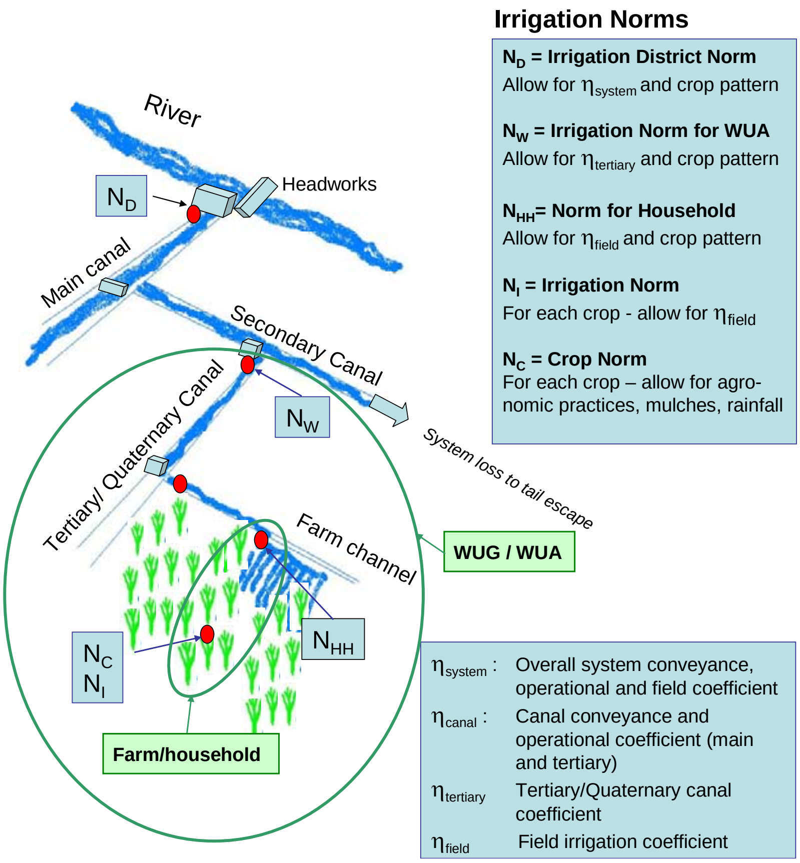
1. WRA

China – UK, WRDMAP Integrated Water Resources Management Document Series

Advisory Note 1.8/2: Agricultural Water Use Norms

May 2010



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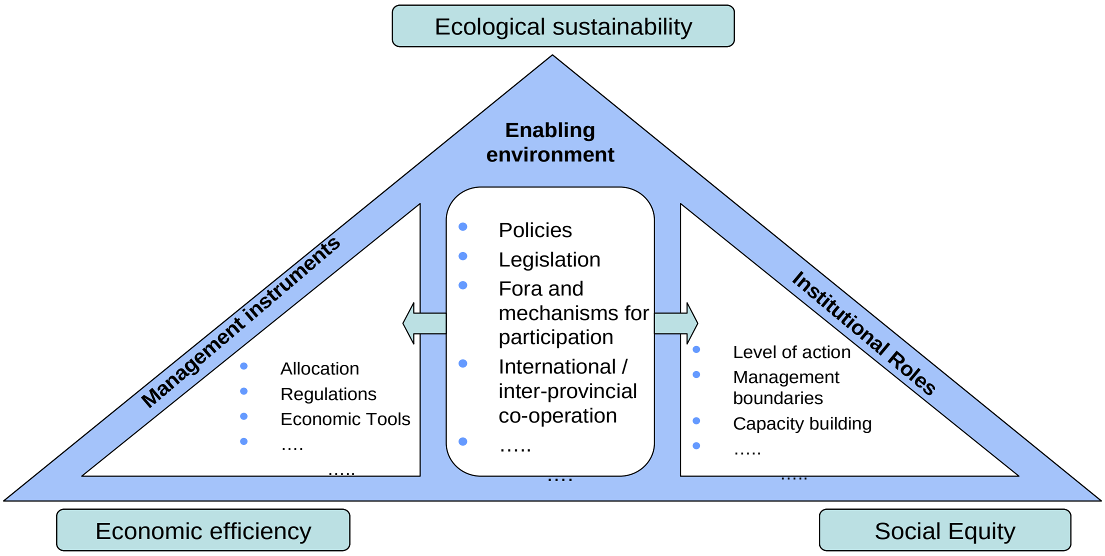
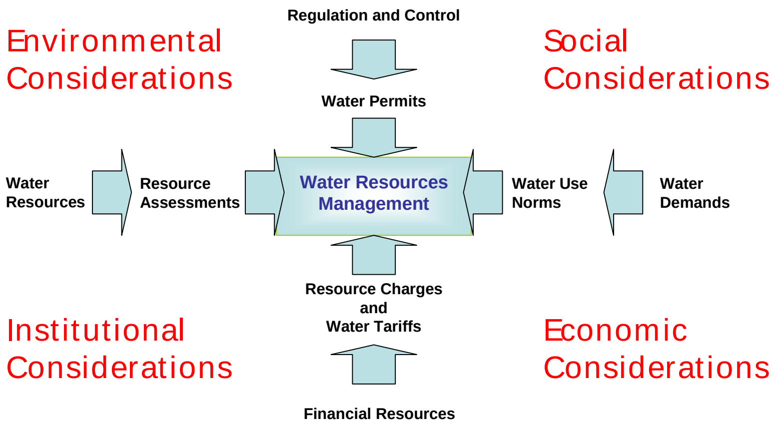
Integrated Water Resources Management (IWRM)

(Basics after Global Water Partnership)



Driving Elements of Integrated Water Resources Management



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Summary: Irrigation norms are a critical input for water management in China, so it is important that they are understood and calculated systematically. The guidance provided in this document outlines the process for preparing norms for irrigation water use. This distinguishes between types of norms; and between norms for overall planning and for routine operation of irrigation systems. This is to help ensure that norms are prepared for different crops and regions (counties, municipalities and provinces) on a consistent basis, and that the basis on which they are prepared is understood by those who use them.

The structure of the guideline is as follows:

- Scope
- Background – nature and purpose of norms
- Definitions and explanations of concepts
- Basis, procedures and factors to be considered for development of norms
- Crop norms – crop water requirements under full irrigation
- Irrigation norms – allowing for losses at various levels in the system
- Verification of norms by monitoring actual performance of the irrigation system
- Modification of crop norms and irrigation norms for water-saving
- Conclusion

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 Scope of this guideline

Norms are a key part of water management in China, but several different types of norms are used and they are not always interpreted or used in the same way if different places. This document is aimed at provincial and municipality authorities, primarily in the water sector, who are responsible for preparing norms and for water resources planning and irrigation system management. It provides technical guidance for them to understand and use irrigation water use norms.

Consistent and accurate use of norms is important to ensure that water resources are managed in a rational, sustainable and equitable way. This document aims to provide guidance on understanding the basis for preparation of norms for irrigation, and adjustment of norms to allow for water savings measures and requirements.

It is important to understand the link betweens the use of a norm, the numerical value of the norm, and the assumptions inherent in the norm. For example the norm is based on assumptions about crop patterns, effective rainfall, irrigation methods, canal condition, and on the way the system is operated, etc. Those calculating norms need to be aware of these assumptions, and to be able to relate them to the actual situation.

This guideline describes the basis for norms, the means of calculating norms applicable for different stages of activity (basin level planning, annual allocations to irrigation districts, and water distribution during the irrigation season), and at different points in the system (for example, at the source or headworks, at point of delivery to a water user association (WUA) or village, and actual supply to individual users).

Once water is actually delivered in accordance with an allocation calculation on the basis of norms, the accuracy of the assumptions and the norms can be tested by observations of deliveries to various points in the system. In practice, adjustments will be required to ensure that the crop water requirements are met as fully as possible. This will require feedback between norms and operation. This guideline briefly indicates how this might be done.

Application of the recommendations in this guideline should ensure that there is consistency in norms between adjacent counties, municipalities and provinces.

1.2 Purpose of the guideline

This guideline has been prepared in order to help water resource department officials to:

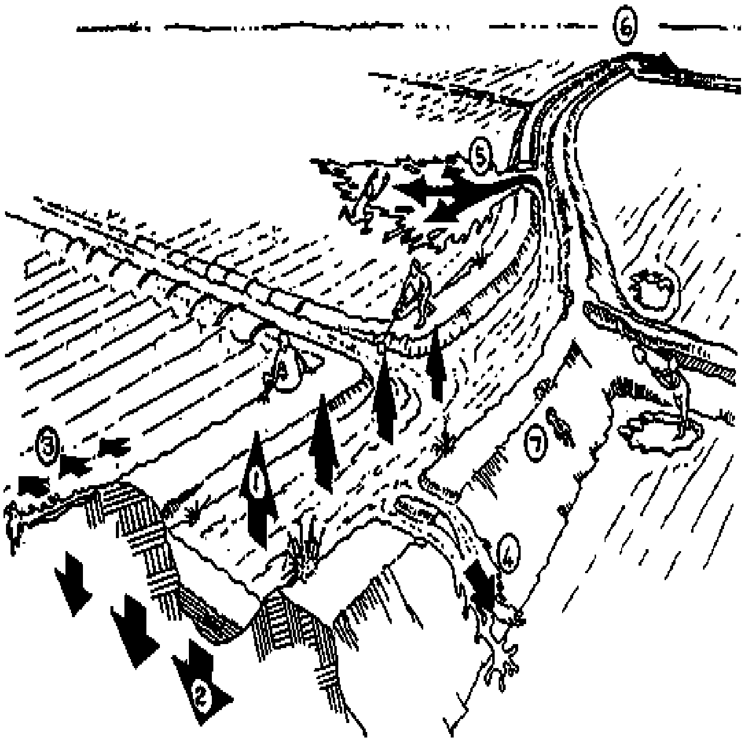
- Understand the relationship between norms and crops
- Understand the assumptions inherent in norms in relation to:
    - Crops
    - Soils
    - Climate / rainfall (including annual variability)
    - Irrigation practices (including water saving techniques)
    - Agricultural practices (and measures to maximise production per unit water)
    - Canal condition and management
- Discuss crop water requirements and implications for irrigation plans and schedules with Agriculture department officials
- Understand the nature and location of irrigation losses and efficiencies/coefficients (Figure 1)
- Understand the use of theoretical norms for practical irrigation management, for example taking account of actual rainfall
- Recommend norms for formal issuance at county, municipality or provincial levels.

The guideline is aimed at officials in the water sector at provincial, municipality and county levels; it draws on and complements existing standards and regulations related to irrigation design (as listed in section 4).

It is important that those involved in water management understand the basis of norms and the assumptions inherent in them. This understanding is essential to ensure that there is consistency of approach, and that the implications of adjusting norms to suit water savings practices are fully understood.

In many areas, norms are now being reduced in order to achieve water savings targets. It is important that both officials and farmers understand the implications and impacts of this. Officials need to be able to justify the decisions to farmers and WUAs. This document provides the technical justification and basis for explaining decisions around revision to norms.

Figure 1 Water loss from canal distribution systems



Water loss through:

1. Evaporation from canal water (and from subsequent empty canal wetted profile)
2. Seepage in canal perimeter
3. Lateral seepage to fields
4. Canal spillage to fields
5. Occasional canal breaks
6. Operational tail escape flow
7. Losses through rat holes, etc

2 Types and Use of Norms

2.1 Introduction

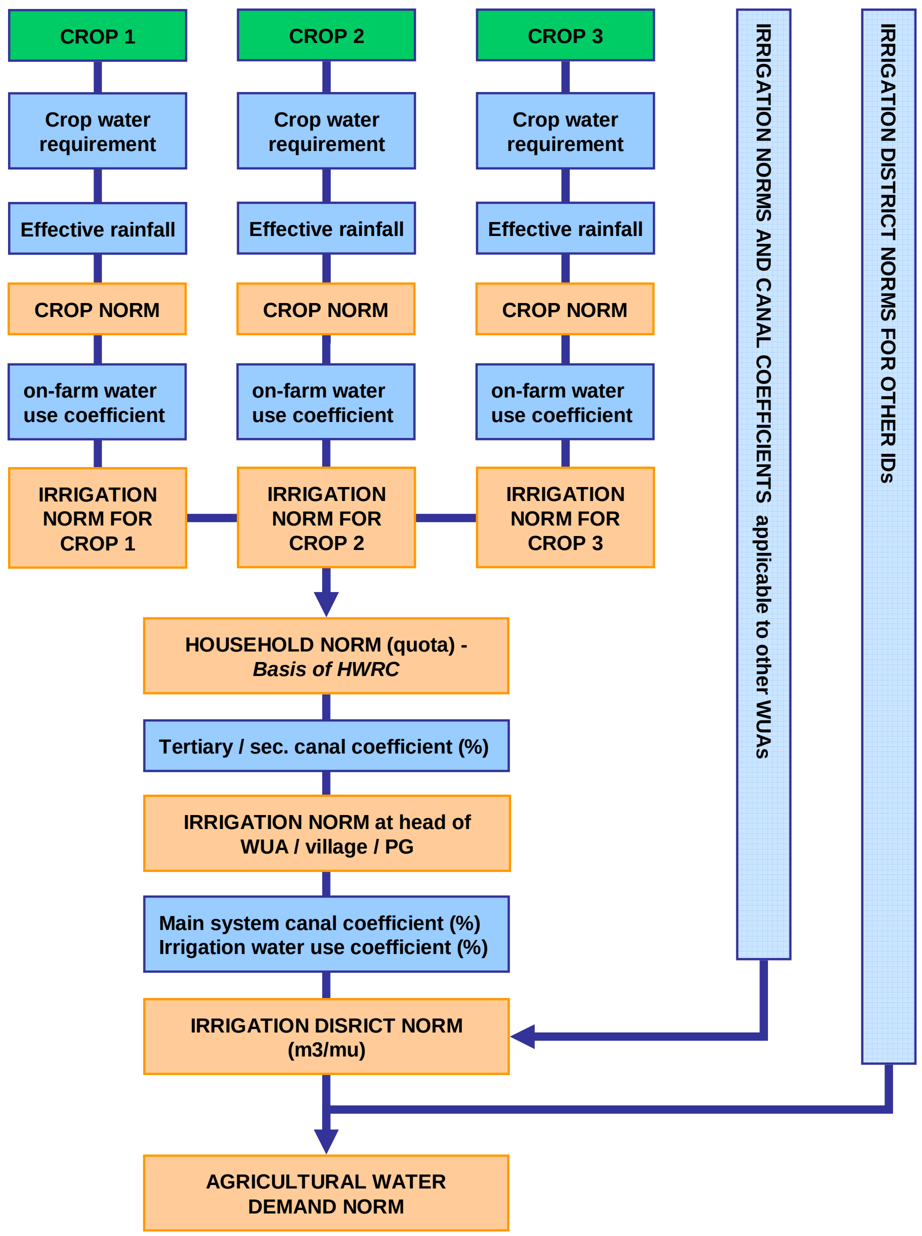
The concept of a norm for irrigation water requirements is widely applied in China, and it forms an important basis for water resources management. However, the term needs to be used carefully, to distinguish between different types of norm and different applications of norms. For example, norms are used both for overall planning, and for the details of irrigation operation. Norms can be calculated at the point of delivery to the crop or field, or they can allow for losses at different points in the system. These norms are quite different from each other, and use of the wrong norm will give very misleading results. It is important to use consistent terminology and methods, to ensure that they are calculated consistently and communicated clearly.

2.2 Use of norms

Introduction

Water demand norms represent the amount of water which needs to be delivered to meet crop water requirements whilst making allowance for irrigation practices (including water savings measures). In areas where water is insufficient, these demand norms may be reduced, preferably on the basis of a scientific assessment of how this will affect yield and production. Norms can be defined at different points in the system (eg. in the field or at head of tertiary canal, or head of the main canal), by making allowance for losses. These norms are used for designing irrigation schemes, and for operational purposes (calculating abstraction permit volumes, allocating water and so on).

Figure 2 Distinguishing between different types of norms



Water use data should be used for regional planning, and for auditing water savings societies. It should also be used for evaluating the accuracy of the assumptions used in the norms,

Norms are often expressed as either net or gross. This is potentially ambiguous, and it is recommended that norms are described explicitly. For example, crop norms refers to the norm for water to be applied to the crop; the irrigation norm for the tertiary canal relates to the amount of water that needs to be supplied to the tertiary canal to satisfy the crop norms for all crops and the losses in the canal system and fields; and the irrigation district norm allows for all requirements and losses in the irrigation system.

Use of norms for farm level management

Knowledge of norms for individual crops is useful for farmers and WUAs so that they can plan their cropping and manage irrigation. This enables them to decide how best to use their individual water entitlement – which crops to grow, what irrigation techniques to use, etc. It also helps the WUA manage water and organise water distribution within the WUA.

Use of norms for abstraction permits and annual water allocation

Abstraction permits and water allotments are planned on the basis of water demand norms for the main crops, in conjunction with knowledge of the total resource available. If the irrigation district norm calculated as described in this document exceeds the overall water resource availability or allotment for that ID, then either or both of two actions need to be taken:

- The individual crop norms need to be cut back gradually to suit savings which can be made on a rational basis (such as by deficit irrigation or improvements to field techniques), or
- The recommended crop pattern or areas need to be revised so that the aggregate irrigation district norm does not exceed the supply.

Simple reductions in crop norms to meet arbitrary targets, without reference to crops or cultivation techniques are not recommended. Such methods may meet short term water use targets, but they are unlikely to be equitable and they are unlikely to maximise the productivity of water.

2.3 Variability of norms

Norms represent the requirement for water by the crops under certain climatic conditions, but rainfall or other conditions will differ and this will influence the amount of water needed from irrigation. Norms are based on rainfall with a specified probability (typically average or 75%-80%), but the actual irrigation requirement will depend on the effective rainfall in the particular year. This cannot be known in advance and thus norms are used for planning purposes but operational management may require that deliveries are different from norms (but still subject to limits imposed by abstraction permits, allocation plans, or drought orders).

In wet years, farmers should use less than the norms and thus allow aquifer recovery. In some cases, they may be able to use more groundwater than the norms in dry years but this will depend on the local drought management procedures. It is unlikely that additional surface water will be available in dry years to offset a shortage in rivers; indeed it is more likely that the surface irrigation system will be unable to deliver even as much as the norm. This situation should also be covered by local drought management procedures.

Optimisation of irrigation to suit actual soil moisture conditions can have a large impact on reducing water use.

3 Definitions of Concepts

Definitions of key concepts are given here, with more details in later sections.

Crop water requirement (ET_c)

The crop water requirement is the evaporation from well-fertilized crops, grown in large uniform fields, under optimum soil water conditions, and achieving full production. It includes transpiration, evaporation from the soil between plants, and the water contained in plants. Given that the water contained in plants is relatively small, it is often ignored and the sum of transpiration and ground evaporation is used to represent crop requirement. Transpiration is essential for crop growth, but ground evaporation is unproductive. Various measures, such as mulches and plastic sheet, can be used to minimise evaporative losses. These may also affect root zone conditions and temperature and thus influence transpiration. The calculation of ET_c should take account of these factors.

Effective rainfall (P_e)

Effective rainfall is that part of rainfall which is used by the crop for maintaining its growth. For crops other than rice, effective rainfall is the portion of rainfall that contributes to evapo-transpiration. It does not include surface runoff or percolation below the root zone. For rice grown in flooded fields, effective rainfall is the portion of rainfall which contributes to maintaining water depth in fields to the optimum depth for the crop stage, crop evapo-transpiration, improving soil environment. It does not include rainfall which results in surface runoff or ineffective deep percolation.

Groundwater utilisation (G_e)

Groundwater utilization refers to the groundwater which rises to the crop root zone through soil capillarity and is used directly by the crop. This depends on soil type, root depth and depth of groundwater etc, and it varies during the season. In general, groundwater utilisation gradually reduces with depth - the shallower the groundwater depth, the more groundwater can be used. This can be derived by calculation or experimentation.

Crop norm (N_c)

The crop norm is the crop water requirement (the sum of transpiration and ground evaporation between plants) minus effective rainfall and groundwater utilisation. It is usually presented as seasonal total water amount per unit area or depth of water. This is not directly related to irrigation process and delivery process.

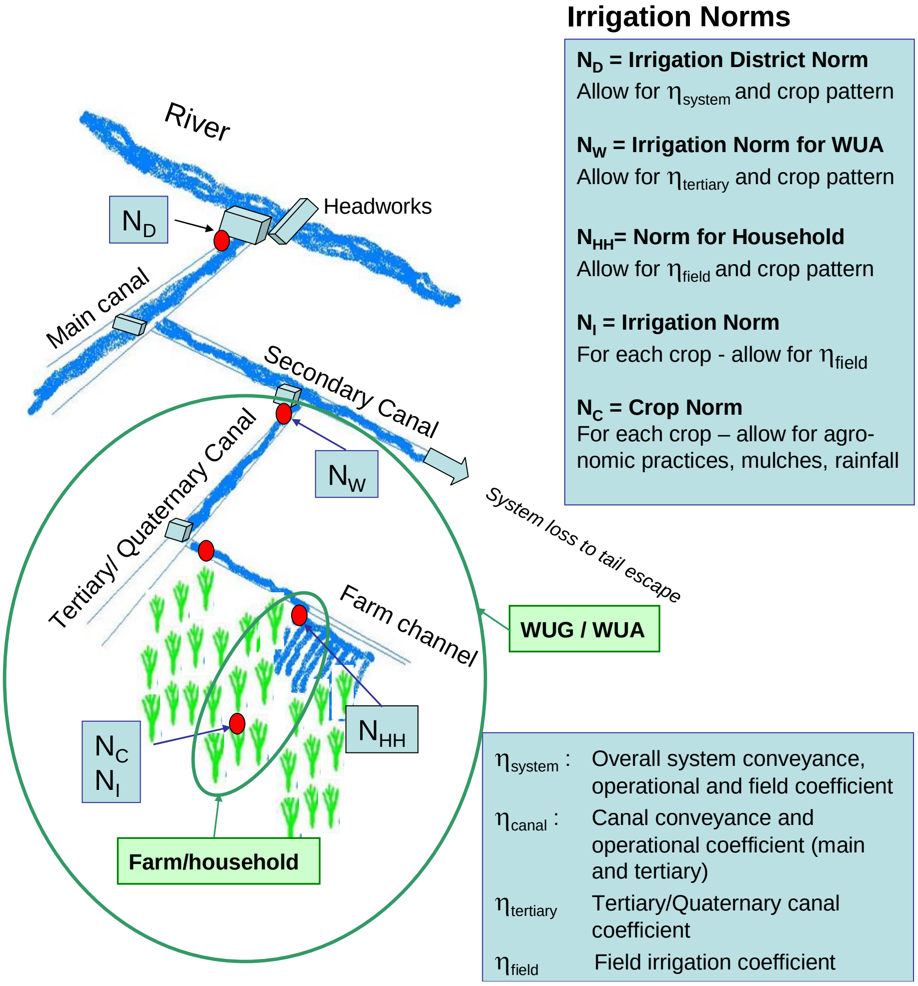
Field irrigation coefficient (η_{field})

Field irrigation coefficient refers to the water use coefficient in the fields and quaternary canals (including temporary farm channel diverting water to the fields). It equals the ratio between crop norm and total water supply from the fixed lateral/tertiary canals.

Household irrigation norm (N_{HH})

Each household needs to know how much water it is entitled to and the point at which this will be delivered. This is based on the cropping pattern and the irrigation norm for each crop, weighted according to the area of each crop. For simplicity of management by the WUA, the household norm includes the same components as the WUA norm, thus it includes conveyance losses within the WUA

Figure 3 Various irrigation norms



Irrigation norm (N_I)

Irrigation norms are based on the crop norms but also allow for field irrigation losses (which are usually calculated by using a coefficient for on-farm water use appropriate to the field conditions and to irrigation and agronomic practices for each crop. These may be presented as a seasonal total, or as the number of irrigations and the depth or volume for each irrigation.

Field irrigation coefficient (η_{field})

This coefficient makes allowance for losses at field level, according to the method of irrigation. It allows for losses by lateral and vertical seepage, water used by unwanted vegetation at the edges of field, etc. It can be expressed as the ratio between the amount of water actually consumed by the crop, and the amount supplied to the field.

Water use coefficient of canal system (η_{canal})

This relates to the conveyance efficiency of the canal system, and takes account of the losses by seepage and evaporation from the canals themselves. This coefficient also takes account of operational losses - for example those which result in excess flows through tail escapes. It equals the ratio between the aggregate of the amounts delivered to fields and the total volume supplied at the headworks.

This coefficient can also be derived for different canal levels. A tertiary canal coefficient ($\eta_{tertiary}$) is useful for calculating norms for WUAs. This equals the ratio between the amount supplied to WUAs and that delivered to farmers' fields.

Irrigation water use coefficient (η_{system})

This coefficient equals the ratio between water used by the crops and the total volume supplied for irrigation (at headworks). It depends on three factors: water diverted from the source to the field; irrigation methods and techniques; and water utilization by the crops.

Similar coefficients can also be calculated for part of the system, for example for WUAs (η_{WUA})

Irrigation norm for WUA (N_W)

Irrigation water requirements at the point of delivery to the WUA based on irrigation norms, considering the transportation and distribution losses within the WUA and farm irrigation losses.

Irrigation district norm (N_D)

This is an overall norm used for design and management of the irrigation system. It takes account of the types of crops, difference between areas, climatic factors, topography, soil type, etc. It is calculated from crop structure (ie area of each crop), water requirements for each crop (crop norms) and water use coefficients.

Agricultural water demand norm (N_A)

This is based on ID norm for all IDs in the region. The main purpose is to provide a basis for estimating agricultural water demand for overall water resource planning.

The norms should be calculated both for the current standard of irrigation and for enhanced levels of management to allow for future projections of water saving.

4 Basis for Development of Norms

4.1 National regulations, standards and guidelines

- Water Law of the People's Republic of China (2002)
- Technical details of the integrated planning of water resources (Ministry of Water Resources)
- National Water-saving program (2000-2010)
- Notice on enhancing water use norm development and management by MWR (No.519) document of Water Resources Division in 1999
- Reference methods for water use norms development: Water Resources Division of MWR;
- Technical specifications of water saving irrigation: SL207-98
- Technical specifications of micro-irrigation works: SL103-95
- Standards for water quality of agricultural irrigation: GB5084-92
- Specifications for irrigation experiments: SL13-90
- Design specifications for irrigation and drainage works: GB50288-1999

4.2 International guidelines and standards

The standard international reference for calculating crop water requirements is FAO Paper 56. This provides a rigorous description of the methods for assessing the requirements for most commonly grown crops.

FAO, the Food and Agricultural Organization of the United Nations, publishes a range of other valuable documents on related topics. Internationally, these are standard reference documents, and they can be downloaded from http://www.fao.org/nr/water/jsp/public-cations /search.htm.

Key papers are:

- **46** - CROPWAT - a computer program for irrigation planning and management, 1992
- **49** - CLIMWAT for CROPWAT, 1993
- **33** - Yield response to water, 1979 (*available in Chinese*)

4.3 Principles and main factors

Underlying principles

- Scientific

The calculation should be based on scientific methods and procedures to develop agricultural water use norms which are accurate and realistic.

- Water conservation is highlighted

The water use norm needs to be developed in a way which helps meet targets for water conservation. The calculation highlights where losses are occurring and where savings can be achieved. The norms should be developed and modified in parallel with methods for achieving the savings.

- Operational

The agricultural water norm is intended to be a practical tool to serve the needs of water resources planning and management. It should provide a true basis for water resources management.

- Suited to local conditions

Agricultural water norms should be developed according to the local natural and geographical conditions, the status of water resources, the socio-economic development level, the agricultural production conditions, and other relevant factors.

It is important to collect, analyze, collate and aggregate comprehensive data for the local area to calculate the norm. Alternatively, the existing norms for nearby regions with similar natural, social and economic conditions can be adapted through comprehensive analysis and adjustment.

- Gradual improvement

The formulation of norms is a major task and requires a range of complex calculations. The development of norms for new areas should focus first on the key issues and then gradually improve the process and calculation.

- Advanced and feasible

Norms should be developed to help improve on the existing situation. The norm should be based on improved techniques, in comparison with current average water use in this region. This is so that it can immediately contribute water conservation, and to strengthened management of water. This will help achieve the overall purpose of saving water.

- Dynamic adjustment

The norm is a dynamic indicator of water requirement. It will be varied with the development of science and technology, and with improvements in management. In order to ensure that it remains scientific, rational and advanced, it will need to be reviewed and adjusted periodically in a timely manner to suit precipitation, water resources, crop requirements, and management, etc.

Detailed factors to be considered

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

- Natural and geographical conditions

Agricultural irrigation is to meet the water requirement of crop growth. However, crop growth affected greatly by many factors, such as rainfall, evaporation, temperature, soil conditions, etc. These natural conditions are the main factors for calculation of norms.

- Irrigation methods

There are many different irrigation methods. These differ in the magnitude of the seepage losses. The losses depend on the condition and type of canals, the use of pipelines, the type of irrigation (such as flood, furrow, sprinkler or drip irrigation). It should be noted the norms will be different for each irrigation method, each type of canal, and system of operation - even if other conditions are the same.

- Source of water

The norms will also differ according to the source of water (surface water and groundwater). The crop norms will be the same regardless of the source, but the conveyance losses for well irrigation are lower than for canal irrigation, resulting in lower irrigation district norms for well irrigation.

- Scale of irrigation district

Irrigation district can be classified as large, medium and small-scale. Generally speaking, when other conditions are similar, the norms will be higher for larger irrigation districts. This is because of the greater losses in the more extensive canal network.

- Types of irrigation district

Generally, for the area that water conditions are good and water sources lie in high land, gravity irrigation will be used. For the area that gravity diversion is not possible because the irrigable land is higher than the water source, pumping will be necessary. Due to the high cost of lifting irrigation, farmers can be expected to use water more efficiently, and thus the norms for lift irrigation are often smaller than gravity irrigation.

- Water-saving techniques

The norms are relatively small if water saving techniques are used to a high standard in the ID. Water-saving techniques that affect the norms include the extent of canal lining, area of furrow (rather than flood) irrigation, and promotion of non-structural measures for water savings.

- Full / deficit irrigation

According to the availability of water resources, irrigation can be planned for either full irrigation or deficit irrigation according to whether irrigation can meet the full water requirement in the whole crop growth period or not. Full irrigation is generally applicable in the southern region of China where water resources are abundant and in some parts of northern China where sufficient diversion of water is possible. In arid northern areas, water resources are lacking and thus deficit irrigation may be used.

Norms should be calculated separately for the two situations. In the case of deficit irrigation, the crop evapo-transpiration must be calculated very carefully. It will be less than the maximum since the crop will be stressed at some growth stages, and norms will be calculated for each stage (FAO Paper 33 is a useful reference for this calculation).

- Crop growth stage

Water requirement is not the same at all stages in the plant growth period. Norms need to take account of the growth stage. If there is enough information and data, it is better to develop norms for each stage.

- Cropping pattern

Different crops have different requirements. In addition, single species cropping and inter-cropping of two different crops at the same time are both common. For example, wheat and maize intercropping, soybean and maize intercropping are common in many northern parts of the country. Water consumption and water use norm are different when a species is grown on its own, and when it is inter-cropped.

- Other factors

There are also some other factors which impact on norms, such as management practices, irrigation practices, agronomic measures all impact on more or less, These factors all need to be.

4.4 Probability analysis of norms

Norms can be calculated for each year, on the basis of conditions in the current year, or they can be calculated on the basis of the probability of the various basic factors.

1. Current year: norms based on the rainfall and crop pattern the previous year is used to represent the current year;

2. Probability: this is based on the rainfall probability of 50% in north China, and 75%-80% in southern China.

The latter method is recommended.

4.5 Zoning

Norms are not usually calculated individually for each irrigation district, but they should be developed separately for different climatic zones since agricultural water use norms are influenced greatly by natural and geographical conditions and type of irrigation as well as other factors. There can be large differences between different regions in terms of natural and geographical conditions. It is important to collect rainfall, evaporation, average temperature data and groundwater level contour map and then zone the area is according to the local geographic and climatic conditions and status of water resources. Generally, the principles to be complied with are as follows:

1. There needs to be a combination of agricultural zoning and water resources zoning, with administrative regions at county level taken as basic units, together with the layout of the canal system to refine the areas

and locations for which norms will apply;

2. Natural conditions (topography, climate, water resources, soil, etc) , social-economic and technical conditions should be relatively consistent throughout the zone;

3. Cropping pattern and crop types and distribution should be similar in the same zone;

4. Cropping system, irrigation works, counterpart agronomic measures, irrigation practice, production management level, irrigated water use coefficient should be consistent in the same zone;

5. Agricultural water saving trends and main measures should be consistent in the same zone.

4.6 Selection of typical ID

There may be several IDs in the zone for which norms are to be calculated. One or more IDs should be selected as the basis for calculating the norms. The main considerations for selecting the typical IDs are the scale of ID, the planting structure, water conservation and management level and other factors. Representative samples of different sizes of irrigation (large, medium and small IDs and well ID) should be selected to develop irrigation norms.

The selected IDs need to be representative of the average condition of infrastructure and management. Observational data, irrigation experimental data, and irrigation water management data should all be available as well as corresponding technical staff.

4.7 Identification of main crops

A comprehensive analysis is needed to identify the main crops in the specified zone, based on the information collected when deciding on the zone boundaries. The selection of appropriate crops in the zone is based on the crop planting structure to calculate and develop crop norms for each zone. Generally, the total area of major crops accounts for 70% ~ 90% of total irrigated area (if there are many types of crops, it is recommended to adopt the lower limit, otherwise adopt the higher limit). The remaining crops are listed as “other crops”, and it is assumed that their requirements are similar to the average of the major crops selected. This enables the calculation of norms to be both feasible and operational.

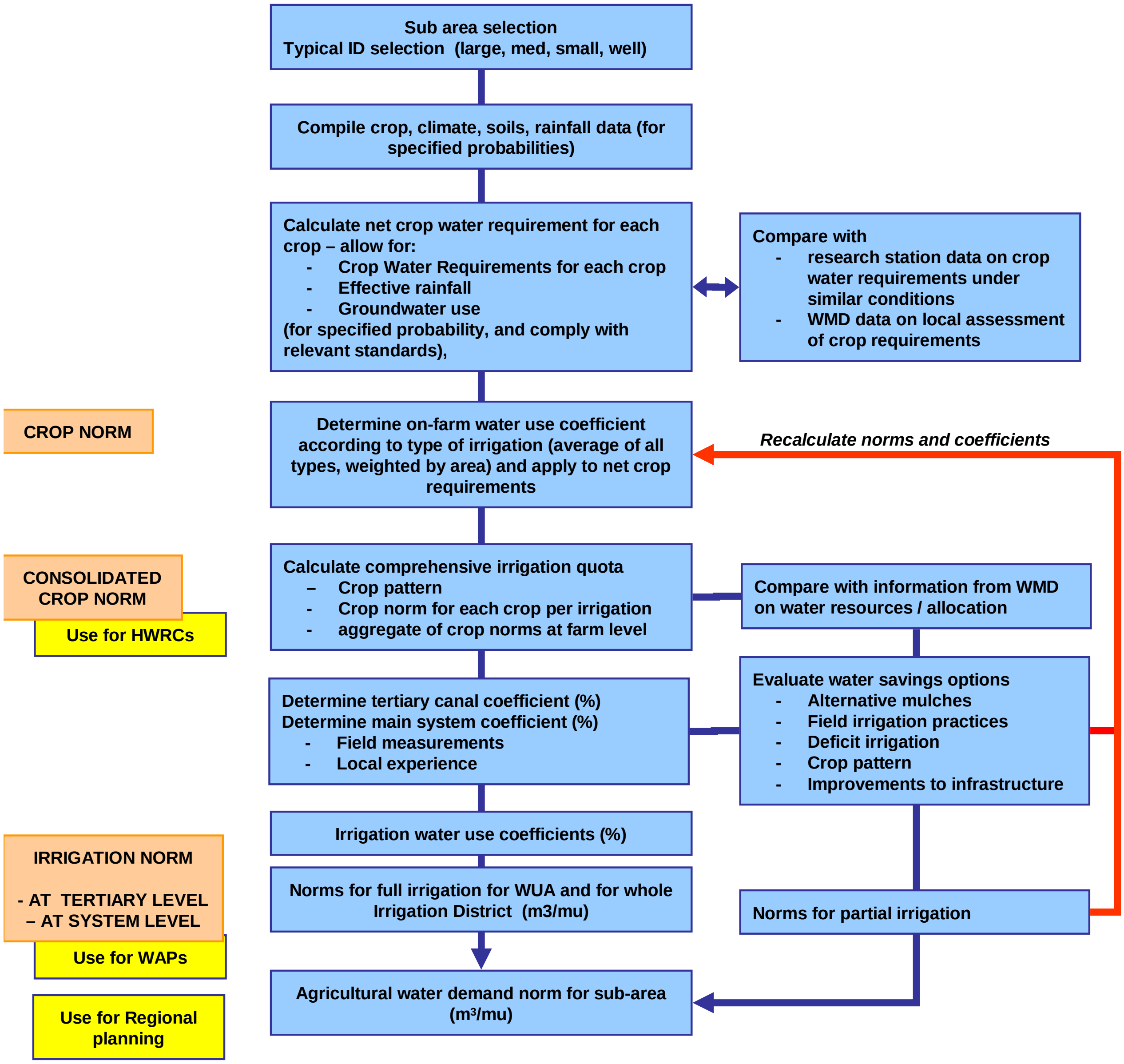
4.8 Method for calculation of irrigation norms

The sections above outline the general basis for calculation of norms. The following sections describe:

- Calculation of crop norm based on crop water requirements, effective rainfall and groundwater utilisation (Section 6)
- Determination of irrigation norms allowing for cropping pattern, water use coefficient / efficiency for different types and standards of irrigation (Section 7)
- Modification of norms to allow for the improvement of water management (including partial / deficit irrigation) (Section 8)

The process is illustrated in Figure 4 below.

Figure 4 Flow chart for calculation of water demand norms



5 Calculation of Crop Norm

5.1 Introduction

It is often possible to use a formula (such as the Penman equation) to calculate the crop norm, i.e. normal water requirement for the whole growth period of crops under conditions of full irrigation to achieve high yields.

Such methods for calculating crop water requirements are well established and procedures are documented in numerous texts. Internationally the standard reference is FAO56. These documents should be referred to for full details of the methods.

5.2 Calculation method for crops other than flooded rice

For all types of dry crops, the irrigation norms are determined through water balance. The balance equation is as follows:

$$M = ET_c - P_e - G_e + \Delta W$$

Where:

M = net crop water requirement during the whole growth period in specific ID (mm)

ET_c = crop evapotranspiration for specific crop in this ID, using Penman-Monteith Formula and the crop coefficient recommended by FAO (mm)

P_e= Effective rainfall (mm)

G_e=Groundwater utilization (mm)

ΔW=Variation in soil water storage (mm)

$$ET_{ci} = ET_{0i} \bullet K_{ci}$$

Where:

ET_{ci} - Actual crop evapotranspiration for each growth stage

k_{ci} - Crop coefficient for growth stage

ET_{0i} - Reference crop evaporation for a given growth stage

Detailed procedures for calculating the components of this equation are available in standard texts and are not repeated here

Effective rainfall (P_e) is the amount of rain which can be actually used

For crops other than flooded rice, effective rainfall is often estimated to be a fraction of the total rainfall - typically:

P_e = 0.8 P if P > 75 mm/month
P_e = 0.6 P if P < 75 mm/month

Where:

P = rainfall (mm/month)

In some case an additional part of the total rain is currently lost through surface run-off and deep percolation, but can be conserved suitable soil management measures.

In general, groundwater utilisation (G_e) and variation in soil water storage (ΔW) are not taken into account when preparing norms, but monitoring actual soil moisture conditions is an important operational task and can result in significant additional water savings (in addition to those allowed for in the standard calculation of norms).

With shallow water table conditions, there can be a significant moisture recharge by capillary action to the root zone and thus reduce irrigation requirements. However, this may reduce the fraction of total rainfall which is effective rainfall. There have been few studies on the relationship between depth of groundwater and effective rainfall, and thus these issues need to be assessed through operational practice and monitoring field conditions rather than in calculation of norms.

An example of the results of the calculation of crop water requirement for maize is shown in Table 1.

Table 1 Crop coefficients of maize and accumulated ET_0 and ET_c in Northwest China

	Monthly accumulated ET_0 (mm)	Monthly averaged crop coefficient	Growth duration in each month(d)	Monthly accumulated ET_c (mm)
May	166	0.203	24	26
June	170	0.583	30	99
July	157	1.573	31	247
August	128	1.61	31	206
September	90	0.66	22	44
Total	711		138	622

5.3 Calculation method for rice

Water requirements for rice are conceptually different from other crops since rice is normally grown in flooded basins throughout the whole growth period (assuming it is grown under the conditions of full irrigation). The calculating equation is as follows:

$$M = ET_C + F_d + M_0 - P_e$$

Where:

M=Net crop irrigation requirement (mm)

ET_c = crop evapo-transpiration for specific crop in this ID, using Penman-Monteith Formula and the crop coefficient recommended by FAO (mm)

F_d= paddy percolation, from local experiment and investigation, (mm) (e.g. The experiments undertaken in Jiangsu, Zhejiang, Guangdong, and southwest China indicates that the 2 ~ 3mm / day is appropriate).

M_0 =flooded field norm (mm)

P_e = Effective rainfall

5.4 Observation and measurement in irrigated fields

Irrigation experimental stations have been established in a number of IDs so that actual irrigation requirements under local conditions can be observed and measured.

The fields selected for the experiment should represent typical fields in this ID. It is possible to estimate the irrigation norm from these fields to represent the whole ID, so that the observation data is representative and the pilot outcomes can be expanded from one point to the whole area

Irrigation norms can also be measured from soil moisture. This method gives the actual amount of water used, and thus it is important that it should be derived from observations of fields which are irrigated in accordance with recommended practices

5.5 Interview with farmers

An alternative approach (in the absence of information and conditions for calculation or for experimentation in research stations) is to derive irrigation norms by observation of actual practice and by interview with farmers. This can be carried out by experienced professionals according to these steps:

1. Prepare survey form including date, location, irrigation methods, irrigation frequency and water volume
2. Select typical villages and groups in terms of irrigation water consumption, based on experience and discussion with experienced farmers
3. Ask detailed questions about irrigation frequency and water volume for specific crops for the whole growth period per unit area
4. Collect data on rainfall in the same period to calculate the normal irrigation requirement after correcting the data to allow for actual and design effective rainfall
5. Collate the data from the same ID and check the integrity and quality of the data. It may be necessary to eliminate extreme data if it is not possible to verify with farmers that it conforms to the actual situation. Averages of the reasonable data can then be used as the basis for calculating irrigation norms for this ID.

This method will provide information on actual practice, and thus it is necessary to observe actual methods so that the extent to which water savings techniques are adopted is known. Observation in different fields and with different farmers may indicate a range of .different values for actual water use. These differences should be correlated with irrigation methods.

Figure 5 Example of a typical irrigation questionnaire

Investigation date						
Survey sites						
Irrigation system type	natural flow		pumped		Well irrigation	
Irrigation methods	flood		furrow		drip	
Crop						
Sowing date			Harvest date			
Precipitation in growth period						mm
Irrigation frequency						Times
Irrigation number	1	2	3	4	5	
Irrigation flow rate (average)						l/sec
Irrigation duration						
Water volume per irrigation						m^3/*mu*
Total water volume						m^3/*mu*
Yield						kg/*mu*

6 Calculation of Irrigation Norms

6.1 Introduction

Individual crop norms are important as a basis for planning, for calculating water rights, and for assessing abstraction permit applications. However, they apply to individual crop requirements. Farmers grow a mix of crops and the requirements for different crops (both the volume and timing of water deliveries) need to be aggregated to calculate the delivery schedule. Furthermore, water needs to be delivered through a network of canals from the source to the field, and they have to apply water to the root zone of the crops. Losses are incurred in this process – in canals and in fields – and thus extra water needs to be provided from the source to ensure that the planned amount is delivered to the crop.

Finally there are risks and uncertainties in this process which makes the calculation difficult and uncertain. Rainfall can be estimated in advance (either average, or some other return period) but the actual rainfall will differ in practice. Farmers' field application practices and WUA or WMS management may not be entirely uniform (either in operation or maintenance). For the purpose of calculating norms various assumptions need to be made, but the basis for these assumptions needs to be explicitly understood.

The following norms need to be calculated:

- Consolidated norms at farm level (which also provides the basis for HWRCs if required) – see Sections 6.2 and 6.6.
- Irrigation norms at farm level (allowing for field application losses) – see Sections 6.3 and 6.6
- Irrigation norms at canal head (allowing for seepage losses in canals, and for management losses in these canals – these norms can be calculated at tertiary, secondary, primary canal level) – see Sections 6.4 and 6.6

6.2 Aggregated norms for multiple crop irrigation

Based on the methods for developing irrigation norms for different crops as described above and the cropping structure the total norms can be aggregated from the irrigation norms for this zone:

$$AQ_n = \sum_{i=1}^{n} AQ_i \times A_i$$

Where:

AQ_n- aggregated irrigation norm for all crops (mm)

AQ_i - crop irrigation norm for crop number i (mm)

A_i - proportion of crop number i planted

If there are three crops (for example, wheat, maize, peanuts) cropped in a specific irrigation district, with a ratio of cropped areas as 5:4:1, that is,

$$A_1 = 0.5,\ A_2 = 0.4,\ A_3 = 0.1$$

The irrigation norms for these three crops are:

$$AQ_1 = 150,\ AQ_2 = 100,\ AQ_3 = 100$$

Then the integrated irrigation norm in this ID will be:

$$AQ_3 = \sum_{i=1}^{3} AQ_i \times A_i$$

$= 0.5*150+0.4*100+0.1*100 = 125m^3/mu.$

This calculation assumes that the three crops require water simultaneously. In fact there will be times when wheat requires water and maize does not, so this scheduling also needs to be allowed for in the calculation.

6.3 Field water use coefficient

The field water use coefficient can be determined through the following methods:

- Calculation
- Experiment (test method)
- Evaluation from experience

Normally the coefficient can be estimated from past experience based on irrigation type. Typical values from Chinese experience are:

- Good quality surface irrigation for dry crops – 0.90
- Good quality surface irrigation for rice – 0.95
- Where irrigation is not so well-managed – because of poor land levelling, large field sizes, long furrow lengths, the coefficient may be 0.7 to 0.8 or even lower

Experimental data is often available from national, provincial and local agricultural research stations and can be referred to.

Since different irrigation methods may be used for different crops, the coefficient may vary between crops and thus may need to be applied to each crop separately (eg. wheat in flooded basins, maize with plastic mulch, and potatoes on ridges).

6.4 Canal water use coefficient

The canal water use coefficient (η_{canal}) refers to the losses between the headworks and the fixed lateral canal. It is an aggregate indictor that reflects the condition of all irrigation infrastructure and management standard. The canal water use coefficient depends on the scale of ID, soil in canal bed, canal length, water conservation and management standard (including frequency and duration of canal filling) and so on.

Canal water use coefficient can be determined through experiment or estimated from experience. For example, the water loss can be measuring the flow at each end a canal reach of standard size and known length, or by closing a section of canal when it is full of water and measuring the rate at which the water level declines. Instruments are also available which can make direct measurements of seepage loss.

Losses are generally expressed as a percentage of the water entering a canal. This is a simple approach and normally adequate, but it should be noted that it does not take account of canal length whereas in fact total losses are greater for long canals than they are for short canals. An alternative approach is to express losses as a seepage rate per unit wetted area (m^3/sec per 10^6 m^3).

It should be noted that seepage is not usually uniform, and there will be some places where losses are high and some where losses are low. Sufficient measurements must be taken to ensure that a reasonable average seepage loss is calculated.

6.5 Irrigation water use coefficient

The irrigation water-use coefficient for the whole system equals the field water-use coefficient multiplied by canal water use coefficient:

$$\eta_{system} = \eta_{canal} * \eta_{field}$$

Where:

η_{system} = irrigation water use coefficient

In addition to this overall system water use coefficient, it is also useful to calculate a coefficient relating to the losses within the tertiary canal system (WUA)

$$\eta_{WUA} = \eta_{tertiary} * \eta_{field}$$

Where:

η_{WUA} = irrigation water use coefficient within the WUA

$\eta_{tertiary}$ = tertiary canal water use coefficient

6.6 Calculation of norms

The irrigation norm can be estimated from crop norms by applying the water use coefficient.

The crop norm for each individual crop combined with the irrigation water use coefficient mentioned above results in the, field irrigation norm as follows:

$$AQ_{gi} = AQ_i / \eta$$

Where:

AQ_{gi}- irrigation norm for crop i (m^3/*mu*)

AQ_i- crop norm for crop i (m^3/*mu*)

η - Irrigation water use coefficient (at system, WUA or farm level, depending on which norm is required as described below).

These norms are required at three locations / levels:

- ID level (N_H), indicating the water requirement at the headworks. This is needed for water allocation purposes and for planning and monitoring water distribution. This should be sufficient to meet the requirements at WUA level and in turn ensure that deliveries to each crop in the field are the same as the crop norms, after allowing for distribution and conveyance losses.
- WUA level (N_W), indicating the water requirement at the point of delivery to the WUA. This is needed as a basis for the agreement between the WUA and Water Management Division. This norm should be sufficient to ensure that water is delivered to the field in accordance with the crop requirements, after allowing for distribution and conveyance losses.
- Household level (N_{HH}), indicating the basis for the household water entitlement (and entered household water rights certificates, if used). For simplicity, this norm usually

includes the distribution losses within the WUA.

7 Verification of Norms

Norms are standards to be applied for irrigation planning or management at various levels. As noted earlier, there are many assumptions in the calculation of the value of the norms. Some aspects can be calculated very precisely (eg crop evapo-transpiration on the basis of climatic data); other components are much more approximate (eg seepage losses from fields). Any errors in these assumptions will be cumulative up the system, but they can be calculated and hence reduced by monitoring actual performance during operation of the system.

If there is a discrepancy between actual flows and the theoretical flow based on norms at any point in the system, this may be because the assumptions are incorrect or because irrigation is not being managed in the way intended. Furthermore, there will be local differences – losses are not uniform, nor are management standards.

Performance of irrigation systems should be monitored by WUAs and WMDs to ensure feedback between planning and performance. This monitoring can be used to identify where water savings can be achieved, to improve management standards, and to enhance the quality of norms.,

8 Modification of Norms for Water-Saving

8.1 Introduction

The methods described above are based on full irrigation needs. It is often necessary to reduce these norms progressively and introduce water saving methods. Thus the norms need to be adjusted as indicated in the following sections.

The procedures for developing agriculture water use norms imply that the norms need to be adjusted periodically to suit water saving, management level and adequacy of water supply.

8.2 Adjusting crop cultivation practises

One way for reducing the irrigation requirement is to use plastic mulching. Water consumption by crops includes transpiration and ground evaporation between crops. However, ground evaporation between crops makes little direct contribution to crop growth. Plastic mulching can reduce ground evaporation but still ensure sufficient water is available for transpiration. In general, transpiration accounts for about 70% during the growth period while ground evaporation accounts for 30%. Since plastic mulching is often just used in the early stage rather than the whole growth period, and it is not possible to cover all farmland, the norms need to be adjusted appropriately based on actual situation. It is recommended that norms are reduced by 5% to 15%.to allow for plastic mulch, according to the proportion of the total area where plastic sheet is used.

8.3 Adjusting cropping structure

As will be apparent from the calculation of norms, the water consumption of crops is variable, some are higher and others are lower. This means that the crop structure can be adjusted to save water in the areas where water resources are seriously short:, The area of high water consumption crops such as rice can be reduced and the cultivation of low water consumption crops can increased so that aggregate irrigation norms will be reduced to some extent. Similarly wheat can be replaced by cotton to reduce water use.

It is sometimes possible to grow higher water consumption crops if the total area of crops is reduced. For example, vegetables have a high water requirement but are valuable, so it is possible to increase income by growing vegetables rather than wheat and leaving some of the land fallow.

8.4 Adjusting field irrigation practices

As already mentioned, field water use coefficients of dry crops are not usually up to the water saving irrigation target of 0.9. It is more usual for the coefficient to be 0.8 or as low as 0.7 or even less. There are many tools that can be used to improve field water use coefficient, such as land levelling (especially laser levelling), changing from large border irrigation to small border irrigation, optimising furrow length, slope and irrigation durations, optimising management to take account of actual soil moisture conditions. If these water saving measures are planned on all or part of the area, the field water use coefficient could be increased appropriately. It is unlikely that these measures will be introduced simultaneously over the whole area, so it is important to consider the actual irrigated areas on which field water saving measures will be implemented.

8.5 Improvement of canal system

The main measures to improve canal water use coefficient include canal lining, canal repair, renovation and repair of structures, replacement of canals by pipelines, and strengthening management.

These measures will not only reduce the seepage losses in canals, but can also reduce canal breaches, spillage and seepage from structures, and thus increase performance of water distribution. The reduction of losses after lining or repair can be measured by dynamic method by current meter at each end of the canal reach, or by the static water method to calculate the loss for per kilometre of canal. This can be done before and after the repairs to calculate the increase in the canal water use coefficient then the increase of canal water use coefficient of the total canal length which is planned to be lined can be estimated. The formulation is as below:

$$\Delta\eta = \frac{\Delta W}{W_s}$$

Where:

ΔW- reduction of loss in lined canal compared with original canal (m^3)

W_s – seepage losses before any measures taken (m^3)

In addition management losses from the canal system can be reduced by monitoring and minimising flows through tail escapes.

The increase of canal water use coefficient also can be estimated from the changes of abstraction after taken water saving measures, assuming all other factors remain constant.

8.6 Revise norms to meet water savings targets

The approach outlined in this document is to calculate norms on a rational scientific basis, to suit the actual crops, irrigation methods etc. Where water savings measures are introduced, reduced water norms can be calculated to suit the new irrigation techniques.

In some situations this is difficult to apply. For example, it is difficult to calculate water demand norms for some practices (eg use of different mulches). In this situation, existing water use norms can be used for guidance, and the potential for further water saving can be estimated on the basis of local experience

In many places existing water use exceeds the norms, and it should be possible to reduce demand without adverse impact. However this must be done incrementally, over a period of say 2-3 years to avoid adverse impacts on farmers who are accustomed to irrigation with excess water.

If greater reductions in water use are required, more extreme measures will be needed. This may entail reductions in water supply below the crop water requirements, which would stress the crop and reduce yields. If any such major reductions are planned, the impact of the volume and timing of deliveries on crop yields should be evaluated, so that this can be compared with alternative measures such as irrigation land area reduction and compensation.

Where norms are reduced it is important that water managers and farmers are aware of the reasons for this (eg because a canal has been repaired or lined, or because they are expected to adopt new water-saving irrigation). If the farmers need to adopt new practices to comply with the norms, it is necessary to ensure that they are aware of this, and of how to achieve the saving anticipated. Training or demonstrations may be needed to help them cope.

9 Conclusions

9.1 Purpose of norms

Norms are required for several purposes:

- Regional water resource planning
- Demand assessments for allocation planning
- Routine local water management

Regional norms cover a large area - a river basin, municipality or county – with relatively uniform conditions, and are used for general planning purposes. The overall demand for water can be derived from these norms, compared with resource availability and hence used to assist with preparation of overall plans including water savings plans. The norms are based on a weighted average of all types of irrigation and cropping in the region, so they should not be used directly at a local level, but they may be developed from local-level norms.

The Irrigation District norms are derived from norms for individual crops, rainfall probabilities, and field irrigation techniques (flood, furrow, plot size / level, use of mulches, etc). They are aggregated into irrigation district by taking accounting of crop patterns and irrigation infrastructure condition (canal lining etc) and overall system management. These irrigation district norms provide a key input into demand assessment for allocation planning.

Individual crop norms are also aggregated into household norms taking account of representative crop patterns and field application losses. These are used for calculating individual entitlements to water, and provide the basis for household water rights certificates (where they are used). The household is not required to grow exactly the crops assumed when calculating the norm, but should be free to use the calculated volume of water to grow the crops of their choice. They should only be limited by the total volume of water allocated, and by their general obligation to adopt water savings techniques.

9.2 Key characteristics of norms

Crop norms relate to the water requirements for each individual crop, making allowance for rainfall. ***Irrigation norms*** are derived from the crop norms by making allowance for field irrigation practices (type of irrigation, use of mulches, and local water savings techniques) and for losses within field distribution system. ***These are the basis for calculating all other norms***

Consolidated norms are the average of the irrigation norms, weighted to allow for the cropping pattern at farm level – **these are used for determining household water entitlements.**

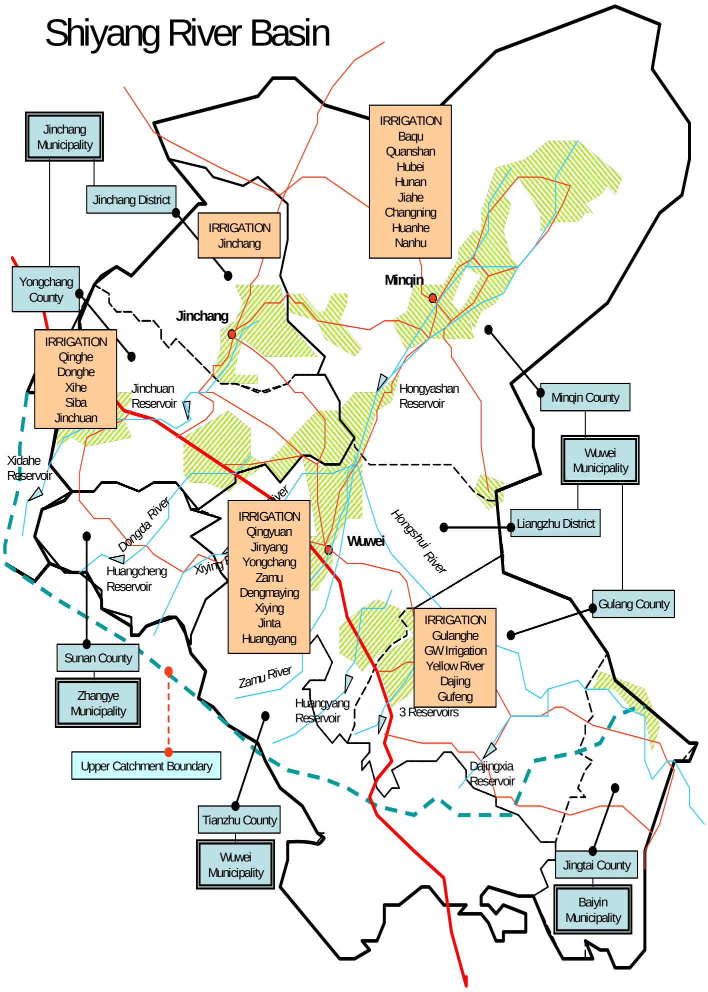
Norms at the head of the WUA (head of tertiary or secondary canal, or at the well) allow for the cropping pattern and conveyance losses in the canals between this point and the farm. **These are used for determining water supply contracts or agreements with WUAs.**

Irrigation district norms allow for conveyance and management losses between the source and the point of delivery to the WUA. **These are used as an input for demand forecasting and allocation planning**. If the ID norms exceed the resource allocation, then appropriate water savings techniques, and crop norms or crop patterns need to be recalculated

Agricultural water demand norms are the area-weighted average of ID norms. **These are used for regional planning.**

Figure 6 Agricultural norms for Shiyang River Basin, Gansu Province

Agricultural Water Demand Norm (N_A)



N_{D1} = Irrigation District Norm for Irrigation District A_1

N_{D2} = Irrigation District Norm for Irrigation District A_2

N_{D3} = Irrigation District Norm for Irrigation District A_3

Etc

$$N_P = (N_{D1}*A_1+N_{D2}*A_2+N_{D3}*A_3+\ldots.)\ /\ (A_1+A_2+A_3+\ldots.)$$

Document Reference Sheet

Glossary:

WUA	Water User Association
WMD	Water Monitoring Division

Bibliography:

FAO Paper 56. Food and Agriculture Organization of the United Nations.

Related materials from the MWR IWRM Document Series:

Thematic Paper 1.8	Water Demand Forecasting
Advisory Note 1.8/1	Water Demand Forecasting

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

China – UK, WRDMAP

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