriers to trade out of irrigation districts. Water trading therefore now allows individual farmers to make decisions about whether to sell the water away from their

[34] J. G. Tisdell, 2001 The environmental impact of water markets: An Australian case-study Journal of Environmental Management Volume 62, Issue 1, May 2001, Pages 113-120

[35] Turral, H. N., T. Etchells, H. M. M. Malano, H. A. Wijedasa, P. Taylor, T. A. M. McMahon, and N. Austin (2005), Water trading at the margin: The evolution of water markets in the Murray-Darling Basin, Water Resour. Res., 41,

[36] Bjornlund H. (2006): Increased participation in Australian Water Markets. In Lorenzini, G. and Brebbia, C.A. eds. Sustainable Irrigation Management, Technologies and Policies. Southampton: WITPress, 289-302.

land and to sell it to outside their community. There are many factors affecting rural livelihoods, but the water trading is perceived to be a threat to rural communities and social sustainability and it has been recommended that these issues should be researched further.

C.4 Water Markets in Chile and Spain

Chile is often said to have a highly developed water market. For example, Hearne and Easter[37] found that that the market transfer of water-use rights does produce substantial economic gains-from-trade for both buyers and sellers. But buyers, especially farmers growing profitable crops (especially large table-grape producers in the Limarí Valley) who buy water-use rights and individuals buying water-use rights for potable water supply, receive higher rents then sellers. Where there is an active trade, transactions costs have not presented an appreciable barrier to trading, but. there have been very few transactions in the large canal systems with fixed flow dividers because of the high costs of modifying fixed infrastructure, for trades between farmers.

Bauer[38], however, found that the experience has been mixed, and that water markets are controversial in both theory and practice: their potential benefits include greater efficiency and flexibility of water use and less state intervention and expenditure; while their drawbacks include social and environmental externalities, vulnerability to high transactions costs, and other common examples of market failure.

These two examples both highlight the need for strong administrative regulation to ensure that the environment is protected when small 'inefficient' users sell their rights to more commercial users who are more efficient and consume a greater proportion of the abstracted volume. Economic instruments are this important to support administrative regulation, but they cannot replace it.

There are limited water markets in Spain, and Panyatou (2007)[39] recently assessed the potential for increasing water trading. Noting the problems with market failures in other countries and the limitations of command and control approaches (administrative regulation), he recommended that water markets should be stimulated by the following actions:

- Identify areas with inefficient water use, where reallocation is possible.
- Establish and protect minimum in-stream flows, which tend to be undervalued by both markets and policy makers have undervalued ecological instream flows.
- Eliminate water subsidies for irrigation and other market distortions before introducing water trading.
- Focus on the agricultural sector first, where most water is used and efficiency improvements are most likely.

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[37] R. Robert Hearne and K. William Easter. The economic and financial gains from water markets in Chile Agricultural Economics Volume 15, Issue 3, January 1997, Pages 187-199

[38] Carl J. Bauer Bringing water markets down to earth: The political economy of water rights in Chile, 1976–1995 World Development Volume 25, Issue 5, May 1997, Pages 639-656

[39] http://jhoney.googlepages.com/water_trading_honey-may07.pdf

- Exploit urban water demand to pay for increased efficiency elsewhere (as for example in California where the Agricultural Water District invested in irrigation water saving technology. The saved water was then allocated to urban dwellers
- Seek to minimize transaction costs.
- Monitor developments in technology – eg desalinization.

Water markets are thus a growing trend in several countries. They are not easy to administer and they may have adverse impacts, but in the right circumstances they can be beneficial for optimising water use.

APPENDIX D Conflict resolution in Water Management

D.1 Background

Conflicts over water are common, with much talk of future water wars. In Australia, a typical industry response to announcements that there should be full cost recovery and increased environmental flows in 1995 was: '*At Deniliquin on Wednesday afternoon 500 irrigators voted unanimously to reject the governments new water policies and demanded consultation'*. Recently, local Griffith irrigators are '*fuming over mid season allocation cuts imposed by the state'* (Daily Advertiser, Wagga Wagga, 13 January 2007) and 2000 irrigators turned out in Deniliquin *'to demand compensation from the government for water they believe was stolen'* (Daily Advertiser, 16-17 December 2006). Other issues creating conflict include: disputes over costing and pricing; paying for infrastructure when no water is delivered; effects of trading on stranded infrastructure; exit fees imposed by irrigation corporations; effects of trading on health of regional communities; conditions under which environmental water might be purchased from irrigators; rural to urban transfers; and use of water for electricity generation across state borders.

In a reflective piece about competition for water resources written a decade ago, Bowmer (1997) wrote: '*What is new is the involvement of a much wider community in considering these issues. Once powerful interests could do deals with politicians in smoke filled rooms. Now such deals are subject to intense media and public scrutiny. We have an emerging set of tools for dispute resolution and the community is slowly learning to use these tools effectively*.[40] But ten years later the evidence for effective public involvement in dispute resolution remains doubtful, and improved procedures still need to be put into place.

D.2 Conflict resolution and demand management

Use of demand management as a conflict resolution technique is recognised as a topic which needs further investigation[41]. Improved management systems can reduce conflicts over water in two ways:

- Conflict avoidance – better management can ensure that water is delivered in a planned, timely and predictable manner to users, and that water users accept the need to comply with rules over the water is distributed
- Conflict resolution – an effective management organisation can provide a basis for resolving conflicts, with agreed rules and penalties for those who break the rules, and effective systems for enforcing these rules

In the context of water demand management, the converse situation – the role that conflict resolution can play in reducing demand also deserves more study. Resolving conflicts can reduce demand for water if, for example, they enable to receive water in a predictable and timely manner, thereby avoiding the need to take water.

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[40] Kathleen H Bowmer Water and conflict resolution: from smoke filled rooms to public participation

[41] http://www.idrc.ca/en/ev-31803-201-1-DO_TOPIC.html

Rising urbanization, denser populations, diversifying economies, multiplying uses of water, global climate change, rising competition for water, and rising water scarcity are all making water conflicts become increasingly pervasive, frequent and intense. The greater the scarcity of water and the severity and frequency of conflicts, the more important it becomes to resolve conflicts quickly. Whether international “water wars” or local disputes between farmers, conflicts can erupt from disturbances caused by rising competition for ever scarcer supplies of water. Such conflicts can develop into much more extensive conflicts, far beyond ‘simple’ disputes over water.

Conflicts or fear of conflict can in turn lead to considerable waste of water and other resources. These conflicts can occur at every level from international down to individual users, within sectors and between sectors. For this reason, conflict resolution is identified as a specific management instrument within the IWRM toolbox.

Water can play different roles in conflicts. In “real” water conflicts, water is the *object* of the conflict; water can also be an *instrument* in a conflict (which occurs over some other issue); or water can be a *catalyst* for conflict and can create internal political instability.

The causes of conflicts can generally be divided in three categories:

- Factual disagreements (or different perceptions of relevant facts),
- conflicting goals (often in regard to environmental or other externalities),
- relational aspects (distrust or battle for power)[42]

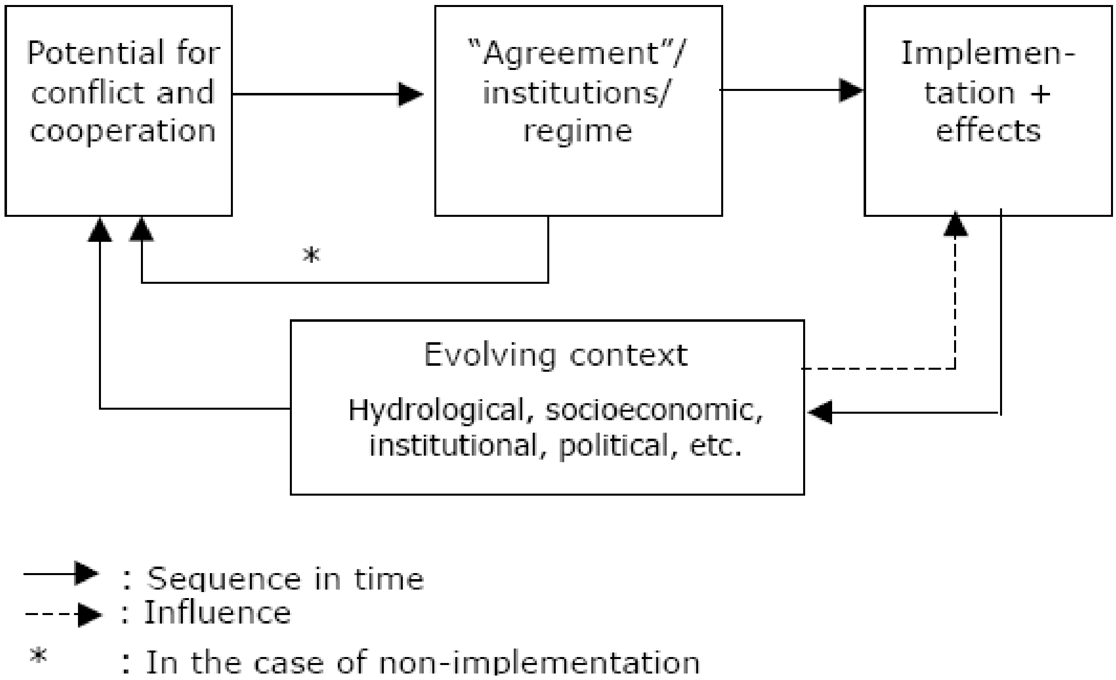
The three are interlinked in a cyclical fashion – bad relations lead to poor communications which leads to different access to information or interpretation of facts, and hence lack of understanding of the interests of others, which in turn contributes to worsening relations. All three aspects of conflicts should be addressed.

Mostert also outlines cyclic process for avoiding conflict (Figure D.3). This starts with an assessment of the potential for conflict and cooperation. This potential is determined by the hydrological, institutional, socio-political, and economic context within which cooperation can develop. This can take form of an explicit agreement or informal understanding, and or even simply shared values. This agreement may change the context, create new potential for conflict or cooperation, and start a new cycle. Conversely, an escalating conflict may develop if the process breaks down – either because no agreement can be reached or there is inability to implement the agreement,

It should be note that the potential for cooperation can be approached from the positive side – the potential for benefits (enhanced access to water, better environmental conditions), or the negative side – the avoidance of the costs of conflict, or the foregone benefits of cooperation in other sectors.

[42] Mostert, E. 1998: “A Framework for Conflict Resolution,” Water International, December 1998

Figure D.1: Overview of the conflict prevention and cooperation process



Source Mostert 1998

Simulation models are a useful support tool for decision-making in water resource management, where most conflicts are ill-structured involving many participants and varied power of decision-making. Such models can help identify courses of action which will promote consensus.[43] Information 'asymmetry' – unequal access to information - is a common factor in disputes. If one party has access to more information than the other, then distrust and conflict is likely (see section 6.7).

Conflicts can however, be difficult, costly and time-consuming to resolve. It is always better to prevent dispute arising than to face lengthy resolution procedures. Even if conflicts arise, local methods of resolution, through negotiation between adversaries possibly with mediation by a third party are likely to be more effective than going to courts. Adjudication by courts, however, remains the mechanism of last resort

[43] Vieira, Braga and Ribeiro: Conflict analysis as a decision support tool in urban water demand management", IAHS, 2005 pp 65-72

Figure D.2: Hierarchy of dispute resolution processes

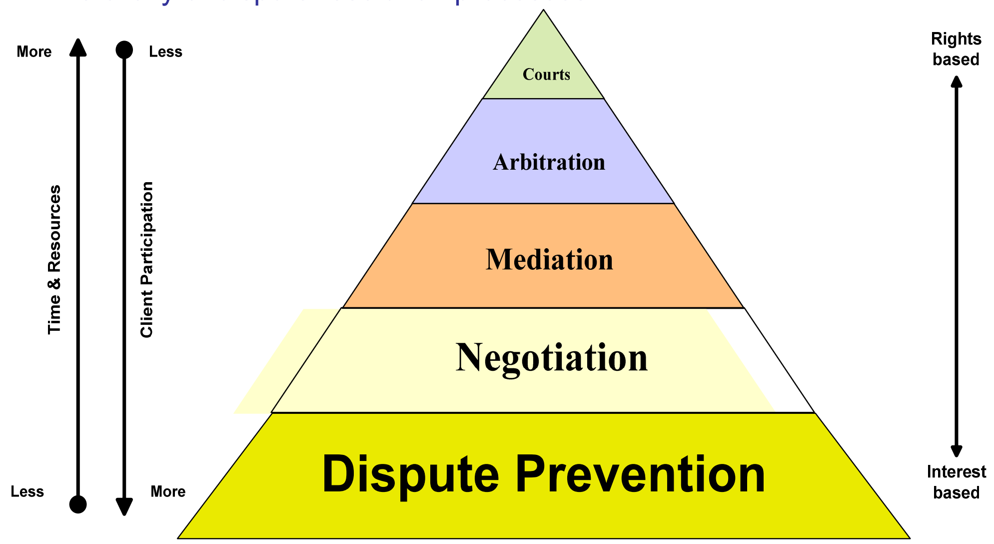


Table D.1: Dispute Prevention and Resolution Methods

Characteristics	Methods				
	Prevention	**Negotiation**	**Mediation**	**Arbitration**	**Adjudication**
Voluntary/ Involuntary?	Voluntary	Voluntary	Voluntary, but can be mandated	Voluntary unless based on contract	Involuntary
Binding/non-binding?	Optional rules mitigate conflict	Agreement put into contract	Agreement put into contract	Mostly binding but with review	Binding but with access to appeal
Third party involved?	Normally not	No third party for negotiation	Parties select mediator/facilitator/ conciliator	Expert decision maker selected by parties	Court-imposed, non expert decision maker
Degree of formality	Low with simple rules	Low with little structure	Low but partly structured	Less formal than litigation, rules set by parties	Formal, structured with predetermined rules
Form of deliberation	Deliberation on preventive mechanisms	Flexible vetting of evidence, arguments & interests	Flexible vetting of evidence, arguments & interests	Each party may present arguments & proofs	Each party may present arguments & proofs
Outcome	Infrequent disputes	Mutually acceptable agreement sought	Mutually acceptable agreement sought	Decision by reason, precedent & compromise w/o opinion	Decision by reason & precedent; rarely compromise w/o opinion
Orientation	Future oriented	Future oriented	Future oriented	Past oriented	Past oriented
Private/public sector	Private	Private sector	Private sector, but may be mandated & regulated	Private sector, but may be mandated & regulated	Public sector
Speed to resolution		Moderate but variable	Moderate but variable	Relatively rapid	Variable but can be slow

APPENDIX E Reference Documents

Water Demand Management (WDM) Document Series

Incorporating Integrated Water Resources Management (IWRM)

The document set in the IWRM Series comprises:

- OV - Overview
- TP – Thematic Paper
- AN – Advisory Note
- EG – Example
- M - Manual

Overview Document OV1 : Integrated Water Resources Management (IWRM)

Overview Document OV2 : Water Demand Management (WDM)

			Elements of IWRM Covered by documents	WDM related
	1	**Water Resources and Demand Assessment**		
		1.1	**Models for Water Resources Planning and Management**	
1		TP1.1	Groundwater Flow Modelling	
2		AN1.1	Models for Water Resources Planning and Management: Selection Procedures	
		1.2	**Groundwater Resources Assessment**	
3		TP1.2	Groundwater Resource Quantity Assessment	
		1.3	**Using the WEAP Model for Water Resources Planning and Management**	
4		AN1.3	Using the WEAP Modelling Software	
		1.4	**Using the MIKE BASIN Model for Water Resources Planning and Management**	
5		AN1.4	Use of MIKE BASIN Simulation Software (Issued in Chinese only)	
		1.5	**Water Quality Modelling for Water Resources Planning and Management**	
6		TP1.5	Use of Water Quality Modelling for Water Protection	
7		AN1.5	Use of QUAL2K Water Quality Model in IWRM Planning	
8		EG1.5	Water Quality Modelling in Chaoyang, Liaoning Province	
		1.6	**Data for Water Resources and Demand Assessments**	
9		AN1.6	Data Preparation for Water Resources Assessment Modelling	
		1.7	**Monitoring for Water Resources Assessments**	
10		AN1.7	Designing a Monitoring Programme for Water Quality Modelling	
		1.8	**Establishing Demands**	
11		TP1.8	Water Demand Forecasting	
12		AN1.8/1	Water Demand Forecasting	
13		AN1.8/2	Agricultural Water Use Norms	
		1.9	**Climate Change Studies**	
14		TP1.9	Climate Change and Water Resources	
	2	**Integrated Water Resources Management and Planning**		
		2.1	**IWRM Planning**	
15		AN2.1	Developing an IWRM plan	
16		EG2.1	Comprehensive (IWRM) Plan for the Shiyang River Basin	
		2.2	**Stakeholder Participation for Water Resources Planning and Management**	

		Elements of IWRM Covered by documents		WDM related
17		TP2.2	Stakeholder Participation in IWRM Planning	
18		EG2.2	Initial Stakeholder Analysis for Shiyang River Basin IWRM Plan	
		2.3	**Developing and Modelling Scenarios for IWRM Planning**	
19		AN2.3	Water Resources Scenario Development and Scenario Modelling	
		2.4	**Environmental Issues in IWRM Planning**	
20		AN2.4/1	Environmental Risk Assessment	
21		AN2.4/2	Environmental Water Allocation	
		2.5	**Drought Management Planning**	
22		TP2.5	Drought Management for Water Resources Managers	
23		AN2.5	Developing a Drought Management Plan – Guidance for Water Resources Managers	
24		M2.5	Using the Standardised Precipitation Index (SPI) to Assess Drought Condition	
25		EG2.5	Preparation of a Drought Management Plan for Chaoyang Municipality, Liaoning Province, Focused on Water Resources	
		2.6	**Groundwater Management**	
26		TP2.6/1	Groundwater Management	
27		TP2.6/2	Groundwater Monitoring and its Importance to IWRM	
28		TP2.6/3	Conjunctive Use of Groundwater and Surface Water	
29		EG2.6	Conjunctive Use of Groundwater and Surface Water in Minqin	
30		AN2.6/1	Groundwater Monitoring – River Basin to County Levels	
31		AN2.6/2	Groundwater Monitoring at Village Levels	
		2.7	**Water Allocation**	
32		TP2.7	Water Allocation Issues	
		2.8	**Economic Analysis for IWRM Planning**	
33		AN2.8	Economics for IWRM Planning	
34		EG2.8	Economics for IWRM Planning - Shiyang River Basin IWRM Plan	
	3	**Demand Management**		
		3.1	**Water Saving in Agriculture**	
35		TP3.1	Water Saving in Irrigated Agriculture	
36		AN3.1/1	Agricultural Water Saving Techniques (WMS/WAB level)	
37		AN3.1/2	Practical Techniques for On-Farm Water Saving	
		3.2	**Demand Management for Urban Water Supplies**	
38		TP3.2	Urban Water Supply Demand Management	
		3.3	**Reducing Unaccounted For Water in Urban Supply Systems**	
39		TP3.3	Active Leakage Control as a Key Component in Increasing Efficiency in Urban Water Supply	
40		AN3.3/1	Implementing an Active Leakage Control Programme for Small to Medium Water Supply Companies	
41		AN3.3/2	Asset management for Small or Medium Size Water Supply Companies	
42		M3.3	Active Leakage Control Manual for Small to Medium Size Water Supply Companies	
		3.4	**Demonstrating Water Savings**	
43		AN3.4	Auditing of Water Saving Society	
	4	**Permitting**		
		4.1	**Abstraction Licensing Systems**	
44		TP4.1	Abstraction Licensing Systems - International Experience	
45		EG4.1	Water Abstraction Permit Management: Current Practise and Alternatives for Shiyang River Basin	
		4.2	**Discharge Licensing Systems**	
			No document – see TP 8.4 for some information	
		4.3	**Regulation of Small Water Companies**	
46		TP4.3	Regulation of Small and Medium Size Water Supply Companies	
	5	**Economic Tools**		
		5.1	**Economic Issues related to IWRM**	

				WDM related
		Elements of IWRM Covered by documents		
			No document – see other documents under '5' and '6'	
		5.2	**Irrigation Service Charges**	
47		AN5.2	Formulation of Irrigation Service Charges for Surface Water Irrigation Schemes	
48		EG5.2	Assessment of an ISC System: Donghe Irrigation District (Jinchang, Gansu)	
		5.3	**Water Resource Fees**	
49		TP5.3	Water Resource Fees	
		5.4	**Tariff Setting for Urban Water Supplies**	
50		AN5.4	Tariff Setting for a Small to Medium Size Water Supply Company	
51		EG5.4	Tariff Setting for Beipiao Water Supply Company	
		5.5	**Willingness to Pay**	
52		AN5.5	Willingness to Pay Surveys (Urban Water Supply)	
53		EG5.5	Willingness to Pay Survey for Beipiao Water Supply Company	
		5.6	**Affordability of Water**	
			No document – see other documents under '5' and '6'	
		5.7	**Financial Management for Small and Medium Water Supply Companies**	
54		TP5.7	Financial Management and Modelling in Small and Medium WSCs	
55		M5.7	The Development and Use of a Model for Financial Analysis of a Small to Medium Size Water Supply Company in China	
	6	**Social Change and Water Saving Society**		
		6.1	**Water User Associations and Water Saving Society**	
56		AN6.1/1	Role of WUA in Water Saving in Groundwater	
57		AN6.1/2	Farmers Guide to Groundwater WUAs	
58		EG6.1	WUAs in Groundwater Areas	
		6.2	**Strengthening of WUAs**	
59		AN6.2/1	Administrative Steps for Developing Strong WUAs	
60		AN6.2/2	WUA Institutional Document Guides	
61		AN6.2/3	Village Level Planning of WUAs	
62		AN6.2/4	Promoting and Training of WUAs	
		6.3	**Social Issues related to IWRM**	
63		TP6.3/1	IWRM, Irrigation and its Social Context	
64		TP6.3/2	Assessing the Impact of IWRM on Women's Status and Conditions	
65		AN6.3/1	Social Monitoring	
66		AN6.3/2	Socio-economic Monitoring in Agricultural Water Management – (Issued in Chinese only)	
67		EG6.3	Socio-economic Monitoring for Agricultural Water Demand Management in Gansu	
	7	**Balancing Interests**		
		7.1	**Multi-criterion Analysis as a tool for allocating resources**	
68		TP7.1	Multi-criterion Decision Analysis – An Introduction	
69		AN7.1	Using a Multi-criterion Decision Model for Water Resources Planning	
70		EG7.1	Simplified Multi-criterion Decision Analysis for the Shiyang River Basin IWRM Plan	
	8	**Information Exchange**		
		8.1	**Data Sharing, Management and IWRM**	
			No document	
		8.2	**Use of Geographic Information Systems in IWRM**	
71		AN8.2	Application of GIS in IWRM – (Issued in Chinese only)	
		8.3	**Monitoring and Evaluation**	
			No document	
		8.4	**Collaborative Working and Data Sharing**	
72		TP8.4	Inter-agency Collaboration for Improved Water Quality Management	
73		AN8.4	Use of Inter-agency Agreements for Collaborative Water Quality Management	

Document Reference Sheet

Glossary:

ELL	Economic level of leakage
EUA	End use analysis
GL	Giga Litre (= million cubic metre)
GWP	Global water partnership
IWRM	Integrated water resources management
NRW	Non-revenue water
O&M	Operation and maintenance
PIM	Participatory irrigation management
RAP	Rapid appraisal programme
SCADA	Supervisory Control and Data Acquisition
SCD460	State Council Decree No 460
WAB	Water affairs bureau
WAP	Water abstraction permits
WC	Water conservation
WDM	Water demand management
WMD	Water management division
WMS	Water management station
WRB	Water resources bureau
WRD	Water resources department
WRFs	Water resource fee
WSC	Water supply company
WSS	Water saving society
WUA	Water users' association

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Where to find more information on IWRM – recommended websites:

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