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China – UK, WRDMAP
Integrated Water Resources Management Document Series

Thematic Paper 1.8: Water Demand Forecasting

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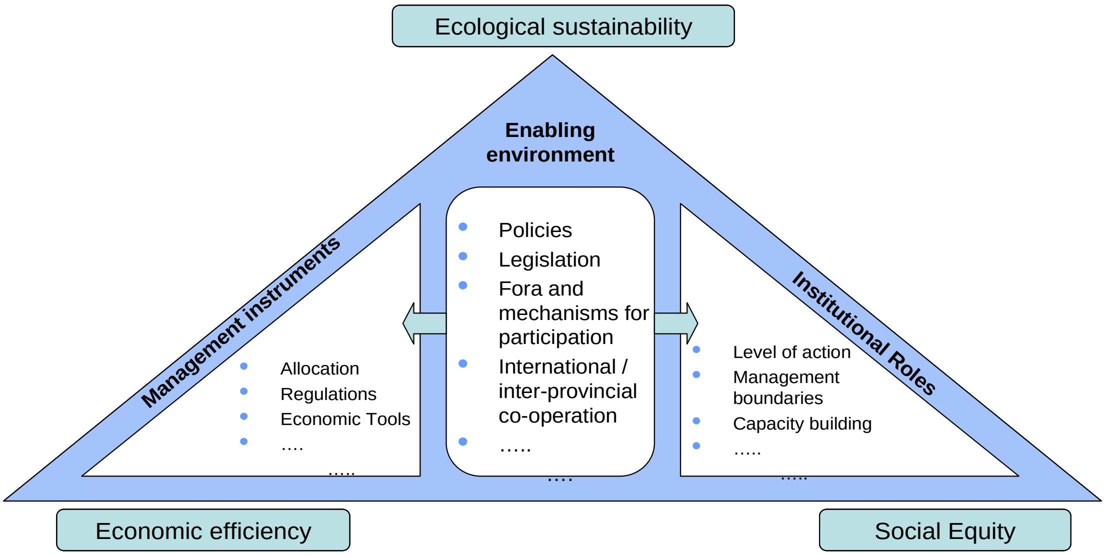
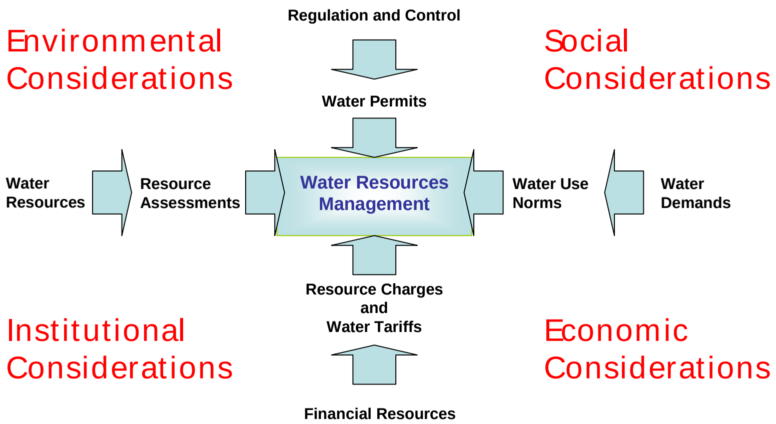
Integrated Water Resources Management (IWRM)

(Basics after Global Water Partnership)



Driving Elements of Integrated Water Resources Management



(Second figure after WRDMAP)

Summary: The guidance provided in this document outlines the process for forecasting demands for water for each sector, and for aggregating these demands.

Demand forecasts are needed to plan and optimize the management of resources, and to improve design and management of water infrastructure.

Various parties need access to this forecasting information, including water resources management organisations, water supply companies, large irrigation schemes, and regulators. Domestic, municipal, industrial, and agricultural water demands should all be considered.

This Thematic Paper includes the following sections:

- Introduction
- Forecasting water demand – International practice
- Forecasting water demand – Chinese practice
- Conclusion

This document is one of a series covering topics on sustainable water resources planning, allocation and management. It should be read in conjunction with documents in this same series, including Advisory Note 1.8/1 'Water Demand Forecasting' and Advisory Note 1.8/2 'Agricultural Water Use Norms'.

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.

1 Introduction

1.1 Background

Water is one of the most critical resources, and its sustainable development and management is essential to any society. Current increases in demand, particularly for urban and industrial use coupled with climate change-induced uncertainty over supply, means that water resources are closer to sustainability limits than ever before and in many areas limits have already been exceeded. The need for good **demand forecasting** becomes important for effective water resources management.

Demand forecasting is essential for any planning activity, especially for more distant planning horizons. Forecasting is concerned with determining what the future will (or may) look like whilst planning is concerned with what the future should look like.

Demand management is increasingly viewed as a key element of a sustainable water resource strategy, but must be supported by accurate demand forecasts, preferably those that address 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 are approaches 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 of water demand are crucial for successful water resources management. Demand forecasts, with different time horizons (see later), are required for amongst other tasks:

- Design and management of infrastructure for delivery of water
- Reconciliation and optimization of competing demands
- Strategic planning for future water resources management.

The approach to demand forecasting will differ depending upon the time horizon over which the forecast is to apply and the use for which the forecast is intended. It is important to appreciate this.

There are no simple rules that can be used to establish which water demand forecasting method should be used and the scale of the resources that should be invested in demand forecasting.

In deciding which method to use in predicting future water demands, a balance needs to be made between:

- Level of accuracy of the forecast required;
- Cost of obtaining the required level of accuracy;
- Costs and benefits of achieving a higher level of accuracy.

The advantages of producing as accurate forecasts as possible are:

- Reduces the misallocation of resources and allows investment decisions to be delayed;
- Enables the effects of water resources policies to be examined with confidence;
- Identifies areas and sectors to be targeted for conservation programmes.

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.
- The question often arises of whether to use a simple or sophisticated forecasting technique.
- This is often viewed as a trade off between cost and accuracy.

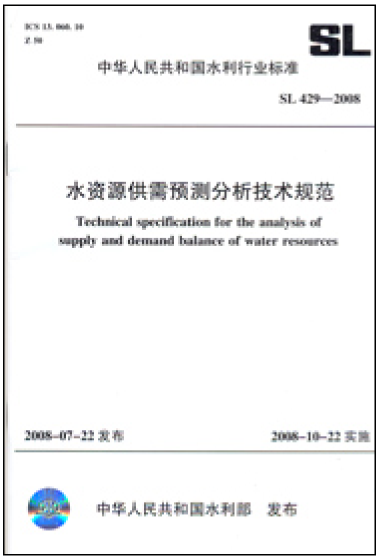
The methods used for long-term water demand forecasts (i.e. forecasts with a horizon of more than ten years) are generally unsuitable for forecasts over shorter periods of time (i.e. for the next two years). Different time horizons generally relate to different planning needs. There is no specific definition as to what a 2-year, 5-year, 10-year, 20-year or 50-year horizon is used for, suffice it to say the forecasts move from operational planning requirements to major infrastructure development needs, see Section 1.3.

In the short term demand is likely to be influenced by the weather or the precise timing of the economic cycle. Often data available for the explanatory variables required by a long-term forecasting model are not available at the necessary level of frequency making the model difficult to apply.

Improved demand forecasting has become necessary as populations dependent on public water supplies have grown and demands for water cannot always be met because of limitations of water resources or the infrastructure to make resources available. Water infrastructure is expensive, with long lead times for construction, requiring long planning horizons. Alternative approaches may be needed to reduce demand through demand management but the overall approach needs to be optimised. Demand forecasting must take into account demand management programmes.

There are many different demand forecasting methods, of varying degrees of sophistication such as single-coefficient methods, multiple coefficient methods and probabilistic methods. Methods used in China, as in many parts of the world, rely on the use of norms or standard water use assumptions for each type of user demand, in conjunction with a combination with forecasts of population growth, urbanisation rates etc. The simplest form is essentially a single coefficient method. Multiple coefficient methods add in considerations such as price elasticities which affect demand and probabilistic methods that allow for the uncertainty in each parameter.

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 are outlined in Section 3 and in more detail in Advisory Note 1.8/1 'Water Demand Forecasting'. It is understood that **national guidelines on demand forecasting** are under preparation (as at January 2010).



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中华人民共和国水利行业标准

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水资源供需预测分析技术规范

Technical specification for the analysis of supply and demand balance of water resources

2008-07-22 发布 2008-10-22 实施

中华人民共和国水利部 发布

The focus of this thematic paper is to provide guidance and perspectives on approaches to demand forecasting as input to water resources planning, including forecasts of potable, industrial, and agricultural (irrigation) water demands, maintenance of environmental flows, navigation, and hydropower production. These will be used in scenarios to be evaluated, as described in a separate Advisory Note 2.3 'Water Resources Scenario Development and Scenario Modelling', which is specifically concerned with scenario analysis that enables optimisation of competing demands.

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 Thematic Paper has used material from the *"Handbook for the Assessment of Catchment Water Demand and Use"* prepared by H R Wallingford (2003) through funding from the Department for International Development (DFID) of the UK Government under the Knowledge and Research (KAR) programme.]

1.2 Purpose of this Thematic Paper

There are many assumptions inherent in water use norms (or standards) and the process of forecasting and thus it is important to understand the inherent uncertainties of these factors and hence to appreciate the potential accuracy of the forecast.

This paper aims to provide clarity on these issues and to provide more details in support of SL429 whilst also putting these into the context of other factors that are (internationally) considered important.

Demand forecasting can range from the very simple - multiplying an estimate of future population by a standard per capita consumption (e.g. 150 l/c/day) for urban demand or by multiplying an irrigated area by an assumed annual irrigation depth requirement (e.g. 600 mm over the future area to be irrigated) to complex probabilistic and neural network analyses. These can incorporate every variable imaginable using complex computer programmes/ software. The intention of this paper is to provide an outline of the basic considerations behind demand forecasting to enable an improved approach to be developed by water resources professionals at the provincial and municipality levels. It does not cover detailed procedures for more sophisticated techniques for which data is unlikely to be available at present.

Improved methods of forecasting are needed as pressure on resources increases. Traditionally, demand forecasting was undertaken by either extrapolating historic trends of per capita consumption or using multiple regression techniques incorporating a range of variables such as population, income, price of water and periods of restrictions. Such models are useful for assessing historical demand and for providing a baseline to compare demand after implementation of a demand management program. However, what was important in the past may not be as important in the future, because of changes in behaviour or technology and both these approaches often result in oversupply. They are limited in their ability to project demand into the future due to the aggregated nature of the variables.

Box 1 End use analysis (EUA)

In a recent study from the Water Services Association of Australia, it was noted that::

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 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.

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

This Thematic Paper covers demand forecasting as applied to all sectors as is required for broad water resources demand forecasting. However, it is appreciated that for the urban domestic and industrial sectors, demand forecasting will be (or should be) carried out in more detail by the water supply companies. Nevertheless, it is useful for water resources professionals to have an appreciation of the increased level of detail that a water supply company would go to in undertaking their water demand estimates.

The paper also builds upon some of the issues encountered during the course of the execution of WRDMAP when demand forecasting was carried out as part of the integrated water resources management planning process in the Shiyang River Basin (Gansu Province) and the Daling River Basin (Liaoning Province), the business planning for the water supply company in the Daling River Basin and the climate change studies in the both river basins.

The issues related to the more general water resources planning being:

- Often, a lack of appreciation of the inherent assumptions and factors related to a ‘water use norm’ (and the significance of this to the demand forecasting process);
- Often, a lack of knowledge of water use efficiency values and their relationship to the condition of a water supply delivery system;
- Sometimes a lack of knowledge of current water use levels in various parts of a supply area, be it for irrigation, an urban supply system or a major industry;
- A tendency to not consult major water users to obtain information to assist in clarifying the above uncertainties and in subsequently discussing with such users the anticipated changes that might take place in these factors in the future.
- The issues related to the urban water supply WSC being:
- An apparent inadequate knowledge of the current water delivery efficiency values in different service areas and their relationship to the condition of a water supply delivery system;
- A lack of knowledge of current household water use levels in different parts of service area;
- A lack of knowledge of the operating performance of flow metering reportedly in place with no meter performance monitoring and repair programme in place;
- A realisation that household leakage was high but that this loss was not being quantified (nor addressed owing to uncertainty over whose responsibility it was to rectify such leaks);
- A lack of a scheduled plan as to how the service coverage was to increase;

- A lack of a active leakage control programme (to reduce losses from the system)

All the above factors affect the ability to undertake a water demand forecast. The need to address the above factors more thoroughly is a key recommendation.

1.3 The reason for demand forecasts

"*Accurately forecasted water demand either in short-term, or medium-term, or long-term time horizons can be very useful for capacity planning, scheduling of maintenance, future financial planning and rate adjustment, and optimization of the operations of a water system. In addition, adequately forecasted demand will be a basis for the strategically decision making on future water sources selection, upgrading of the available water sources and designing for the future water demand management options, so that water resources are not exhausted, and competing users have adequate access to those resources*".

Reliable demand estimates are always important, but they take on a particular significance in places where water is scarce and livelihoods are highly dependent on access to water (notably places where the majority of households are dependent on irrigation for production basic food crops).

Forecasts are needed at different timescales. These might include, from an international perspective:

- **Short-term forecasts or projections** is generally for operational and management requirements and need to take into account the demands based on current resource situations, anticipated climatic variability and the estimated monthly variability and perhaps peak daily requirements. Such planning might be for six months to perhaps 5 to 10 years. The shorter term forecasts would relate to irrigation system scheduling, annual water allocation plans, water supply company annual budgeting planning. The longer term plans would be used for WSC business planning.
- **Medium-term forecasts or projections** can also have a monthly component but would in the main part be a relatively accurate estimate of the demands over the next 10 to 20 years or so. This would have a focus on management planning and short gestation development programmes and perhaps changes to water allocation policies and practices. Short term measures might mean the development of new groundwater sources or the introduction of new pricing regimes where these might have a demand management influence on supplies to industry and urban users. Climate change considerations are these days necessary. The forecasts would be used for preparation long term water annual allocation plans and

water supply company investment planning.

- **Longer-term forecasts or projections** for design of infrastructure, on the basis of an optimal allocation between sectors, taking account of the productivity or value of the water in each case. (Sustainability of the resources becomes a critical issue as scarcity increases). Climate change would now be a key consideration.
- **Long term forecasts** (50 to 80 years) would have a focus on long term trends and would be intended for development planning, major infrastructure design and major management policy change requirements. In long term planning, it is now considered necessary to take into account climate change factors that are themselves highly uncertain over this period.

Demand forecasting is generally an estimate of what water will be required by future water users at a particular time horizon based on a set of assumptions. However, a number of time horizons may be required for a particular planning or management use.

Demand forecasting will be required for different organisations for different purposes. Some of these are summarised below:

For ***water resources management organisations***:

- Formulating long term water allocation planning;
- Undertaking water resources planning that will include:
    - o Proposals for new resource development schemes;
    - o Proposals for demand management programmes;
- Granting / varying water abstraction licensing;
- Assessment demand management measures.

For ***water supply companies***:

- Investment planning;
- Financial planning;
- Tariff policy;
- Resource planning;
    - o Leak control plans;
    - o Industrial and commercial metering programmes;
    - o Domestic metering programmes
- Performance monitoring
- Overall demand management monitoring and evaluation

For ***large irrigation schemes***

- Investment planning;
- Financial planning;
- Tariff policy;
- Resource usage planning;
    - o Canal leakage reduction plans;
    - o Improved irrigation techniques plans;

  - Agronomic and crop selection planning;
  - Metering programmes;
- Performance monitoring.
- Overall demand management monitoring and evaluation

And for ***regulators***, where they are performing a real active role in water resources management:

- Overview of national and/or regional demands
- Monitoring water sector investment plans;
  - New water resource development
  - Leakage control plans
  - Adoption of improved water use efficiency equipment (and retrofitting)
  - Customer metering programmes
- Monitoring water supply company performance;
  - Investment plans
  - Operating expenditure
  - Tariffs
  - Setting Price limits
- Monitoring water use in the industrial sector.

Generally, demand forecasting is not a climate related series of annual or monthly demand projections although climate change considerations are these days required. Inter-annual and season climatic variability is more concerned with the planning process, system engineering design or operational planning and is often taken as a separate exercise. However, some short term planning activities clearly requires careful consideration of climatic factors both in terms of daily, weekly or monthly demand. These short term forecasting for irrigation scheduling methods are not covered by this document.

Demand forecasting information varies for each stakeholder. For example, regulators need information on leakage control plans.

It should be noted that the accuracy needed for forecasts depends on the use to which they will be put. There is no absolute level of accuracy that is appropriate in all demand forecasting circumstances. The level of forecast detail should be sensitive to purpose. The cost of improving the demand forecast should always be balanced against the additional benefits derived from the greater accuracy. Generally a greater level of accuracy is required the higher the potential resulting investment might be.

1.4 Categories of demands

General

Demands are generally classified into categories, such as domestic, agricultural, industrial and environmental. In addition, there is a distinction between in-stream demands (such as hydropower or environmental) and out-of-stream demands. The precise classification system and nomenclature varies from place to place, depending on the nature of demands. For example, in China agriculture is referred to as primary industry.

- **Domestic water demands**– demands generally based on population growth forecasts
- **Other municipal demands**– demands from public buildings, hospitals, schools, government offices, etc. These can be estimated on the basis of population, or as a percentage of the total domestic demand
- **Industrial water demands**– these include a range of different type of demand, some met from municipal water supplies, others by dedicated water supply systems managed by the industry itself
- **Agricultural water demands**– in areas where irrigation is common, it is likely to be the dominant user of water. In many cases but it is also the demand which is most likely not to be met at times of shortage.

Demand forecasts may be required for each of these sectors either separately for sector planning or for all for regional water resources planning.

Demand forecasts may also be required for business planning for a municipality water supply organisation or alternatively for the development of an irrigation scheme area.

Water user groups or sectors should normally be divided into more detailed categories that better capture the different behavioural and use characteristics.

For Regional water resources planning, it will generally be necessary to place the greatest importance in estimating water demands in the sector with the highest usage since this has normally the greatest stress on water resources. For example in many countries in Europe demand forecasting and management for the industrial and domestic sector is critical whilst in many countries in Asia, the irrigated agriculture sector is the biggest water user and area for potential large water savings.

Demand forecasts 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 once delivered and billed at the property level.

This approach fits in to the requirements related to demand management.

However, all water demand forecasting should be internally consistent wherever possible.

Return flow forecasts

A large part of the water demand – whether from domestic, municipal, industrial uses - is not actually

consumed but is returned to the river system or aquifer and may be available for reuse. Forecasts should also include estimates of these return flows, as these are needed for both water resources planning and for design of wastewater treatment works. This applies in varying degrees to all categories of water demand.

Environmental flows and ecological water requirements

There should be a requirement in all river basins for water to meet minimum flow requirements, groundwater levels and water quality standards.

1.5 Demand forecasting basic approaches

There are a number of forecasting methods that are commonly used to predict future water demands and use. These include:

- Judgemental forecasts;
- Extrapolation of historical data;
- Forecasts based on population growth and per capita consumption;
- Trend analysis;
- Component analysis;
- Multiple linear regression analysis;
- Multiple non-linear regression analysis.

Judgmental forecasts

Judgmental forecasts are based on personal or group knowledge. They may be purely subjective or merely an adjustment of a more formal forecast. Judgmental forecasts have a number of disadvantages in that they are subject to a number of biases that may add to or filter existing knowledge and thus effect the overall forecast. These biases can be classified as follows:

Professional biases – the profession of a person may influence their judgement e.g. professionals who are used to supply oriented solutions may produce forecasts greatly in excess of professionals who look at demand management issues. Different professions may also use different methods and data;

Spatial and project biases – The forecasts may be based on areas that have common factors (e.g. accessibility) and these areas may not be representative;

Person biases – The stakeholders interviewed and assessed to determine demand forecasts may in some cases overestimate their needs to ensure supplies under extreme conditions;

Seasonal and climatic biases – Judgements may have been made during untypical dry or wet periods.

Although judgmental methods may prove useful in conjunction with other methods it is not recommended that such techniques are used solely for demand forecasting of future water use.

Judgemental forecasts tend to be 'quick estimate' procedures.

Extrapolation of historical data and trend analysis

A wide range of methodologies are used for forecasting water demand and use at a national, regional and local level. Extrapolative techniques have been used frequently in the past but there is a need to improve forecasts in line with more comprehensive planning approaches and changing priorities (such as demand management techniques).

This method falls under the category of the non-causal models of demand forecasting that do not explain how the values of the variable being projected and determined. Here, the variable to be predicted is expressed purely as a function of time, rather than by relating it to other economic, demographic, policy and technology variables. This function of time is obtained as the function that best explains the available historic data, and is observed to be most suitable for short term projections.

Extrapolative techniques cannot be used where there is limited historical data or where demand management programmes are going to be introduced that will invalidate the base data set.

Extrapolative techniques suffer from a number of major drawbacks including:

- Very different predictions can be gained from trends which fit past data equally well;
- The methods assume past trends will continue into the longer-term future, can be a dangerous and costly assumption;
- Any errors that occur in the forecast do not provide a sound basis for future learning.
- This is because the errors occur owing to changes in trends;
- Extrapolation techniques tend to use aggregate demands rather than components of demand.

Forecasts based on a trend analysis use time as the independent variable and utilise mathematically fitted functions to historical water demand and use to forecast future demands and use. The function used to fit the data depends on the user and can have a significant effect on future predictions.

The method does have the following advantages if the above mentioned drawbacks are unlikely to exist:

- It is relatively cheap to implement and takes account of past uses;
- It is generally not very demanding in terms of the data that is required
- It can be related to separate water demand and use sectors if the information is available.

The method has the following disadvantages:

- It assumes the historical water use and demand is representative of future water demand and use. (Where major demand management programmes are being implemented or are to be implemented the method is inappropriate);
- It can produce inaccurate results because the forecast

is dependent on the fitting function;

- The method cannot account for the effects of a reduction in unaccounted for water.

A variant of this is the **'Time series analysis approach'**. This method of forecasting future values of a variable involves the fitting of a trend line to the historical data of a certain variable, using a method of least squares. The method uses auto regression i.e. previous values of a variable are used to predict the future values.

Forecasts based on population growth rate and per capita or other water use norms.

The estimated demand is derived from projected population growth figures multiplied by an estimated per capita water use or demand. The per capita figure may be derived either directly where water use is divided by the population (normally for a year in which a census has been undertaken) or from international estimates for average water use, minimum standards or from selective surveys. Urbanisation change rates are generally also applied.

The method has the following advantages:

- It is relatively inexpensive to carry out;
- It requires a limited amount of data.

The method has the following weaknesses:

- The accuracy can be poor for long term forecasts;
- The method does not take into account variation in water use between sectors or even within sectors;
- Past trends of total water demand are projected into the future; and
- Estimates of population and per capita consumption are made for future dates without reference to past trends in water consumption.

This latter technique is the most commonly used because it does not require a large quantity of data.

There are three main disadvantages with this technique. These are:

- It assumes that the factors influencing demand in the past will remain the same in the future;
- It makes no attempt to understand why water consumption fluctuates over time; and
- It relies on data about past water demand that may be poor or non-existent and which may well under-estimate the actual water requirements of the population.

Data to carry out the forecast can be acquired as follows:

Primary data sources – Water usage is based on amounts delivered by public supply and licensing authorities for private abstractions. Population data is taken from national or regional census.

Secondary data sources – Water use data is taken from records of municipal authorities of water delivered, or from surveys or direct measurement. Population data is taken from local estimates.

Derived data – Data can be derived from restricted surveys to obtain per capita demand or use. Population figures can be extrapolated using statistical methods. Water usage may also be estimated from levels of service.

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 affect the total water use.

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

- It requires a large amount of data;
- The analysis required is detailed;
- Representative surveys to collect the relevant information needed to carry out the analysis can be costly; and
- The method may not produce reliable results.

Component methods are more complex and rely on greater data and information needs.

However, if more accurate demand forecasts are required, these techniques are likely to be of greater value to the users than the simpler techniques discussed earlier. Water demands and use are disaggregated into major components e.g. the water demand of an individual component, be it household appliance or crop, is estimated or measured.

Future changes in each component are predicted separately and then aggregated. For water demand and use forecasting carried out at a sub-catchment and catchment level, the following should be taken into account:

- Population levels and growth;
- Socio-economic factors;
- Changes in unaccounted for water; and
- Policy decisions affecting water resources management.

The first two components in the list are relatively easy to incorporate as data is usually available. The population component tends to be based on information about demographic characteristics such as age, sex, fertility rates, death and birth rates and migration and available from government statistics and/or demographic projections. The socioeconomic situation component includes information on personal incomes, employment and industrial production. Components such as changes in unaccounted for water and policies affecting water resources management such as water pricing, metering, subsidies and water quality standards, are harder to forecast, although they will have a significant impact on water demand.

This technique requires more input and therefore cannot be implemented unless the requisite data is available. In most countries specially designed surveys are undertaken to provide the data build up for component based demand forecasting. One such requirement would be a 'domestic consumption monitoring' (DCM) type survey, see Section 2.4.

Where data is available on other uses of water that are likely to affect future demand, then they too should be incorporated into the forecast.

This builds into an **'End use forecasting'** type approach when large number of surveys and end user analysis work has been built into the approach.

Multiple linear and non-linear regression analysis

Multiple linear or non-linear regression analysis can be used to relate water use to the various parameters such as Gross Domestic Product (GDP), tariff levels or population levels. The main disadvantage of this method is that it is time consuming to set up multi-variable relationships and it requires large data sets to produce a reliable relationship. It is not recommended that such techniques are used at a catchment or sub-catchment level to forecast water use.

This is equivalent to an **'Econometric regression approach'**.

Econometric regression analysis uses historical annual water use and economic data to determine customer elasticities. Elasticity is measure of how a customer will change a purchasing pattern in response to a change in price, convenience, reliability and other factors. Based on customer elasticities and assuming that that these elasticities do not change through time, a demand forecast is made.

Econometric analysis combines economic theory with statistical methods to produce a system of equations for forecasting water demand. In this method of forecasting the functional relationships are established between the dependent variable, in this case the water demand and explanatory variables like GDP, water price (tariffs), water efficient technologies and delivery systems etc.

The approach can appear to be a 'black box' statistical approach, reliant to a large extent on historic data.

1.6 Demand forecasting initial considerations

Assessing the background and setting the rules

Before deciding which forecasting method to implement, the following questions should be considered:

- What was the previous forecast and are the results available?
- What are the previous forecasts errors and why did they occur?
- What is the objective of the new forecasts? (e.g. long term or short term planning, sub-catchment or catchment level);
- What data are available and over what period and at what level of detail? (e.g. water demand data, data on population growth, demand management measures to be implemented);
- What are the possible forecasting methods available?
- Which of these are feasible given the various constraints on data, budget and skills available to implement the method?
- Is the method used previously still satisfactory for the purpose? (e.g. is a sophisticated method still preferable to a simpler method);
- Do additional data need to be collected in the future?

Applying the forecasting method

Once the forecasting method to be used has been decided upon the following issues need to be considered:

- What specification is to be used?
- How well did the forecasting method perform in the recent past? (e.g. can any large discrepancies be understood);
- What assumptions need to be made for the forecast? (e.g. implementation of water demand management measures, changes in tariff structures);
- Is there any information available to help form the assumptions? (e.g. are details of future tariff levels available, are demand management measures to be implemented);
- Is the last year a “normal” year to predict from? (e.g. were water demand figures affected by water rationing brought about by a drought);
- Are the forecasts plausible? (i.e. how do the forecast changes in demand compare with the historical changes in demand).

Whatever approach is selected, it is very important that the methodology used, the input assumptions and any adjustments made within a demand forecast are clear and transparent. This will allow debate to concentrate on the assumptions used and the suitability of the methodology rather than clarifying terminology.

Additionally, such reporting and 'process logging' is extremely useful when a subsequent forecast is made. Any inaccuracies in an earlier forecast can be analysed against what actually occurred in terms of water use characteristics. This relates to the first couple of bullet points above.

In addition it is important to assess consistency and reliability of the underlying data.

Current water use

An important aspect of demand forecasting is a good knowledge of current water use characteristics in the various sectors. It is often assumed that this is known, however, in many instances in developing countries or where metering has insufficient coverage, actual existing water use might not be known. Apart from metering and the income from water sales, another source of information that should be investigated is water abstraction permit information and the annual reporting of water usage most permit holders are duty bound to report to the permit issuer on an annual basis.

Understanding actual existing water use is important

Another often encountered shortcoming is that water use information is held by different offices and is not available in a consolidated form. Those organisations undertaking water demand forecasts can sometimes be found to be making estimates of historic and current water usage on the basis of similar assumptions as are then being made in the forecast. Although this might serve a particular purpose, sound demand forecasting needs a knowledge and understanding of past and current water use. This information should be analysed to understand the characteristics of current use in terms of the reliability of norms that might be used and in terms of knowing what the current water wastage/loss levels are currently in the various systems.

Without a thorough knowledge of 'where we are now', any forecast of future water demand will have an inherent shortcoming from the outset. This statement might appear obvious, however, there are often many situations where current water use levels and supply characteristics including levels of water loss) are poorly known and instances where what is actually known by a user or operator is not known by the 'forecaster'.

In any forecasting process an analysis of historic trends and assessment of the drivers of the trends is essential. This is seldom mentioned but will inherently be in the mind of any professional. However, it is important that historic trends are systematically analysed and used as one of the bases for demand forecasting.

However, great care is required in projecting historic demand into the future. If historic trends are taken out of context, in other words without a knowledge of the supply and user characteristics of the time, errors can be made in forecasting since account is not taken of perhaps a major adoption of demand management practices as part of government policy after a forecast has been made.

One of the difficulties in a trend analysis if disaggregated data is not available is in interpreting the underlying causes of change in water used.

Other factors to consider include:

Climate change

Climate change is a not a demand in itself, but it does and will affect both resource availability and demand.

Water trading

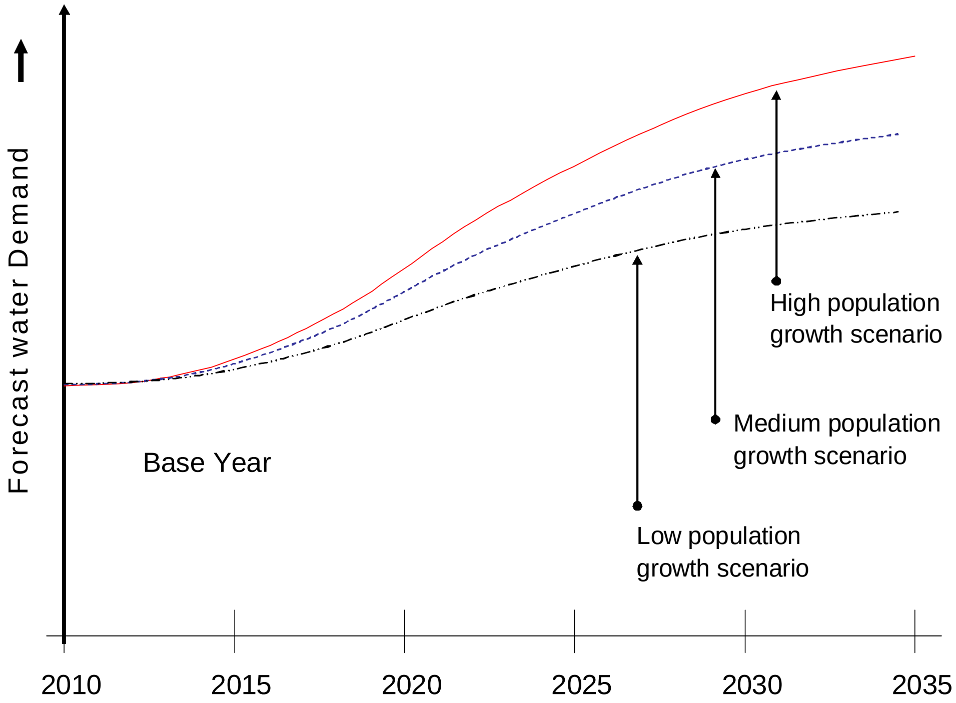
In many countries, agriculture's impact on water resources is not sustainable. Policies and actions are beginning to place a high priority on new management approaches, using better regulation as well as instruments like market based water trading. Such situations must be taken into account in any demand forecasting process, however, trading should not impact too greatly in most countries, it can be viewed as an internal re-allocation of resources.

1.7 Uncertainty and elasticity of demand

Uncertainty is an integral part of water demand and use forecasting. All forecasting methods for water demand and use are subject to uncertainty. It would be desirable to present a forecast with statistically based confidence limits around it. However, in practice most forecasting methods do not yield objective confidence limits, and in some cases the data are inadequate to permit statistical analysis to yield precise estimates. Uncertainty is therefore better considered through the construction of a various scenarios. Incorporating scenario modelling into forecasts allows the sensitivity of long-term forecasts to various factors to be established. For example water demand and use forecasts are often carried out based on high, medium and low population growth rates or a variety of demand levels, or levels of reduction of unaccounted for water.

A typical sensitivity analysis is shown in the figure below for different population growth scenarios. Changes in various assumptions will yield different future demand profiles.

Figure 1 Forecasting water use for three population growth scenarios



Demand for water is not absolute but is affected by the way it is managed. If demand forecasts are based on norms, these norms will take account of implicit assumptions about the impact of pricing policy and other water savings measures. Actual demand will differ from the forecast – between individual users within a sector, between sectors, and over time. For long-term, large scale planning the uncertainty can be very high requiring that 'plan reviews' are undertaken to ensure that development is matching plan assumptions or estimates.

This is particularly true of industrial demand which is often currently at a low level in many developing countries, but is increasing rapidly in some locations. Different industries use very different amounts of water per unit output and there is a wide range even within a single type of industry. In some cases excess water may be used so that wastewater pollutants are diluted prior to discharge to meet 'end-of-pipe' discharge standards.

Price influences some categories of water demand in very significant ways – increasing domestic water prices generally reduces demand by discouraging wastage and use of more efficient appliances. Irrigated agriculture is usually only sensitive at much higher levels than prevailing prices, but industrial demand can be highly sensitive to pricing policy, as well as to effluent standards and other regulatory measures.

2 Forecasting Water Demand – International Practice

2.1 Introduction

Internationally, water demand forecasting is usually based on one of three approaches: end-use, econometric, and time series forecasting.

- ***Time series approach*** forecasts water consumption directly, without having to forecast other factors on which water consumption depends. (This has several drawbacks within a demand management environment, see earlier).
- ***End use forecasting*** is an approach that bases the forecast of water demand on a forecast of uses for water, which requires large amounts of data and assumptions but is adopted in many urban water supply situations where demand forecasting is critical to their commercial performance. This is basically equivalent to the ***component analysis approach*** that is being adopted in many countries.
- The ***econometric approach*** is based on statistically estimating historical relationships between different factors (independent variables) and water consumption (the dependent variable) assuming that those relationships will continue into the future.

In some places, sophisticated methods, such as artificial neural network (ANN) models are being used as they outperform traditional methods. Such methods are mostly used for detailed forecasting for large urban water supply systems; demand forecasting as a whole for water resource management is more commonly done using simpler approaches and methods.

All demand forecasts are estimates. The aim is to get the best estimate possible and minimise uncertainty. The approach will depend on:

- Nature of community and of the uses of water
- Data availability
- Policy of government and/or water service supplier
- Climate change assumptions

In addition to average and dry year (1 in 4 or 1 in 5 year) annual demands, it is necessary to determine demands for different seasons, and for some situations, peak demands in critical periods

Many data sets should be geo-referenced to some level or other. Increasingly data is managed through a GIS and this can enable spatially specific demand forecasting to be undertaken. This can readily be linked to any water resource modelling process that is to be used to support the planning process. Additionally, in terms of water resources planning a knowledge of demand centres in relation to water sources facilitates planning and the result of demand forecasts can feedback to the identification of stress areas in the resource network and thereby enable demand management programmes or source development to be focussed to particular areas or urban centres.

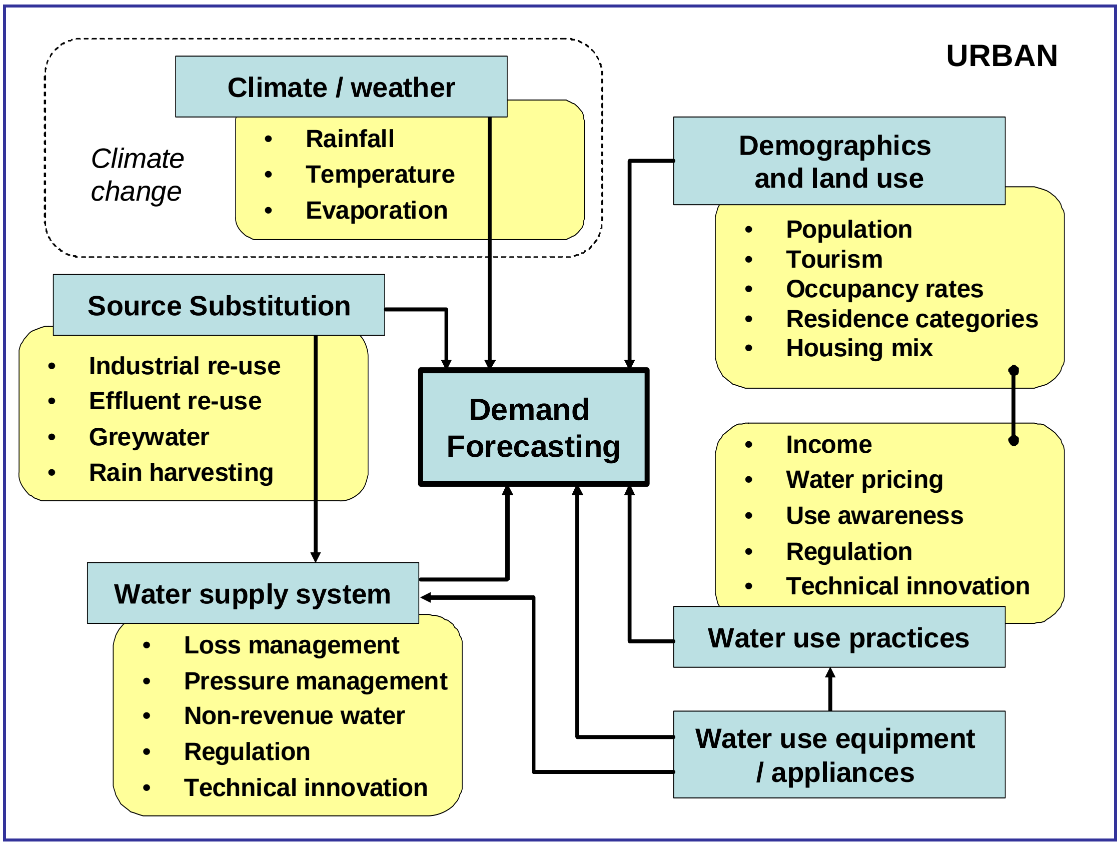
As outlined earlier, demand is split into components, and it is important to consider the main sources of uncertainties associated with the demands, for example:

- Population growth
- Socio-economic changes (degree of urbanisation, industrial development, changes from subsistence-based farming to market-based farming)
- Future technical changes (development of new water saving techniques, industrial processes, and crop varieties etc)
- Climate change

Urban and domestic water demands

Some of the factors influencing demand in the urban water supply sector are illustrated in Figure 1. All have variability and uncertainty associated with them.

Figure 2 Direct and indirect factors influencing urban water demand forecasting



The longer the forecast period the greater will be the level of uncertainty owing to the growing inaccuracy of the assumptions. It is essential to treat assumptions explicitly in long term forecasting. Using any form of dynamic simulation, scenarios can readily be produced based on different assumptions or by using different values for parameters and initial variables. This can create a sufficient output data set to undertake a frequency analysis and thus a probabilistic form of forecast. This approach is desirable in order to demonstrate to the ‘manager’ or politician, or other stakeholders the impact of the various assumptions being made and for these stakeholders to hold a view as to which is the ‘most realistic’ assumptions for the forecast or projection.

Urban water demand forecasting from a regional perspective can be highly complex and take into account potential changes to the national and regional economies, population elasticity in response to numerous factors, immigration, emigration, tourism factors, technological changes both in industry and in household appliances, income elasticity, changes in food consumption characteristics (impacts on/of irrigation) and many other factors. These detailed analyses are normally only accounted for explicitly at the national level for longer term forecasting. However, the level of sophistication of the demand forecast is often determined by the level of data that is available, the skills and knowledge of the individuals responsible for the particular forecasting and the basic use to which the forecast is to be put.

Domestic water demands are generally built up from forecasts of:

- Population growth
- Per-capita water consumption
- Internal household loss rates
- Distribution system leakage rates.

Population forecasts are generally available from national statistics, but may need to be adapted to suit regional development plans. Factors involved are presented in the Figure 2 above.

Leakage rates are often not known to a great degree of accuracy, and may well be under-reported for several reasons.

Upper and lower bound estimates can be prepared for each of these three components of demand projections, resulting in considerable uncertainty and variability in overall domestic water demand. Urban Water Demand is likely to be fairly uniform throughout the year, although it may increase slightly in hot weather. (In many western countries with low rise urban areas rather than high rise, high summer peaks in demand can occur purely related to irrigation of household gardens. Metering and increased water charges, especially block tariffs are used to address this issue).

Estimates of actual water consumption are also required, as a large part of potable water supply (perhaps over 90%) will be returned to the resource system as sewage effluent in urban areas, or groundwater recharge in rural areas.

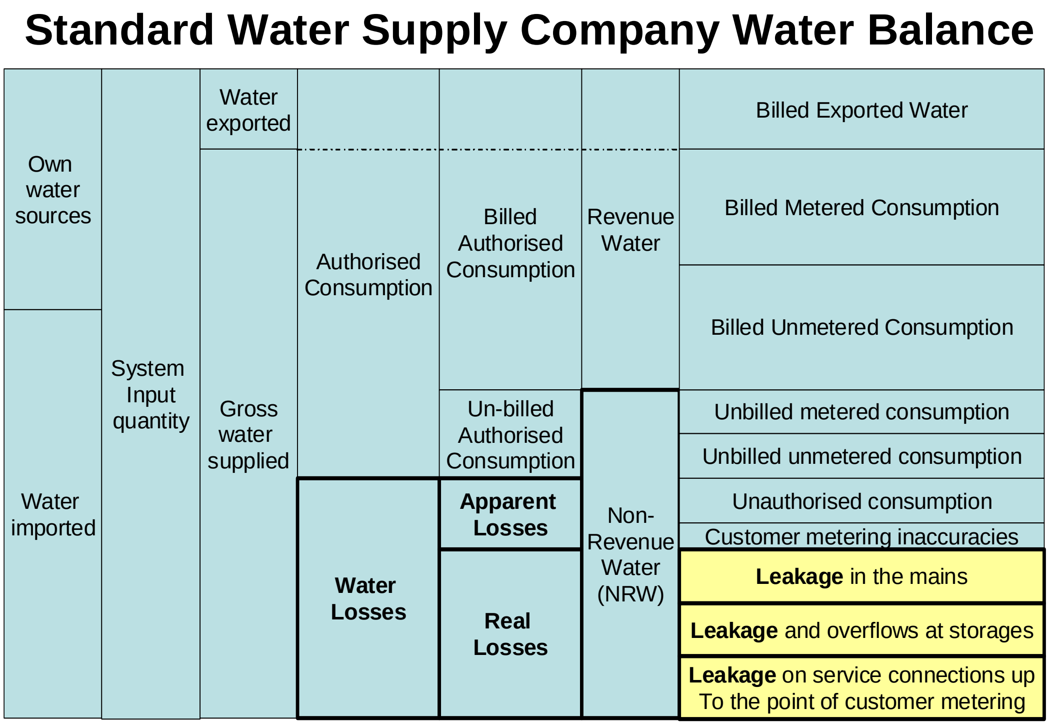
Some basic elements of an urban water supply system is presented in the figure below. The eventual demand forecast has to be satisfied by the sources on the left hand side of the diagram. The basic elements that will build up the demand forecast are shown on the right hand side of the diagram. Within the elements on the right hand side of the diagram the basic components of water use should be evaluated. This often requires sample surveys and/or detailed component assessments.

Other municipal demands

These include public buildings, hospitals, schools, government offices, etc. These can be estimated on the basis of population, occupancy, floor area or as a percentage of the total domestic demand. Different countries have different norms for such estimates.

Such water demands can also be forecast by a component analysis should there be adequate data available.

Figure 3 Water balance of a standard water supply company



Source : International Water Association (IWA)

Industrial water demands

Industrial demands include a range of different type of demands, some met from municipal water supplies, others by dedicated water supply systems managed by the industry itself. These are most commonly met from groundwater sources. However, mining enterprises have high demands for water and these are invariably obtained from surface water sources, often direct abstractions or diversions from rivers.

Industrial demand is increasing in some economic regions, and is often given high priority because of the high productivity (expressed as output per unit water consumption), but in some places is decreasing as existing industry adopts water-saving practices, reduces output, is closed or moves to other areas (or countries).

Where industry is well-established, and is not expected to change substantially, demands can be based on past performance or on existing norms (making allowance for future improvements in process, which will generally but not always reduce water consumption). However, considerable scope exists for water saving (or re-use) and such measures are increasingly being encouraged as part of demand management programmes and needs to be accounted for in the demand forecasting.

Elsewhere, future industrial development will be guided by regional development plans, but will also be influenced or driven by national and international policies whilst economics, national and international, may influence future industrial growth. There can be considerable uncertainty in the estimates, but it should be possible to establish upper and lower limits to industrial demand forecasts. It is vital that the inherent assumptions in these estimates are clearly defined.

Agricultural water demands

In areas where irrigation is common, it is likely to be the dominant user of water. However, it is also the demand which is most likely be un-met at times of shortage. Unconstrained agricultural irrigation demands are likely to much greater than can actually be supplied – volumes used on traditional gravity fed irrigation adjacent to rivers are typically 5 – 10 greater than the theoretical requirements because of the complexity of managing deliveries to each field in accordance with the varying requirements during the season and the high losses in such systems.

Demand forecasting in the irrigation sector is based on a knowledge of the areas of land irrigated, the crops being irrigated and the methods an efficiencies of the irrigation and water delivery systems. It is also necessary to know whether the irrigation source where the demand relates is from surface water or groundwater.

The first step in any demand forecasting exercise for the irrigation sector is to look at trends from the past and consider foreseeable changes.

Then consider:

- Which crops will be grown in which regions; how many hectares (mu) of each will need to be irrigated;
- How much water is needed for each crop, each unit area – how is that affected by the weather;
- What is the total of areas planned to be irrigated, and where will those be located;
- Which water sources will be used for each;
- How much water will be withdrawn and applied.

In many countries, the areas served from surface water systems have become relatively static over the last twenty years or so after a spate of constructing large irrigation schemes many years ago. New irrigation development has generally been based on groundwater usage and this has been the focus of most demand forecasting projections.

Changes in irrigation technology used has a direct impact on water demand, especially switches from traditional surface irrigation systems to modern systems. Even changes in the use of different forms of modern irrigation will have an impact on any forecast demand. In many countries, inefficient forms of traditional surface irrigation often dominate the irrigated agricultural sector.

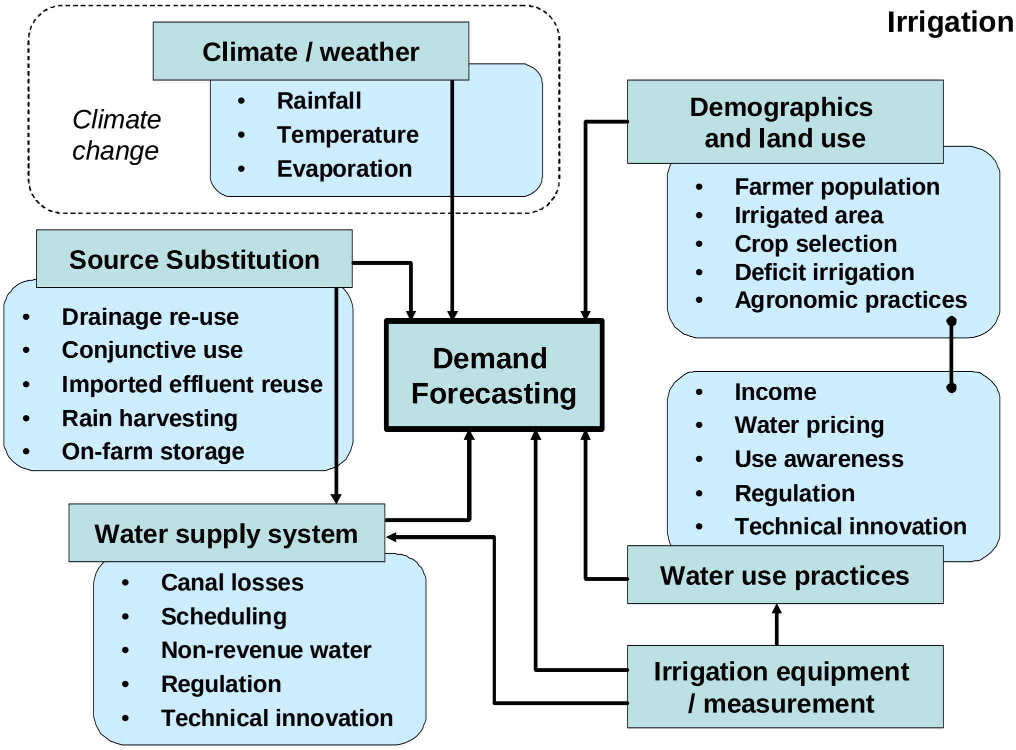
As demand forecasting in the irrigation sector is generally based on water use norms such as an irrigation depth for a particular crop type on a particular soil type for a particular climatic condition for a particular irrigation method, many assumptions can be inherent in the actual value of the 'norm'.

The subject of irrigation or crop norms is often seen as confusing since a norm can relate to many different parts of the irrigation delivery process and be related to several different assumptions. When using a particular norm for demand forecasting it is important to know the 'situation characteristics' of the 'value'. Refer to Advisory Note 1.8/2 'Agricultural Water Use Norms'.

Future changes to irrigated agriculture will influence both overall demand, and the requirements for operation of the system, but the extent to which these can be met will be constrained by the design of the infrastructure. The high cost of modernisation of irrigation systems, means that agricultural norms should reflect both the theoretical demand and the ability of the system to deliver it.

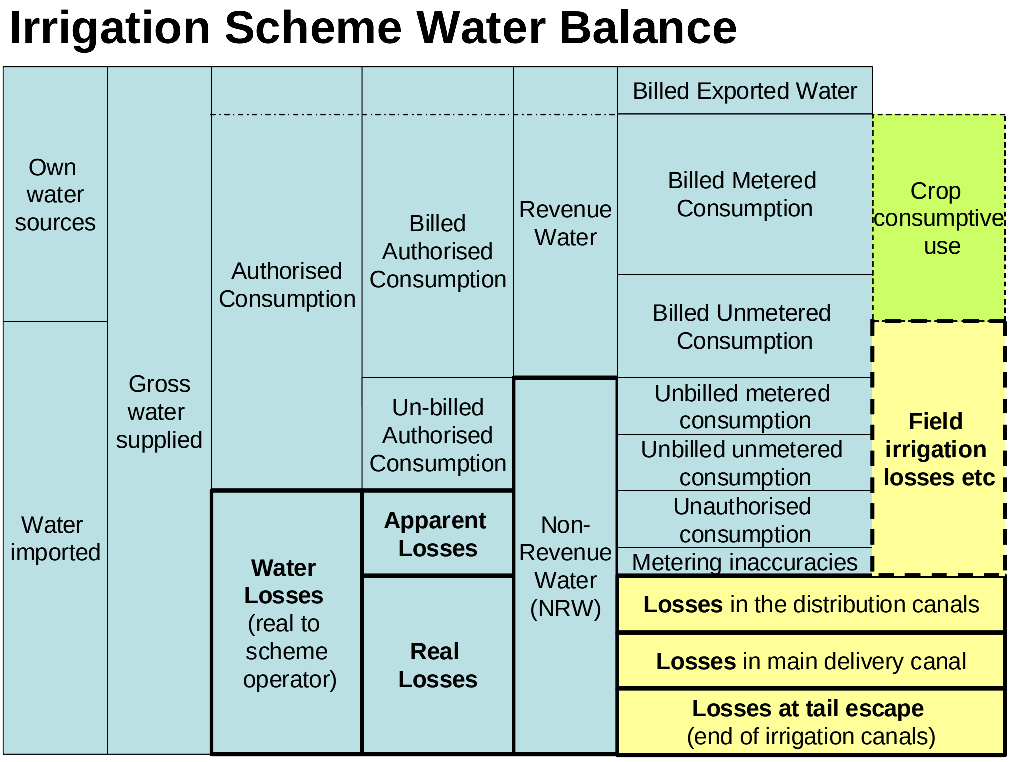
The main factors involved in a water demand forecast for modern irrigation systems are based more precisely on areas, crop water requirements and delivery and application losses, and depend on schemes being managed in accordance with the design as presented in the figures below.

Figure 4 Direct and indirect factors influencing agricultural water demand forecasting



From a water balance perspective the demand forecast, from a business (revenue generation) perspective would consider the details presented in the figure below. Business planning is a common use of demand forecasting. From the perspective of the manager of a surface water irrigation scheme, the losses in the system are the losses in the canal system and any 'tail escapes' before water is delivered 'at the point of sale' to farmers. There will be other 'unseen' or apparent losses where water is abstracted illegally from the system. After 'sale' or delivery to water to farmers, other losses will take place, however, these are the responsibility of the farmer, however, the farmer needs to be encouraged to reduce such losses. In any demand forecast where demand management programmes are to be affected, the quantification or estimation of each of these components is required.

Figure 5 Water balance of a typical irrigation / agricultural system



Environmental flows and ecological water requirements

There is, or there should be, a requirement in all river basins for water to be allocated to maintain or enhance the natural environment. These allowances or allocations are needed, for example, to:

- Meet minimum flow requirements
- Maintain river water quality
- Maintain groundwater levels to sustain vegetation and to avoid land degradation.

These 'environmental provisions' can sometimes be expressed as volumetric water demands, or regarded as constraints in resource planning models. To some extent, these flow requirements or environmental/ ecological allocations can be met by return flows (as long as quality factors are acceptable), but it is usually necessary to make specific arrangements to ensure adequate environmental flows (see Advisory Note 2.4/2 'Environmental Water Allocation').

Climate change

Climate change is a not a demand in itself, but it does affect both resource availability and demand. There are many uncertainties in the impact on demand, but they include factors such as:

- Domestic response to higher ambient temperatures;
- Commercial and industrial response to higher ambient

temperatures (e.g. cooling requirements);

- Effect of CO_2 fertilization of crops on water demand in irrigated agriculture;
- Change in cropping as a result of temperature changes;
- Change in irrigation needs as a result of rainfall changes; and
- Changes in environmental flows, and requirements for urban environmental enhancement.

Climate change is unlikely to affect domestic or industrial demand by much, but it may have a large impact on irrigation demand, and also on environmental demands.

2.2 Urban demand forecasting

It is interesting to see the variation in per-capita urban consumption as applied in different countries. Such values are presented in Table 1 below.

Table 1 Per-capita urban consumption

Country	l/c/day 2001	Country	l/c/day 2001
United Arab Emirates	500	United Kingdom	153
Canada	326	Austria	153
United States	295	Luxembourg	150
Japan	278	Ireland	142
Australia	268	France	139
Switzerland	252	Germany	129
Finland	213	Netherlands	129
Italy	213	Belgium	112
Spain	200	Hungary	101
Portugal	194	Bulgaria	101
South Korea	183	Poland	98
Greece	175	Czech Republic	95
Sweden	164	India	25
Demark	153		

Source :Eurostat 2001 + IFEN 2002

Note: The above values include showers, baths, toilet use, dishwashing and drinking water and other household use.

Per-capita water consumption tends to increase with socio-economic development, but this is mitigated by trends towards adoption of water-saving appliances, changing attitudes to water use and water saving, and the impact of tariffs. Local variations can be expected, but they are relatively uniform. This change in per capita consumption levels is demonstrated from the average per consumption levels in the USA over a period of 100 years. See Figures 6 and 7 below.

Figure 6 Per-capita water withdrawals in the USA

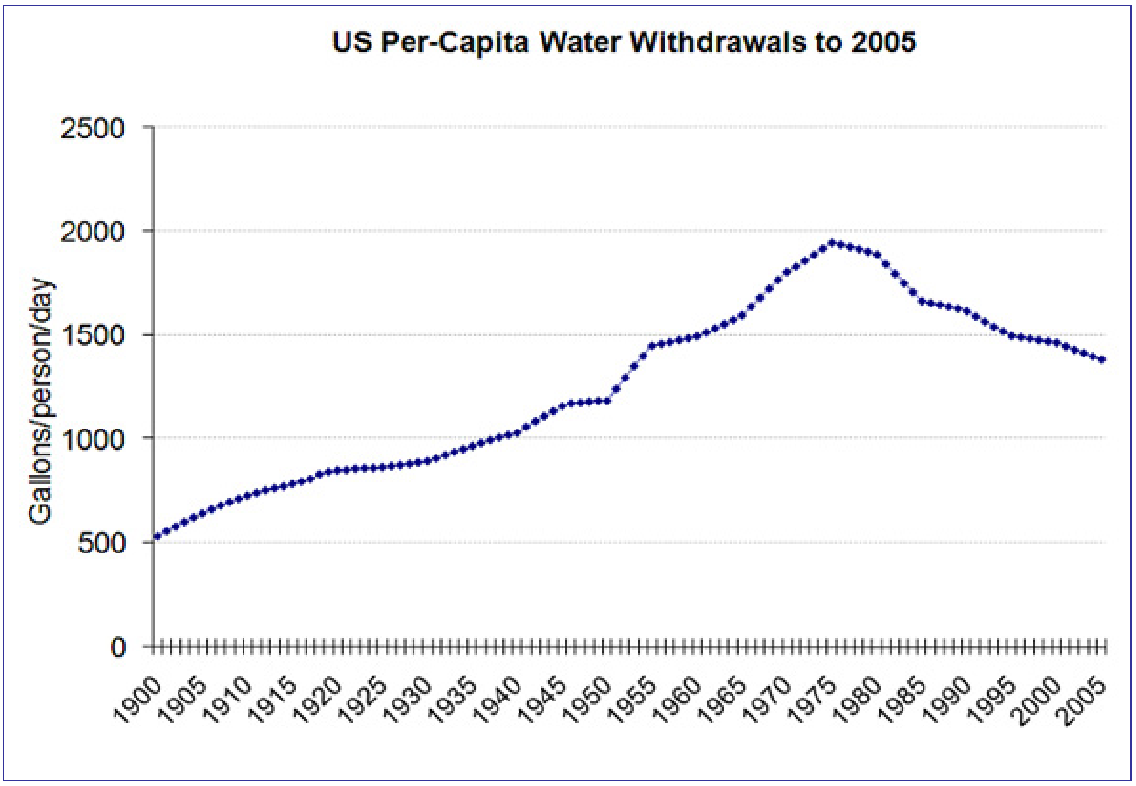
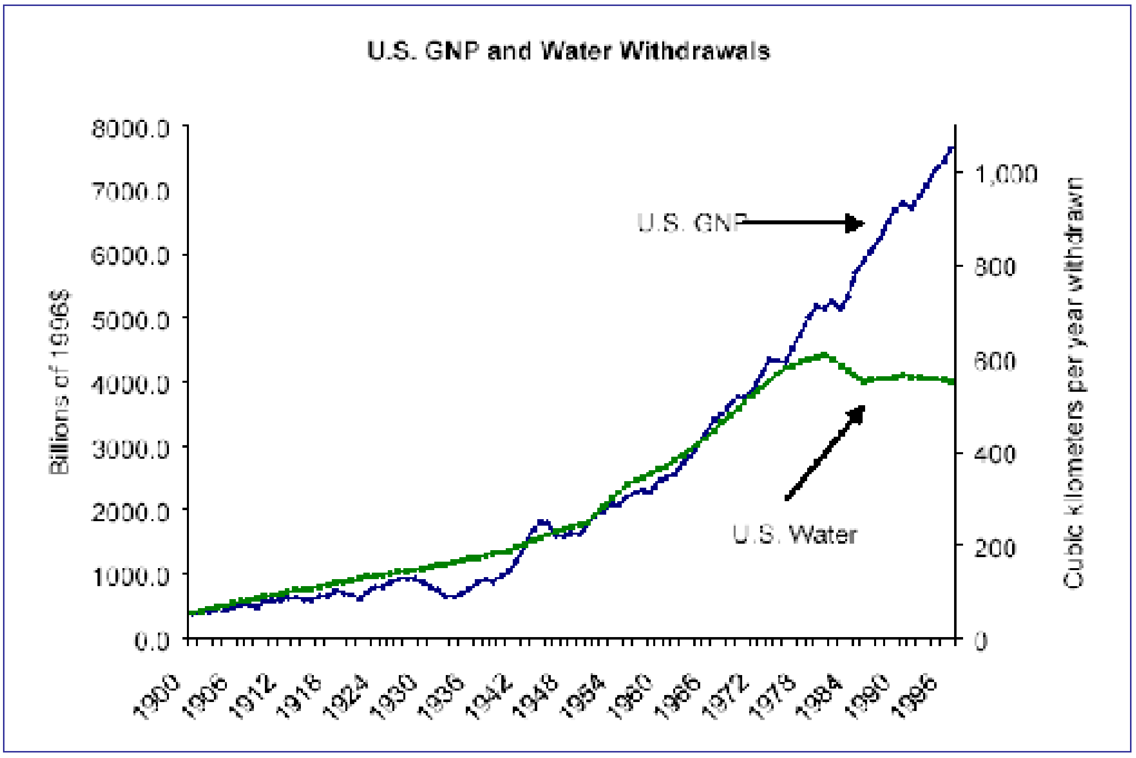


Figure 7 Comparison on per-capita water withdrawals and GNP in the USA



In the USA for example, in the city of San Francisco the following basic approach is followed for urban water demands:

- Projecting growth in the number of water user accounts;
- Applying the fixture models to accounts with applicable end uses, using yearly estimated replacement rates and plumbing codes to arrive at end use percentages for each account;
- Adding up the water usage per end use in each billing category to get total new consumption per account per year;
- Multiplying the per-account usage by the number of accounts;
- Adding unaccounted for water (UFW) as a fixed percentage per year;
- Adding recycled water.

In many **European countries**, domestic water consumption demands can be determined through two principle routes; the first is **micro-component based** and the other is **domestic consumption monitoring (DCM).**

However, such approaches are generally applied to large urban water supply systems. Both approaches require considerable data and a sound knowledge of current water use characteristics. The systems are generally developed at the national level and then applied, sometimes in a modified form to regions within the country. To a certain extent the information can be used between countries provided that water use characteristics are similar.

Micro-component measurements have the advantage of simplicity and breakdown consumption into components of specific water use (e.g. showering, toilet flushing etc). DCM based analysis has the potential to model demand by estimating the total consumption for a particular household profile (e.g. occupant class/category, numbers, no. of bathrooms etc.).

It is sometimes best to employ the strengths of both approaches to enable more descriptive and robust demand forecasting models for to be developed for the urban sector.

Micro-component strengths

The major strength of the micro components approach is the breakdown of water consumption into idealised components (e.g. bathing, washing, toilet flushing etc.). This elemental approach aids deterministic modelling of consumption components.

If the survey through which data is obtained is representative and/or the resulting water-use components properly balanced such that it reflects the demographic average, it can be applied to the larger region to calculate the proportions of water used by the larger populace for specific purposes.

Micro-component limitations

The idealised micro-components are best applied to fairly large and demographically representative groupings of people. However there is usually little detail as to the demographic profile that the 'typical' quantities of micro-components are based on. Thus micro-components may deviate significantly from reality when applied to areas which differ demographically. It should be emphasized that micro-components are idealized quantities for the averaged population or housing sample. The quantities generally do not specifically correspond to any occupancy and/or house type combination. Though micro-components are sometimes presented as per-capita figures because of the non-linear relationship between consumption and occupancy the act of doubling the figures does not yield the average component consumption of a two person home. Variations also exist between micro-component surveys, the quantities maybe small on a domestic scale however these may have large supply balance implications. Good surveys and demographic data is required. Due to the effort and expense of carrying out micro-component surveys they tend to be carried out on fairly small samples of housing (a few hundred sometimes, but usually less). As the sample is small it maybe subject to local bias effects if conducted on one local site, this can introduce errors if used for modelling demand in another region. As micro-components collection is fairly elaborate there is a significant probability that the household occupants will be subject to monitoring based bias.

DCM strengths

DCM surveys tend to have the benefit of size and long duration. Though they ideally should be developed to be cross-sectionally representative of the wider region the large number of households involved (typically many hundred) mean that analysis can select groups and types of housing to better achieve a desired representation.

Most DCM surveys adopt a panel survey approach involving the participant household completing an annual questionnaire. This annual data enables demand to be analysed with demographic, socio-economic and household information, some which are known to have an influence on demand. The detail in the surveys can be very fruitful, most surveys collect data about house type, appliance, occupant and water use information. This allows consumption to be correlated with household attributes. Moreover, some DCMs contain a metered cohort or enabling a monitor of households converting to metering (and thus leaving the survey).

As the consumption is recorded from a single meter or logging devices for the whole household the survey process is less obtrusive than micro-component surveys and thus participant bias is reduced. A consequence is that DCM's exhibit far greater variation in observed consumption and also cases of extreme water usage – known to exist in the real world, but difficult to record and clarify. What is more the panel-survey type approach may give some clues as to the likely cause of extreme and non-typical consumption.

DCM weaknesses

Issues relating to the administration of DCM's generally affect their accuracy. For example questionnaires are usually completed in a roughly annual periodicity, though changes occurring in-between questionnaires are only picked up at the next survey. The range of variation of household consumption can be so great that error removal is important.

Though bias is expected to be reduced in a DCM it cannot be completely factored out. The contact between the water company and the household, the means of data collection and the selection process all contribute to the potential of socio-economic and survey related effect bias.

Where water demand forecasts are based on micro-component approach or a domestic consumption monitoring (DCM) approach, this basic information can assist in the development of **demand management strategies.**

Current increases in demand, coupled with climate change-induced uncertainty over supply, means that **UK water resources** are closer to sustainability limits than ever before. Demand management is increasingly viewed as a key element of a sustainable water resource strategy, but must be supported by accurate demand forecasts, preferably those that address micro-scale multi-component demands as these can provide better information on which optimal decisions about water allocation can be made.

In the United Kingdom the water industry (private sector companies) 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. The Environment Agency (EA) for England and Wales also use the ***micro-component approach to water resources demand forecasting***. Such approaches are applied on a zonal basis and the adoption of a 'Maximum Likelihood Estimation' to reflect a specified potential probabilistic situation..

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. Demand forecasting needs to consider micro-simulation (local level) and econometric models to produce small area forecasts of water demand for upscaling. Demand estimations can be developed to address sustainability issues with respect to future generations, disadvantaged social groups and the environment.

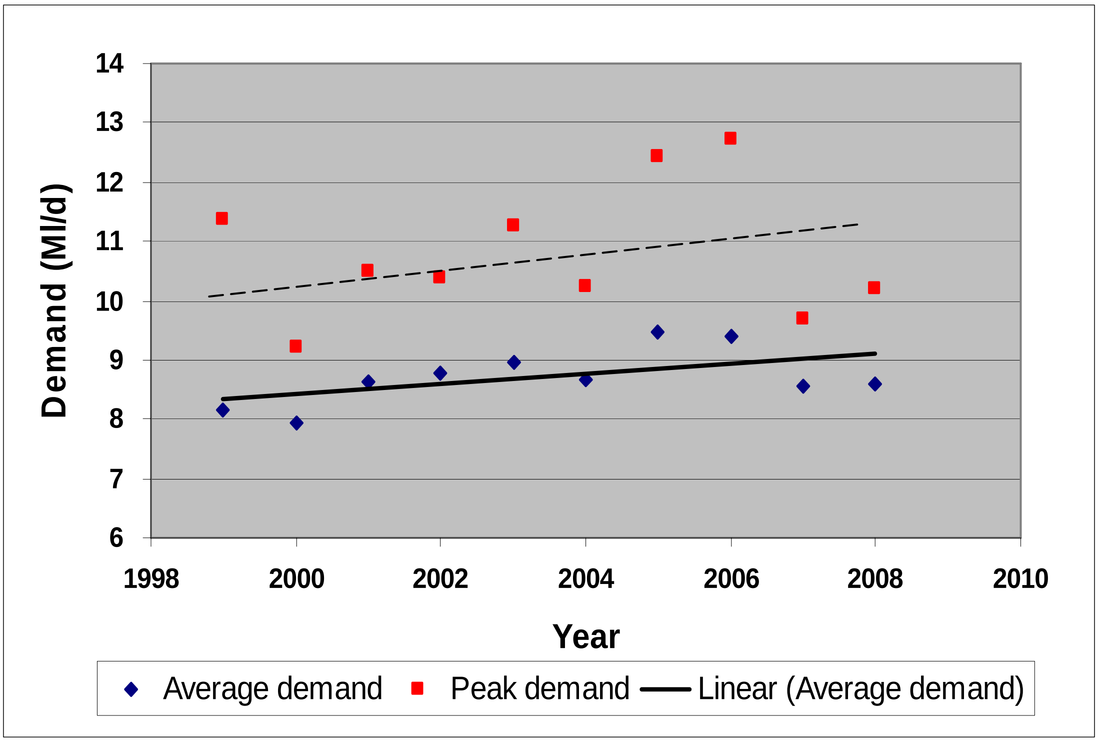
Relatively detailed data is available in the UK and many other countries on water use norms at both the macro and micro level and thus accurate water demand forecasts can be expected. Agriculture is proportionally a minor consumer of water in the UK (1% of total), with most water being provided for domestic and industrial purposes by private sector water supply companies. The forecasting procedure is briefly as follows:

- Household demand is calculated as population multiplied by per capita consumption (pcc)
  - pcc may be divided into micro-components

through separate analyses or from domestic consumption monitoring programmes :

  - Population statistics are based on Government projections;
- An informed assumption is made of how pcc will vary in the future
  - Pcc may be projected forward according to trends in the micro-component population which will be influenced by changes in demography, household affluence and habits / response to water saving propaganda.
  - Allowances for garden watering and household cleaning.
- Factors leading to savings in water consumption:
  - Building regulations for new homes
  - More efficient appliances
  - Public awareness and willingness to use less water (reinforced by water and energy charges)
  - Water-reuse (grey water systems)
  - Metering coverage
  - Water pricing.
- Factors leading to higher water consumption:
  - Rising Living standards
  - Increases in single occupancy
  - Climate change
- Projections of non-household demand are based on:
  - Past trends in billed consumption
  - Specific requirements of major consumers
  - Regional development plans
  - Efficiency savings and water re-use
  - Estimates of unbilled water use and operational requirements (mains flushing, fire fighting, etc.)
- Leakage is divided into:
  - Distribution losses
  - Supply pipe losses
- A peak factor is calculated relative to the normalised average demand for a return period commensurate with the company's level of service. Ideally factors should be calculated for each component (see Figure 8 below). The greater variability in peak demands is likely to be related to climatic conditions whereby high summer temperatures have led to high demands for garden watering, a common issue in the UK.

Figure 8 Average and peak water demand (annual average) – typical example



In the UK, although per capita consumption demands are often quoted and used in demand forecasting, the information on per capita water use is extremely variable across the regions. A recent statement by OFWAT (the water regulator in England and Wales) in a paper to the UK Government in May 2009 says:

Consumption data are unreliable. Consumption estimates vary substantially, even within the same region. 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 should require companies to use consistent methods for measuring consumption, so that it can secure better data on per capita consumption.

Ofwat cannot explain fully the variations in consumption. Research eight years ago suggested that 60% of the difference was due to socio-economic factors. Ofwat has not commissioned more recent research. Ofwat needs to gain a much better understanding of consumption before it determines price limits in the next periodic review.

If consumption data is considered unreliable in the vicinity of London, estimates used in developing countries can therefore also be open to question. However, an important factor in the UK is that only 28% of households are currently metered. In relation to the data in the above box, it is of interest to note that 'Tendering Hundred area' has one of the highest coverages of metering (64% coverage). Metering can greatly increase the knowledge base on consumption characteristics and therefore aid demand forecasting whilst where water pricing is high, serving as an important demand management tool. [Note in the UK, some water companies assume that an un-metered customer uses some 30% more water than a metered one].

Overall demand forecasting in the urban sector is highly dependent on such per capita consumption values, hence more emphasis needs to be placed on determining correct current values. Values are likely to vary from city to city and from region to region within a country however, in order to determine a justifiable 'average', the data for a representative 'population' must be determined. Adopting unrepresentative or 'uncalculated / unestimated' per capita consumption values seriously jeopardises any forecasting process and in fact any demand management initiative. It is important that true consumptions values are estimated and that the breakdown of such numbers by use and misuse is known.

Industrial water 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 2 shows some typical water usage figures based on real situation water audits in the UK, 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 and the caution required in the process. Great care is required in using such data and making associated assumptions and it is important that the uncertainty in the data and the assumptions are fully appreciated by those using the end demand forecast values.

The high level of variability in 'actual water use' data presented in Table 2 provides strong support to the importance of demand management strategies which, if implemented effectively would reduce the coefficient of variation of such data, moving water use norms to a less variable value.

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.

Table 2: 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

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 m^3/unit value, since local pricing may differ). In other cases norms are relatively transferable. For example, the norm for breweries in Wuwei, Gansu Province, is 14 m^3 water per m^3 beer produced, compared to an actual water consumption at an example brewery in 2006 of 10 m^3/m^3 and a future target of 5 m^3/m^3 (data reported by Xiliang Brewery in July 2006). The average water use by breweries in the UK is 7 m^3/m^3 and maximum is 21 m^3/m^3 beer produced.

Investigating the demand scenarios in detail allows a water supply organisation to identify the potential level of contingency or 'headroom' that should be provided to ensure supplies are guaranteed. The concept of headroom in relation to a demand forecast has been used in the UK for several years.

Modelling demand forecasts can range from the use of a simple spreadsheet analysis for each sector but with limited number of variables (perhaps 3 to 5 for each sector) to a highly complex geo-referenced bespoke software package containing multiple variables and assumptions with a specific user interface and output forms. An example of a complex demand forecasting model used by a private sector water company is presented below for a region in the UK.

Box 2 Target Headroom

Target Headroom is defined as the minimum buffer that a prudent water utility should introduce into the annual supply-demand balance to deal with uncertainties such as:

- The impact of climate change on deployable output (a resource contingency);
- The demand forecast variation (population, housing and other assumptions that introduce uncertainty)

Uncertainty of climate change demand influences.

Figure 9 Software for demand forecasting showing scenario selection

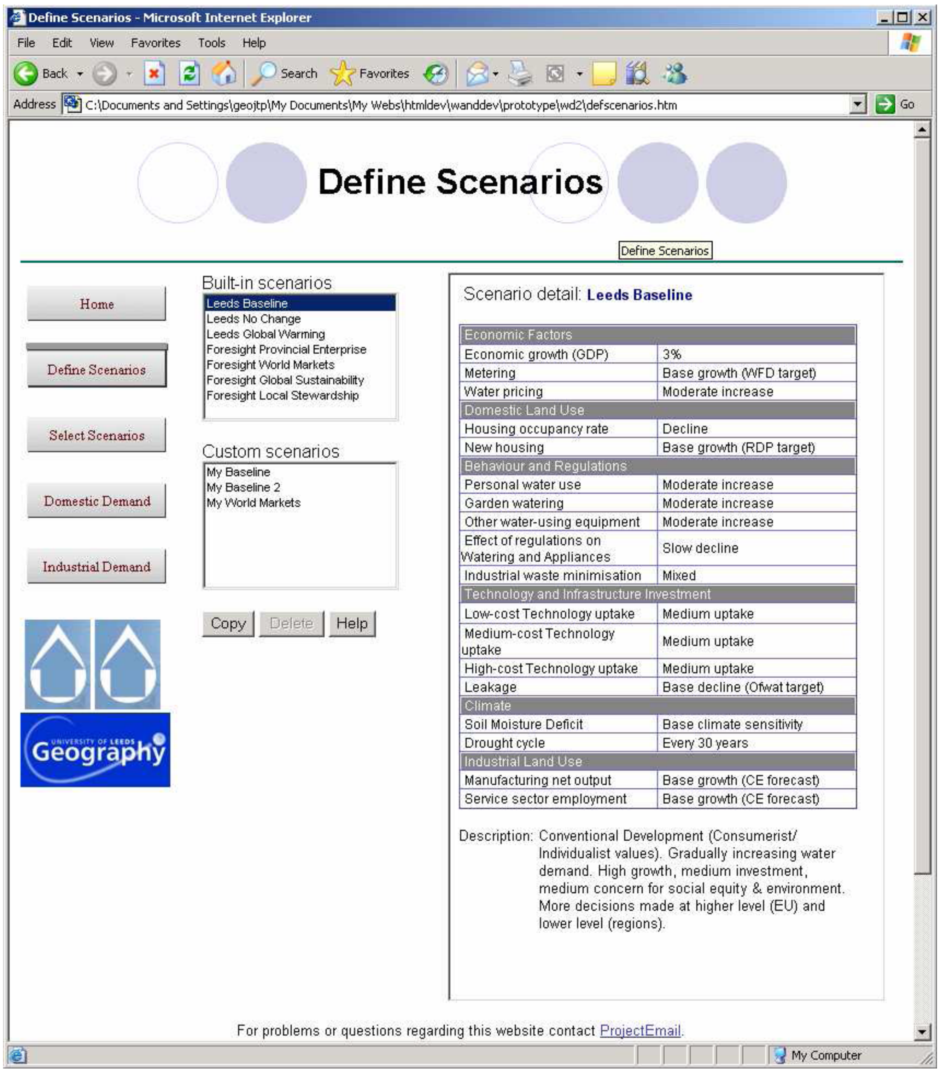
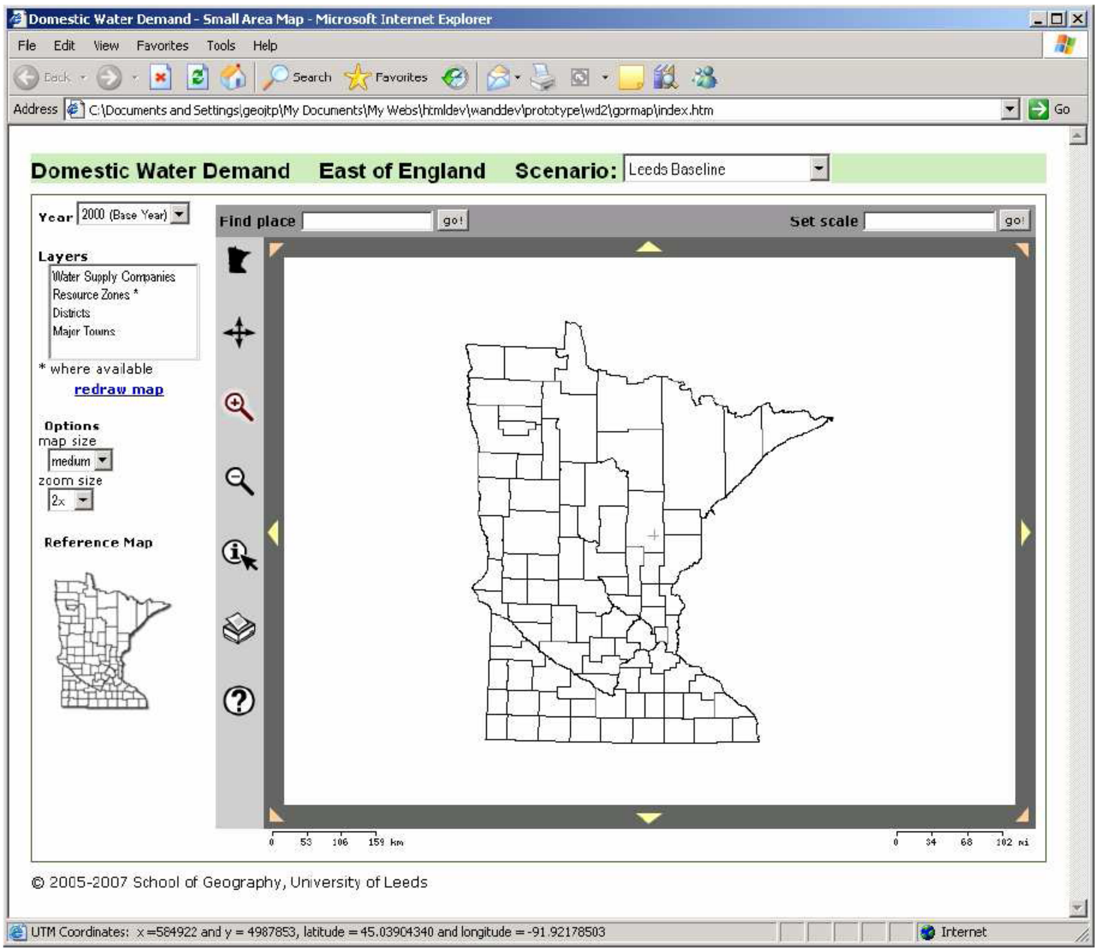


Figure 10 Software for demand forecasting showing spatial information



2.3 Irrigation demand forecasting in agriculture

All the demand management approaches defined above in Section 2.3 applies in different forms in overseas countries. The level of sophistication followed depending on the importance of irrigation in terms of the overall water use in the particular country or region and the level of data that is available. The greater the level of data and knowledge often reflects on the potential capacity of the water resources professionals to undertake the forecasting procedures.

In the USA, considerable amount of supporting information is available from government departments, particularly the USDA (Department of Agriculture). In the USA over the last 30 years or so the development of agriculture has been related to the growth in groundwater irrigation and the use of wastewater, there has been little growth in surface irrigation coverage. Such knowledge provides indicative trends that assist in demand forecasting. Some typical examples of these trends is presented in the figures below.

Figure 11 Water use changes in the state of Georgia, USA

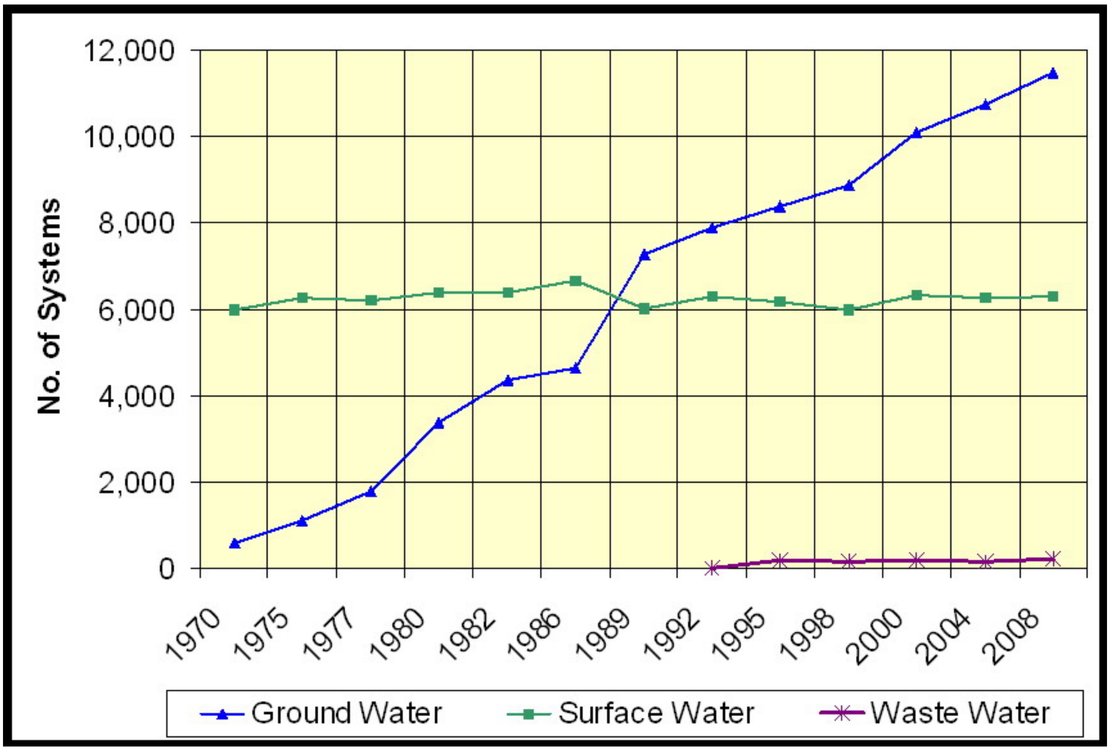


Figure 12 Modern irrigation type changes in the state of Georgia, USA

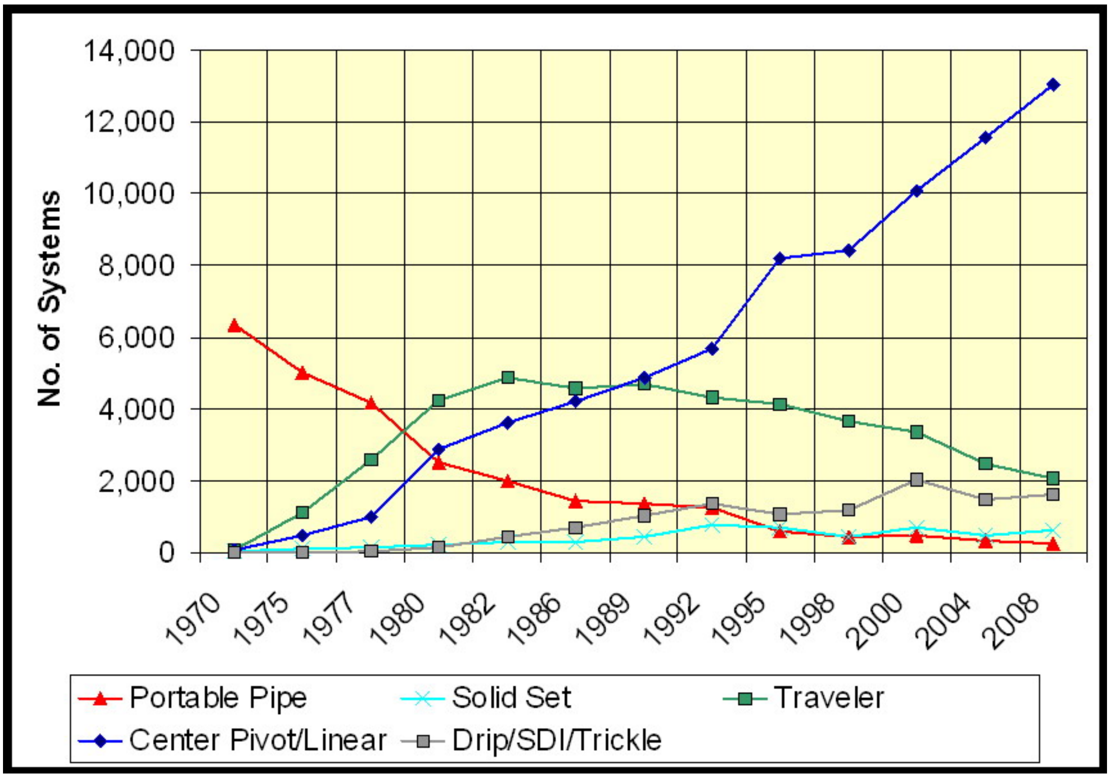
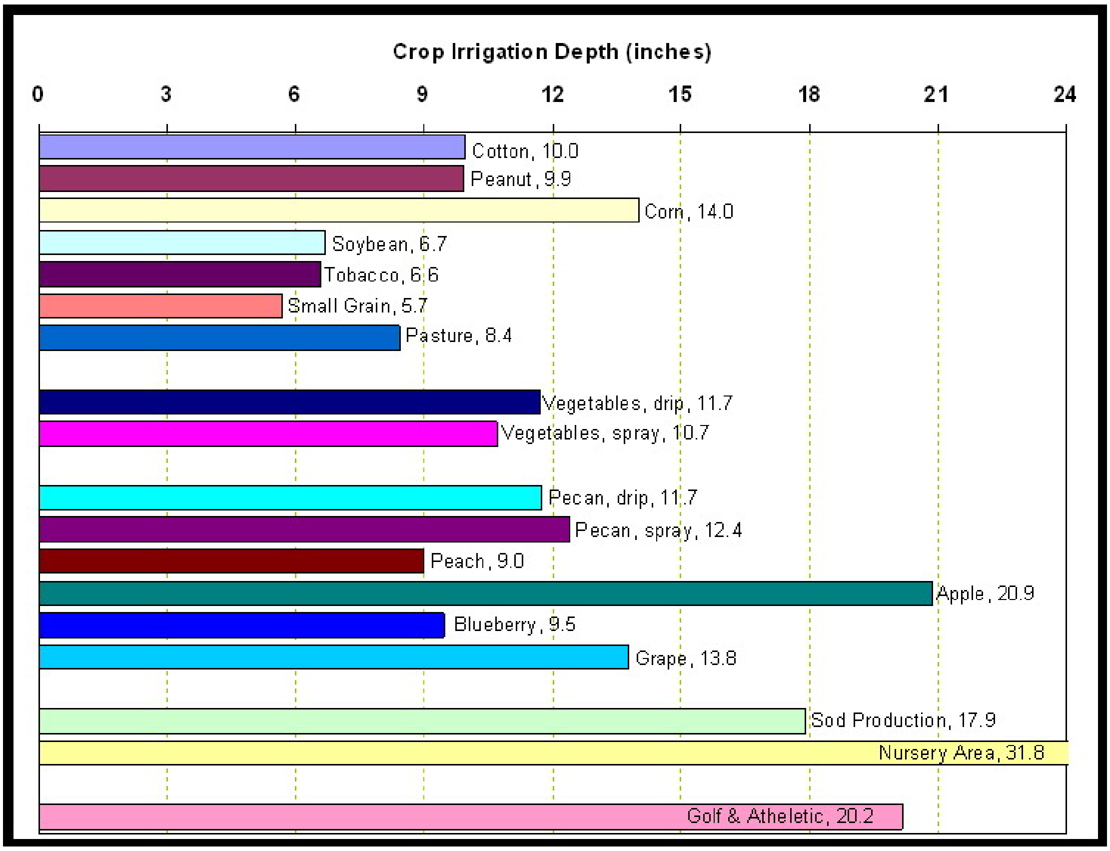


Figure 13 Typical irrigated crop requirements in the state of Georgia, USA. (Note 1 inch = 25cms)



In many western countries where irrigation is primarily a private sector activity, forecasting on a regional scale requires projections of possible changes in irrigated areas as well as changes in crop production to meet consumer demands and economic factors such as export requirements. Such projections can be difficult for a 'water resources professional' to make and recourse must be taken to obtaining the advice in the field. The approach in the USA is presented in the following Box 3.

Box 3 US approach to irrigation

Irrigated acreage projections are based on long-run projections conducted by the United States Department of Agriculture (USDA). The USDA makes ten-year, national acreage projections for the following major field crops: corn, sorghum, barley, oats, wheat, rice, upland cotton, and soybeans (USDA, 2009). Broad categories of horticultural crops are also projected, namely, fruits and nuts, vegetables, and nursery and greenhouse products. Fruits and nuts are further divided into three categories: citrus, non-citrus, and tree nuts. Vegetables are divided into fresh, processed, and potatoes. Nursery and greenhouse products are not further divided. The reason for the highly aggregated projections is a lack of sufficient data.

Where such information of cropping pattern projections are unavailable, many assumptions will need to be made. However, a sound knowledge of the current land areas of different irrigated crops within the region and a knowledge of recent changes can form the basis on which a projection can be made. However, expert advice from agriculturalists and agricultural economists is essential since cropping patterns respond to both product demand and agricultural output (produce) prices.

In the USA, the USDA (1996) has also generated acreage response elasticities with respect to output prices. Estimates were produced at national and regional levels. Thus data and information to support water demand forecasting is clearly more extensive in some countries than others.

2.4 Developing countries – urban demand

A simplified approach to urban water demand forecasting is often used in developing countries and this is basically dictated by the social conditions and the availability of data.

Household consumption is dependent on:

- How many people want water from the public supply?
- Do they want water for all purposes or only for consumptive use?
- Do they want a connection into their house or a tap in the yard, or will they collect water from a standpipe?

The information required for forecasting demand may be obtained from:

- Published local statistics
- Water company billings data
- Local knowledge on water resources usage
- A socio-economic survey of a sample of existing and potential users of the water supply system

Surveys can provide valuable information on:

- Availability and quality of existing sources of water, how much they cost and/or how much time is spent collecting water depending on the source of supply.
- Housing, including facilities such as baths, showers, flush toilets, numbers of taps.
- Household income (not usually asked directly, but can be assessed by questions about expenditure, and can be checked against ownership of goods such as TVs, radios, motor cycles)
- Whether or not people want a water supply.
- Willingness and ability to pay (These need special approaches and skilled practitioners to elicit accurate answers)

The demand forecast can be built up as follows:

- The number of people wanting a full house connection to a property with full internal plumbing facilities

– This is a key element as people who can afford such a house need a connection and should be able to afford water bills.

- The number of people who would like a connection to a single tap in the yard. Generally this will be wanted by people who have no access to an open well near their home, but will depend on affordability of the connection. It helps if they can share with neighbours.
- The number of people wanting a standpipe or communal hand pump. Rarely popular in urban areas except in areas of severe water shortage
- Water consumption from house and yard connections may be determined from norms - typically:
  - House - 150 l/d
  - Yard connection - 50 l/d
  - Standpipe - 25 l/d
- Consumption by house connections will be influenced by the tariff. The consumption from standpipes is limited more by the ability to carry water.
- Non-household demand is generally taken from existing billings. Typically, allow about 20% of household demand, but may need to add for any major industrial or institutional customer.
- Leakage is often high in existing systems. Need a realistic programme to reduce it to an acceptable level (say 20% to 25% of water production)
- Uncertainty is usually accommodated by including high and low estimates.

For all the above, scenarios of growth of each particular supply characteristic needs to be designed and included as the driving element of the demand forecast.

Peak factors, where they are required, can be assessed from basic consumption data but:

- Billings records may not accurately reflect monthly consumption.
- Consumers may be billed quarterly of even half yearly.
- If production data is used, the leakage should have a peak factor of 1.0, so the overall peak factor will increase as leakage is reduced.
- In the absence of any data, peak factors may be typically about 1.2, but vary according to climate, size of supply area and degree of industrial demand.

In a developing country, the situation normally encountered by a water supply organisation will encompass approaches outlined in Section 2.2 and 2.3.

2.5 Developing countries - rural demand

Agricultural irrigation demands dominate the water use profile in the rural areas of many countries. These demands are governed largely by:

- Irrigated area coverage

- Cropping patterns
- Crop water requirements
- Rainfall (which reduces need for irrigation)

And to a lesser extent by:

- Domestic Consumption
- Livestock
- Fisheries

There are usually constraints imposed by the irrigation system on both average and peak demands. Farmers cannot necessarily grow all the crops they desire, or irrigate them at the precise time of their choosing. Irrigation systems that can respond fully to demand require a very large capacity and sophisticated operating systems which are rarely feasible. Demand has to be assessed in the context of these system constraints.

Irrigation water demand estimates can be built up from:

- Areas irrigated by surface water and by groundwater systems
- Existing agricultural data and likely changes to agriculture (through existing and anticipated crop calendars) ,
- Crop norms or more sophisticated methods of calculating crop water requirements.
- Allowances for losses in the irrigation system – taking account of irrigation type and conveyance system characteristics (which may be variable and are often only known very approximately).

The calculation of agricultural water demands on the basis of norms for different points in the system is covered in a separate document, Advisory Note 1.8/2 'Agricultural Water Use Norms'.

Changes to irrigated agriculture in future will influence both overall demand, and the requirements for operation of the system. For example new peak demands may exceed system capacity even if the average demand can be met, or conversely it may not be possible to schedule deliveries for new crops which require small amounts of water at times when canals are not normally in operation. This is particularly true where crop diversification from cereal monoculture to mixed cropping with small areas of high value cash crops is envisaged.

Demand forecasts are thus needed for both annual totals and for weekly or monthly demands

Livestock should be treated separately on the basis of current and trends in numbers of large and small livestock and poultry.

Livestock water demands should be treated separately from agricultural irrigation demands

2.6 Uncertainty in demand forecasts

Demand forecasting can only be as accurate as the underlying data and assumptions. Data on the existing situation should be relatively accurate, but variations in conditions and unexpected future trends can make the forecast unreliable. To cope with uncertainty, a sensitivity analysis approach is adopted to determine the potential impact of this uncertainty in both the original data and the assumptions made in the forecast.

Three aspects need to be considered in relation to uncertainty:

- Accuracy of basic initial data (populations, crop areas etc)
- Accuracy of derived information (water use norms, water use and supply efficiencies)
- Variable, unpredictable factors (climate etc)

Data accuracy

For urban situations uncertainty can exist in relation to the population served and the validity of the water use norm being used.

For irrigation water demand estimates, crop norms and irrigated areas are a well established and simple approach to calculating crop water demands, but they do depend on accurate data on irrigated areas and crop types which is easy to collect in theory but can be difficult in practice. Farmers may choose to partially irrigate a larger area than irrigate a small area fully – this will reduce evapo-transpiration per unit area to less than the norms for full irrigation to an extent which cannot easily be quantified. Even if the total area can be quantified, the actual cultivated area – allowing for multiple cropping, intercropping, relay cropping etc can still be uncertain.

Modern techniques such as remote sensing are valuable, objective and simple, direct methods for assessing total crop water demand whilst taking all of these factors into account. They can provide a second or supporting estimate. However, this requires expensive equipment and a relatively high skill level to undertake the task.

Variable factors

A range of factors can contribute to unavoidable uncertainty in forecasts, whatever methods are used. Different uncertainties will relate to different types of forecast.

Some uses of water – such as domestic consumption - are virtually inelastic in many developing countries and will need to met almost regardless of other factors. Others can be partially met without significant harm or can be compensated for by greater supply of water in the future. So it is also important to know the range of demand estimates.

Forecasting procedures

Norms may not represent actual demand, particularly when broken down to small time periods and then aggregated for different uses at any particular time. Procedures can be refined, but the effort worth putting into forecasting techniques depends on the uncertainty in the underlying data, variable factors which cannot be quantified and the sensitivity of the impact of resulting forecast. Highly sophisticated methods may be appropriate in large urban centres, whereas simplified methods are suited to rural environments which may be more resilient.

Potential implications of 'impaired' demand forecasting

As an example of the impact of 'impaired demand forecasting, in a irrigation scheme where the demand forecast was for annual irrigation delivery planning, if the forecast differs from the actual demand by say 10%, what impact does this have? Does it result in a 10% reduction in output, or does it because of the timing result in a crop dying and hence a 100% reduction in output. Different uses of water have different sensitivities, and in each case it is necessary to consider what impact any inaccuracy in the demand estimate would have. These could be, variously:

- No impact – because there is sufficient flexibility in the system to deliver the actual rather than forecast demand
- Sub-optimal design of infrastructure and possibly excess costs
- Reduction in output for all or some uses of water,
- Total loss of output for a particular use
- Impact on livelihoods and health
- Impacts of ecosystems (which are likely to be dependent on residual flows, after all other uses have been met to what ever extent decided)

2.7 Sensitivity analysis in demand forecasting

Sensitivity analysis is a technique for investigating the impact of changes or uncertainties in data or variables on an output value. Typically, only adverse changes are considered in sensitivity analysis, ie is there a level of risk that the forecast could result in inadequate supplies being available or alternatively unnecessary investment programmes. Neither of which is a desirable consequence of a water demand forecast.

Internationally, undertaking sensitivity analyses in relation to water demand forecasting is common practice. Managers and decision makers need to be aware of the potential variability of demand forecasts to the base data and the assumptions being made. [It is appreciated that in some countries there is a tendency for senior managers and decision makers to only want a single value answer. The reason for this is uncertain but may be due to the fact that it limits their decision making responsibility if they are given a single technical answer. This approach needs to be changed].

The purpose of sensitivity analysis is therefore:

- To help identify the key variables which influence the water demand forecast
- To investigate the consequences of likely

adverse changes in the key variables or data quality assumptions

- To assess whether decisions are likely to be affected by such changes
- To identify actions that could mitigate possible adverse effects of the uncertain data sets or key variables.

Sensitivity analysis needs to be carried out in a systematic manner. To meet the above purposes, the following steps are normally suggested:

- Identify key variables to which the water demand forecast may be sensitive in water use each sector (some of these variables have been outlined already e.g. water use norms)
- Calculate the quantitative effect of likely changes in these variables on the demand forecasts
- Consider possible combinations of variables that may change simultaneously in an adverse direction resulting in a combined impact on the water demand forecast
- Analyze the direction and scale of likely changes for the key variables identified, involving identification of the sources of change.

The information generated can be presented in tabular form with an accompanying commentary and set of conclusions and recommendations or qualification on the demand forecast in question.

Sensitivity analysis is made easier if the water demand forecasting is being undertaken through a series of inter-linked spreadsheets. Bespoke demand forecasting software, for example, will incorporate sensitivity analysis options.

Table 3 Example of possible sensitivity analysis topics

Element of Demand Forecast	**Base estimate**	**95% confidence interval of the estimate (or other sensitivity value, even subjective)**
Population growth	X	+/- 5%
Water use norm for ‘A’	Y m^3/mu	+/- 10%
Adoption rate of new irrigation systems	Z%	+/- 25%
Increase in canal lining (needs link to volume saving)	V kms	-20% (assumed unlikely to exceed target)

2.8 Water demand forecasting – summary

Key points to note are

- A realistic demand forecast is an essential starting point in water resources planning as well as for individual water supply schemes, but they will never be exact.
- A sound knowledge of current water usage and usage characteristics is essential.

- Demand forecasts must be built up using all available data and the approach must reflect the conditions in the communities for which they are required and the information that can be obtained. There is normally a need for specific data collection and surveys to be undertaken to improve forecasting ability.
- Water use norms must be clearly understood by all and be based on quantifiable components.
- A sound knowledge must exist of water loss levels (water use efficiencies) in various parts of a supply system.
- Urban water supply forecasts start with household demands, and then add on non-household demand and leakage.
- Peak demand periods are usually critical for urban supplies and peak factors must be assessed from past records for system design.
- Seasonal and annual variations in irrigation demand can be very high, and they are likely to be structural as well as resource constraints on meeting peak demands.
- Uncertainty analysis needs to be undertaken with respect to both data and assumptions and associated sensitivity analyses undertaken.
- Demand forecasting needs to be carried out in consultation with stakeholders, particularly the major water users and/or those advising or supervising the main water users.
- Demand forecasting analysis needs to be transparent and fully documented and shared with stakeholders once complete to clearly indicate the assumptions made in the prediction.

Municipal supplies can usually be designed to supply water to meet best estimates of demands and system capacity can be expanded at short notice if needed. Irrigation systems are less flexible and the ability to meet demands is often constrained by the existing infrastructure or by economically or socially feasible development of the infrastructure. Demand estimates need to take account of what the system can deliver.

Agricultural demand estimates need to take account of these constraints, and there may need to be an iterative process to optimise estimates.

3 Forecasting Water Demand – Chinese Practice

3.1 Basic principles and requirements

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.

Water demand forecasting or prediction should be made in accordance with SL 429 and other official documents that take account of several guiding principles that generally follow international practices:

- Consistent statistics should be used for all sectors and demands
- Rational method should be followed, typically based on norms but this may be checked by use of other methods
- Base year and planning horizons should be clearly defined
- Consider variations in demand through the year – agricultural demands, in particular, are very seasonal.
- Consider uncertainties in demand

The resulting prediction should be checked for reasonableness, and consistency with water use savings/efficiency targets

Both economic and social development are primary factors that influence demand. Key factors include:

- Population and urbanization characteristics including the growth rate of each,
- Economic development targets (GDP, structure, trends and forecasts)
- Agriculture and land-use indicators (irrigation, livestock, fisheries)

It is important that demand forecasting takes note of the development proposals and plans of all sector agencies as well as including for the expectations or plans of the private sector.

The document "*National integrated water resources planning – technical details of water demand prediction*" provides a comprehensive method statement for the preparation of water resources demand forecasts. The main guidance provided by the document being provided by a series of over 28 standard tables that are intended to assist in the demand forecasting process. These tables lend themselves to developing through a series of linked spreadsheets. However, the tables, although providing a good perspective as to what is required to be undertaken to prepare a water resources demand focus, require a lot of data. The process of obtaining this data and processing it for incorporation within the tables should be well documented since this will indicate all the assumptions that will have to have been made. These assumptions will be a key element in understanding the basis for the forecast. Detailed equations are presented as to how to process data and information to complete the tables allowing for such issues as trend projection allowances, water use efficiencies and re-use factors.

3.2 Forecast for water abstractions

Water demand for all abstractions – agricultural, industrial, construction and tertiary industry and domestic demand – are covered by the MWR 2004 document. This document provides tables wherein the following characteristics are to be completed by a province, autonomous region or municipality under the central government:

- Population development indicators *(urban and rural populations, urbanisation ratio and the percentage of populations with piped water in urban and rural areas)*;
- Main economic indicators for different sectors in the national economics *(covering the agriculture sector, high water consuming industry, other industry, thermo(nuclear) facilities)*.
- Indicators for agricultural development and land utilization *(arable areas, irrigated areas defined as areas of paddy rice, vegetables, horticulture with additional information on aquaculture and livestock numbers)*.
- Indicators for irrigated areas by different irrigation type *(for irrigation by surface water, groundwater, conjunctive use the areas of overall irrigation and paddy rice, vegetables, horticulture served by each)*.
- Indicators for socio-economic development in urban districts *(by industrial category and defined primarily as added values)*.
- Domestic water demands forecast *(based on population in urban and rural areas together with l/c/day norms and water use efficiency assumptions to yield gross water volumes at each annual time horizon)*.
- Water demand forecast for farmland irrigation for two scenarios (base and recommended). *(irrigation norms (m^3/mu) for paddy rice, other (grain), vegetables, horticulture for various rainfall probabilities (50% (average year), 75% and 90% (1 in 10 dry year)), assumptions for field irrigation efficiency, canal efficiencies at different levels presenting water demands at tertiary level and a gross value each under the different rainfall assumptions);*
- Water demand forecast for grassland, forest, husbandry, fishery and livestock for the two scenarios (based on areas, numbers, net norms (m^3/mu or l/c/d), and irrigation efficiencies where applicable).
- Monthly water distribution coefficients for irrigation.
- Monthly water distribution coefficient for forest, husbandry and fisheries.
- Industrial water demand forecast for out-of-stream water use *(based on $m^3/10^4$Yuan and $m^3/10^4$Kw type norms).*
- Water demand forecast for building industry and tertiary industry *(based on $m^3/10^4$Yuan norms for building industry and tertiary industry plus allowances for delivery efficiencies).*
- Summary of urban and rural net water demand forecast as net and gross values *(incorporating the rainfall*

probability categories carried through from the irrigation demand forecast determination).

- Eco-environment water demand forecast for main in-stream control nodes *(based on mean monthly flows, environmental flow as a % of this value grossed up into an annual volume. Other allowances are given for flushing, prevention of sea water intrusion and for ecological purposes).*
- Eco-environment water demand forecast for towns and cities *(estimates for urban landscaping, sustaining urban water channels and lakes etc).*
- Out-stream eco-environment water demand forecast *(estimates of ecological requirements of off-stream lakes and wetlands, groundwater recharge (artificial) as well as further demands for forests all based on norms of the form m^3/ha, $m^3/m^3 x10^4$).*
- Summary tables for the above.

The tables can provide a useful basis for water resource demand forecasting at river basin or municipality level. At municipality level, the tables and supporting calculations and assumptions used at provincial level would be useful in any forecasting the municipality had to undertake. The same tables and supporting information for provinces would also be useful for river basin authorities to review and include in any water resources demand forecasting they would be undertaking.

Domestic water use

Domestic uses of water are estimated on the basis of household norms, population projections and allowances for losses (through delivery efficiency allowances etc). However, as stated earlier, these estimates will be influenced of demand management measures (eg tariff levels, active leak reduction programmes) and the projected impact of socio-economic development. Projections should be reconciled against current levels of water use. In the tables mentioned above, such changes will be reflected in the 'norms' being assumed to apply in the future. The difficult task is in ensuring that these 'modified norms' are determined on the basis of assumptions of the impact of demand management and of the changes in water use characteristics of the user population in the future. There has to be a rational relationship between changes in water use norms and future user characteristics and demand management programmes.

Additionally, there must be documented information as to the basis for population changes, urbanisation rates.

For urban and industrial demand forecasting, the following considerations are necessary:

- Household demand is population x per capita consumption (pcc)
  - Per capita demand may be divided into micro-

components, allowing for changes in living standards, and adoption of water saving technology :

  - Population will come from Government projections of growth by location, including rural-urban migration;

- Projections of non-household demand are based on:
  - Specific requirements of major consumers
  - Regional development plans
  - Past trends in billed consumption
  - Estimates of unbilled water use and operational requirements (mains flushing, fire fighting, etc.)
  - Efficiency savings and water re-use
- Leakage is divided into:
  - Distribution losses
  - Supply pipe losses
- A peak factors for each component.

Waste water flows from domestic use are estimated as a percentage of water consumption, and is usually about 80% to 90% of water supplied, the remainder being lost to evaporation from house cleaning, yard cleaning, plant watering, etc.

Domestic uses of water are estimated on the basis of household norms

For all data and information in relation to urban water demands the local water supply companies and any related industries should be consulted. All such data and information and data so obtained should be scrutinised and full clarification obtained.

All data and assumptions used in the water demand forecasting process should be copied to the respective organisations from which the data and information has been obtained for confirmation.

Industrial water use

In the build up of the numbers to be included in the tables, industrial water demand will be broken down by type of industry and norms applied to each type on the basis of:

- Output
- Consumption per unit output
- Leakage
- Recycling and reuse.

Current water use conditions need to be determined for the different industries and demand forecasts need to take account of:

- Likely change in output of each industry
- Potential impact of demand management in each industry through:
    - Pricing policies
    - Process improvement
    - More water use efficient equipment
    - Re-use
    - Leakage reduction.

Realistic targets should be applied for future levels of each of these aspects for each type of industry. These all need documentation and to be built up from basic data and principles

The forecast changes in industrial development and the associated norm changes associated with industry related to improved processes/equipment and re-use must also be well documented to understand the forecast and in the future to enable comparison to be made between the forecasts and actual demand management programmes put in place.

Wastewater flows from industry depend on the type of industry, and need to be built up separately. It should be noted that an industry may be entirely reliant on the municipal system, or have its own supply yet discharge waste to the municipal system, or it may have its own waste disposal arrangements as well.

For all data and information in relation to industrial water demands, both the local water supply companies and the major industries should be consulted. All such data and information and data so obtained should be scrutinised and full clarification obtained.

All data and assumptions used in the water demand forecasting process should be copied to the respective organisations from which the data and information has been obtained for confirmation.

Irrigation (and other rural) water use

Irrigation requirements are usually assessed on the basis of norms, with an allowance for water losses.

Factors which need to be considered include:

- Crop structure and areas
- Rainfall (monthly and daily figure - both average and dry years. However these requirements will depend upon the form of the demand forecast and its intended use)
- Irrigation techniques
- Water savings measures.

This should also be compared with actual delivery since it may be necessary to adjust water demand to suit availability - this will then be reflected in reduced crop yields or gross area irrigated. It is relatively easy to estimate annual totals on this basis, but seasonal demands will vary according to the irrigation schedule.

Livestock and fishery demands can also be assessed on the basis of populations and norms. The consumption element of such generally small demands will not often have a major impact on resources except when major livestock or aquaculture exists.

In relation to forecasting irrigation demands, other considerations include:

- General factors:
  - Climatic factors – short term variations in temperature and rainfall (particularly impact on irrigation demand and the way irrigation management is adapted to allow for rainfall)
  - Timing of demands – variability can mean that the peak overall demand is not the sum of the peak demands for each component activity
  - Longer term climate change
- Water savings measures can be applied very variably:
  - Mulches for crop production
  - Uniformity of irrigation techniques (e.g. accuracy of field levelling)
  - Other agronomic and field conditions such as field land levels
  - Leak control (irrigation channels)
  - Irrigation scheduling and timing of water deliveries to individual users

For all data and information in relation to irrigated agriculture water demands, both the irrigation scheme water management stations, irrigation districts etc and the agricultural departments should be consulted. All such data and information and data so obtained should be scrutinised and full clarification obtained.

All data and assumptions used in the water demand forecasting process should be copied to the respective organisations from which the data and information has been obtained for confirmation.

Conventional approaches to water demand forecasting based on norms, as described earlier are a valid approach, but it should be possible to improve the accuracy of forecasts by careful attention to various aspects.

In relation to demand forecasting for irrigation system design or operational requirements (and scheduling), the factors requiring consideration are:

- Crop norms and irrigation timing at field / WUA level can be calculated for individual crops using improved methodologies.
- Changes to areas of each crop can be assessed to meet overall water consumption targets, and then the impact on required volumes and timings for the overall combination of crops can be checked. This should also be checked against the ability to deliver water to this schedule, given the nature of the infrastructure and the management system.
- The impact of water savings techniques can be gauged on the basis of past experience and other research data, but it will remain relatively uncertain and will need to be carefully audited so that actual residual water

demands can be quantified more accurately. This will require monitoring water saving methods, uptake rate and impact.

- Land and crop consolidation. Changes to crop pattern and areas will be more efficient in water resource terms if land is consolidated, so that cropping is homogenous and fallow land is not interspersed amongst cropped land. Fragmented cropping is likely to result in higher losses and lower conveyance and management efficiency. However, the scope for consolidation is constrained by land holding policy and social factors together with the policies of other sector organisations.
- Irrigation management is most simple if water is delivered to a simple rigid, infrequent schedule. However, this does not meet the crop demands very well and can require excess system delivery capacity (which needs to be considered carefully if upgrading works are planned). Flexible scheduling is more responsive to crop and farmer needs and may save water but is more complex to manage. It may also increase demand for water if canals are not well-managed. This may depend on a process of irrigation management transfer to WUAs and more rigorous monitoring of flows in canals.
- Canal conveyance losses, management losses, inequity factors all need to be reassessed in accordance with the actual management system and should not be assumed to be a uniform percentage across the water management station command area.

The demand forecast calculated in this way should be compared with the overall annual and long term allocation, also derived through a separate less refined but more long term demand forecast. If it exceeds the overall availability of water, then the underlying assumptions may need to be reviewed. Revisions to crop structure / patterns etc may be needed to suit total overall demand constraints and then the entire calculation repeated.

3.3 Forecasting for non-environmental requirements within river

In some locations there may be needs to protect navigation, hydropower, tourism and recreation / leisure activities. This also includes the need to maintain a degree of dilution and self-purification capacity. The 2004 MWR guidance document provides tables whereby such requirements can be recorded.

3.4 Environmental demands within river systems

Water managers should be familiar with the requirements for environmental impact assessment of plans under the 2002 Law on Environmental Impact Assessment. MWR has issued guidance relating to environmental allocations and to

EIA in the context of river basin planning.

The 2004 MWR guidance document recommends the use of the Tennant Method for the estimation of environmental flow requirements. Various hydrological analyses are recommended to obtain low flow probability estimates. The difficulties here being the need for flow naturalisation to be undertaken to provide a complete picture of the system and secondly the need to take the impact of climate change into consideration. It also includes a need to consider the flow regime in a river to maintain a stable sediment transport regime. (See Advisory Note 2.4/1 'Environmental Risk Assessment' and Advisory Note 2.4/2 'Environmental Water Allocation' for more details.)

Overall, the estimation process advised for these considerations is quite thorough and could be seen by some local organisations as too complex to undertake. An example calculation, together with advice on the source of data and typical values for coefficients might be useful.

3.5 Summary

Demand forecasting on the basis of norms is well-established in the country. Since delivery of water is often also on the basis of norms rather than true demand, this should be a fairly accurate approach to matching supply and demand. However, it depends on the accuracy of calculation of the underlying norms, and there are also factors – such as rainfall – which may make the actual demand significantly different from the norm.

It is, therefore, important to consider the uncertainties in the norms and the way they are used in order to improve demand forecasts.

Water use norms must have a meaning. They must be based on known data and information. Any norm will have associated with it a number of assumptions as to the conditions to which the norm applies. Anyone using a 'norm' in a demand forecast must have a full understanding of the background to the norm and degree of potential standard deviation of the value for a particular situation. This 'knowledge need' was indicated in the case of the international cases described earlier. Detailed analyses of water use by different similar water users can yield different unit water use information; refer back to Table 2 This indicates the care that needs to be taken in adopting a single 'norm' for a water user type, or more problematically for a group of industries. A sensitivity analysis approach is required. But again any sensitivity analysis must be based on known information that may question the main 'standard norm' being used in the primary analysis.

In terms of future 'norms' these must be determined based on some form of 'component' analysis. Advice also needs to be given on water use norms in this respect.

Apart from the 'norms', the other area where there is often a high degree of uncertainty is in terms of **water losses or 'delivery efficiencies'** depending upon the terms being used. Again delivery efficiency values used in demand forecasting must be reasonably accurate representation of the situation. Water losses are generally better known in an urban or industrial water supply system, however water delivery and irrigation efficiencies in irrigated agriculture are often little known. There is also a tendency, when estimating such efficiencies to bias towards the high side. If for example a higher than actual efficiency is assumed for an irrigation scheme and demands are based on such a value, when the deliveries take places and there are higher conveyance losses than has been assumed, it is the irrigator who does not receive his/her crop related water use norm. The same will apply to the urban sector.

Water demand management relates strongly to both water use norms and water delivery and use efficiencies. If the norms and efficiencies are poorly known quantitatively, demand management programmes are difficult to target and design. Similarly, the changed norms and efficiencies brought about by a demand management programmes will also be difficult to predict. All this impacts on the potential accuracy of a demand forecast in the first place.

This highlights the need for more attention to be paid to practical knowledge water use norms and water use and delivery efficiencies. Where water is becoming scarce and demand management is becoming increasingly important, these two factors need more knowledge (and research) than was previously the case in a 'supply driven' water resources usage situation.

Improved water demand forecasting can be achieved by a better knowledge of, and level of representative accuracy of, water use norms and water use and delivery efficiencies.

4 Conclusions

This paper reviews current approaches for demand forecasting internationally and in China. Although demand forecasts may be needed for many different purposes, the primary focus in this paper is on the use of water demand forecasts for small river basin or catchment basin-level water resources planning and management however, the content has a broader use.

Current techniques in China are based on (single) norms for each category of use, combined with growth forecasts for each user. A sound knowledge of 'norms' is essential particularly where demand management programmes are becoming increasingly important.

Internationally, it is common to allow for uncertainty in the value of demands, rather than allow on a single figure. There is potentially a large degree of uncertainty when individual demands are aggregated, especially when data is inadequate or fragile.

A water demand forecast must take account of plans or assumptions about future demand management measures. Programmes need to be put in place to ensure that these measures achieved the impact on which the forecast is based.

Document Reference Sheet

Glossary:

DCM	Domestic consumption monitoring

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Related materials from the MWR IWRM Document Series:

OV2	Water Demand Management
Advisory Note 1.8/1	Water Demand Forecasting
Advisory Note 1.8/2	Agricultural Water Use Norms
Advisory Note 2.3	Water Resources Scenario Development and Scenario Modelling
Advisory Note 2.4/1	Environmental Risk Assessment
Advisory Note 2.4/2	Environmental Water Allocation

Where to find more information on IWRM – recommended websites:

Ministry of Water Resources: www.mwr.gov.cn

Global Water Partnership: www.gwpforum.org

WRDMAP Project Website: www.wrdmap.com

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