Mapping Systems and Service for Multiple Uses
in
Fenhe Irrigation District

SHANXI PROVINCE - CHINA

MASSMUS APPLICATION

CURRENCY EQUIVALENTS

Currency Unit = RMB
US$1.0 = 6.8 RMB

MEASURES AND EQUIVALENTS

1 ha	=	15 mu
1 mu	=	0.067 ha
MCM	=	Million Cubic Meter

ABBREVIATIONS AND ACRONYMS

NRLW	Water Service of the Land and Water Development Division of FAO
CA	Command Area
CCA	Culturable Command Area
CR	Cross regulator
FAO	Food and Agriculture Organization
FID	Fenhe Irrigation District
FO	Farmer Organization
GCA	Gross Command Area
ICA	Irrigated Command Area
ITRC	Irrigation Training and Research Centre (California Polytechnic University)
IWHR	China Institute of Water Resources and Hydropower Research
LMA	Local Management Agency
LSM	Local System management
MASSCOTE	MApping Systems and Services for Canal Operation Techniques
M&E	Monitoring and Evaluation
MOM	Management Operation and Maintenance
NCA	Net Command Area (irrigable)
O&M	Operations and Maintenance
OFWM	On-Farm Water Management
RAP	Rapid Appraisal Procedure
WUA	Water Users Association

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Introduction and background

Mapping systems and Services for Multiple Uses (MASSMUS) is a module for assessing non-crop water uses in an irrigation scheme within the general approach developed by FAO for auditing the irrigation system management called MASSCOTE (Mapping Systems and Services for Canal Operation Techniques). The need to develop specific approach to multiple uses of water in an irrigation system stemmed from an analysis of 20 irrigation schemes (Renault, 2008), which revealed that non-crop water use and multiple functions of irrigation schemes were more of a norm than the exception.

The MASSMUS module is developed in the same way as MASSCOTE, with a stepwise progressive process starting with a rapid appraisal procedure (RAP), which is followed by further steps on capacity, water balance and cost. MASSMUS then moves towards the development of a vision and corresponding interventions to modernize the management regime and the operation techniques. A specific excel sheet for multiple uses (MUS) is included in the RAP Excel workbook with specific information on all the services provided by an irrigation system and the value generated by these services.

The MASSMUS application presented is the first application of the methodology in China as the result of MASSMUS training workshop in Shanxi Province for engineers and managers from 14^{th} to 23^{rd} June, 2010. The contributions of participants made during the working group sessions at this workshop have been largely included in this report under the supervision of the supporting FAO team composed of Daniel Renault (NRLW-HQ) and Louise Whiting (FAO RAP). The workshop was co-organised with CNCID under the leadership of Dr Gao Zhanyi and the support team of Dr. Gao Benhu, Mis Hu Yaqiong and Mis Yang Shujun from IWHR of Ministry of Water Resources.

MASSCOTE methodology and MASSMUS module

The generic methodology used in the study is called Mapping System and Services for Canal Operation Techniques (MASSCOTE). It has been developed by the Land and Water Division (NRLW) of FAO on the basis of its experience in modernizing irrigation management in Asia (FAO, 2007). MASSCOTE integrates/complements tools such as the rapid appraisal procedure (RAP) and benchmarking to enable a complete sequence of diagnosis of external and internal performance indicators and the design of practical solutions for improved management and operation of the system.

MASSCOTE is a methodology aiming at the evaluation of current processes and performance of irrigation systems management and the development of a project for modernization of canal operation.

Operation is a complex task involving key activities of irrigation management. The different aspects of irrigation management have to be combined in a consistent manner. These aspects are:

- service to users
- cost of producing the services
- performance monitoring and evaluation
- constraints and opportunities on water resources
- constraints and opportunities of the physical systems.

MASSCOTE aims to organize project development into a stepwise revolving frame including:

- mapping the system characteristics, the water context and all factors affecting management;
- delimiting manageable subunits;
- defining the strategy for service and operation for each unit; and
- aggregating and consolidating the canal operation strategy at the main system level.

MASSCOTE is an iterative process based on ten successive steps. More than one application of MASSCOTE is required in order to determine a consistent plan. Phase A focuses on baseline information, Phase B aims at characterizing the relative size of each water service, and Phase C then focuses on the vision of the scheme and the options for improving water service management.

A preliminary step (Step 0) is introduced for MASSMUS module to map multiple services provided to different users by the irrigation system (Table 1). These services could be intentional and/or official or un-intentional and/or unofficial. Steps 0 to 6 are conducted for the entire command area, and step 7 onwards deals with various scales of management units. The objective of step 7 is to identify homogeneous managerial units for which specific options for canal operation are further sought by repeating the various steps of MASSCOTE for each unit separately. Then, aggregation and consolidation of the outputs are carried out at the main system level through steps 10 and 11. Thus, the methodology uses a back-and-forth or up-and-down approach for the different nested levels of management.

Table 1. The stepwise process of MASSMUS

Mapping	Phase A – Baseline information
0. The water services	Initial mapping of the various services provided by the irrigation system to different users either intentionally or unintentionally.
1. The performance (RAP)	Initial rapid system diagnosis and performance assessment through the RAP. The primary objective of the RAP is to allow qualified personnel to determine systematically and quickly key indicators of the system in order to identify and prioritize modernization improvements. The second objective is to start mobilizing the energy of the actors (managers and users) for modernization. The third objective is to generate a baseline assessment, against which progress can be measured.
2. The capacity & sensitivity of the system	The assessment of the physical capacity of irrigation structures to perform their function of conveyance, control, measurement, etc. The assessment of the sensitivity of irrigation structures (offtakes and cross-regulators), identification of singular points. Mapping the sensitivity of the system.
3. The perturbations	Perturbations analysis: causes, magnitudes, frequency and options for coping.
Mapping...	Phase B – Sizing each water service
4. The share of water uses and benefits.	This step consists firstly of assessing the share of water for different uses through a comprehensive water accounting procedure and secondly determining the benefits associated to each water services (monetary, value, etc..)
5. The O&M cost to produce the services	Mapping the costs associated with current operational techniques and resulting services, disaggregating the different cost elements; cost analysis of options for various levels of services with current techniques and with improved techniques.
Mapping	Phase C – Vision of SOM and modernization of canal operation
6. The Users and the service to users	Mapping the user's representatives that should be involved in the stakeholder process. Mapping and economic analysis of the potential range of services to be provided to all users and uses of water.
7. The management units	The irrigation system and the service area should be divided into subunits (subsystems and/or unit areas for service) that are uniform and/or separate from one another with well-defined boundaries.
8. The demand for operation	Assessing the resources, opportunities and demand for improved canal operation. A spatial analysis of the entire service area, with preliminary identification of subsystem units (management, service, O&M, etc.).
9. The options for canal operation improvements / units	Identifying improvement options (service and economic feasibility) for each management unit for: (i) water management, (ii) water control, and (iii) canal operation.
10. The integration of SOM options	Integration of the preferred options at the system level, and functional cohesiveness check. Consolidation and design of an overall information management system for supporting operation.
11. A vision & a plan for modernization and M&E	Consolidating a vision for the Irrigation scheme. Finalizing a modernization strategy and progressive capacity development. Selecting/choosing/deciding/phasing the options for improvements. A plan for M&E of the project inputs and outcomes.

The MASSMUS module follows the similar steps as MASSCOTE (see Plate 1), with some adaptation to the specific function and constraints, inputs and outputs for MUS.

The rationale for MASSMUS is a stepwise methodology to map the performance and plan management modernization. In a nutshell, the "Services Provision" is analysed for capacity *vs* the demand, sensitivity or reaction to perturbations, water sharing, the cost, the services descriptions, the demand for operation and finally the management improvements.

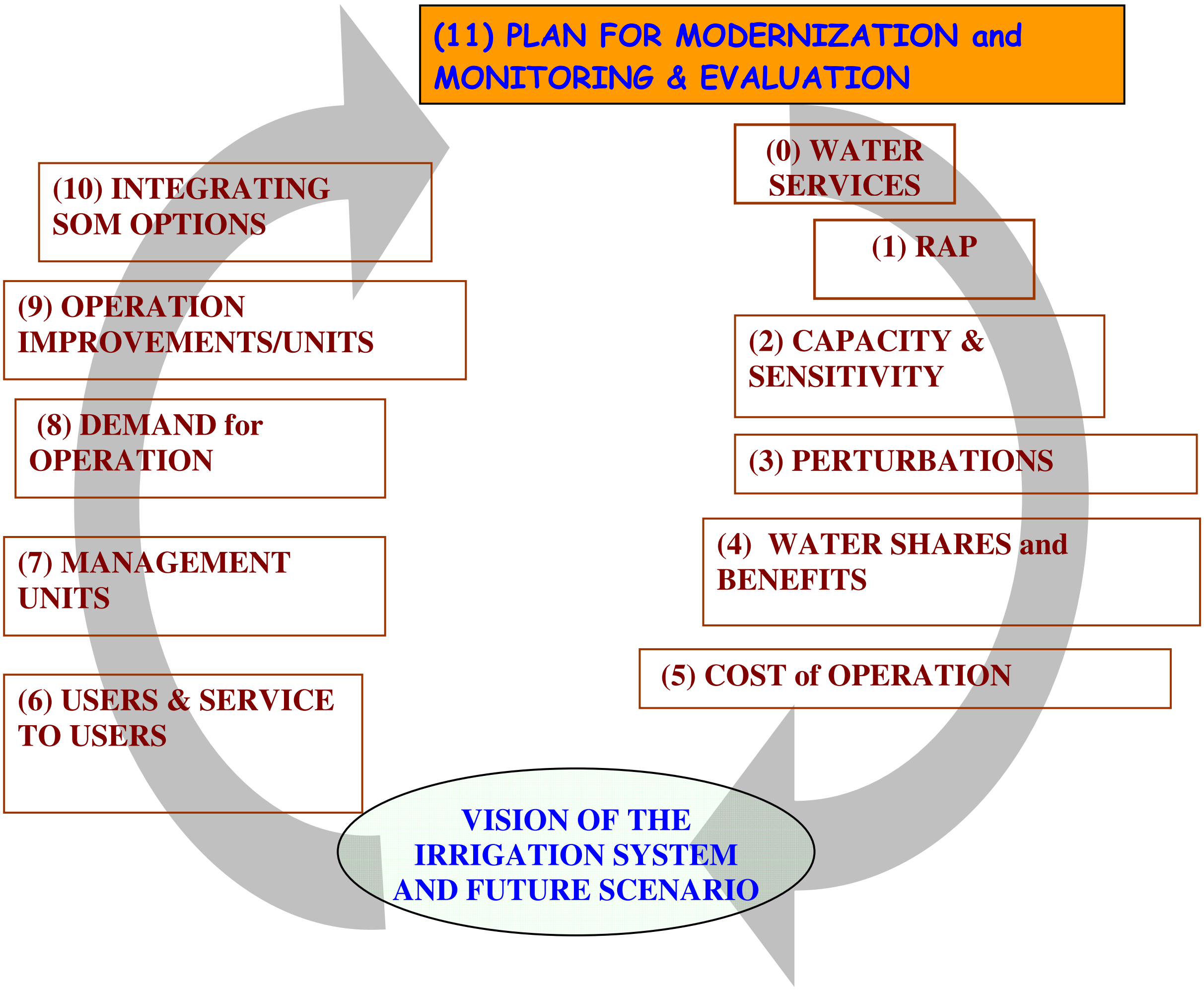

Plate 1. Stepwise MASSMUS process

Introduction to the Fenhe Irrigation District

The Fenhe Irrigation District (FID) is located in the Shanxi Province, which falls in the western quadrant of North China and the middle reaches of the Yellow River. The province has series problems related to drought, flood and increasing water pollution.

The system consists of two reservoirs, three diversion dams and five main canals. It has been built in 1950 and it is managed by the Shanxi Fenhe Irrigation Administrative Bureau (the Bureau), which is part of the Shanxi Water Resources Department. The total project area covers a gross command area (GCA) of 100,000 hectares. Due to water shortage irrigation covers essentially a winter irrigation allowing to prepare the field, sow the crop in good conditions and start the growing season either for winter wheat or for corn, the later benefiting from rainfall in July. This limitation of irrigation applications has led many farmers to engage in diversification to rely mainly and often exclusively on groundwater resource. Therefore the initial command area of about 86000 hectares has been over the years reduced to 45,330 hectares at present.

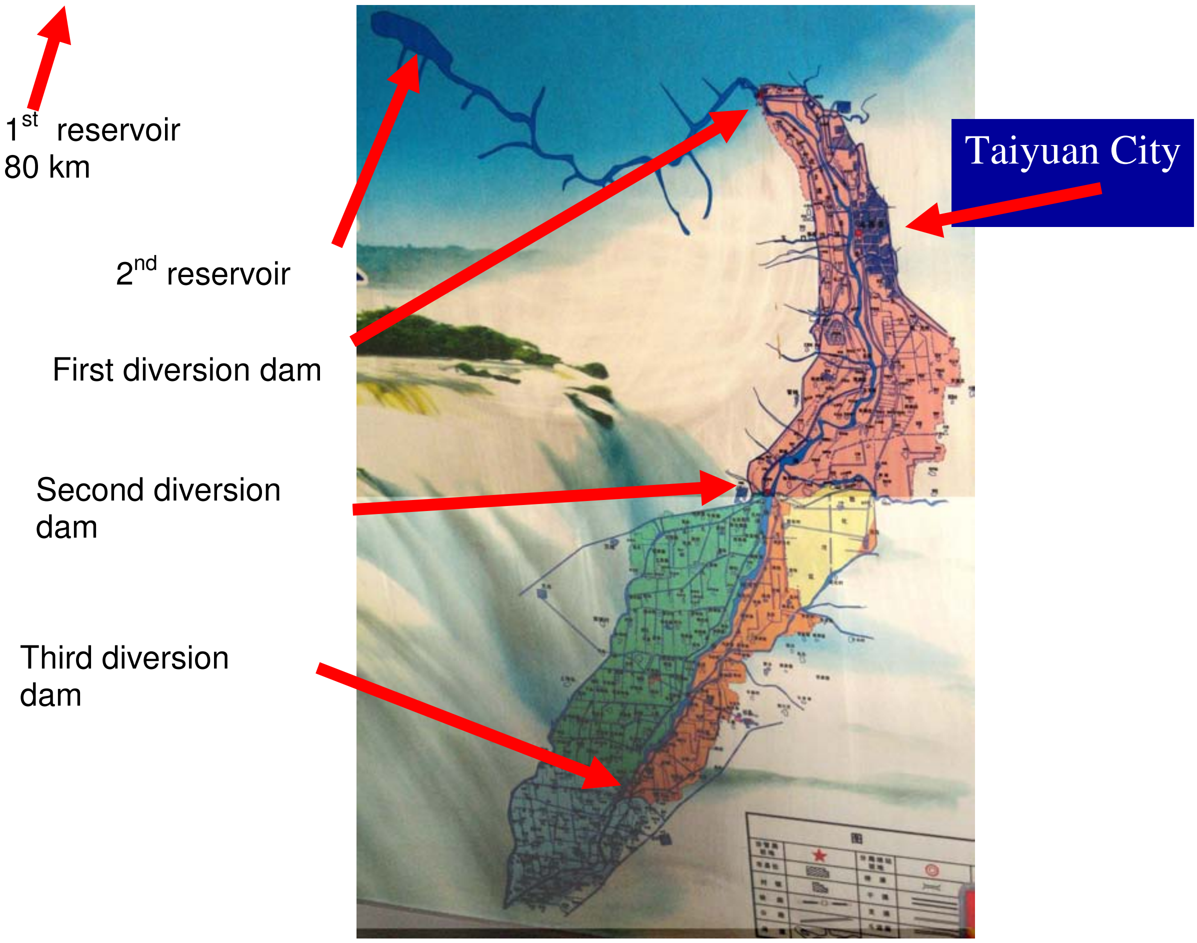

Figure 1. Map of Fenhe Irrigation District.

Plate 2. View of the Fenhe river plain upstream of Fenhe Irrigation District and Taiyuan City

The institutional arrangements for irrigation management are as follows:

- The FID manages water from the main reservoirs down to the head of tertiary canals.
- WUAs manage water along tertiary canals
- An 'irrigation team' manages water application at field level for the farmers.

The FID sells water to WUAs on volumetric basis at 0.2 RMB/m3 whereas WUAs charge farmers for irrigation on area basis 40 RMB/ Mu (600 RMB/ha).

Groundwater from the shallow aquifer is widely used for irrigation throughout the command area. A licence is required before sinking a well, however monitoring of extraction does not occur.

MASSMUS application in Fenhe Irrigation District

Note: For various reasons, such as peculiarity of the single winter irrigation and gaps in the availability of data, it has not been possible to obtain the usual quality for the RAP-MASSCOTE outputs during the short period of the exercise. Therefore, readers must consider with care the ranking of performance agreed upon by participants and the assessment of MUS carried out. For instance, some indicators strangely ranked very high simply because they refer to a single irrigation. As a consequence the one fundamental recommendation of the exercise is that given the complexity of the situation one should undertake thorough studies before making any decision on investing on options for improvements of irrigation management.

Step 0: Water services

Step 0 is a specific step introduced in MASSMUS module in order to start the process from the mapping of the multiple water services provided by an irrigation scheme to different users. These multiple services could be included in the design of the irrigation scheme or could informally/unofficially emerge by practice.

FID irrigation scheme was originally built for two key services:

- irrigation water supply, and
- flood control.

Several water services have since then been purposely added, such as the services to large coal and steel industries which employ large numbers of people and make an important contribution to the local and regional economy. The most recent addition is an extensive urban park network designed to improve the amenity of Taiyuan city and quality of life for its residents. In addition groundwater recharge resulting from canal seepages and irrigation practice at field level is a de facto ecosystem service that must be considered.

Current water services are listed in Table 2 based on the classification proposed by the Millennium Ecosystem Assessment (Box 1).

Table 2: Current Water services met in FID, classified with the MEA grid.

Provisioning Services	Regulating Services	Supporting services	Cultural Services
Irrigation Industry (Steel manufacturing, coal power generation, coal production) Hydropower Tree plantations	Flood protection Drainage	Groundwater recharge Support to natural ecosystems	Recreation and tourism

Box 1 . Service classes as defined by MEA (2003)

Provisioning Services, the product obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water.
Regulating Services, the benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.
Supporting Services, those are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.
Cultural Services, the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience as well as knowledge systems, social relations, and aesthetic values.

Irrigation services

The service to irrigation was established in 1950. Due to water scarcity the service to irrigation is very unique in the sense that it consists essentially of one irrigation during the dry winter on bare soil to refill the soil profile and create a protective layer which freezes over the winter period. Its purpose it to allow land preparation, crop sowing and the start of the cropping development during spring time. This winter irrigation may occur anytime between November and March.

Another irrigation application might occur in July, but this is rare: when rainfall is enough there is no need for irrigation and when rainfall is low there is usually no water in the upstream reservoir.

While the main crops are wheat and corn, extensive cash crops (fruit trees and vegetables) were observed. Farmers have installed wells, which are sometimes shared by a cooperative, to pump water from the shallow aquifer when there is no availability of irrigation water (which is most of the year).

Domestic water services

Taiyuan city utilises a water reservoir from outside the FID area and local villages use deep aquifer wells (200m) that are not connected to the shallow aquifers used for irrigation. Therefore, FID does not contribute to any domestic water supply.

Flood control

The Yellow River is well known for its frequent and devastating floods. Protecting Taiyuan city from serious flooding is one of the key reasons that the two reservoirs were constructed. Flood mitigation is a fundamental service provided by the reservoirs and drainage canals of the Fenhe irrigation infrastructure. Flood control is managed by a separate authority within the Shanxi Water Resources Department. Flood control is achieved by controlling the levels in the reservoirs, particularly during the flooding season, and diverting flood waters to canals and drainage canals. Flood control takes priority over irrigation deliveries, and conflict between the two uses has occurred.

Recreation and improvement of the urban environment

The environmental dimension of water management is gaining momentum in Shanxi province, particularly in relation to the improvement of the natural environment within the city of Taiyuan for the benefit of residents. Irrigation water is used by various urban parks, a forest education and recreation centre and one natural wetland site. All are within Taiyuan city.

Parks

The Fenhe Park is installed on the right side of the Fenhe river bed. It is composed of a 300 meter wide and 21 kilometer long water body which is flanked by a landscaped and irrigated green belt on both sides. This water body is usually kept isolated from the river flow between four rubber dams. The channel is only opened during major flood events to protect the city from flooding.

Plate 3. Aerial view of the Fenhe Park (Right reach and right green belt)

Natural Wetlands

Natural wetland areas within Taiyuan city have been restored, and irrigation water is used to ensure a regular water supply. These wetlands exist as a rare natural system within a highly urbanized environment and improve the amenity of the area for Taiyuan residents.

Plate 4. Natural Wetlands restored with the support of irrigation water.

Forest Park
A forest park covering 2,930mu (195 ha) is used as an education, recreation and tourism facility. The park has an artificial lake, 450,000m^3 in volume, which is filled with water from the irrigation system and used to irrigate the grasslands and 173 different species of trees on the site. The park received 700,000 visitors in 2009.

Plantation timber

Along the main canal and secondary canals (Plate 5) rows of trees have been planted by the Shanxi Fenhe Irrigation Administrative Bureau. Historically these trees have been harvested for timber, however new environmental restrictions have prevented any harvesting in recent years. The trees are irrigated upon initial planting, and it can be assumed that they continue to benefit from irrigation water either directly through irrigation or indirectly through groundwater recharge. While they no longer provide a direct source of income, the trees provide bank stability and shade for Bureau staff.

Groundwater recharge

Where canals are unlined it is expected that seepage will yield to groundwater recharge. Also, where surface irrigation is prominent, such as in FID, percolation becomes another source of recharge.

The groundwater system is composed of two aquifers:

- a shallow aquifer with an average depth of 3.8 meters, which is used for irrigation (once permission is given); and
- a deep aquifer (60 to 100 meters) which is used by the villages for domestic supply.

Plate 5. Example of tree belt found along the main canals of FID.

There is no connection/recharge between the two aquifers.

Groundwater is used extensively by cash crop farmers, whose estimated gross production is over US$70 million per year. It is also used by the timber plantations that line the canals and the environment in general.

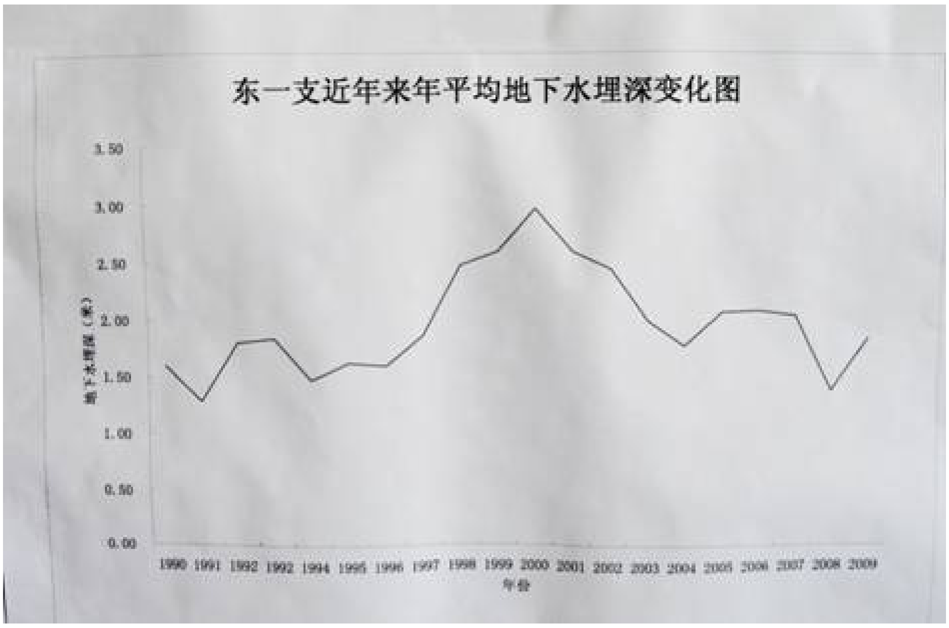

Figure 2. Example of water depth monitoring of the shallow aquifer at a station along a secondary canal.

Fisheries

There is a very small fishing industry, which is managed by staff at the second reservoir hydropower station. Up to 35,000 kilograms are caught per year, at a value of 210,000RMB.

Hydropower

Two hydropower plants totally 22.6 mega watt capacity have been installed on the upstream reservoirs to take advantage of the energy producing potential of irrigation releases to the Fenhe river. As the plant is run only when irrigation is issued, generation is limited to approximately 100 days per year. The annual production is 20 million KWh per annum, which at a selling price of 0.25 RMB/KWh represents a monetary outcome of 5 million RMB. Both flood control and irrigation releases take priority over energy production, therefore there is no conflict between users.

Plate 6 Power generation station Upstream FID at second reservoir

Large industry

Two large industries, a coal-fired power plant and steel manufacturer utilize water from the Fenhe system. The two plants employ 3,000 staff and make a significant contribution to the Shanxi economy. The Bureau receives 30,240,000 RMB per annum for the 16.8 million cubic meters delivered (1.8 RMB per cubic meter).

Industrial water is guaranteed to 95 percent and therefore takes higher priority over water for irrigation. During times of shortage conflict can occur. Extraction points are on the main and secondary canals and special deliveries are made for this purpose. Water is recycled on site and no wastewater re-enters the system.

Small industry

Two smaller coal production plants also utilize Fenhe irrigation water. Through special arrangement, these plants pay 0.6RMB per cubic meter which is less than other industries but still higher than for irrigation. The plants employ 3,250 staff and produce 2 million tonnes of coal per year, at a value of 111,000,000 RMB.

Plate 7: Steel production in Shanxi province

Step 1. RAPID DIAGNOSIS

A RAP (Rapid Appraisal Procedure) was carried out as part of the first step of the exercise during the workshop. The following sections is the RAP executive summary.

Step 1.1 RAP Methodology for Canal System

The RAP is a quick and focused examination of irrigation systems and projects that can give a reasonably accurate and pragmatic description of the status of irrigation performance and provide a basis for making specific recommendations related to hardware and management practices. The first step in evaluating irrigation performance, whether at the farm level or an entire irrigation project, is to perform a rapid appraisal (RAP) of the system as it is being operated.

The RAP can be described as follows:

> The Rapid Appraisal Process (RAP) for irrigation projects is a 1-2 week process of collection and analysis of data both in the office and in the field. The process examines external inputs such as water supplies, and outputs such as water destinations (ET, surface runoff, etc.). It provides a systematic examination of the hardware and processes used to convey and distribute water internally to all levels within the project (from the source to the fields). External indicators and internal indicators are developed to provide (i) a baseline of information for comparison against future performance after modernization, (ii) benchmarking for comparison against other irrigation projects, and (iii) a basis for making specific recommendations for modernization and improvement of water delivery service.

Use of a systematic RAP for irrigation projects was introduced in a joint FAO/IPTRID/World Bank publication entitled *Water Reports 19 (FAO) – Modern Water Control and Management Practices in Irrigation – Impact on Performance* (Burt and Styles, 1999). That publication provides an explanation of the RAP approach and gives the results from RAPs the authors conducted at 16 international irrigation projects. Refer to Water Report 19 for further background to the RAP approach, available directly from FAO (http://www.fao.org/icatalog/inter-e.htm).

RAP is now fully integrated as the STEP 1 or the foundation of the new approach developed by FAO for modernization strategy and plans which is called MASSCOTE.

Key performance indicators from the RAP help to organize perceptions and facts, thereby facilitating the further development of a modernization plan through the different steps of MASSCOTE. From the RAP we have already some good indications on:

- Further investigations that should be carried out for the development of the modernization plan.
- Specific actions that can be taken to improve project performance
- Specific weakness in project operation, management, resources, and hardware
- The potential for water conservation within a project

Broad goals of modernization are to achieve improved irrigation efficiency, better crop yields, less canal damage from uncontrolled water levels, more efficient labour, improved social harmony, and an improved environment by reducing a project's diversions or increasing the quality of its return flows. In general, these goals can only be achieved by paying attention to internal details, or the internal indicators. The RAP addresses these specific internal details to evaluate how to improve water control throughout the project, and how to improve the water delivery service to the users.

Looking at different management levels

When one analyzes a project by "levels" (office, main canal, second level canal, third level canal, distributaries, field), a huge project can be understood in simple terms. The operators of the main canal only have one objective – everything they do should be done to provide good water delivery service to their customers, the distributary/minor canals (and perhaps a few direct outlets from the main canal). This "service concept" must be understood and accepted by everyone, from the chief engineer to the lowest gate operator. Once it is accepted, then the system management becomes very simple. Personnel on each level are only responsible for that level's performance.

An important step of MASSCOTE is precisely to start from this diagnosis and re-organize the management of the system into units which are functional, responsible and responsive and consistent with the main features diagnosed in the gross command areas. On large system the partitioning into management units is fundamental to allow an effective service oriented management from one level to the other down to the end-users.

Main canal operators do not need to understand the details of that day's flow rate requirements for all the individual fields. Of course, in order to subscribe to the service concept, operators generally need to know that their ultimate customer is the farmer. But the details of day-to-day flow rates do not need to be known at all levels. Rather, the main canal operators have one task to accomplish – to deliver flow rates at specific turnouts (offtakes) with a high degree of service.

Performance indicators

The external indicators compare input and output of an irrigation system to describe overall performance. These indicators are expressions of various forms of efficiency, for example water use efficiency, crop yield, and budget. But they do not provide any detail on what internal processes lead to these outputs and what should be done to improve the performance. They, however, could be used for comparing the performance of different irrigation projects, nationally or internationally. Once these external indicators are computed, they are used as a benchmark for monitoring the impacts of modernization on improvements in overall performance.

The internal indicators quantitatively assess the internal processes (inputs - resources used and the outputs - services to downstream users) of an irrigation project. Internal indicators are related to operational procedures, management and institutional set-up, hardware of the system, water delivery service etc. These indicators are necessary in order to have comprehensive understanding of the processes that influence water delivery service and overall performance of a system. Thus they provide insight into what could or must be done to improve water delivery service and overall performance (the external indicators).

Participants spent 2.5 days on the field and gave ratings to all internal indicators. During a plenary session rating were reviewed and finalized.

External performance indicators

The productivity of land (3000$ US/ha) is very high compared to other systems studied by FAO worldwide as seen in Figure 3 (ranked tenth on 57 systems and twice as much as the median).

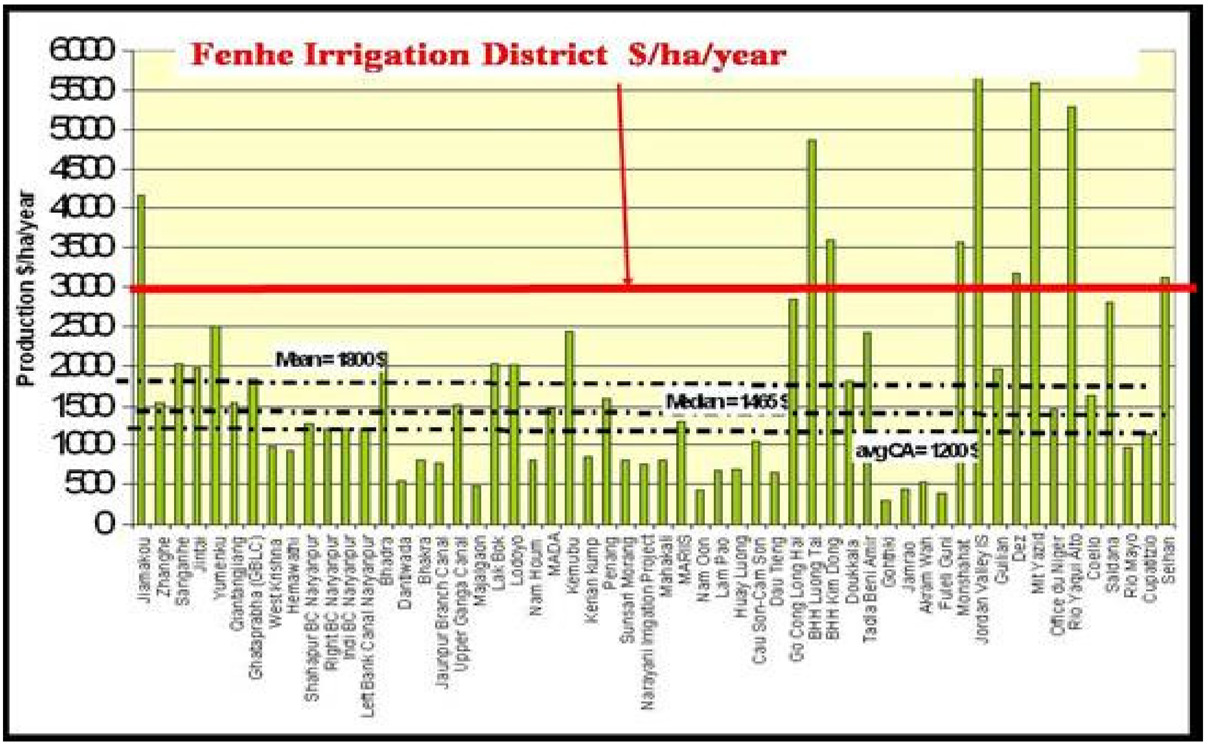

Figure 3. Output per unit area in FID compare to 56 other systems.

The performance in terms of productivity of canal irrigation water is even higher (rank fifth out of 57 and eight times the median). One reason for this extremely high productivity of canal irrigation water is that the water supply to crops is actually complemented by rainfall and pumped water. Irrigation in that regard is probably more used as a supplementary irrigation rather than full fledge irrigation supply and therefore it is quite normal to report a very high productivity.

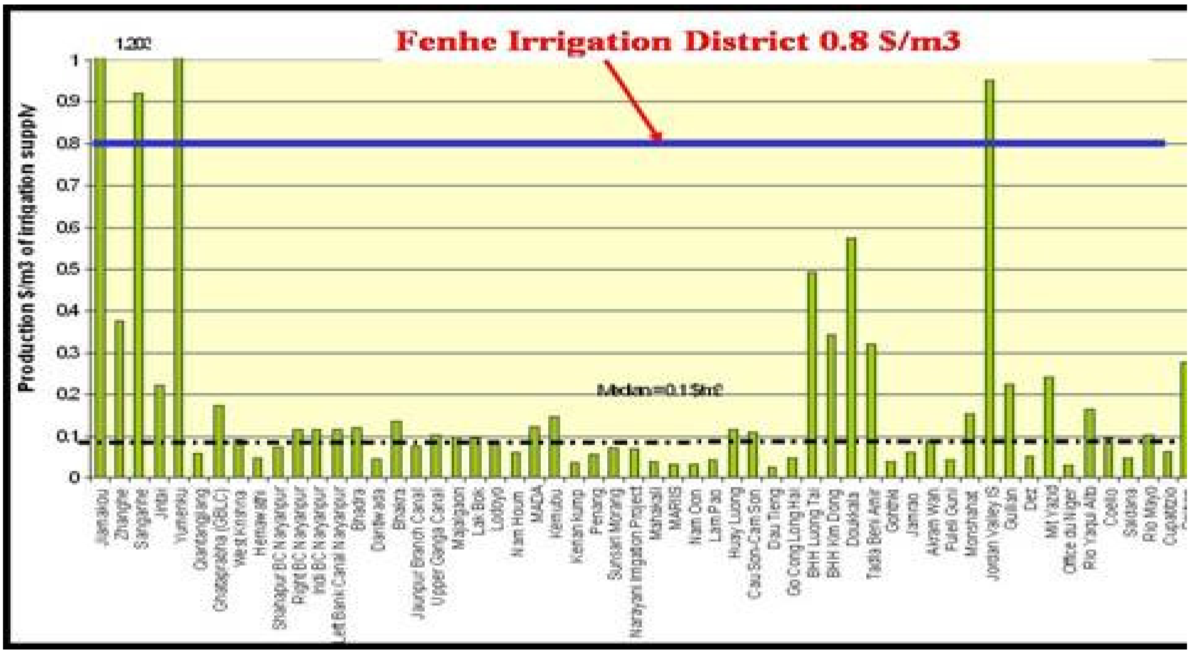

Figure 4. Output per unit of water in FID compare to other systems

Internal performance indicators

The values of the primary internal indicators of the RAP reflect an evaluation of the key factors related to water control and service throughout the command area. The internal indicators and their sub-indicators at each level of the system are assigned values from 0 to 4 (0 indicating least desirable and 4 indicating most desirable).

Table 3 summarizes the internal performance indicators for the Main Canal of FID.

Table 3. FID Internal Performance Indicators for the Main canal (estimated for the downstream dam)
(Maximum possible value = 4.0, minimum possible value = 0.0)

Internal Performance Indicator	**Value (0-4)**
Cross regulator hardware	2.7
Headgates (distributaries/minors) from the Main Canal	3.7
Communications	3.3
General Conditions	2.3
Operations	3.7
Actual Water Delivery Service by the Main Canals to the Secondary Canals (overall index)	**3.4**

Secondary Canals

The performance of the secondary canals (branch and main distributary) in the FID is summarized by the key internal indicators in Table 4.

Table 4. Internal Performance Indicators for the Branch /Distributaries in FID
(Maximum possible value = 4.0, minimum possible value = 0.0)

Internal Performance Indicator	**Value (0-4)**
Cross regulator hardware	2.6
Turnouts (watercourses) from the Distributaries/Minors	3.5
Communications	3.2
General Conditions	3
Operations	3.7

Tertiary Canals and final deliveries in FID

The internal indicators that characterize the actual water delivery service at the farm and field levels are summarized in **Table 5**. Following the usual grid for ranking indicators of performance the water delivery service being provided to the farmers is high. However this is the result of a peculiar service limited to one winter irrigation for which reliability and equity are high. In that sense this type of irrigation systems cannot be compare with others which are ranked on the basis of delivering water throughout the cropping season.

The social order indicator reflects the degree to which irrigation deliveries are being taken either from unauthorized locations or in quantities greater than allowed, in FID the social order ranks very high at 3.8.

Table 5. Internal Performance Indicators for the Minors/laterals/Field channels in FID
(Maximum possible value = 4.0, minimum possible value = 0.0)

Internal Performance Indicator	**Value (0-4)**
Cross regulator hardware	2
Turnouts (watercourses) from the Minors/Laterals	3
Communications	2.7
General Conditions	1
Operations	3.7

Table 6. FID Final Delivery Point Internal Performance Indicators (0-4)
(Maximum possible value = 4.0, minimum possible value = 0.0)

Actual Water Delivery Service to Individual Ownership Units (e.g., field or farm)	3.5
Measurement of volumes	0
Flexibility	3.5
Reliability	4
Apparent equity.	4

The ratings for the internal indicators describing employees ranks medium at 2.4. Water User Associations show significant room for improvement. Employees, especially field operations staff, had little or no incentive to provide excellent service to farmers and were not empowered to make decisions on their own. The farmer organization indicator is low [see Table 7] due to the fact that they had little ability to influence the real-time management of the system or to rely on outside help for enforcing rules and policies.

Table 7. FID Water User Association Internal Performance Indicators (0-4)
(Maximum possible value = 4.0, minimum possible value = 0.0)

Water User Associations	**1.1**
Percentage of all project users who have a functional, formal unit that participates in water distribution	**0**
Actual ability of the strong Water User Associations to influence real-time water deliveries to the WUA.	**2**
Ability of the WUA to rely on effective outside help for enforcement of its rules	**1**
Legal basis for the WUAs	**2**
Financial strength of WUAS	**2**

The key findings of the field visit are summarized below:

1. High water scarce system
2. Infrastructure generally good
3. One irrigation per year on bare soil
4. FID – WUAs – Irrigation team: farmers not involved in canal water application!
5. Numerous private wells + small scale pipe network.
6. Cash crops – Large areas under green houses
7. Canal water under regression for groundwater
8. Large Urban area upstream: Taiyuan
9. MUS: a total of seven water uses.

External indicators: ASSESSING the various VALUES of MUS

In a classical RAP, the external indicators (productivity) based on the gross value of the agriculture production are easy to estimate and are already included in Step 1. In MASSMUS module these indicators are discussed in more details in Step 4: water uses and benefits.

Internal Indicator 1: Number of Services

Although FID was designed for two additional services (power production and flood protection) than providing water for crop production, it is actually providing services to many more uses. The first internal indicator of MUS is the number of services reported. In FID this indicator establishes itself to a high 7 services as reported earlier.

Internal MUS indicator 2: how MUS is integrated by management?

A special MUS internal indicator in worksheet 5 "Project Office question" assesses the way managers see MUS. From the discussion with the managers during the MASSCOTE exercise the FID system has been ranked as 3.5 for MUS integration. Table 8 below provides the criteria used for ranking MUS integration. For two reasons the FID does not rank 4 on MUS: the governance of FID is not yet fully geared for MUS and one major service recharge to groundwater is not clearly integrated into the management.

Internal MUS indicator 3: Importance of each use/service

The absolute and relative importance of each reported service is normally appreciated during the RAP exercise through a 0-4 ranking from the discussion with managers and among the participants.

The importance of each service should be assessed by the irrigation managers on the basis of absolute importance. They should also considered alternative sources of water available for each water use, and what would be the impact on different water if there were no canal irrigation. Both quantity and quality of water must be considered for the rating of importance.

When plotted against the number of water uses in the system (figure 6) and compared with other irrigation systems in the world, evaluated by FAO, FID falls in the category of numerous services well integrated.

Table 8. Ranking of integration of MUS in management & operation

Indicator value	Management attitude
0	Ignoring or denying MUS and/or its magnitude
1	Blind eye on MUS practice by users *Manager is aware of some MUS related practices but do not consider them as part of his job.*
2	Positive marginal practices to support MUS *Manager is aware of some MUS and consider positively some related practices.*
3	Integration of other services concerns into the operation *Manager knows and organise the management to serve other uses or to ensure that operation for irrigation do not penalised the other uses.*
4	Integration of Multiple Uses Services into the management and governance. *MUS is fully integrated in the Management Operation and Maintenance. Governance is made on the basis of multiple services with multiple users/stakeholders.*

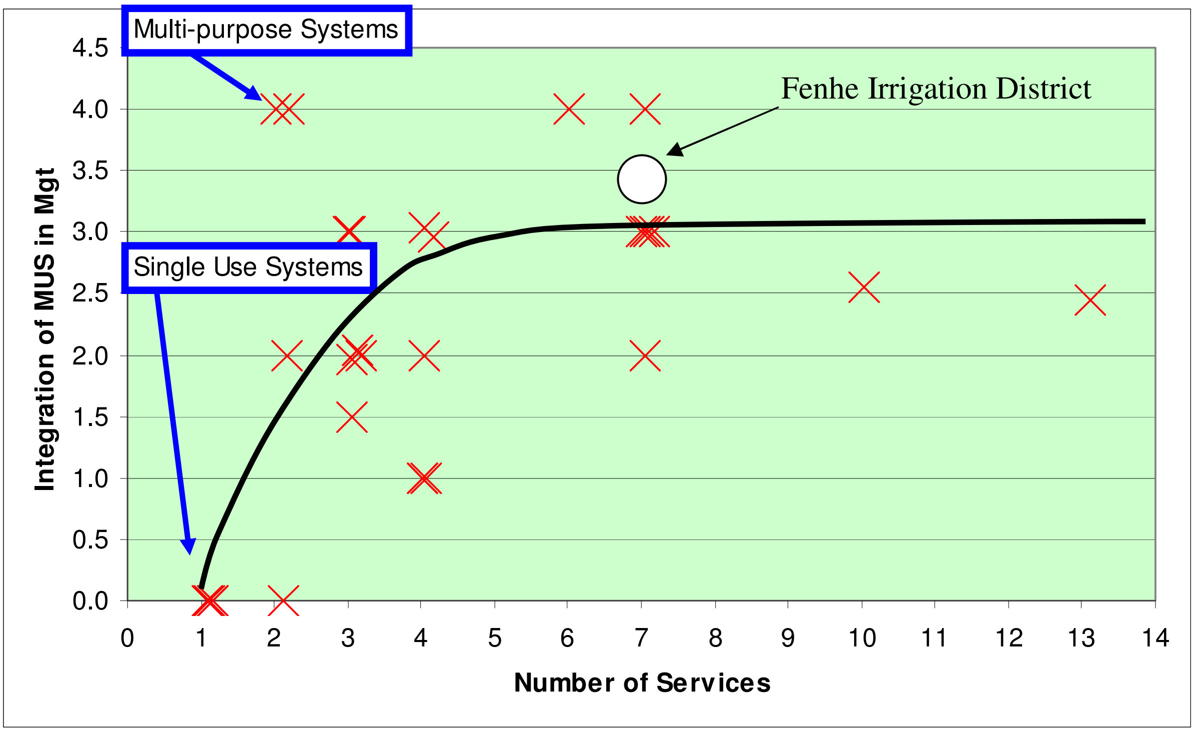

Figure 6. Degree of MUS and integration in management 30 irrigation systems audited by FAO

STEP 2. CAPACITY & SENSITIVITY

Capacity and sensitivity

Capacity and functionality of canal system are assessed for each physical structure with respect to four main features:

- **functionality**: whether the infrastructure/structure is functional or not;
- **capacity**: if functional, what the actual flow capacity of the structure is with regard to its function (possibly compare with design and/or ideal target);
- **ease of operation**: how easy the structure is to operate;
- **interference**: whether the structure has adverse impact on the behaviour of other structures (perturbations to other hydraulic structures).

Among the key functions of an irrigation infrastructure from storage down to transmission of information, none of them appears to face capacity problems: Capacity for some uses is constrained by the irrigation. For instance the hydropower production at the upstream dam is limited to 100 days per year due to limited issues for irrigation.

Based on the visited structures the sensitivity appears to be medium about 1, if confirmed for all structures sensitivity should not be a source of problem for operating the canal systems.

STEP 3 PERTURBATIONS

With a regulated inflow, no obvious illegal offtakes or overtapping, no return flow no runoff entering the canal it is felt that the system is not subject to perturbations.

STEP 4.1. WATER ACCOUNTING for MUS

The share of water use, water consumed are critical elements for assessing the various services. For some water uses volume is measured, for others estimation or assumption has to be made.

The irrigation canal entering the system is divided into two uses: the fraction that is evapotranspired by irrigated crop and that of recharging groundwater through seepage and percolation. The balance between these two depends on the efficiency along the canal system and at field level. The efficiency indicators for both segment are not known accurately in the case of FID. Assuming a canal efficiency of 80 percent and field efficiency of 70 percent the breakdown of the 127 MCM water input at canal headworks is thus 71 MCM for crop consumption and 56 MCM for groundwater.

Hydropower counts for nil in terms of actual water consumption with a fraction of 100 percent of return flow. For flood control it is very difficult to estimate the loss of water to increase storage capacity, without any particular information a volume of 1 MCM has been arbitrary affected to this use only for the sake of not having a value of zero. The result of the estimated water balance is shown in Figure 7.

Irrigated crop consumption ranks first with 47 of the total surface water supply, groundwater recharge ranks second with 37 percent, large industry ranks third with 17 percent and urban ecosystems fourth with 3 percent.

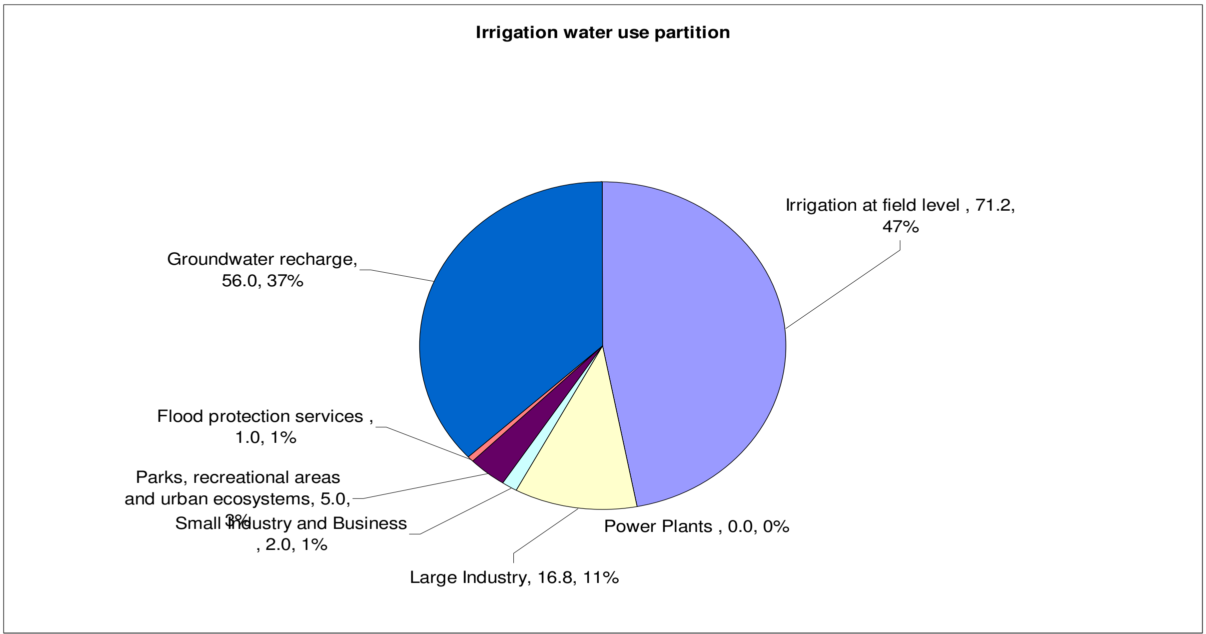

Figure 7 Water balance for FID

STEP 4.2. Accounting the benefits of water uses

Valuing Benefits

Undertaking a cost-benefit analysis for each use of water is critical for several reasons. A cost-benefit analysis helps to develop methodologies for improving management, raises awareness of multiple uses with decision-makers and can help enhance the stakeholder participation process.

Water shortage is a serious issue in Shanxi province, and conflict between the different uses has occurred during periods of low rainfall. These problems will escalate as the volume of water required for other uses expands. Knowing the exact contribution of each use to both the Bureau's budget and the economy at large will assist decision-makers with the difficult decisions that need to be made when allocating scarce water resources. Estimates of value are also important when managers attempt to secure external funding for projects within the system.

In FID seven different uses of water were found, namely: irrigation, flood control, hydropower, industrial with steel manufacturing and coal production, coal-fired power generation, natural park enhancement and groundwater recharge. The estimated benefits associated with each are summarized in Table 9.

Without further in-depth study, it is not possible to get a reasonably accurate measurement of the value as part of the rapid MASSMUS process for a variety of reasons. For example, while steel is a marketable good and should therefore be relatively simple to calculate, the annual productive output for steel production is considered commercially sensitive information, and estimates based on salaries or water use were not considered reasonable by the group. Even in cases where the gross production value is known, such as the coal producing plants, the exact contribution that water contributes to this value can only be very roughly estimated within the confines of the rapid MASSMUS process.

For uses that do not produce a marketable good, rapid valuation becomes even more difficult. For example, the value of the flood protection benefit provided by the system could not be estimated without a comprehensive assessment of future flood predictions and the property and other values within the protected area. The value that can be placed on the enjoyment provided by a park or forest area is also difficult to quantify.

Attempting to compare the value of each benefit without accurate estimates for some of the largest users (such as industry) is dangerous and the lack of data should be made clear whenever such a comparison is made.

In the absence of further economic study, it is possible to estimate one aspect of value by calculating the contribution each use makes to the Bureau's budget via water use fees (see Figure 8 below). This comparison was useful in helping to highlight the importance of the other uses of water, particularly when comparing these uses with irrigation. Despite using much less water, large industry contributes the greatest proportion of the water use fees, which should have bearing on the decisions made by the management entity.

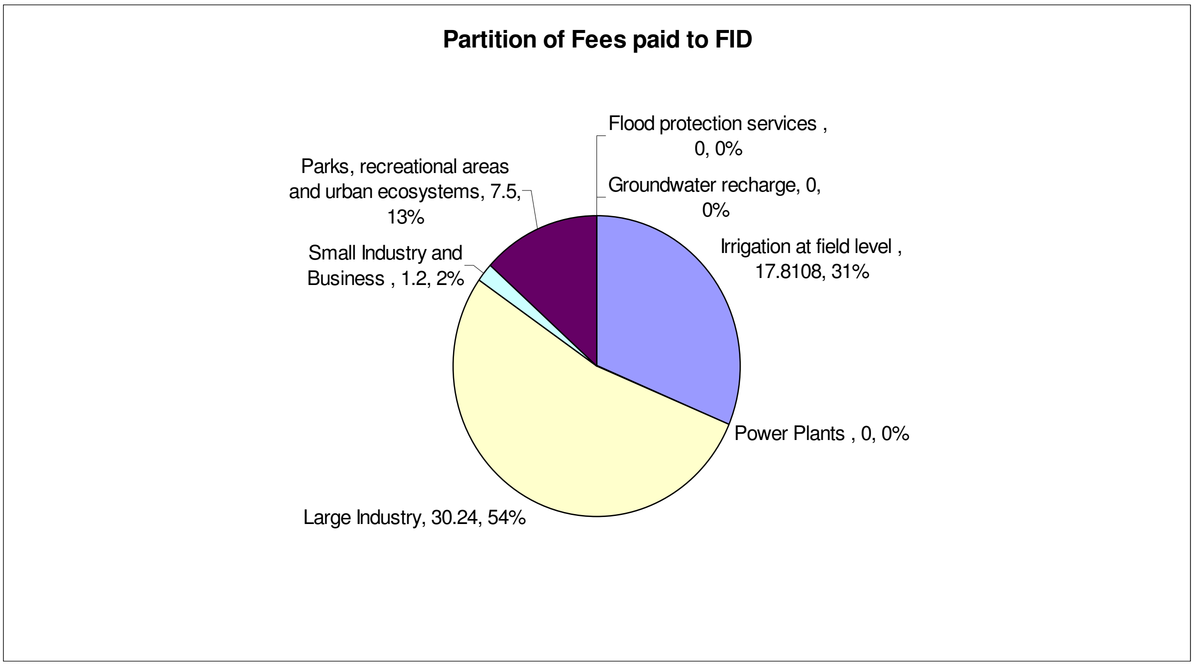

Figure 8. Breakdown of the fees contribution to FID

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Table 9. Summary of Cost and Benefits for all water uses

Service	Use	Benefit	Water use (MCM/year)	Price (RMB/m^3)	Value			Notes
					Staff and/or Visitor No.	Paid to Bureau (Million RMB)	Productive Output (Million RMB)	
Raw water supply	Irrigation for agricultural production	Agricultural output/product	89.1	0.2	96,000 farmers (canal water)	17.8	980.1	
Raw water supply	Hydropower stations (x2)	Electricity	150	Nil	30 staff	Nil	50	5% of power is used on-site
Raw water supply	Steel Factory	Steel production	8.8	1.8	1500 staff	15.84	Commercially sensitive	
Raw water supply	Coal Power Station 1st canal only	Electricity	8	1.8	1500 staff	14.4	960	3 billion KWh per year sold at 0.32RMB/kwh
Raw water supply	Small coal plants (x2)	Coal	2	0.6	3,250 staff	1.2	111	2million tones of coal sold at 1,800RMB/t
Raw water supply	Fenhe Park	Recreation, Tourism and City Environment	4	1.5	50 staff 3million residents	6	Amenity Relaxation Exercise	
Raw water supply	Forest Park	Education Tourism Recreation	0.3	1.5	60 staff 700,000 visits in 2009	0.45	Education Tourism Recreation	Artificial lake 450,000 in volume used for on-site irrigation
Raw water supply	Other parks (West)	Recreation, Tourism and City Environment	0.6	1.5	100 staff 3million residents	0.9	Amenity Relaxation Exercise	
Groundwater recharge	Trees lining canals Shallow aquifers are pumped for irrigation	Bank stability Shade for staff Agricultural output	Share of 56 MCM (total groundwater recharge) 4 - 13	Nil No water use fee, but consider pumping energy costs		Nil	Environmental improvement (trees are no longer sold)	Managed by Irrigation Dept Irrigated when first planted Need Govt permission before harvesting – not given in recent years

Recommendations for further study

As environmental values (particularly within the human/urban environment) grow in importance in Shanxi Province, the water used by the Fenhe park network and forest centre will become increasingly valuable. Unfortunately, the benefits of recreation, improved amenity and improved quality of life are notoriously difficult to quantify, however economic valuation methods have been developed.

The contingent valuation/stated preference method is the most common way of assigning monetary value to environmental benefits. The contingent valuation method involves directly asking people in a survey how much they would be willing to pay for a specific environmental service. In some cases, people are asked how much they would be willing to accept to give up a specific service. It is called the ‘contingent’ valuation method because people are asked to state their willingness to pay contingent on a specific hypothetical scenario.

Applying the contingent valuation method is generally a complicated and lengthy process, however the information obtained would represent a very valuable investment when difficult allocation decisions between irrigation, industry and the social welfare of the Taiyuan residents need to be made.

While it is clear that the flood control aspect of the FID is already highly valued (above irrigation and industry) it would be useful to put monetary values on this service. The damage cost avoided or substitute cost methods are relatively easy to apply, however data outlining property values and flood pattern predictions is needed.

Cost
No assessment of the costs of each use to management, operation and maintenance were undertaken at the workshop.

Following steps 5 to 10 and perspectives

The MASSMUS following steps are meant to address the cost of operation, the users and the services, the management units the demand for operation the improvements and integration in order to generate a consistent plan for modernization.

The final report presented by the participants at the end of the workshop identified the following key problems:

- Water shortage.
- Main and secondary canal seepage.
- Aged infrastructure
- Information management
- Comprehensive water saving technologies are needed

Due to lack of time it was not possible to carry out these steps for the FID during the workshop however a vision of FID was discussed and elaborated by the participants.

A vision for FID

A sound modernization plan for management of *Fenhe water system* would contain the following elements:

1. **A Modernized infrastructure:** the central government funded China-wide irrigation rehabilitation program should be utilized in the following ways:

a. Improve the quality of the tertiary and quaternary canals
b. Enhance communication and information within Fenhe water system, with the aim of reducing water losses and improving water use efficiency and value

2. **Increased services to industrial and ecosystems**: the scale of industrial and ecosystem water use should be increased to further supplement the water management budget which can be reinvested in improving infrastructure and management.

3. **Strong Water Users Associations:** to further the implementation of participatory management through effective WUAs. It requires to adjust the model towards association with a critical size, and then to expand (there are currently 62 and participants would like to see 1,000). The Bureau will give guidance to the WUA and help them to build institutions, rules and regulations. The Bureau would also conduct training of WUA staff to enhance their professional skills and ability to help farmers.

4. **Towards a Water Management Agency:** Management institutions along the Fenhe water system should be enhanced and should strive for integrated water resources management (IWRM). New management institutions should be created to more reasonably and scientifically distribute and schedule water deliveries to meet farmer requirements.

This vision concluded the work carried out by the workshop participants. A tentative workplan to implement that vision for the short term was discussed but not enough elaborated to be adopted.

Fenhe District Shanxi Province 23th June 2010.