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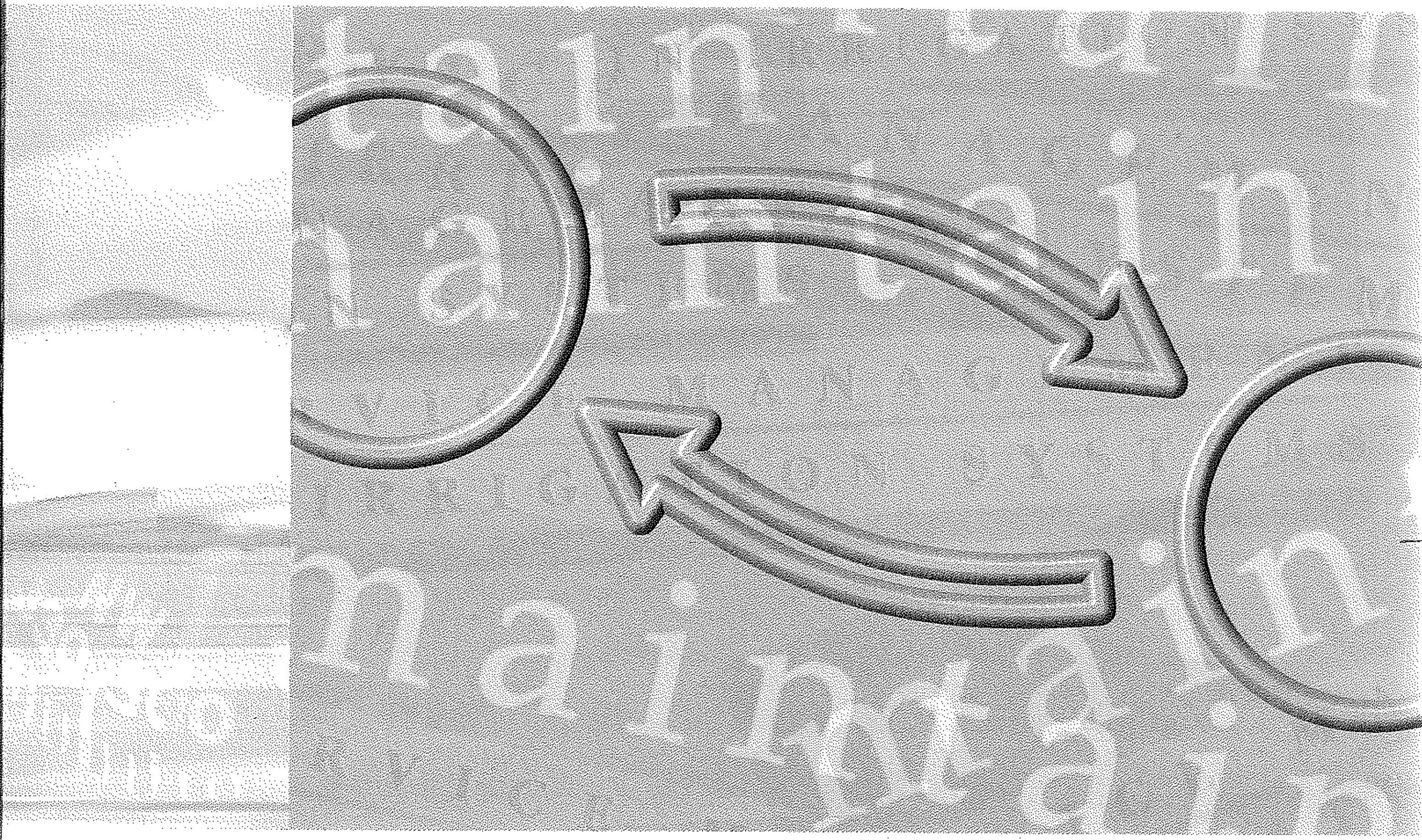

Martin Burton

Using Asset Management Techniques for Condition and Performance Assessment of Irrigation and Drainage Infrastructure

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Abbreviations and Acronyms

AMP	asset management plan
I&D	irrigation and drainage
O&M	operation and maintenance

Weights and Measures

ha	hectare
km	kilometer
m	meter
m^3	cubic meter
s	second
$	US dollar

Executive Summary

The purpose of this paper is to outline asset management procedures and then adapt these to produce rapid asset appraisal procedures to fit with the institutional studies carried out under the Maintain project.

Asset management, as a term, originates from the world of business and finance, and has been adapted as a tool for the long-term sustainable management of infrastructure. It is currently employed in the water supply, transportation and property sectors. It is not currently applied in the irrigation and drainage sector to the same degree, and opportunities exist for developing such application. A relevant current application is in the turnover of irrigation and drainage systems to water users. In this context asset management procedures can be used to carry out an audit of the infrastructure, define performance standards and level of service provision, and develop understanding and ownership amongst the water users of the relationship between level of service provision and water fee payment.

Asset management seeks to maximise the potential benefits arising from the use of the infrastructure by applying engineering and management procedures which identify the function, utility, cost, value and current condition and performance level of each asset, and thus of the asset base as a whole. In irrigation there is a strong relationship between the location, function, condition and performance of certain assets on the overall performance of the system.

As part of the asset management procedure asset surveys are carried out, either of all assets, or of statistically selected sample sets, to determine asset condition and performance. Integration and analysis of the information on all assets leads to the development of the asset management plan (AMP). A crucial part of the preparation of this plan is the identification of the current and desired level of service provided by the infrastructure. The current level of service is determined through the asset surveys and through interviews and discussions with water users and irrigation service provider staff. In order to determine the level of service standards and performance measures need to be identified. Determining the desired level of service is a complex issue, in many cases mainly because the concept has not been explicitly formulated and discussed with water users in the past. New approaches are required to develop procedures for this situation; these are briefly touched on in this paper.

Following the formulation of the asset management plan (AMP) a 20-year strategic investment plan is prepared. This plan results from financial modelling of the components of the AMP with an analysis of the water users' ability and willingness to pay for the stipulated level of service. Different levels of service, and their associated cost, can be identified, and the potential options modelled for discussion with farmers. Such financial models are available in the transportation and water supply sectors, further research is required to further develop these for the irrigation sector. At present subjective judgement has to be applied for decision making at this level.

In order to link in with the institutional survey approaches developed under the *Maintain* project, aspects of asset management procedures can be adapted to enable a rapid assessment of the asset base, and to identify current and desired levels of service. Such rapid asset appraisal procedures can be linked with the *Maintain* institutional and economic/financial appraisals to provide a complete picture of the infrastructure and maintenance situation. These rapid appraisal techniques will require significant stakeholder participation. In particular the rapid appraisal will seek to distinguish between the level of performance of the (inert) infrastructure and the level of performance of the management in using the infrastructure. Each can have significant impact, a canal filled with sediment will adversely affect downstream users, failure of management to plan and schedule irrigation water supplies to match demand will affect all users.

Some of the procedures outlined in this paper are new and innovative, further work is required to develop them for wider application. The adoption of asset management procedures in the irrigation sector has been slow, though it is the author's belief that their adoption in the long term is inevitable if a sustainable base is to be provided for management of I&D infrastructure. In the case of the turnover of irrigation and drainage systems to water users it is believed that such procedures should form part of the process of turnover, particularly as an integral part of the process, outlined in this paper, is the involvement and development of ownership by the users of concepts of level of service, infrastructure condition and performance, and payment of water fees.

1. Introduction

This paper aims to:

- outline asset management for irrigation and drainage infrastructure;
- outline how current and desired level of performance of the irrigation and drainage system can be ascertained;
- outline how an asset audit can be carried out within a short time frame to quantify the condition and level of performance of irrigation and drainage infrastructure;
- investigate the relationship between asset condition and performance, and level of service provision.

Asset management as a term originates from the world of business and finance. The Chambers Twentieth Century Dictionary defines assets as "the entire property of all sorts belonging to a merchant or trading association". Asset management is then the process of managing assets so as to maximise or optimise the benefits arising from them.

The application of asset management to engineering infrastructure, though a relatively new concept, is currently applied in a variety of sectors, including water supply, transport (roads and bridges) and property. It is not widely applied in the irrigation sector at present, though some developments have recently been made (Burton et al. 1996; Malano et al. 1999; Plantey 1999; Moorhouse 1999). One of the key philosophies behind the use of asset management for infrastructure is that such assets (canals, drains, structures, etc.) serve a function, from which benefits can be derived. Maintaining or enhancing that function results in sustained or enhanced benefits, either financial or social.

An important current application of asset management is as part of the process of irrigation and drainage system transfer. Applying asset management procedures at the transfer stage can have important benefits, including: an audit of all infrastructural assets; identification of water users' desired level of service; development by the water users of an understanding of the relationship between infrastructure condition and performance and system performance; development and ownership by the water users and the irrigation service provider of the relationship between fee payment and service provision.

The paper is set in the context of the *Maintain* project, which is looking primarily at institutional issues related to the maintenance of irrigation and drainage systems. This paper focuses more on the technical aspects but aims to integrate these within the institutional and economic/financial context.

A word of caution is required regarding the use of asset management. It is a management tool; how it is used, and how effective it is, depends entirely on who uses it, and in what context. In the wrong context, where management is weak, or lacks control over finances and budgeting, asset management will not work. What asset management can do, if used correctly, is identify infrastructural constraints to performance, and formulate plans to address these within the context of the ability/willingness of the users to pay for a specified level of service provision.

As stated above the application of asset management to irrigation and drainage infrastructure is relatively new. Some of the concepts outlined in this paper are also new and further work is required to develop and refine them. As outlined by Burton et al (1996) there remains significant scope for further research and development in this subject.

2. Outline of Asset Management

2.1 Overview

Asset management planning is at the core of strategic investment planning for long-term investment and expenditure in irrigation and drainage infrastructure. Strategic investment planning seeks to relate investment and expenditure to specified, user-defined levels of service. The process involves defining the level of service to be provided, quantifying the ability of the water users to pay for the specified service, identifying the condition and performance of the assets (canal, drains, structures, roads, etc.) and quantifying the investment and expenditure required to maintain, improve or extend the assets in order to satisfy the specified levels of service (Figure 1).

An explanation in terms of the asset management of a group of houses owned by a housing association helps to explain asset management. In the group of 30 houses there are, say, 10 houses which are Grade A (4 bedrooms), 10 which are Grade B (3 bedrooms) and 10 which are Grade C (2 bedrooms). The monthly rental value of Grade A, B and C houses are $500, $400 and $250 respectively. The houses will require different levels of maintenance at different intervals, possibly painting of the exterior woodwork every 3 years, painting of the interior woodwork and walls every 6 years, etc. In addition there will be major capital expenditure at generally longer intervals, rewiring of the electricity circuit every, say, 20 years. It may also be that the housing association at some stage decides to modernise the houses by providing new kitchens. This modernisation will enhance the level of service provided to the tenants for which an increased rental may be charged.

A similar process can be applied to irrigation and drainage infrastructure. The function and value of the infrastructure can be assessed and the infrastructure categorised according to the potential level of service that it can provide[1] (ability to deliver water to match crop demands). The level of expenditure required to keep the system operational at a specified level can be ascertained and the fee level to be charged to the water users determined. If further investment is made in the irrigation or drainage system and the system is modernised then the fee level can be changed to reflect the increased level of service provision. For example, the conversion of a system with manually operated gates to a system with automatic level control gates will increase the level of service by facilitating water distribution on-demand, thereby better matching supply and demand leading to enhanced agricultural production. There will be capital expenditure to remove and replace the control structures whilst the day-to-day operation costs may be reduced due to the saving of labour costs. The balance of the costs and savings will need to be determined by discounting over a 15-20 year time frame to ascertain if the irrigation service fee level needs to be increased or decreased to pay for the changes made.

[1] It is important to note that there are at least two aspects here, the condition/performance of the physical infrastructure, and the performance of the people/organisations which operate the infrastructure. Whilst asset management primarily focuses on the infrastructure, an assessment of the ability of management to use and operate the infrastructure is also essential.

Figure 1: Framework for asset management and strategic investment planning for irrigation and drainage infrastructure

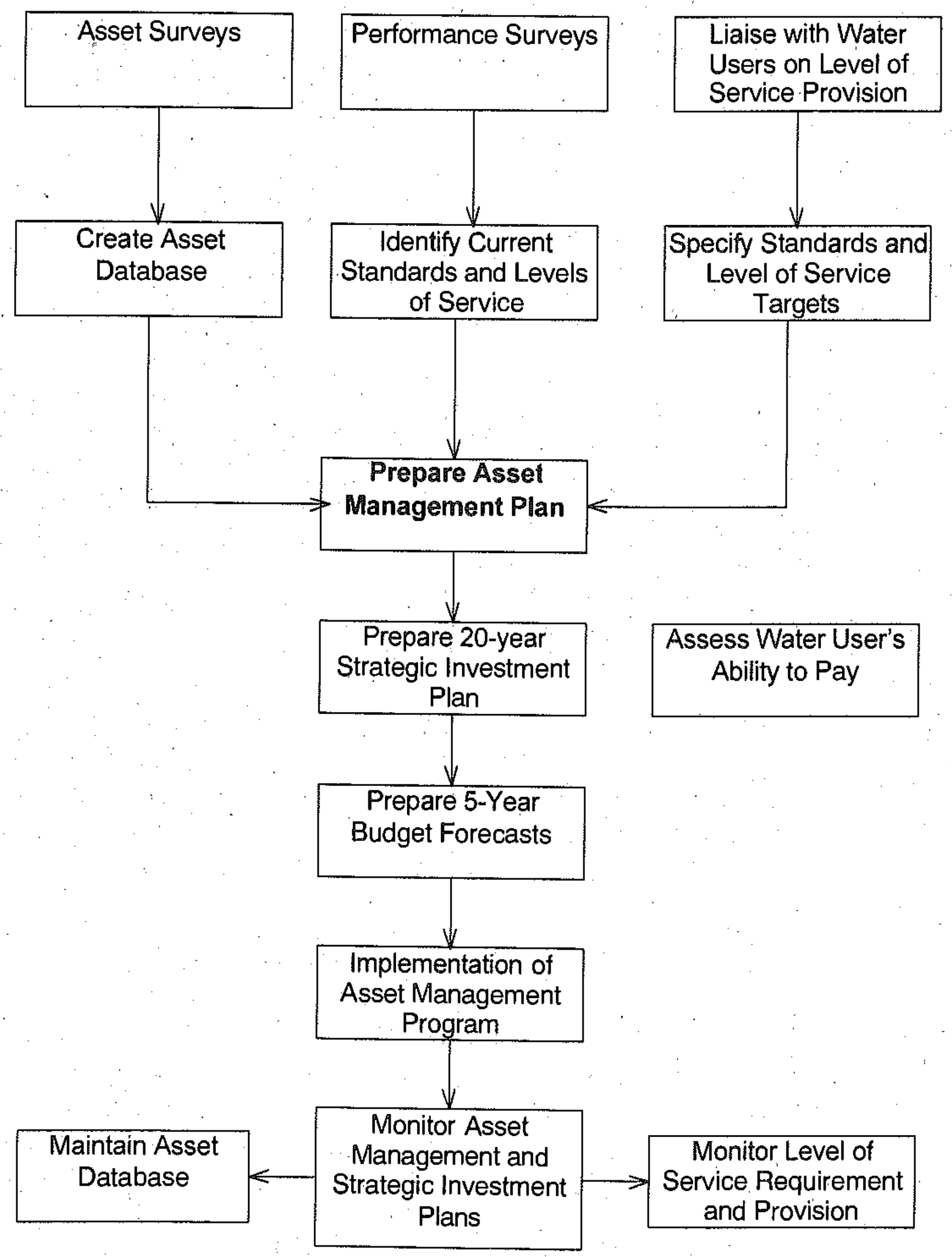


Table 1 shows conceptual relationships between level of investment, canal control systems, level of service, O&M costs and potential income levels. The level of service potential outlined in Table 1 assumes a close relationship between the control infrastructure and the management capability. Some authors (Horst 1990; Horst 1999; Berkoff 1988; World Bank 1990) argue that, in certain circumstances, more flexible, fully-adjustable control systems result in lower actual levels of service provision due to the failure of management to properly regulate the control structures.

Asset management planning thus enables the determination of expenditure and investment planning over both the short and the long term. In the context of the UK water supply sector it has been described as (OFWAT 1995):

"A rolling integrated approach to the planning, management and running of the monopoly business with the objective of ensuring the effective, economic and financially viable long term provision of appropriate quality services to the customers and the community".

In its simplest form it can be defined as (Burton et al. 1996):

"A structured and auditable process for planning investment in infrastructure to provide users with a sustainable and defined level of service"

2.2 Procedures

The key elements of preparing an asset management plan are outlined in Figure 1 and Table 2.

The setting of the standards and policies to act as benchmarks against which to assess the achieved performance is a key part of the process. Possible criteria for setting standards and performance assessment in terms of water delivery are discussed in more detail in Chapter 3.

Having defined the performance standards the existing performance of the irrigation and drainage system is assessed against these standards. This provides a benchmark against which to assess the level of improvement arising from the investment programme.

The ability to deliver the desired level of service will primarily depend on

(i) the type of irrigation infrastructure provided

(ii) the performance of the infrastructure

(iii) the capability of the O&M management

Assessment of the desired level of service can be made prior to the preparation of the asset management plan through interviews and discussions with water users, though the cost of a given level of service will not be know until the asset survey has been completed and the asset management plan prepared.

Establishing the desired level of service will not be easy, as in many schemes such a concept has never, explicitly, been communicated to water users. The Warabandi system[2] used in Northern India and Pakistan is an exception, in this instance farmers are well aware of the stated level of service provision, with time-shares, and times and duration of water turns being set out well in advance of each irrigation. One of the benefits of the asset management process is that it requires the stipulation of the standards by which performance will be measured, and that it also requires the stipulation of the desired level of service. Making these explicit facilitates communication between the irrigation service provider and the water user.

[2] A system which defines the allocation and distribution of irrigation water on a time-share basis which is in proportion to the size of each farmer's landholding within the tertiary unit.

Table 1: Indicative relationship between level of investment, canal control, level of service and O&M requirements and costs

Type	Canal control system	Water delivery system	Level of service potential	O&M requirements	O&M costs	Capital investment level	Indicative O&M cost level $/ha	Possible potential income level
1	Fully automated downstream level canal control, fully adjustable and responsive to farmer demands	Demand	Very high, fully responsive to farmers demands for water. Highly efficient in water use	Low staffing levels due to automation, but work force need to be highly skilled.	Low on day-to-day basis but high over time as control equipment is expensive. High capital cost, low O&M cost.	High	30	High
2	Manual control with some automation at key locations. Discharge measurement at flow division and delivery points.	Arranged-demand	High, responsive to farmers' demands for water though farmers need to order water in advance. High interaction between service provider and farmer.	High staffing levels due to manual operation and need for measurement to match supply to demand.	High due to cost of O&M staffing and associated facilities (offices, motorbikes, etc.). Maintenance costs high to maintain and replace gates over time.	Moderately high	60	Good
3	Manual control throughout the system. Discharge measurement at flow division and delivery points.	Supply-demand	Moderate. Supply driven with irrigation service provider controlling/ allocating available water taking into account farmers cropping patterns. Relatively low interaction between service provider and farmer	Moderate staffing levels due to manual operation and need for some measurement to match supply to demand	Moderate due to O&M staffing and need for some O&M facilities. Maintenance costs high due to need to maintain control gates.	Moderate	40	Moderate
4	Manual control at main control points, ungated and/or proportional distribution at lower locations. Limited measurement.	Supply	Moderate, not responsive to farmers' demands, limited control over water distribution to match demands.	Moderate to low staffing levels due to manual operation, though little measurement	Moderate to low due to O&M staffing and need for some facilities. Maintenance costs moderate due to need to maintain main control gates, kept lower by low-cost control at delivery points.	Low	30	Low
5	Fixed proportional control system, supply controlled, not responsive to demand. Measurement at water source intake only.	Supply	Moderate to low, not responsive to farmers demands for water but farmers can plan ahead and adjust cropping pattern to suit supply. Inefficient in water use.	Low level of staffing, only low skill levels required	Low due to low O&M staffing levels and to low-cost proportional division structures.	Very low	10	Subsiste nce

Table 2: Key elements of an asset management plan

Definition of procedures	The detailed methodology used in producing the AMP set out so that it can be traced and audited over time
Standards and policies	Standards are the benchmark against which the achieved performance is to be measured. Policies set out the irrigation service provider's approach to investment decision making
Existing level of service	The level of service currently provided under each output performance measured against the declared standard
Desired level of service	The desired level of service required by the customer, and for which he/she is prepared to pay.
Asset extent, value, condition and performance	A report summarizing what assets exist under various category headings, their 'Modern Equivalent Asset' value, their current condition and performance
Long-term (20 year) investment plan	The investment need identified through engineering studies to rectify the performance shortfalls and to extend or improve the service to meet demand and the needs of the customer
Program of planned activities accounting for the investment	A schedule of specific works identified in the engineering studies as requiring to be undertaken, showing when it is intended to implement them
Program of performance benefits accruing from the investment	A report of how the investment will be rewarded by improvements in performance over time against the declared targets
Short term (5 year) expenditure program	Budgets for the first five years, and how these are arrived at
Operating costs	A summary of the service provider's operating costs consistent with the capital expenditure program
Revenue requirements and ability to pay	The implications of the plan for customer charges, and, in some cases, an assessment of their ability to pay.

A major component of asset management planning is the assessment of the extent, function, condition, value and performance[3] of the individual assets. This is carried out through asset surveys within the irrigation and drainage system. If a large area of irrigation and drainage is to be surveyed, statistically based asset surveys of representative areas can be taken and extrapolated to provide information for the whole asset base.

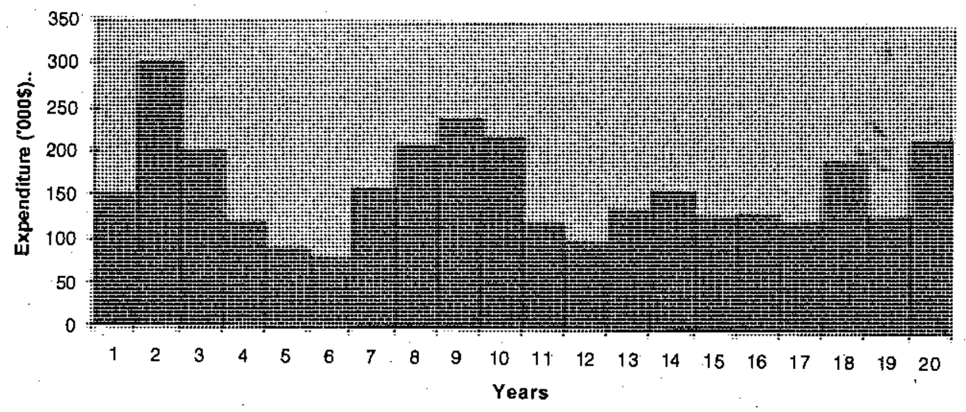
Engineering studies are required to study generic issues such as the deterioration rate of different types of asset and asset components (facets); development of Cost Models (costs for

rebuilding/upgrading/rehabilitating assets); relationships between individual asset performance and system performance. For the latter hydraulic modelling offers exciting possibilities for the future (El-Askari 2000).

Through engineering studies the cost database for maintaining or enhancing the condition/performance of each type of asset (river weir, canal head regulator, aqueduct, culvert, etc.) can be ascertained and applied to the asset condition/performance of each asset. In this way the cost of maintaining or enhancing the condition/performance of the irrigation and drainage system is determined. An indication of the possible relationship between the condition, performance and importance is presented in Table 3. Importance relates primarily to the asset's function, position in the irrigation or drainage network, and its replacement value. A river diversion weir is more important than a secondary canal head regulator, for example, because of its central function in diverting and controlling inflow to the scheme, its position at the head of the system, and its (usually) significant replacement cost.

Through the engineering studies the recurrence interval of the expenditure is assessed (e.g. rubber gate seals may need replacing every 5 years, metal gate plates every 20 years), and the long-term investment plan can be drawn up (Figure 2). This plan needs to be broken down into a schedule of planned activities, and a short-term budget prepared for the first 5 years.

Figure 2: Example of a 20 year investment plan profile



The engineering studies will also have identified the anticipated improvements in performance benefits arising from different levels of investment, these need to be assessed against the investment costs. The benefits will arise to the irrigation (investing) service provider from the revenue generated from the water users, who will, in turn, derive their income from agricultural production generated as a consequence of the water delivery service provided by the irrigation service provider. The link between level of service provision and fee payment is central to the process of asset management planning.

[3] Asset performance: the degree to which the asset is able to perform its required function.

The investment plan may need to be revised to match the ability of the water users to pay for the service. If this occurs the potential level of service provision arising from the condition and performance of the infrastructure may be reduced. A reduced level of service may result in a reduction in crop yield and a diminished ability to pay for water. There is obviously a balance to be struck between these two factors[4].

It is important to note that there is a difference between the water users' *ability* to pay and their *willingness* to pay. For this reason it is important that the asset management process is clear, transparent and auditable, and that the water users are active participants in the process.

[4] In practice this is not a direct one-to-one linkage, it has to be moderated by other factors.

Table 3: Possible performance, condition and importance relationships (Burton and Hall 1999)

Performance	Condition	Importance	Priority	Explanation of situation	Consequence
Good	Good	High	Low	No problem with asset. Performance and condition are good, indicating that asset is new and in serviceability grade 1 or 2.	Low probability of structural failure.
Good	Good	Low	Low	No problem with asset. Performance and condition are good, indicating that asset is new and in serviceability grade 1 or 2.	Low probability of structural failure.
Good	Poor	High	High	The situation is hazardous because the asset is close to failure, but its good performance may provide a false sense of security. High priority status because of the importance rating.	High probability of sudden structural failure which could have high direct and indirect cost consequences
Good	Poor	Low	Low	The situation is hazardous because the asset is close to failure, but its good performance may provide a false sense of security. Low priority status because of the importance rating.	High probability of sudden structural failure which could have moderate direct or indirect cost consequences.
Poor	Good	High	High	High priority status as performance is low and importance is high. Condition is good indicating that performance is affected by something other than condition.	Engineering assessment required to identify the problem causing the poor performance.
Poor	Good	Low	Low	Low priority status since importance is low. Condition is good indicating that performance is affected by something other than condition.	Engineering assessment required to identify the problem causing the poor performance.
Poor	Poor	High	High	High priority status as performance and condition are poor and importance is high. This indicates that the asset has failed and is in serviceability grade 4 or 5.	High probability of sudden structural failure which could have high direct and indirect cost consequences.
Poor	Poor	Low	Low	Low priority status as importance is low. However, the poor performance and condition indicate that the asset has failed, or is about to fail, and is in serviceability grade 4 or 5.	High probability of sudden structural failure which could have moderate direct or indirect cost consequences.

3. Linking Asset Management to Level of Service Provision

3.1 Overview

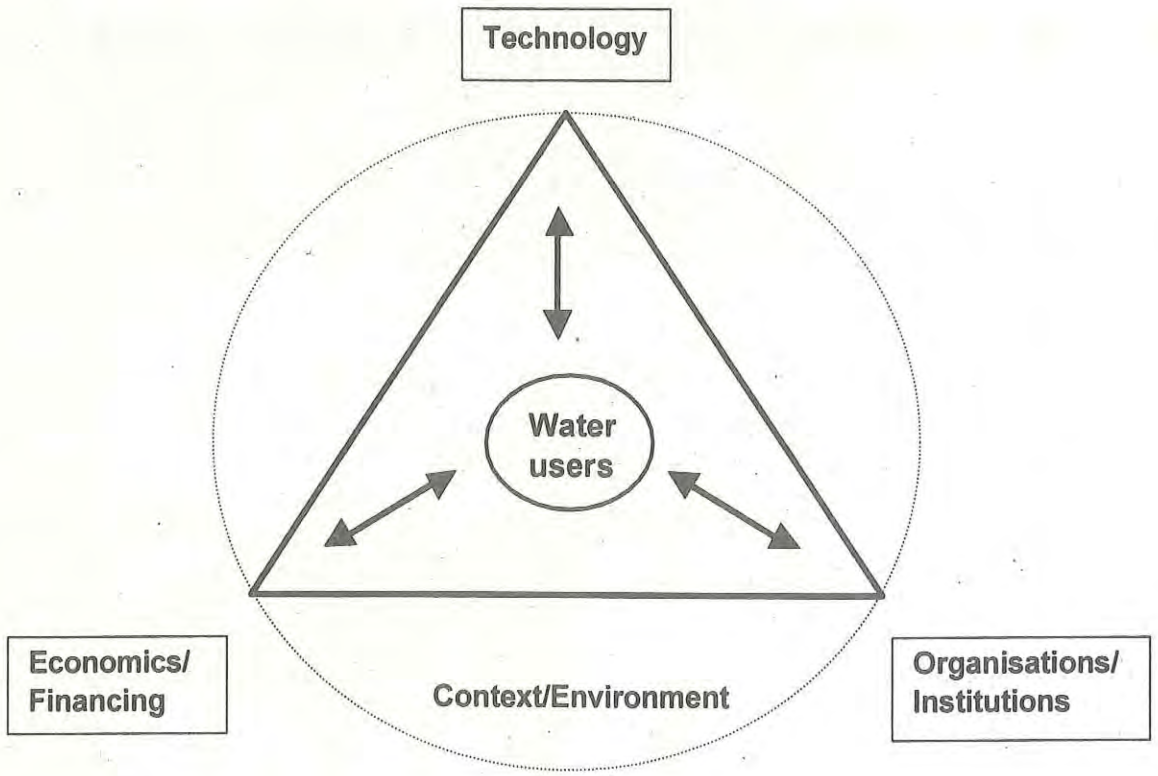
As outlined in Chapter 2 the performance of an irrigation scheme is dependent, amongst other factors, on the condition of the physical infrastructure. This chapter investigates the various relationships that exist and strives to set the performance of the infrastructure in context.

3.2 The 'Maintain' Framework

The Maintain framework sees irrigation systems as service delivery systems with three major domains fitting within its broad environment (Figure3):

- Technology
- Organisations/Institutions
- Economics/Financing

Figure 3: Irrigation systems as service delivery systems: Major domains

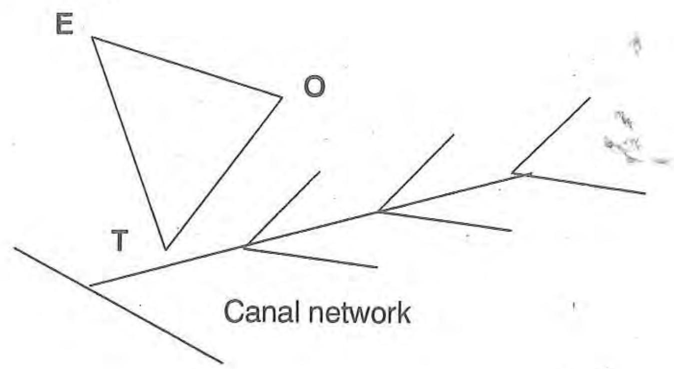


This framework is not dissimilar to that used in business management analysis, where the acronym PESTLE is used to investigate the domains of:

- Politics
- Economics
- Social
- Technology
- Legal
- Environment

Another way of viewing the E-T-O triangle is to see it overlying the physical irrigation network, and having different mixes at different locations (Figure 4). At the main system level the mix will focus on the irrigation service provider's technology (control systems, etc.), financing (staff pay, incentives, etc.) and organisational structure. At the field level the mix will focus on the farmer's technology (irrigation methods, etc.), financing (crop production, market price, etc) and organisation. There will be interactions between the E-T-O domains and the behaviour of the physical system at the different levels. The behaviour of one part of the physical system may influence the behaviour or outcome in another part of the system. At all levels there will be interaction between the human and physical dimensions.

Figure 4: Inter-relationship between the major domains and the performance of the physical infrastructure



3.3 Nested Systems

Another way of looking at the inter-linkages that exist is that of "nested systems" (Figure 5) proposed by Small and Svendsen (1992). This approach is helpful as it clearly shows the distinction and linkage between the physical canal network (the irrigation system) and the "production" base (the irrigated agriculture system and the agricultural economic system). Thus the performance of the agricultural economic system and its components (market price, cost of labour, etc.) is dependent on the performance of the irrigated agriculture system and its components (crop yield, availability of labour and machinery, etc.). This in turn is dependent on the performance of the irrigation system and its components (water delivery, gate operation, canal capacity, etc.). It is essential in the analysis of performance that these systems are identified, separated out and their individual performance assessed. Such performance assessment will be in terms of the system's *inputs, processes, outputs* and *impacts.* The outputs from one system will depend on the quantity and quality of the inputs (as outputs from the "lower" system). The performance of the system will depend on the processes used in converting inputs to outputs, in the case of the irrigation system these will be the operation and maintenance processes. Measurement of performance will be in terms of the *efficiency* of converting inputs to outputs and the *productivity* consequent upon the processing of the inputs. Account will need to be taken of actual or potential impacts of the process, waterlogging and salinisation, for example, which are often a consequence of poor irrigation system operation may take years to develop to a point where they adversely impact on production.

3.4 Causal Chains

A further form of performance analysis is through the development of *causal chains* linking the various contributing factors. Causal chains help to knit together the influencing elements from the different domains and systems discussed above. They are particularly useful for highlighting points of weakness.

Figure 6 shows a possible causal chain relating the level of service provision in terms of water delivery to the condition of the physical infrastructure. Figure 7 shows a similar possible causal chain linking level of service provision to system operation. In complex systems there may be several causal chains acting, these can be brought together in a branching network diagram (Figure 8). Note that causal chains do not have to be looped as shown in Figures 6, 7 and 8.

Figure 5: Irrigation in the context of nested systems (after Small and Svendsen 1992)

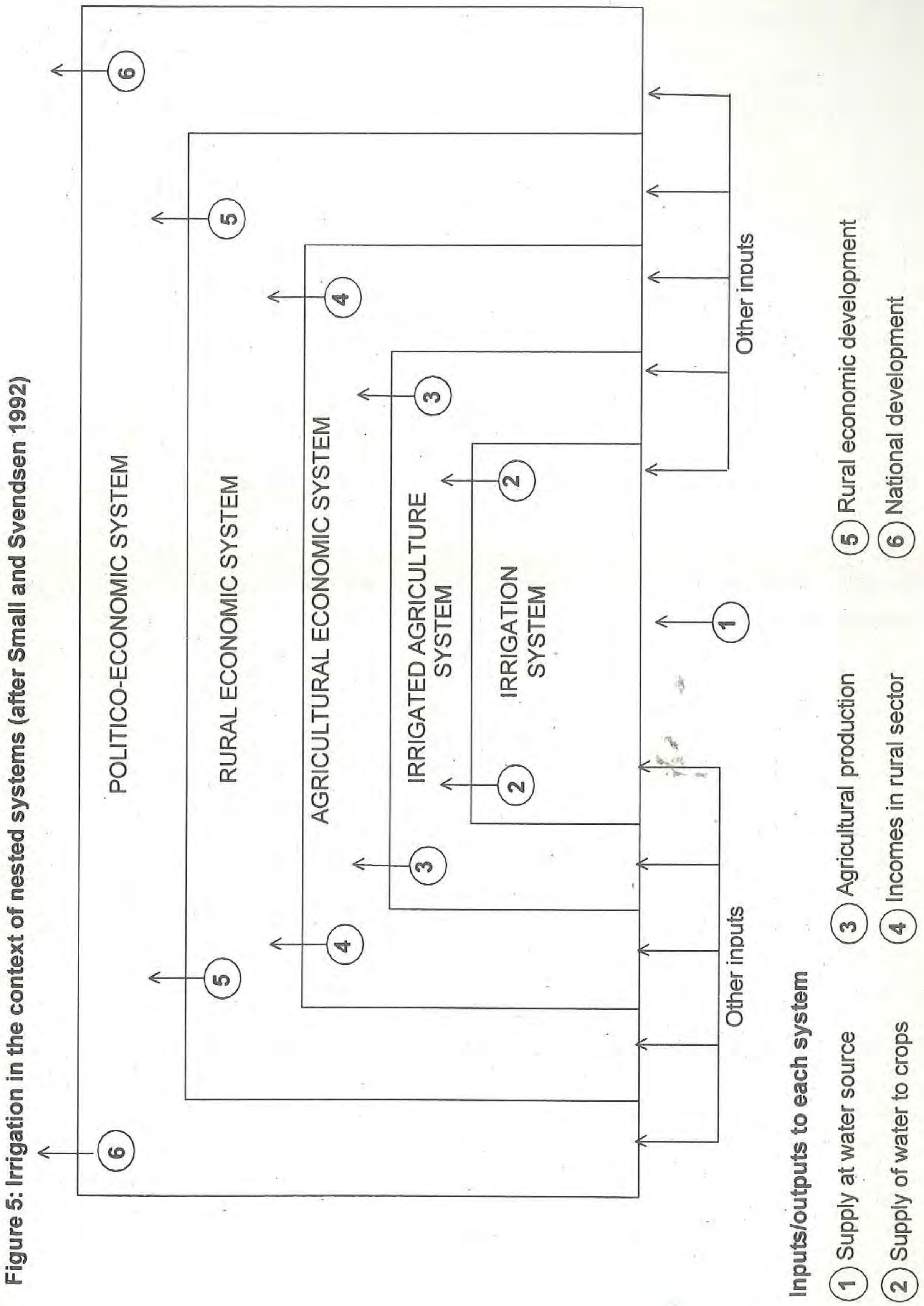


Figure 6: Possible relationship between level of service provision and irrigation infrastructure condition

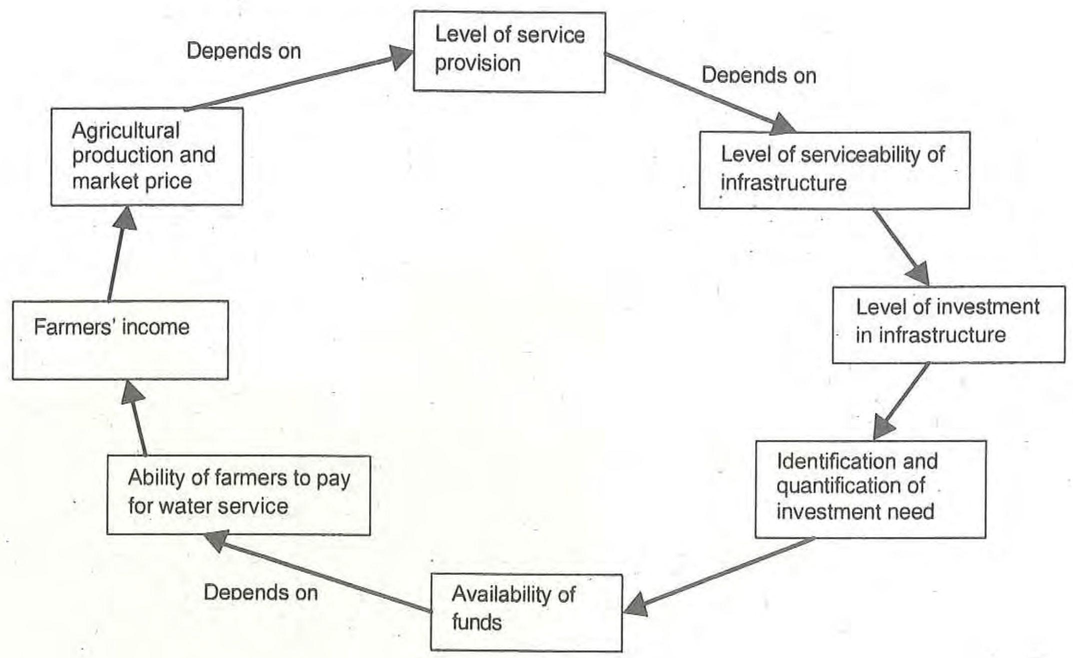


Figure 7: Possible relationship between level of service provision and operation of irrigation infrastructure

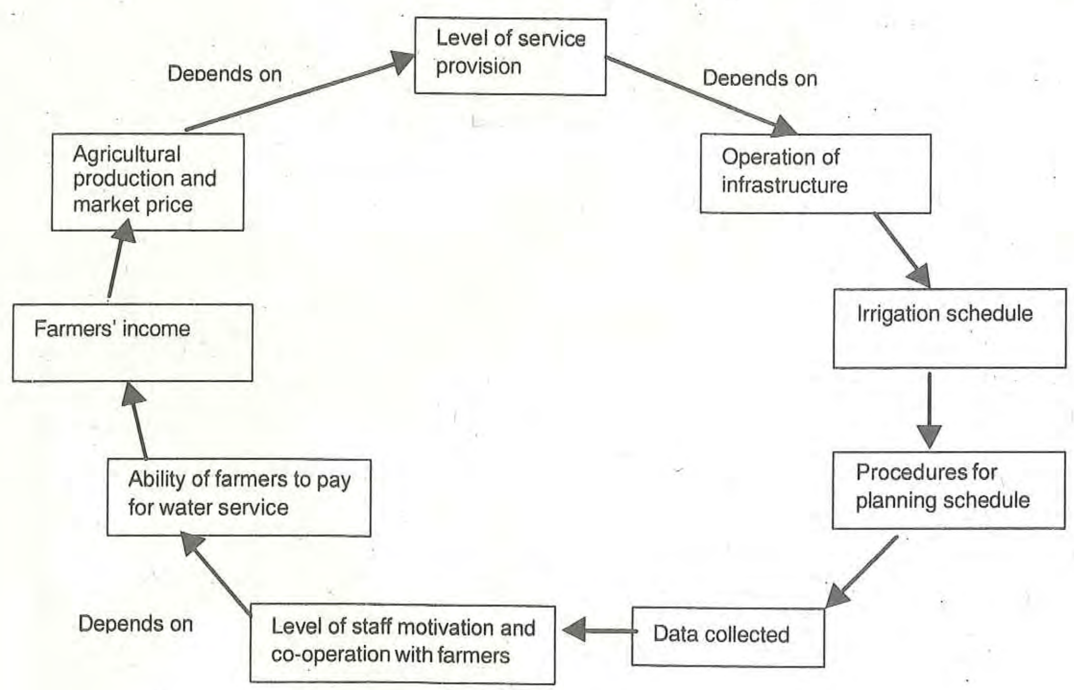
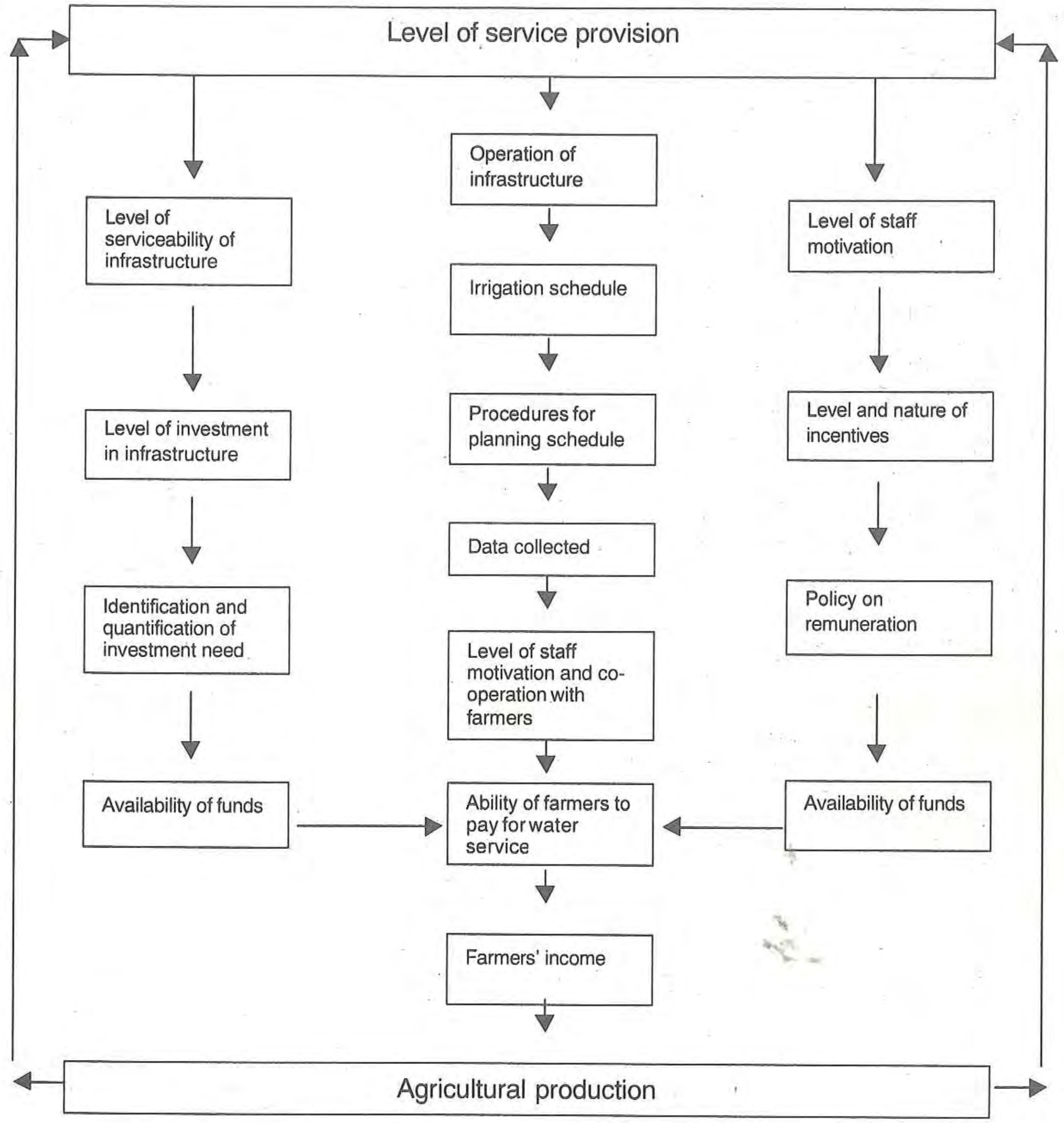


Figure 8: Complex causal chains represented as a branching network



3.5 Performance of the Irrigation System

As has been discussed above the performance of the irrigation system is one component in the overall performance of an irrigated agriculture system. In turn the performance of the irrigation system is dependent on how it is operated and maintained. It is helpful to assess performance in the context of 'evel of service provision, either in terms of the system operation or its maintenance. The two are inter-linked, maintenance can affect operation, and operation can affect maintenance. In general adequate maintenance is a necessary prerequisite for operation.

The analysis of the performance can be carried out in terms of the system's *inputs, processes, outputs* and *impacts*, and in terms of the perspective from which the assessment is carried out. The farmer is probably only directly concerned with the output, the delivery of water to the tertiary unit, farm gate or field to suit the farmer's needs.

Focusing on the level of service provision from the perspective of the farmer the performance of the system can be assessed using the following criteria for the delivery of water (after Burton and Hall 1999):

Table 4: Possible criteria for assessment of level of service provision (of irrigation water supply) from farmers' perspective

High priority	Moderate priority	Low priority
• Command (Water level) • Adequacy • Timeliness • Reliability • Security	• Cost • Quality • Convenience • Flexibility	• Efficient • Equitable (Fair) • Safety

These criteria have been ranked to emphasise the fact that farmers have different levels of priority for the various criteria, and will be prepared to forego some and not others. The ranking is scheme specific and may vary between farmers. Obtaining these expressed preferences and rankings is not easy, but is essential if the desired level of service is to be defined. To the author's knowledge little, if any, work has been done on assessing farmers' desired level of service in smallholder irrigation schemes in developing countries. If performance of the water delivery system is to be improved, and farmers expected to pay for the water service provided, this issue needs to be addressed.

A useful criteria for ranking, or inclusion of a criterion in the ranking, will be to ask if the farmer would be prepared to pay for this service, and if so how much. It may not be necessary to exactly quantify (even if it were possible) the linkage between, say, the cost and increased timeliness of supply. Rather the farmer could be asked if they would be prepared to pay, for

example, an extra $5 per irrigation for delivery of a water supply which was within (say) 30 minutes of the scheduled time (rather than the present (say) 1-2 hour delivery time range).

Performance indicators can be identified for each criterion (Table 5) enabling their level of achievement to be quantified and measured. A variety of performance indicators have been identified, though they have not yet been classified in the manner proposed here (Molden and Gates 1990; Murray-Rust and Snellen 1993; Rao 1993; Bos 1997)

Table 5: Selection of possible performance criteria and indicators for defining performance within the irrigation "system"

Criteria	Indicator
Command	Relative Water Level, RWS Water Level Variability Index, WLVI
Adequacy	Relative Water Supply, RWS Water Delivery Performance, WDP Management Performance Ratio, MPR
Equity	Relative Water Supply, RWS Water Delivery Performance, WDP Management Performance Ratio, MPR
Reliability	Relative Water Supply, RWS Reliability Index, RI
Efficiency	Project Water Use Efficiency, PWUE Conveyance Efficiency, CE

The highest priorities are probably command, adequacy, timeliness, reliability and security of supply. The cost and quality of the water supply are probably a lower priority unless these are extreme, either high in terms of cost or low in terms of quality. Convenience and flexibility are desirable but not essential, farmers will often adjust to suit rigid irrigation schedules. Farmers are probably not worried about efficiency (in the main system), unless water is in short supply and the adequacy is affected, nor are they particularly worried about equity (unless they perceive that they are not getting a fair share!). Safety of the irrigation system in terms of risk to people or animals drowning is probably seen as a low priority by farmers.

This hierarchy of priorities can be linked to Maslow's hierarchy of needs (Maslow 1943). Maslow postulated that people have 5 levels of basic needs: physiological (food/water) needs, safety needs, love needs, esteem needs and need for self-actualisation. Maslow argued that people strive to satisfy these needs, starting with physiological needs moving up to the need for self-actualisation, and that once a need is satisfied it is no longer a felt need. In the same way it can be argued that different farmers and farming communities have different felt needs depending on their particular circumstances, and that they are at different points in the hierarchy.

A similar table of criteria and priorities can be constructed for the irrigation service provider, though the priority of the criteria may be different as the service provider will be focusing on inputs and processes as well as outputs. The service provider may have to compromise output as a consequence of limitations related to inputs (river flow pattern) and processes (control infrastructure).

Thus these criteria and their associated performance indicators form the basis for defining and describing the level of service provision in an irrigation system. The current level of service can be determined through separate questionnaires to both the service provider and farmers and from data collected by the irrigation service provider. The priority of each criterion needs to be ascertained, and the conditions under which such rankings apply investigated. Questioning of farmers and service provider staff will provide useful insights into how the farmers and service provider see the system and their environment. In a water scarce, arid environment it can be expected that reliability and timeliness would be paramount criteria for farmers, whilst in water abundant systems reliability, adequacy and timeliness might be taken for granted and cost, convenience and flexibility be seen as more important.

As stated previously the ability to deliver the desired level of service will primarily depend on:

- the type of infrastructure provided
- the condition and performance of the infrastructure
- the O&M management capability.

In relation to asset management it is important that the performance of the infrastructure is separated out from the performance of the management. For this a two-part process has been developed (Burton and Hall 1999; Hall et al. 1999).

The first part of the process is to identify the performance of the system as described above. This is done by using the Serviceability Matrix given in Table 6 which shows the performance at four levels: scheme, system, farmer and statutory. Scheme level relates to overall performance of the scheme and uses criteria and performance indicators that produce an overall assessment for the scheme. System level relates to the irrigation network and uses criteria and performance indicators that relate mainly to the inputs and the processes of water conveyance. Adequacy and timeliness and command in this respect relate specifically to input (at water source) and process (throughout the network), *not* to output. Equity, efficiency (conveyance and pumping where used) and financial cost are key criteria at this level. The farmers' requirements (which are also the irrigation service provider's requirements) cover criteria that are important to farmers', as discussed above. Statutory requirements are those, such as drainage outfall from irrigation schemes into rivers, which might be stipulated by law.

Table 6: Possible Irrigation Serviceability Matrix A: criteria and classifications (after Burton and Hall 1999)

	SCHEME PERFORMANCE				SYSTEM PERFORMANCE				
Grade	Productivity	Cropping Intensity	Cost (Economic)	Efficiency (Resource use)	Adequacy and Timeliness	Command	Equity of supply	Efficiency	Cost (Financial)
1	Greater than 90% of potential	Greater than 90% of potential	Very highly economic	Very high	Adequate and timely at all times	Target levels maintained at all times	Water distribution equitable	Efficiency levels match target values	Highly viable
2	70-89% of potential	70-89% of potential	Highly economic	High	Generally adequate and timely	Target levels generally maintained	Distribution generally equitable	Efficiency levels generally adequate	Very viable
3	50-69% of potential	50-69% of potential	Moderately economic	Moderate	Adequate and timely on average	Target levels maintained on average	Distribution equitable on average	Efficiency levels adequate on average	Moderately viable
4	30-49% of potential	30-49% of potential	Marginally economic	Low	Frequently inadequate/ untimely	Target levels frequently not maintained	Distribution frequently inequitable	Efficiency levels frequently inadequate	Low viability
5	Less than 29% of potential	Less than 29% of potential	Uneconomic	Very low	Completely inadequate/ untimely	Levels not maintained.	Water distribution is inequitable	Efficiency levels unacceptable	Not viable

	FARMERS' REQUIREMENTS						STATUTORY REQUIREMENTS	
Grade	Adequacy and Timeliness	Command	Reliability of supply	Security of system	Water quality	Waterlogging and Flooding	Health and Safety	Environment
Grade 1	Adequate and timely at all times	Target levels maintained at all times	Fully reliable	No risk of failure	No constraints	None	Complies	Complies
Grade 2	Generally adequate and timely	Target levels generally maintained	Generally reliable	Some risk of failure	Some constraint	Some incidence	Not applicable	Mild hazard
Grade 3	Adequate and timely on average	Target levels maintained on average	Reliable on average	Moderate risk of failure	Moderate constraint	Moderate incidence levels	Not applicable	Moderate hazard
Grade 4	Frequently inadequate and/or untimely	Target levels frequently not maintained	Frequently unreliable	High risk of failure	Serious constraint	Serious incidence levels	Not applicable	Serious hazard
Grade 5	Completely inadequate and/or untimely	Command levels not maintained.	Completely unreliable	Failed or failure imminent	Quality fatal to agricultural production	Unacceptable incidence levels	Non-Compliant	Non-Compliant

Table 7: Irrigation Serviceability Matrix B (Burton and Hall 1998)

Canal section	Asset number	Description	Performance	Condition	Importance	Priority Index	Color Code*	Estimated cost (£)
M1/C1	1101	Head regulator	1	3	1	-		-
M1/C1	1102	Tertiary offtake M1/C1/1	2	2	3	-		-
M1/C1	1103	Tertiary offtake M1/C1/2	1	4	3	002	BLUE	1,200
M1/C1	1104	Cross regulator	5	5	2	001	RED	5,237
M1/C1	1105	Tertiary offtake M1/C1/3	1	3	3	-		-
M2/C4	2401	Head regulator	1	2	1	-		-
M2/C4	2402	Tertiary offtake M2/C4/1	1	2	3	-		-
M2/C4	2403	Tertiary offtake M2/C4/2	2	4	3	003	BLUE	2580
M2/C4	2404	Tertiary offtake M2/C4/3	1	3	3	-		-
M2/C4	2405	Tertiary offtake M2/C4/4	5	2	3	004	YELLOW	3200
M2/C4	2406	Cross regulator	2	2	2	-		-

Note: 1. The entries are indicative only
2. In the database the row is color-coded and this column is not required

KEY TO COLOUR CODING

Asset failure	Performance	Condition	Description
RED	1,2,3,4,5	4,5	Asset has, or is about to, completely fail, and must be repaired/replaced

Warning Indicator	Performance	Condition	Description
BLUE	1,2	4	High risk of asset failure. Low perception of risk due to high performance of asset

Problem Indicator	Performance	Condition	Problem
YELLOW	4,5	1,2	Problem with asset. Engineering assessment to determine nature and extent of problem e.g. inadequate canal capacity.

4. Procedures for Rapid Asset Appraisal

4.1 Context

The procedures detailed in Chapter 2 describe a process that an irrigation service provider might undertake, often over a period of several years. When carrying out institutional appraisals as part of the *Maintain* project information is required on the condition and performance of the irrigation and drainage infrastructure within a short time frame. The procedures outlined in Chapter 2 can be adapted to achieve this.

In looking at maintenance of irrigation and drainage systems it is important to be aware that the condition and performance of the infrastructure is a function of its:

- design
- construction
- operation
- maintenance.

The quality of the design and construction influence the rate at which the infrastructure deteriorates and how it performs its intended function. How the infrastructure is used and operated can affect its condition and performance, as can the level of maintenance.

In relation to maintenance, the condition and performance of the infrastructure is influenced by the level of:

- day-to-day maintenance
- annual maintenance
- emergency maintenance
- deferred maintenance
- capital replacement.

Information on the first three components is relatively straightforward to obtain from records kept by the irrigation service provider and discussions with service provider staff. The information required relates to the expenditure, type and extent of the work carried out.

Information on deferred maintenance (which is an accumulation of a failure to adequately carry out all requirements under the first three categories) is difficult to obtain as records of total (outstanding) maintenance requirements are often not kept. Failure to carry out necessary maintenance work has essentially "mined" the asset base, resulting in system deterioration.

The final category, capital replacement, represents expenditure to replace assets as they reach the end of their useful life, or become obsolete. Failure to adequately maintain the assets during their lifetime can obviously lead to a more rapid deterioration and a reduced life expectancy. This category is often not considered in maintenance studies.

For the fourth and fifth maintenance categories identified above a detailed study is required of the asset base to assess it current condition and level of performance. During an appraisal of the institutional issues related to maintenance there is not the time to carry out a detailed study of the asset base and simplified measures have to be used. The full asset management process cannot be followed, particularly in respect of ascertaining potential expenditure required to upgrade the irrigation and drainage system to enable it to provide the desired level of service.

4.2 Procedures for Rapid Asset Appraisal

For this purpose data need to be collected to determine the current condition and level of performance of the infrastructure and includes determining:

- the extent of the asset base
- the condition of the assets
- the performance of the assets
- the importance of individual assets

Such a study will complete the analysis of the maintenance situation on a given scheme. Where the asset base is maintained in a good state of repair, and assets are replaced as they reach the end of their useful life, as is the case with the Neste System in Southern France (Huppert and Hagen 1999), such a study might not be required. In this case the charges made for maintenance reflect the true cost of maintaining the system over time.

The steps required to carry out a rapid asset appraisal are summarised in Table 8 and discussed below.

- *System overview*

  A preliminary survey of the irrigation and drainage system and scheme are essential in order to gain an overall view of the situation. During this period the infrastructure should be inspected, discussions held with farmers and service provider staff on their perception of scheme performance and levels of service provision. Note should be taken of the appearance of the crops, crop yields, marketing, soil conditions, farming practices, etc.

- *Obtain general background data*

  The next step is to obtain background information on the scheme. This will include maps and aerial photographs (if available), and records of cropping over recent years. This data will form the backbone of subsequent data collection and analysis.

  The extent and quality of the data available will provide an insight into the standard of management, operation and maintenance on the scheme.

- *Obtain and process detailed system performance data*

  Detailed data will be required to enable an assessment to be made of the performance of the irrigation scheme and to identify potential areas of concern. Secondary data will be required for this analysis, there will not be time to collect primary data.

- *Identify current and potential performance level and current and desired level of service provision*

  The analysis of the data will help to identify the level of performance within the scheme. Discussions with farmers and service provider staff will enable the identification of the perception of the current level of service and the desired level of service. From the analysis of the actual performance an assessment will be possible of the potential performance level, leading on to identification of the gaps and current constraints to production. This analysis is a major activity, the degree to which it is carried out depends upon the time available and the experience of those performing the assessment. Arising from the analysis will be an assessment of the potential impact the current condition and performance the irrigation and drainage infrastructure has on scheme performance.

- *Obtain maintenance data*

  Information needs to be collected on the extent and type of maintenance work carried out, and the expenditure on maintenance. This information is required for a period of at least 5 years, if possible, to assess trends. From analysis of the data it will be possible to form an opinion on the maintenance situation and its likely impact on the condition and performance of the infrastructure.

- *Determine extent of asset database, stratify and select sample base*

  The ease with which the asset base can be obtained varies from scheme to scheme. Many schemes have asset inventories and schematic diagrams that provide information on the asset base and the location of the assets. Some schemes have as-built construction drawings which can prove invaluable. Having such records obviously simplifies the task of preparing an asset database. The validity of the database can be assessed during the asset survey. From the asset database and field inspections the stratification of the assets can be carried out and the number of samples sets and their size determined. It is important that the assets to be inspected in each sample set are selected randomly. Appendix A1 outlines procedures for stratification and selection of sample sets.

- *Carry out asset survey*

  To save time it will be necessary to map out the location of the assets selected for inspection and to move through the system inspecting them. In almost all cases the headworks will be a one-off assessment, the asset survey can start there and proceed downstream. During the asset survey it is valuable to be aware of the system as a whole and note any features/factors which might influence scheme performance. Standard proforma can be drawn up for the asset survey, or notes made in a notebook using a data collection checklist for each asset type. An example of a data collection proforma is given in Table 9. Examples of asset condition performance grading are given in Appendix A2.

- *Formulate asset condition and performance report*

  Once the sample sets of assets have been surveyed the data set can be expanded to the whole population and a picture obtained of the condition and performance of the scheme's infrastructure. The assessment of the impact of the current condition and performance of individual assets on the overall performance of the scheme has to be made once all the data has been collected. This assessment is not easy, and some subjective judgement will be required to make the assessment. Recent studies by El-Askari (1999; GICC 1998) have shown the significant value of using hydraulic modelling to aid such assessment. In these studies El-Askari used hydraulic modelling to identify linkages between asset performance in one part of the irrigation system with impacts at other locations. Amongst others, the impact on downstream water delivery of sediment levels within canal sections was investigated, as was the impact on downstream water delivery of damaged or poorly maintained control structures.

Table 8: Summary of steps for rapid asset appraisal

	Data and Details	Purpose
System overview	• inspect canal and drainage system • preliminary talks with farmers and service provider staff on system management, operation and maintenance	To gain an overview and the "feel" of the irrigation and drainage system as a guide to the approach to be adopted for the asset survey. Note the general type and condition of the infrastructure, the type, condition and quality of the farming.
Obtain general background data	Background data includes: • maps • climatic data • scheme cropping pattern • average crop yields and production • system operation and maintenance procedures	Gain more detailed insight of the scheme, the layout, production levels, management, operation and maintenance procedures. Start to formulate initial opinion of the management, operation and maintenance, and its implications for scheme performance.
Obtain and process detailed system performance data	• crop type, yields and production per tertiary unit • irrigation water supply at primary, secondary and tertiary head regulators • process data ready for analysis	Obtain and process data to quantify scheme performance and potential problems.
Identify current and potential performance level and current and desired level of service provision	• analyse performance data to identify production problems: low yields, differential production performance • hold discussion with farmers and service provider staff to ascertain views and perceptions on current and potential performance level and level of service provision • identify and quantify current level of performance and level of service provision • identify and quantify potential/desired level of performance and level of service provision • identify nature and cause of gaps and constraints • decide if infrastructure condition and performance may influence overall system performance	Analyse data to quantify current and potential levels of performance and current and desired level of service provision. Identify the gaps and constraints and assess the likelihood that the condition and performance of the infrastructure might be a factor.

(continues from previous page)

Obtain maintenance data	• recurrent maintenance budget and allocation • annual expenditure on maintenance contracts • annual expenditure on emergency maintenance • maintenance requirements • maintenance staff, equipment and facilities • form opinion on maintenance situation	Understand situation in relation to maintenance. Answer questions: Is maintenance funding high, moderate, low? Is maintenance work being deferred? Are maintenance procedures (for work identification/ prioritisation, etc) adequate? Is lack of maintenance an issue?
Determine extent of asset base, stratify and select sample base	• obtain asset database • obtain design drawings (if available) • decide on stratification, sample sets and size • decide on sample sets • decide on normalisation measures for each sample set	Identify and categorise asset types, sizes, function etc. Prepare stratification of the system and decide on sample sets and sizes, and normalisation measures for each sample set. Preparatory work for carrying out asset surveys.
Carry out asset survey	For selected sample sets: • categorise and record asset condition • categorise and record asset performance • categorise and record asset importance	Obtain the fieldata for the sample sets from which to be able to formulate asset condition and performance inventory report.
Formulate asset condition and performance report	• expand sample set data to full population ("normalisation") • assess impact of infrastructure on scheme performance and level of service provision • finalise findings of influence of infrastructure on current system and scheme performance and level of service provision. • Finalise findings on gaps between current and potential scheme performance and current and desired level of service in relation to infrastructure condition and performance • prepare Asset Condition and Performance Report	Formulate final findings on the influence of infrastructure condition and performance on current and potential/desired scheme performance and level of service provision. Write up findings as Asset Condition and Performance Report.

Table 9: Example of proforma for asset survey data collection

Canal/drain name:

Chainage Start-Finish		Asset type	Facet	Condition Rating (1-5)	Perfor-mance Rating (1-5)	Importance Rating (1-5)	Discharge capacity (m^3/s)	Leading dimensions				Remarks
Start (Km)	Finish (Km)							Height (m)	Width (m)	Length (m)	Other	

Survey conducted by:

Name: **Date:** **Position:**

5. Conclusions and Recommendations

Procedures for long-term asset management planning, and rapid asset condition and performance studies have been outlined. Some procedures developed for long-term asset management planning can be used for rapid appraisal of asset condition and performance. A central issue is the identification of overall system performance and the separating out of performance issues which are due to management and those which are due to the condition and performance of the physical infrastructure. This is not an easy task, and has to be approached in a systematic manner. To facilitate this Serviceability Matrices have been developed which can be used to define the level of service and which can then be used to measure performance.

Experience is increasing in respect of defining the level of service, and involving the farmers in the process. The historical top-down approach is changing in many countries and more democratic and user-defined procedures and standards are emerging. These processes can be expected to increase in the coming years.

Asset surveys as outlined in this paper are relatively new. Standardised approaches need to be developed which can be used internationally to classify the condition and performance levels of irrigation and drainage infrastructure. In addition further research is required to develop understandings of generic relationships between an asset's condition and its performance. These relationships are imperfectly known at present, further knowledge is required if investment and expenditure on infrastructure is to be made more effective.

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Annex A1 Stratified Sampling for Asset Surveys

A.1.1 Steps

Where time and resources are limited sampling techniques can be used to determine asset condition and performance. Sampling is the process of choosing items from a larger population in a representative way, with random samples being chosen to avoid bias in the selection. For surveys of individual irrigation and drainage systems the following steps are required:

- sub-divide the irrigation and drainage scheme into sets of assets ("stratification")
- decide on how many samples to take for each set
- carry out the asset survey in the sample sets
- expanding the findings to the whole population ("normalisation")

A.1.2 Stratification and Subdivision

Stratification is the term used for dividing up the members of a set into groups, termed 'strata', having similar characteristics. The more homogenous the members within each strata the more reliable the estimates obtained from studying a limited number of samples. For an asset survey of an irrigation system the physical infrastructure (Table A1.1) can be sub-divided into various groups or sets. Possible criteria for forming these sets are:

- physical size of assets
- hydraulic capacity of assets
- location of assets
- function of assets
- area commanded by assets

Within each stratification group the assets can be further sub-divided by "banding" them into size ranges.

The selection of the stratification will depend mainly on:

- the size of the system
- the homogeneity in the design of similar types of assets
- the complexity or uniqueness of individual assets.

For a straightforward system where standard designs have been applied throughout the scheme the stratification might be (for the main system only):

- the headworks
- canals banded into sizes based on hydraulic capacity
- drains banded into sizes based on hydraulic capacity
- all cross regulators, banded into sizes based on hydraulic capacity
- all head regulators, banded into sizes, based on hydraulic capacity
- pipe culverts banded into three sizes based on hydraulic capacity and length
- bridges banded into sizes based on span and width
- roads grouped separately as surfaced or earth, and banded into sizes based on width

Table A.1. 1: Physical components of irrigation and drainage schemes

Component	Levels	Function
Canals	Primary Secondary Tertiary Quaternary	To convey water
Drains	Primary Secondary On-farm	To remove water from the field
River weir	Main canal	To divert and control irrigation supplies
Headworks	Main canal intake	Used to describe the structure(s) at the intake to the main canal. These may be a group of structures including a river weir, head regulator, settling basin, measuring structure, or one structure such as a pump station.
Pump station	Main canal Main drain	To lift water to command level for irrigation. To remove water from drainage channels which are below river level
Settling basin	Main intake canal	To settle out sediment
Cross regulator	Primary and secondary canals	To raise and maintain water surface at design elevation
Head regulator	Primary, secondary and tertiary canals	To regulate discharge entering a canal
Measuring structure	Primary, secondary and tertiary canals	To measure discharge for operational purposes
Aqueduct	All levels of canal	To pass canal over an obstruction (another canal, a drainage channel, etc)

Culvert	All levels of canal or drain	To pass canal or drain under an obstruction (road, drainage channel, etc)
Drop structure	All levels of canal or drain	To "drop" the canal or drain bed level in a safe manner. Used to slacken canal or drain slopes on steep land
Escape structure	All levels of canals	Used to escape water from a canal into the drainage network in the event of oversupply or under-utilisation.
Syphon underpass	All levels of canals	Used to pass the canal below an obstruction such as a road or drainage channel.
Distribution box	Quaternary canal	Simple distribution structure to distribute the water between quaternary channels
Night storage reservoir	Main canal or on-farm	Reservoir to store irrigation water during the night. Main canals thus operate 24 hours/day whilst lower order canals can be operated during the daytime.
Tubewell	On-farm	Abstraction of groundwater for irrigation. Often used in conjunction with surface water system
Bridges	Road bridges Foot bridges	To allow human and animal traffic over the canal or drain
Roads	Inspection roads Access roads	To gain access to the irrigation system and villages. For inspection and maintenance
Fields	Within tertiary unit	Prepared land to cultivate the crop. Laid out for different methods of irrigation (basin, furrow, sprinkler, etc)
Villages	Throughout scheme	Habitation for the farming community
Access points	Main canals	Access points into the canal for human and animal traffic for obtaining water, washing, etc.

An alternative approach might be (for the main system only):

- the headworks
- sections of the primary canal(s)
- selected secondary canals and structures
- sections of the main drain(s)
- selection of secondary drains and structures

In the first approach representative samples would be taken of each of the sets of assets of a similar type, in the second approach the sets would contain different types of assets with the mix of types and size of assets within a set being similar throughout the scheme.

A.1.3 Selection of Samples for each Set

Reference needs to be made to standard texts on sampling theory to be precise about the correct number of samples to take for each set. A sample of 10% of the population is usually adequate, with an absolute minimum of 5 individual assets in the set. For one-off assets, such as the headworks or other large structures, an individual survey for the asset has to be carried out. If time and resources are limited a compromise has to be made between the accuracy of the final analysis and the sample sizes.

It is important to select random samples within each group though this may also be stratified by selecting a certain number of samples from different locations within the system.

A.1.4 Carrying out the Asset Survey

Having decided on the stratification and number of samples the surveys can be carried out as described in Appendix A2.

A.1.5 Normalisation

The final part of the sampling process is to expand the analysis from the samples up to the full population, this is termed "normalisation". Typical normalisation measures include:

- irrigated area/command area
- volume/length of canal/drain
- number of similar assets

If the stratification has been based on the type and size of assets then normalisation of the samples to represent the whole population is achieved by multiplying up by the total number of that type/size of asset in the whole population. Thus if 30% of the assets sampled are in Condition Grade 2, 20% in Condition Grade 3 and 50% in Condition Grade 4 then these percentages will apply to the whole population of that asset.

If the stratification has been carried out using the second approach described in Section A1.2 above then the results obtained will have to be normalised based on the length of the primary canal and main drain samples, and the areas commanded by the secondary canal samples in relation to the total lengths and areas within the scheme.

Annex A2 Asset Condition and Performance Assessment

Differentiating between Asset Condition and Performance

A distinction needs to be drawn between the condition of an asset and the impact that condition level has on the performance of the asset in its defined function. It is possible to find an asset, such as a cross regulator, which is in poor condition but which is still adequately performing its function. In the UK water industry it was found that money was being spent on improving the condition of assets whilst there was little visible or felt improvement in the system's performance (Southern Water 1998). With limited availability of funds the focus has turned towards expenditure on assets to maintain or enhance performance leading towards maintaining or enhancing the level of service provision to the customer.

Splitting the assessment of the asset into two parts, condition and performance creates difficulties in:

- surveying of the assets
- deciding on priorities for expenditure
- deciding how performance and condition are linked.

The key to overcoming these difficulties is to be clear and explicit about the function of each asset.

In the sections below the procedures are outlined for condition, performance and importance grading.

Condition Grading of Assets

Asset condition inventories are now becoming fairly standard in many civil engineering systems. In some cases significant steps have been made towards standardising the condition grading (Banyard and Bostock 1998; McKay et al. 1999; Andersen and Torrey 1995).

For condition grading the asset must be divided up into it main component parts, termed "facets", and the condition of each of those parts assessed separately. Thus a gated cross regulator might be divided into its upstream wingwalls, upstream base and cutoff, throat section, downstream wingwalls, downstream base and cutoff, and gate.

For condition grading there are two basic questions which need to be borne in mind when surveying the asset:

- Is the asset safe?
- Does the asset require repair?

Much condition grading relies on visual observation, though in the U.S. Army Corps of Engineers (USACE) Directorate of Civil Engineering the condition assessment includes physical tests, such as load testing (McKay et al. 1999; Andersen and Torrey 1995). In the UK water industry a 5-point grading system has been adopted as shown in Figure A2.1. In addition colour photographs illustrating the various condition grades have been used to minimise the subjectivity involved when assessing asset condition (Glennie et al. 1991).

Figure A.2. 1: Example of standardised condition grading for a concrete bridge over a canal or drain

Concrete Bridge Structures	
Condition Grade	**Description**
1	No visible defects. No more than hairline cracks, no signs of any honeycombing or spalling.
2	Wider cracking, greater than 0.5 mm. Localised honeycombing and spalling. Concrete flaking. Signs of previous repair.
3	Rust staining. Spalling of concrete or exposure of reinforcement. Extensive or widespread honeycombing. Evidence of weathering/erosion. Surface covered in vegetation
4	Extensive/widespread concrete spalling. Extensive exposure of reinforcement and rust staining. Signs of reduced structural integrity.
5	Clear evidence of structural failure or that failure is imminent.

Performance Grading of Assets

Performance grading seeks to assess the degree to which the asset is able to perform its function. The assessment is for the asset as a whole if it has only one major function, or for relevant aspects if it has several functions. The main questions, which need to be borne in mind when carrying out the performance survey, are:

- can the asset perform its function?
- can the asset perform to its design capacity?
- how does the performance of the asset influence system performance?

The performance grading system is similar to that for condition grading, with five grades. To focus on the functionality aspect a Function Statement is attached to each asset that defines its function. An example of performance grading for a canal head regulator is given in Figure A2.2. The performance grading must relate carefully to the Function Statement, thus for a head regulator the performance relates to the structure's ability to *control* flow entering the canal, whether it be to the design maximum, or to zero.

A feature of performance grading of the asset is that it may require testing of the asset. Thus in the case of a head regulator the gate must be operated during the survey to see that it can pass the design discharge, or close off the supply completely. This can be in conflict with condition grading which may require the system to be drained in order to inspect parts of the asset which are normally submerged.

Figure A.2. 2: Example of standardised performance grading for a canal head regulator

Canal head regulator	
Function Statement	To control and regulate water entering a canal from design maximum discharge to zero flow.
Performance Grade	**Description**
1	The structure can pass the design maximum flow, and can be shut completely to pass zero flow. There is no seepage around or under the structure into the canal.
2	The structure has restrictions on its ability to pass the design maximum flow, cannot be shut completely, and/or there is seepage around or under the structure into the canal. Canal discharge is limited to 80% of design, or the discharge entering the canal cannot be reduced below 20% of design.
3	The structure has significant restrictions on its ability to pass the design maximum flow, cannot be shut completely, or there is significant seepage around or under the structure into the canal. Canal discharge is limited to 60% of design, or the discharge entering the canal cannot be reduced below 40% of design.
4	The structure has severe restrictions on its ability to pass the design maximum flow, cannot be shut completely, or there is severe seepage around or under the structure into the canal. Canal discharge is limited to less than 40% of design, or the discharge entering the canal cannot be reduced below 60% of design.
5	There is no control of discharge through, around or under the structure. Discharge entering the canal may be zero or greater than 100% of design.

Importance Grading

The importance of an asset is a measure of its strategic importance to the overall functioning of the irrigation system (Cornish and Skutch 1997; IIS 1995). Factors which influence the decision as to the importance of an asset include:

- function
- area served downstream
- area affected or influenced by structure
- cost of replacing the structure
- number of people affected by structure
- danger to health and safety of asset failure
- impact on scheme performance

There is no consensus yet as to a standardised approach to classification of importance. Based on the work of Cornish and Skutsch (1997) and IIS (1995) the following algorithm is proposed to develop an Importance Grading for an asset:

Importance Grading = $(a_i/A) \times FI$

Where:

a_i is the area influenced by the asset. Bridges, roads, escape structures, etc, are assigned a service area equal to that of the canal reach on which they occur

A is the total command area of the irrigation scheme

FI is the Function Index taken from Table A. 2.1

Table A.2. 1: Asset Function Index for determination of Importance Grading for irrigation and drainage infrastructure (after Cornish and Skutsch 1997)

Function Index(classes)				
5	4	3	2	1
Diversion weir Embankment dam Intake works Pump station Barrage	Scour sluice Cross drainage culvert Aqueduct Syphon Sediment trap	Canal reach Head regulator Cross regulator Measuring structure	Drain reach Drop/chute Side weir Tail escape	Inspection road Bridge

The classification of Table A2.1 is somewhat subjective, for a given scheme or schemes it may be adjusted to suit. Note that a_i relates to the area influenced by an asset, thus a cross regulator and a head regulator at a secondary canal division point will have the same Importance Grading as they both influence the same total command area.