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BETTER IRRIGATION BETTER ENVIRONMENT BETTER FUTURE

Understanding and valuing the economic, social and environmental components of System Harmonisation

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Executive Summary

The aim of the Products and Markets component of the System Harmonisation project is to value the economic and environmental outcomes from an irrigation scheme that is operated by and in the interests of society. In this conceptual note the thinking underlying this component of the project are outlined. The aim of this note is to provide elements for debated.

The nature and requirements of System Harmonisation demands that a "systems approach" be taken throughout the project. What becomes important within this approach is how the different elements within a system are isolated and yet linked with one another. In many instances the extent and nature of irrigation systems are defined by the relevant Regional Irrigation Business Partnership (RIBP) under investigation.

It is recognised that society has multiple uses for the water (agriculture, industry, households, recreation and the environment) as well as non-use (intrinsic) values for which it derives benefits from and incurs costs in distributing the water in any select manner. Further, it is assumed that the irrigation schemes are run for the benefit of society as a whole. Thus, there is a necessity to evaluate both the private and public costs and benefits associated with irrigation schemes.

In order to identify what society values from an irrigation scheme, it is argued that a social matrix approach is needed. This analysis allows for a clustering of the issues people feel is important to them regarding the use of an irrigation scheme. Such an analysis will allow identification of the perceived most and least beneficial activities connected to water allocation, economic modelling of the most productive activities, evaluation of externalities and Cost Benefit Analysis.

The net economic benefits that arise from irrigation need to be evaluated. The sectors where benefits are derived can be segregated into agriculture, households, the environment, recreation and industrial uses. The largest of these, by pure scale of the use of water, is agriculture.

A gross margins approach is used to evaluate the returns for water in the agricultural sector. In the industrial and household sectors, a simple evaluation approach is used where the quantity of water demanded is multiplied by the price paid in each sector. Non-market valuation techniques are used to evaluate the recreational and environmental uses of water.

The difficulty that arises in this analysis is how to evaluate the performance of irrigation schemes, where the outcomes are multifaceted. A 'meta' model approach is suggested in which the different elements from the project are brought together and assessed using a technique derived from the theory surrounding production possibility

frontiers. This technique can be used to hypothesise a value for the ecosystem services derived from an irrigation scheme.

The performance of an irrigation scheme is evaluated in terms of the suggestions raised to change it. Cost Effective Analysis is to be utilised to evaluate this performance.

Then two issues need to be addressed. First, it is necessary to converse with those from other components, particularly those involved in the hydrological programs, to determine the nature of the schemes to be investigated. Second, it is necessary to implement the approach in each of the RIBPs. This work needs to commence with the evaluation of the social values in each region.

Contents

1. Introduction

The purpose in this conceptual note is to outline the Products and Markets component of the System Harmonisation project coordinated by the CRC for Irrigation Futures. The aim of this component is to value the economic and environmental outcomes from an irrigation scheme that is operated by and in the interests of sectors of Australian society. Thus, in this component it is necessary to draw together three elements, one which controls the system (social) and the other two (economic products and the environment) which are outcomes from the system.

As this note is designed to outline the thinking and processes involved in undertaking just one component of a much larger project, it is necessary to also provide details of how this component fits in to the whole project. It should be noted that this paper does not represent a definitive argument on the process that would be followed through out the project. Rather, the aim is to provide a position upon which wider discussions can proceed.

The aim of the System Harmonisation project is:

> To increase profitability and reduce environmental footprints from improved irrigation systems as part of an improvement in water productivity in a total catchment management context.

To achieve this objective the following would need to be undertaken:

- Develop frameworks that can lead to a quantitative and qualitative assessment of the factors currently affecting irrigation regimes.
- Estimate the effects future irrigation regimes may have to enhance yields and outcomes from improvements in water productivity.
- Apply the conceptual frameworks to both the current situation and future plans in different Regional Irrigation Business Partnerships (RIBP).

In the Products and Markets component of this project the aim is to value the outcomes from the systems. To that end, in this paper, some effort is made to pursue part of the first objective stated above.

2. Systems Thinking and Harmonisation

In this Markets and Products component of the System Harmonisation project the aim is to connect with a biophysical hydrological component and an institutional component to become some entity (or system) that is capable of being harmonised, in a practical situation. In this component it is important to value the economic and environmental products that are derived from a socially driven irrigation scheme. Prior to detailing any individual components of this system it is necessary to come to terms with the what system thinking is all about, how to go about constructing a system model and how it could usefully be applied in the context of irrigation systems.

2.1 A Systems Approach and its Alternative

The many ways of thinking about an object or entity have occupied the minds of philosophers since Plato. These ways are so multitudinous, complex and varied, that a number of philosophers have reached the conclusion that the very existence of anything could be questioned. While not wanting to dismiss these thoughts entirely, but in the hope of clarifying them and moving forward, thinking about an object or entity in a logical manner can be classified into two broad and alternative categories.

The first is to take a marginalism approach, in which the major and important elements of an entity are identified. The less important, insignificant and peripheral elements are ignored. This approach has proved valuable, especially to scientists, as it allows an investigator to concentrate on what they consider to be important, relegating the unimportant to a constant status. In an ideal world, each element is separated and its influence evaluated. A major problem with this approach is one of "fundamental attribution error", where the importance of a key trait is over estimated, while the context and situation in which it exists is underestimated. Another major problem with this approach is that if problems are not well defined and involve multiple players, such as many social planning issues, it may be impossible to define a solution.

The second alternative method is to analyse a situation using a "systems" approach, where all elements are considered important. Dillon (1990) defines a system is an organised unitary whole which is composed of two or more interdependent parts and delineated by an identifiable boundary from the environment. Mathematically, a system can be defined as a set of elements, each of which is related, either directly or indirectly, to every other element and no subset of which is unrelated to any other subset.

Systems approaches are an all-encompassing way of looking at things. Systems are pervasive, complex and realistic. While the marginal approach involves reductionism and mechanism, the systems approach relies on expansionism. In a systems approach individual components, the links between them and the whole system need to be analysed. It is not just the sum of the parts. Consequently, in systems analyses, unlike the marginal method, a single disciplinary approach does not tend to dominate.

The problem with the approach lies in understanding its complexity and modelling it such that it is useful and purposeful. It is also important to note that systems' thinking is not just another way to get to the same 'answer' as the marginal approach. With systems thinking the idea of a single, knowable endpoint is questioned. However, it transpires from previous assessments that systems approaches are good for description purposes, but are not as useful an analytical tool as those derived from the marginal approach.

In reality, any study undertaken lies somewhere between these two extreme approaches. Describing a system and its important elements is crucial in undertaking a marginal study. Testing the links between different elements in a systems analysis requires all the tools that a marginal analysis would employ.

In this study the approach undertaken is closer to the systems alternative, while employing the tools of a marginal technique to assess individual components and the links between them. Most past studies of the irrigation sector could reasonably be classified as marginal analyses, where relatively small segments of the sector are assessed separately and in isolation to the rest of the sector. Many examples of this tendency exist. For instance rarely has the interaction between ground water and surface supplies been analysed. Further, until recently, due consideration of the hydrological inputs and economic outputs arising from irrigation were not assessed with equal importance, with greater emphasis being placed on one side or the other. In addition, many studies of the institutional frameworks underpinning water have not been aligned with the hydrological constraints.

2.2 An Approach to Modelling Systems

To undertake a systems approach to irrigation it should be recognised that various disciplinary approaches are required, that they will need to be used appropriately and that all important components need to be evaluated and linked to one another. The difficulties that arise with this approach lie in deciding what elements are important and in splicing the various elements together. In other words, the fatal attribution error problem (by ignoring an important component and the context within which it exists within the system) needs to be avoided, while attempting to model a system that is not specified to be so complex that it defies estimation.

In modelling a system, many approaches could be taken. From Dillon (1992) the following steps could be followed:

1. Setting the boundary between the system itself and the environment as a whole.
2. Identifying the individual components within a system.
3. Identifying the influences or links between the components from both outside and inside the system.
4. Accounting for the resources of the system
5. Formalising the goals of the system.

6. Describing the system.
7. Evaluating the performance of the system.

2.3 Setting the Boundary

In the case of an irrigation scheme, to set the boundary with the environment it is necessary to first define what it is and then what should be included becomes more apparent. Watson (1999) defines irrigation as:

> *the (physical) movement of water in time and space that results in agriculture moving in time and space*.

Recognising that it is not only agriculture that is affected by the movement of water, that industry and households if not humanity as a whole could all be affected, the purpose of the system must be widened to incorporate more than just agriculture. In addition, irrigation involves more than just the physical movement of water. There is a purpose to which it is directed, people who benefit and those who lose, sectors that are affected and constraints that impede its flow. Thus, to assess the physical flows of water alone would underestimate the extent of this system.

Consequently, a definition of an irrigation scheme could be:

> *A system that encompasses all activities involved in moving water in time and space and assessing the outcomes that arise from that act over time and space*.

It is accepted that this definition, *per se,* is wider than that usually applied to irrigation. Irrigation schemes usually only relate to those constructed to facilitate agricultural pursuits. This definition could refer to any built water system. However, this definition is an improvement on those that are more narrowly defined, as it allows for the multiple outputs that arise from a scheme to be evaluated. Given that the approach outlined in this paper is applied to schemes that have a major agricultural component, it is the application of this approach to a specific problem that will constrain the definition. Despite this limitation, the definition specified above can be used to initially identify what should be in the system and what should be excluded.

It is necessary to curtail the exuberance of those (such as those who follow the Gaia philosophies of James Lovelock) who believe that water is essential to life. Defining the system in this way would necessitate including everything within the globe over the whole expanse of history. In this study two constraints can be imposed: those of time and space. A spatial constraint can be imposed by determining the region within which the scheme or system operates. So in the case of an irrigation scheme this could be at a mirco-farm level and intermediate scheme level or at a more macro catchment level. A temporal constraint can be imposed by first observing the system as it currently exists. Thus, the sunk costs associated with previous investments and activities can be ignored. Furthermore, future investigations can be constrained to issues that affect those who are currently affected or likely to be affected by any change. In this study both the spatial and temporal constraints are defined by the relevant RIBP.

2.4 Identifying the Components

In identifying the components of a system, it is necessary to think about what needs to be modelled. In this system, three major components can be identified:

- Physical, involving framework, "clockwork and control mechanisms" of the water system. This includes where the water comes from, where it is directed to, where it is lost from the system, what it is used for (cropping, households industry) and the impacts it has when extracted from alternative use (the environment)
- Economic, social and environmental, involving assessing the impacts the physical component has on the system. This involves calculating the costs and benefits of operating the system from a monetary, community and natural perspective.
- Institutional settings (some of which will be enabling, while others are constraining), involving assessing the factors that control the system, particularly the legal aspects.

As each of these is important to the system, any one could not be considered to dominate any of the others. In addition, each could be modelled separately, as each emphasises a different aspect of the system. Finally, within each of these components, sub components will exist.

In terms of the whole system these three components could be aligned linearly. Using this approach, the biophysical Hydrological components feed into the valuation of the Markets and Products component, which in turn feeds into the Social, Cultural and Institutional component. However, such an approach does not adequately represent the dynamic interactions embodied in an irrigation system. A better approach is to think about each component acting individually and feeding into a "meta" model framework (see Figure 1). This, more dynamic approach means that each component could be estimated separately, each using different techniques and then spliced together after each has been estimated. Care must be taken in specifying the links between each component (i.e. that a set of common units are employed, etc.).

Individual subsystems will exist within each individual component (specified in Figure 1). What each sub-system requires is the establishment of a border that separates it from the rest of the system. In undertaking this task a definition of where one starts and the others finish is required. For the Markets and Products component (or sub-system which is what it will become) this can be defined as:

> *the quantification (valuation) of all the activities that arise from moving water in time and space within a specified region that pertains to the economic and environment sectors, as they relate to society's needs.*

In other words, it is recognised that irrigation schemes are run for the benefit of the societies that build them. Society has multiple uses for the water (agriculture, industry, households, recreation and the environment) for which it derives benefits from and incurs costs in distributing the water in any selected or given way. It should be noted that the environment is taken to be another market (just like that for agricultural output) and the social aspects of this system are now incorporated in its 'purpose'.

2.5 Identifying the Influences and Links in a Subsystem

Overseeing the choice of what should be included in each individual component within each subsystem is governed by what society deems to be important. Failure to be selective could lead to a degree of complexity that would render the model inoperable. Alternatively, too strict a set of choices would lead to a fatal attribute error. The importance of each component will need to be established and could usefully be done within each subsystem using the techniques available in each. For instance, in the Markets and Products subsystem a clustering approach could be used to verify the importance of individual components. The importance of each in this case is determined by the values society places on them.

An important element in estimating any system is the identification of the links between both the subsystems and the individual components within a subsystem. These links come in many forms and can be measured in many different ways. They are in some sense instruments that govern the system, some of which may be passive, but all which govern the way the system runs. In the Markets and Products subsystem (described in Figure 2) the links from the physical component are the flows of ground and surface water and the environmental factors considered important to the system. Flows to the Markets and Products subsystem are biophysical elements measured in physical terms. Within the Markets and Products subsystem the links are specified in terms of monetary costs and benefits. In other words, within the subsystem, the links can be isolated by observing the financial flows between components, which in turn are derived from the physical flows from both within and from outside the subsystem. It is implicitly assumed in the Markets and Products subsystem that supply and demand forces underlie all activities and flows. This even applies to the environmental outcomes, all of which are the outcome of some demand by members of society.

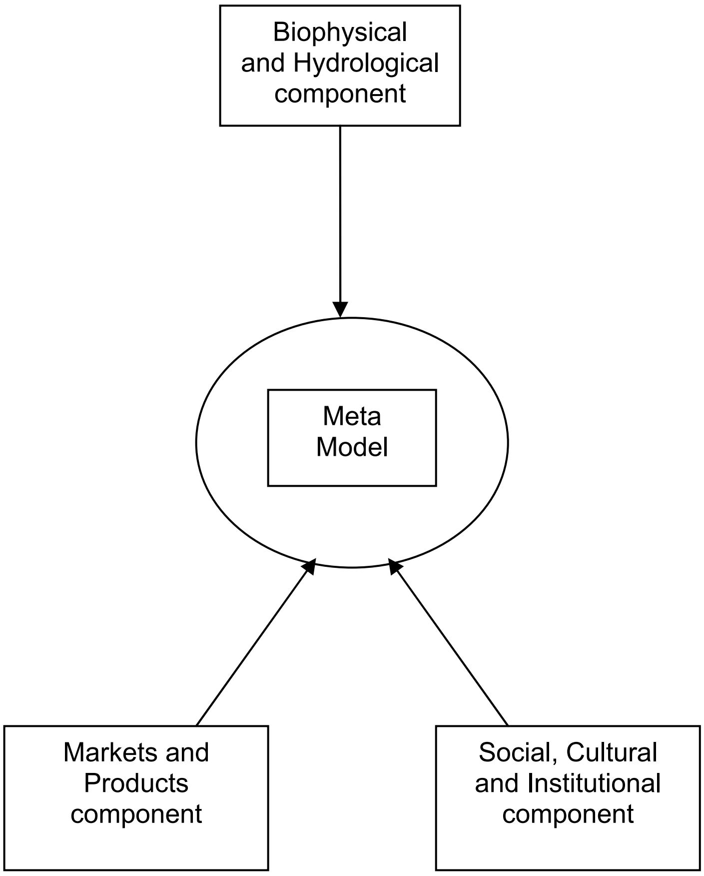

Figure 1: A Dynamic Approach to Observing Irrigation Systems

It may well be the case that the links between the subsystems are all very different. For instance, the outputs from the physical subsystem of the model could be specified in terms of quantities of water, yet those from the Markets and Products subsystem may all be in monetary units. Each would need to be converted using some form of yield equation, within each subsystem (where required) and placed individually within the meta model.

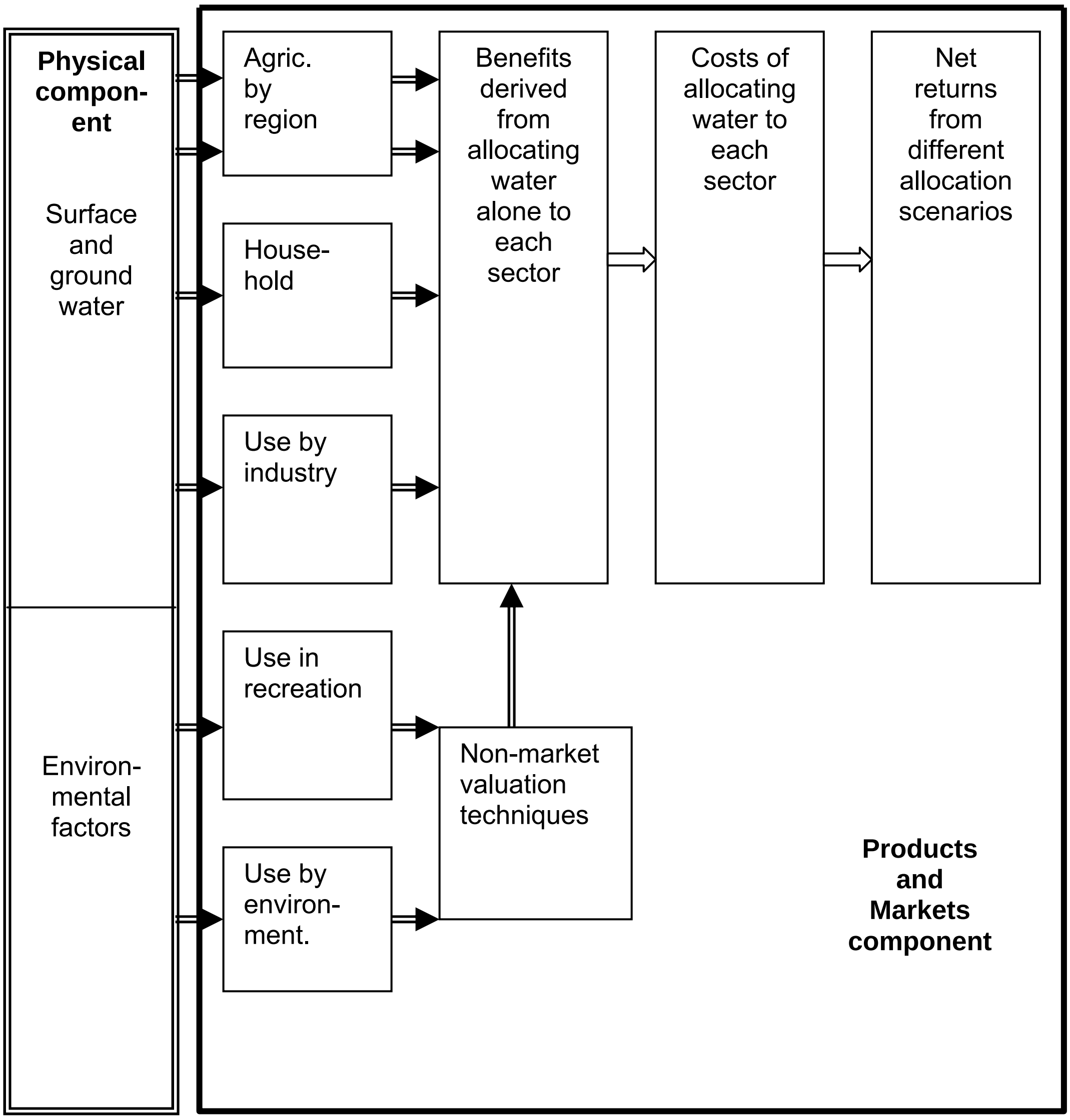

Figure 2: The Products and Markets Component of System Harmonisation

2.6 Describing the System and Accounting for its Resources

Once constructed, a subsystem, and ultimately the system as a whole, needs to be described. What this would involve is a snapshot of how the system currently operates. This in turn would act as the baseline analysis for all future scenario testing. It should be noted that the assumption invoked by taking this approach to description is that all costs and benefits currently involved in the system are sunk. This assumption, when applied to irrigation schemes is not unrealistic.

The description of the subsystems should also allow for an audit of the resources of the system. These could well provide information that can be used to verify the system and each subsystem within it.

2.7 The Purpose of the Subsystem

Any system analysis needs to be undertaken with a clear view of the purpose(s) of the system in question. In terms of the irrigation system as a whole, there may well be multiple objectives, including maximising profit, sustainability of occupation or of the environment, lifestyle issues or any other purpose involved. In reality, all these uses serve the purposes proposed by society. The problem arises when there are multiple, and sometimes conflicting, societal goals. Adding to this complexity is the fact that each is measured differently, making an evaluation of the trade-offs between them difficult. So, while the systems purpose is governed by the desires of society, the very nature of society means that the system is required to satisfy many different demands.

2.8 The Performance of the System

This leads one to ask the relevant question: How is a systems performance evaluated? This depends on how one perceives a system and what one wants from it. It is the trade-offs between outcomes, with all its different measures, that has to be assessed within the Markets and Products component in order to assess the whole system. Thus it could be argued that people's willingness to accept trade-offs is a measure of how certain performance measures are being met. The evaluation of the trade-offs, in light of proposed changes to the system, will determine the performance of the system. The method of accounting for these trade-offs in a systematic manner are described in the following Section (3).

2.9 Summary

It is necessary to understand a system in a general sense, before an evaluation of its the performance is undertaken. Such an act requires some understanding of the:

- Boundary.
- Constraints and influences from outside the system.
- Components and how are they related.
- Resources of the system and their share amongst subsystems.
- Goals being pursued.
- Management of the system and individual subsystems.
- Way people describe it.

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To make this approach operational, three issues need to be resolved. It must be asked:

- How can the purpose(s) of the system be determined?
- How should the outcomes or outputs of individual components of the system be evaluated?
- How should the performance of the whole system be evaluated, given that multiple outputs are derived from it?

The resolution to these questions is specific to the system being investigated. As such they need to be discussed separately (in the following 3 sections).

3. Determining the Purpose of an Irrigation System - An evaluation of the economic, environmental and social values

The reason for an irrigation system is perceived to be economic, a means of gaining productive outcomes and social benefit from natural resources. Being part of an extended system however, with wider social and environmental connections means that unintended or unknown outcomes can affect the value to the community of such activities. The term ‘sustainability’ is currently used to describe economic activities within a social and environmental framework. In understanding ‘sustainability’ the full value across a community (including for future generations), the compatibility with the environment and the risk to these values can be identified. An analysis of these factors is termed Triple Bottom Line analysis (TBL) (Harding 1998).

3.1 Conceptualisation

Initially a generalised conceptual modeling framework for describing key environmental aspects in all RIBPs is needed. This will involve development of a systemic framework for irrigation environmental interaction regarding identified local issues through stakeholder and expert input through two stages.

Stage 1: Stakeholder Perceptions

Irrigation and its associated activities can interact with the environment in negative but also positive ways. It is usual to address these interactions in a direct manner, termed primary impacts, but these can flow on to social and economic consequences (Appendix 1). It would be useful in terms of relevance and prioritisation therefore to identify ‘flow on’ impacts when identifying the interaction between irrigation activities and the environment. A common and generic way to identify these interactions is to use an Environmental Impact Assessment (EIA) framework for predictive purposes or an Environment Audit (EA) framework for current irrigation activities. A general model can be established by identifying generic irrigation activities and generic environmental values to protect. As a start, lists of the latter can commonly be found in EIA and EA literature. A numeric process similar to a Leopold matrix (Harrop and Nixon 1999) can be used to rank the importance of these interactions. This method has been used recently and successfully to determine environmental impacts of the tourism industry (Appendix 2). Environmental management methodology uses assessment and audit is the basis for planning action to address revealed issues (for example, Standards Australia etc).

It is proposed to build upon the sustainability reporting process and framework where higher order sustainability and environmental principles have been identified, to develop a generic matrix and general model framework to be applied in each of the RIBP case study areas. This would involve appropriate CRCIF researchers, working with RIBP committees and other local stakeholders to develop (within the light of previous work) and to test the framework. The framework can then be used to assess local environmental values (and flow on social and economic effects) at each RIBP site. Various local groupings would be invited to participate, thus allowing understanding of specific interest grouping of the area to be accounted for. These may include: irrigators, government and local government personnel, business associated with connections to the water industry, environmental groups and the general community.

Stage 2: Systemic and Cause: Response Analysis

The causes of some environmental impacts are well documented (eg. nutrients and eutrophication). However, other impacts may be obscured by time lags and intermediate stages. These can be identified by systemic analysis which can be used not only to identify consequences but likelihood of occurrence (risk analysis). The pathways of interaction need to be identified by the scientific panel and verified in the data collection stages to follow. Specific aspects to model include salts, nutrients, biocides and water balance. Remediation actions will be identified and promoted. In the first instance, models of common issues need to be developed to allow refinement through insertion of data at the local level. A generic set of indicators to determine environmental condition can be developed by a scientific panel drawn from the partners.

3.2 Implementation

Preliminary environmental framework implementation and baseline assessment of environmental situations will also involve two stages; data collection and analysis using the environmental framework:

Stage 1: Stakeholder Perceptions

In order to identify current and possible future impacts of irrigation activities on environmental values it is proposed to run a series of workshops with the various stakeholders associated with the irrigation industry and environmental custody. The workshops will use the generic matrix as a starting point for identification of environment values; however, local values not generically identified can be added to the list by the participants. Understanding environmental values of different groups of stakeholders would requires that the workshops be run on a particular interest group basis and hence at least six will be conducted.

Stage 2: Systemic and Cause: Response Analysis

Possible environmental impacts and perceptions of them identified by stakeholder analysis will be informed by the collection and collation of existing environmental data using standardised indicators identified by the CRCIF researcher panel and reference sources (eg, water quality and soil health indicators). Additional data sets may be gathered where lag-times and indirect impacts may obscure stakeholder perceptions but not scientific analysis. Data gathered will be placed in the developed model framework to test interactions and potential change impacts.

Collation of existing bio-physical data will allow comparison with standard indicators of environmental condition of landscapes, soils and waterways. Quantitative data sets will be collected, modified and placed in the modeling framework. Gaps in knowledge will be identified and potential interactions between data types will be tested. The predictive capacity of the model will be tested.

3.3 Issues and Options Methodology

An integration of environmental framework and concepts for all RIBPs will be undertaken. First, there will be an integration of current situation analysis involving values analysis and scientific verification for each of the RIBPS collation and testing for common attributes in process and content. Then the theoretical framework is to be compared to the tested outcomes.

Refinement of environmental frameworks following workshops will involve:

- Refinement of environmental frameworks following workshops and biophysical model development
- Relate stakeholder perceptions to bio-physical indicator data across the four RIBPs
- Identify matches and mismatches
- Identify data needs to confirm existing perceptions
- Identify clear cut causal relationships
- Identify critical points in the systemic relationships between irrigation practice and environmental responses
- Undertake risk assessment of irrigation activities on environmental values

With the final version of the environmental framework completed and the model verified through ongoing monitoring, issues and risk management processes will be identified and applied in the context of the water resource planning options at play in the RIBP sites.

4. Valuing the Products and Markets in an Irrigation System

Valuing anything can be achieved in a variety of ways. Some things, such as valuing a crop, can be achieved with a good degree of accuracy in a relatively easy manner. Other things, like the environment, are far more subjective and difficult to do. The purpose in the Section is to outline the methods that will be employed to value the activities that are derived from the irrigation sector. The activities reviewed are those derived from the agricultural, household and industrial sectors, along with that associated with the environment and recreation.

4.1 Agricultural Output

Valuing agricultural output is best achieved using a gross margins approach. From the hydrological component, the area cropped and yields can be derived. By multiplying these two elements together, the level of production can be determined. This can then be multiplied by the ruling market/export price to determine the gross value of output. To determine the net value of production some idea needs to be gauged of the costs of production. Taking the costs of production from the returns provides an estimate of the returns per unit of water employed

The model used to determine the net values of agricultural output was derived from Perry (*pers. comm*. IMWI, Colombo. November 2006) and developed in Davidson and Hellegars (forthcoming). The model has been developed from assessing farm level data to being capable of handling multiple regions over two seasons. The set up for each RIBP is to be determined from the hydrological component of the system. The information needed to populate the model can be derived from existing studies (usually undertaken by State Departments of Primary Industry). This use of secondary data is an acceptable practice.

It should be noted that the assumption using this approach is that the regardless of the quantities produced, the price of good in question will not change. This assumption is not necessarily unrealistic in this case. Does this approach accurately account for the value added by water? Not necessarily, but it should provide an indication of the marginal value of changing water allocations within a region.

4.2 Industrial and Household Users

Determining the value of industrial and household use is not nearly as easy as that involved in valuing agricultural output.

It is impossible to place a value on water used by households. If water is taken to be essential to life, then it can not be valued adequately, as the answer would be that it has an infinite value. The simplest way of valuing water is to take the price paid by industrial and household users and multiply it by the quantity used. Such an approach is not ideal as presumably the own price elasticity of demand for industrial processes is not perfectly elastic. In addition, water is not the only input to the industrial process. Despite these deficiencies such an approach does provide an insight into the value of water. Once derived, by multiplying the amount used by the price paid by households and industrial users should suffice.

In both cases (industrial and household uses), it should be noted that the price consumers pay for water in many cases possibly does not reflects the true social cost of making that water available. But for that matter, agricultural users also do not pay a true social cost for water either. In general, industrial and household users tend to pay a higher price, as the costs of treatment and distribution are higher than for agricultural users. In addition, as the products going to different end uses have different characteristics, it must be asked if it is reasonable to compare them. To over come the problem of price not reflecting the true social cost, an attempt needs to be made to derive the shadow (or unsubsidised) price. Given, that water used for industrial and domestic purposes is not the same as that destined for agricultural use, two different shadow prices need to be determined. These shadow prices can depend on many attributes, including reliability, quality, distribution infrastructure etc.

4.1

4.3 Recreation

Unlike the previous case, a market does not exist for the recreation value of water. If important a travel cost method would have to be employed. Once again, many studies have been completed using this approach (see Sinden 1990). The price implied in these should be employed and multiplied by data obtained from the social components of this study. This is not an easy task, yet some data exists in the National water Audit.

4.4 Ecosystem Services

By far the most difficult component in this study is valuing the environmental components of irrigation activity. High on many researchers' agendas is to place a value on "ecosystem services" and that by doing this a value can be put on the environment. The very nature of ecosystems makes them difficult to value. Davidson and Wei (forthcoming) have attempted to assess this with respect to an assessment of water applicability and nitrogen fertilization on the North China Plain, and the methodology used there, provides a foundation for the present work.

A traditional market for ecosystem services does not exist for a variety of reasons. There are no identifiable buyers and sellers of these services and no one owns the ecosystem services. A commodity can not be transferred if any dispute exists as to who owns it. It is really this final point that is at the heart of the problems in valuing ecosystem services. The inadequate specification of property rights is a form of market failure that leads to no market existing at all. In the absence of a market, it is impossible to determine a market price and no way of achieving a value for the services provided.

The usual solution to this form of market failure is for the government to specify who owns the rights and then allow them to trade them in a market. A lot of clarification needs to be undertaken on the property rights before a market can be defined. Be that as it may, such confusion has led to two diametrically opposed views. The first would suggest that ecosystem services should be valued at nothing, as a market does not exist. Alternatively, it could be argued that ecosystem services are priceless and invaluable if lost. The truth surely lies somewhere between these two extremes.

The real shortcoming lies with gaining the information on prices. Without really knowing what constitutes an ecosystem service, it is impossible to know what it is worth. Attempts to value a system usually involve a survey of a small component of the ecosystem. Could this small segment of what is a complex system actually provide a true picture of its worth? This is known as the ecological inference or aggregation problem (see King 1997). Furthermore, establishing the value of an ecosystem in this manner is an expensive activity. It certainly has none of the advantages of a market where prices are established in a relatively cost free environment. In reality, all a survey establishes is a picture of what could be there, and yet this picture could well be incomplete. It has little to do with establishing prices and hence values for ecosystem services. To do this requires an evaluation process that is derived from the 'meta' model, something undertaken in the next Section.

5. Determining the Performance of the System - Constructing the 'meta' model

The purpose in this Section is to specify how the performance of a multi-objective irrigation system could be assessed. It is taken as a given that the whole system should be evaluated together. To do otherwise would be an illogical step away from a systems approach towards a more marginal approach. The difficulties with this task lie with the number of objectives to be assessed systematically and that some of them (relating to the environment and ecosystem services) do not exist.

5.1 The Information Required

The performance of a system can only be gauged once all its component parts have been estimated and assessed. Thus, it is necessary to understand what is delivered from the biophysical and hydrological subsystem and what is required by those undertaking the social, cultural and institutional element. While at this stage of the analysis, this is not known with certainty, some elements are known. In general from the physical subsystem information on the allocation of ground and surface water supplies will be given, along with the areas cropped and a range of environmental indicators. Those undertaking the institutional subsystem analysis require information on the economic returns from irrigation activity and the social acceptability of the sector (which needs to be assessed after the analysis has been completed. In particular, the returns and social acceptability from irrigation activity should include the net values from agriculture, industry, urban and household use and recreation. The values of ecosystem services are unknown and will need to be estimated (see section 5.3). In addition, it is necessary to develop some technique by which these competing uses can be evaluated as if they are a set of trade-offs. It is from this basis that the performance of a system can be evaluated.

Social Acceptability Analysis should occur after some modelling and analysis of trade-offs has occurred. This approach was tested in the Seasonality of Flows project (reference?). Social acceptability is about judgments. What is provided in the analysis in this study is the provision of sound and understandable information that allows societies to make informed judgements.

5.2 An analysis of the Trade-offs Between Outcomes

An essential element in this study is to combine economic components (agriculture, industrial, households and recreation) with those that concentrate on the environmental elements. This is needed as it is in this subsystem of the study that the different elements are mixed. The evaluation of the individual components (economic and environmental) need to be placed in a form that can be evaluated jointly.

Except in those rare cases of a win-win situation, an economic decision almost always benefits some group or outcome at the expense of another group or outcome. Thus, trade-off exists between (say for the purposes of simplicity only) two outcomes, say between economic returns and environmental outcomes. In reality there will be a multitude of outcomes, and what is presented below can easily be extended beyond the two discussed. These tradeoffs are encompassed theoretically in a transformation curve, (sometimes known as a production possibility curve). These curves have an economic interpretation, as they show the opportunity cost of what must be given up in one dimension to obtain more in another, along the curve (see Figure 3). It should be noted that an assumption of this analysis is that the points along the curve represent the maximum possible outputs, given the current technology.

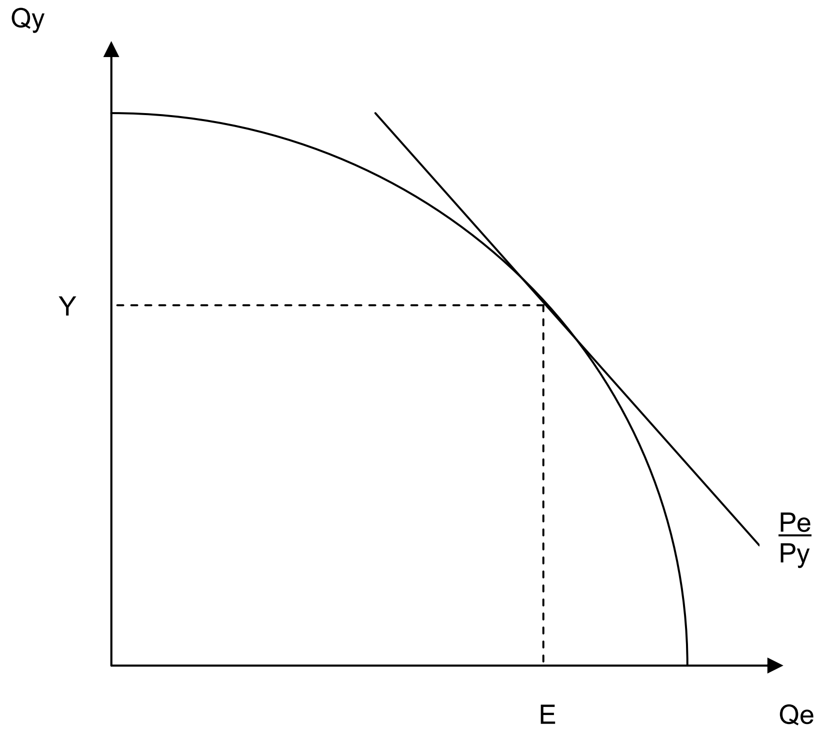

Figure 3: A Trade-off Analysis of Outcomes

Systems theory implies synergy in which ‘win-win’ solutions, rather than just ‘win-lose’ solutions implied by monotonic convex trade-off curves specified in Figure 3, can exist. This can be shown in Figure 3 if the curves have a positive slope. However, given that the economic and environmental outcomes can only be derived from a scarce supply of water, then it can be envisaged that in general the curve would be negatively sloped over most of its range. Certain segments could be positively sloped over a short range. This would imply that the curve is not smooth. In a similar way, there is no necessity for the curve to be continuous either.

The key features of transformation curves are their location in a quadrant and slope at a point along it. The slope of the transformation curve reveals the opportunity cost of increasing agricultural production in terms of foregone environmental quality. Thus, the curves allow for an assessment of whether a given improvement in environmental quality is worth the sacrifice in, say, agricultural production or income. The marginal rate of transformation, the slope of the transformation curve is equal to the change in one outcome (say the yield of a crop) divided by the change in the other (say an environmental outcome) or:

$$MRT = dY/dE, \tag{1}$$

where MRT is the marginal rate of transformation,
dY is the change in agricultural yield, and
dE is the change in environmental outcomes.

The particular location on a curve is determined by economic and biophysical factors and can be constructed by simulating the response of farmers to various combinations of input and output prices.

5.3 Valuing Ecosystem Services – The missing part of the picture

According to economic theory the optimal point on the curve is one where the marginal rate of transformation is equivalent to the ratio of the prices of outcomes, or

$$MRT = dY/dE = Pe/Py, \tag{2}$$

where Pe is the price of the environment,
Py is the price of the agricultural outcome, and
all other variables are as defined above.

By rearranging equation (2) the one unknown variable (Pe) can be determined as:

$$Pe = dY/dE.Py. \tag{3}$$

Thus, in this study, the value ecosystem services can be determined as a residual.

It should be noted that the concepts and ideas presented above could be considered to be highly controversial. Suggesting that a price for the environment exists is an anathema to many environmental theorists and eco-centrically inclined person. Furthermore, while it is difficult to determine the prices and quantities of agricultural output (as that output is usually highly diverse) determining the quantities of environmental outputs and the changes that result are much more difficult to achieve in a manner that is acceptable to all. Regardless of how this is done some degree of aggregation is required. One solution to this problem is to use a Lancastrian approach to estimating demand for environmental goods.

5.4 The Need for a Meta Model

The 'meta' model brings the whole system together. In the Trade-off Analysis, measures of the physical outputs from the system are displayed on each axis. In addition, the changes in ground and surface water allocations will not only change the position on each frontier, but may well result in a change in the shape of the frontier. Finally, the values of all outcomes are either given or derived from the Trade-off Analysis. Thus, the Trade-off Analysis is a 'meta' model in itself and it can be used to assess the performance of the system and any changes to it.

In assessing the performance of a system, there is a necessity to ask: Compared to what? Performance is not something that can be thought of in isolation. The four irrigation schemes evaluated in this study can not be compared to one another, as each operates on its own and under individual circumstances. The arguments that are raised in criticism of benchmarking can also be raised against comparing different irrigation schemes. Comparisons of performance need to be made using marginal principles, in which changes in net outcomes arising from changes in water allocations are compared within each system.

5.5 Assessing Performance – The use of Cost Effectiveness Analysis

The aim in this study is to evaluate the change in water allocations or uses have on different desired outcomes from each irrigation scheme. There are many ways of doing this, with arguably the ideal being to conduct a social Cost Benefit Analysis. However, undertaking a social Cost Benefit Analysis would involve converting every value into monetary terms. Given the problems associated with estimating the value of ecosystem services, and what was suggested in the Trade-off Analysis, this is not only difficult, but also not needed. A far more effective and illuminating method of determining the performance of the system is to employ a Cost Effective Analysis approach.

Cost Effective Analysis is used to evaluate different treatments. In this case a new treatment regime (for instance) is evaluated against an existing treatment. The cost effective ratio for each treatment is found by taking the cost of each treatment against its perceived benefits and then comparing the ratios.

In a Cost Effectiveness Analysis it is necessary to have some idea of the impact of irrigation on the economic, social and environmental outcomes from a catchment or system. From an economic perspective, the current net value of agricultural, industrial and domestic water use needs to be assessed and offset against the costs of providing that water. In addition, the known costs of environmental damage can also be included. Any change to the economic outcomes resulting from a change in the flow of water can be calculated from this base and the effects of changing water flows on social and environmental outcomes can also be hypothesised. Then it must be asked: Are the hypothesised changes (gains) to the environment and society worth the change (loss) is economic net benefits?

The benefits of a Cost Effectiveness Analysis over a social Cost Benefit Analysis go beyond the need to overcome data deficiencies. Cost Effectiveness Analysis also allows for a comparison between alternatives, with the existing situation. In addition, there is no need to compare situations with a hypothesised ideal (Parato Optimal) position. Finally, the approach means that any benefits to either the environment or society that arise from changing water regimes must be articulated.

6. Conclusions – The analysis that lies ahead

The aim in this document was to outline the conceptual approach that will be taken to assessing the Markets and Products component of the System Harmonisation project. In order to understand the task being undertaken, it was first necessary to understand the concepts underlying a 'systems' approach to the analysis in general and the role the Markets and Products component plays in the whole project. Only then could the concepts and procedures underlying this component of the project be outlined.

6.1 A Synopsis – The story so far

The purpose in this component of the project is to value the outcomes from different uses of water within an irrigation scheme. In addition, this component of the project links with a biophysical hydrological component and a social, cultural and institutional program. Any system is a mix of the physical, social and economic subsystems. How these subsystems are organised and delineated are particular to each system analysed.

It is important to recognise that it is assumed that any system must be purposeful. In this case it is operated to serve the purposes of society and it serves to not only produce agricultural outputs, but also those of other sectors and of the environment. The desired outcomes from the system are identified using an economic, social and environmental (Triple Bottom Line) matrix approach.

Valuing the economic outcomes from agriculture and the industrial, household and recreation sectors that arise from different ways of operating irrigation schemes can be assessed to a reasonable degree of accuracy. A reasonable approximation of the value of environmental outcomes can also be attained once all the components are gathered into a 'meta' model. It is the values that are derived from the products and markets within which irrigation schemes operate that need to be evaluated in this component of the project.

However, obtaining a value, even a monetary one, on its own is of no use to the outcomes of this project. What this project is about is using the value obtained from this analysis to compare different scenarios within an irrigation system. The desirability of different scenarios can be determined using Cost Effectiveness Analysis. The next stage would be about making judgments (i.e. to determine the social acceptability). This can only be achieved after all the information, including the outcomes of the Cost Effectiveness Analysis, is known. The analysis itself doesn't determine what should be chosen, it provides information for that choice. This is the work of policy makers.

6.2 Future Analysis – The concerns of the Regional Irrigation Business Partnerships

Before proceeding with the analysis the objectives pursued in various RIBPs need to be understood. A variety of economic tools may need to be employed if the problems in each RIBP are to be assessed. Taking into account the problems faced in each RIBP, the following should be noted:

- South East South Australia RIBP problems revolve around industry development projects designed to improve water quality. What is required is a catchment wide analysis of the net returns from irrigation and an assessment of the costs and benefits of introducing new technologies. In addition, an assessment of different market based instruments to pay for the innovations will need to be undertaken.
- Coleambally RIBP issues revolve around the impact of innovations that occur both on- and off-farm. On-farm they include factors that improve on-farm efficiency and change the range of outputs. For this type of analysis a gross margins analysis of different types of farms is required. For off-farm developments, such as managing outflows and stranded assets, a system wide analysis of the costs and benefits is required, before it can be included into a Cost Effectiveness Analysis.
- Sydney Urban/peri-urban RIBP is associated with using waste water in conjunction with existing supplies. A system wide analysis of the economic components is required. In addition, an assessment of the net benefits of investing in a range of measures designed to reuse and treat water is needed.
- Macintyre Brook RIBP involves assessing the impact of new water control and reliability measures. Once again, an assessment of different measures is required within a system wide analysis.

At this stage of the project the participation of these RIBPs is not confirmed.

6.3 Implementation of the Approach

In each RIBP it is first necessary to undertake the social matrix analysis. This analysis can be used to identify and determine the values people place on the outcomes of the irrigation enterprise. Then, it is necessary to collect data on a catchment/system wide basis. In addition there is a need to come to terms with what is undertaken in each catchment/system and how the water is delivered. Data is required on the net economic returns from each activity within the system/catchment and the costs of delivering the water. In addition, it is necessary to specify the costs and benefits of any proposed changes.

In each RIBP additional data is required. A whole farm budget will need to be developed for each representative farm. These budgets will have to be comprehensive enough to account for all activities, especially those associated with using both ground and surface supplies. These budgets can be used to determine water productivity which in turn is an input into the biophysical models developed in the hydrological component. In addition, these budgets will need to be able to accommodate any on-farm investment required to make system harmonisation work.

Once done, the results need to be combined with the outcomes from the environmental and social analysis. The scenario analysis then needs to be conducted and comparisons made using Cost Effectiveness Analysis.

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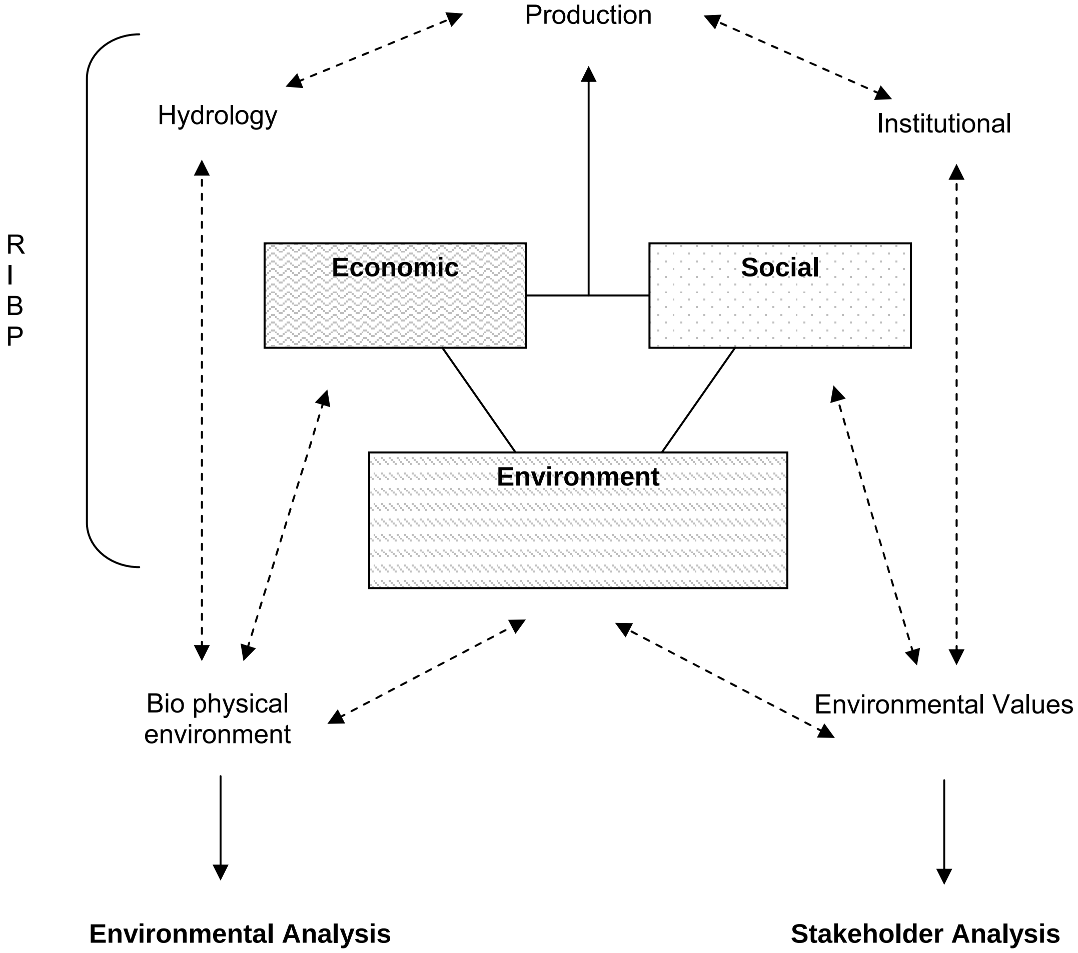
Appendix A: Environmental Analysis Process



Appendix B: Generic Matrix

The Generic matrix (Bushell et.al. 2007) has value components for economic and social as well as environmental to ensure that environmental services (which have social and economic outcomes) are identified in addition to altruistic environmental values.

Conceptually the method relies upon the ESD principles and incorporates the 'precautionary principle' to isolate key activities and their effect on local values. The precautionary principle is analysed using probability and consequence to identify significant costs and benefits and rank them in magnitude. The methodology comprises four parts:

- data gathering
- probability analysis;
- consequence analysis; and
- testing and validation of results

The TBL evaluation is to be undertaken by the stakeholders. The workshops involve participants individually completing the TBL matrix, plus group discussions of the issues surrounding 'the designated activity' in the region, validating the values and the impact of irrigation activities on them.

A matrix identifies the interaction and degree of interaction of 'the designated activity' on the values of the region. The ranking of - ve to + ve reflects the cost or benefit that is imposed on each value by each irrigation-related activity. For example:

Probability and Consequence of Cost:	-1 (low)	-2 (med),	-3 (high)
Probability and Consequence of Benefit:	+1 (low),	+2 (med),	+3 (high)

Participants complete the matrix by assigning a value between -3 (strongly negative), +3 (strongly positive) or 0 (no effect) to specific Value/Activity interactions. Where the participant has no opinion the box is left blank. Data is then summed in columns and rows to determine the greatest perceived benefits and impacts and the greatest impacting or beneficial activity. This can be analysed for individuals, stakeholder groups or across the sample.

The second phase takes high probability and high magnitude issues and analyses the following questions:

- the nature of the cost or benefit
- where the costs are currently being borne
- what information exits on the topic
- what further information is required

Note: this is not only an economic analysis and cost/benefits can be expressed in different forms.

Appendix C: Proposed Timeline for Social and Environmental Analysis

Stage	Activities	Timeline and Comments
Conceptualisation (Generic Frameworks)	Recruit CRCIF personnel to develop frameworks (at least one from each RIBP area)	Nov – Dec 06
	1. Stakeholder Perceptions	Draft Framework developed & distributed for a March 2007 Workshop
	2. Systemic and Impact Analysis	Draft Framework developed & distributed for a March 2007 Workshop
	To produce a: 1. Workshop process and materials for stakeholder analysis. 2. Generic environmental condition assessment protocol and materials.	Finalised by 30 June 07.
Implementation	Framework Applied to each RIBP area	To be completed and reported by 30 November 2007
	1. Stakeholders. Workshop several stakeholder groups using the developed process and materials.	Requires dedicated staff time for each RIBP area.
	2. Systemic and Impact Analysis Collect and collate data to understand environmental condition and risk for each RIBP area in the developed format.	Requires dedicated staff time for each RIBP area.
Issues and Options Analysis	Review of the RIBP implementation results. Analysis of perceptions, risks and management options.	To be completed and reported by 30 November 2009

- NOTES -

Partner Organisations

CHARLES STURT UNIVERSITY

CSIRO

GOULBURN-MURRAY WATER

Australian Government
Land & Water Australia

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Queensland Government
Natural Resources and Water

Government of South Australia

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

SunWater

THE UNIVERSITY OF MELBOURNE

UNE
THE UNIVERSITY OF NEW ENGLAND

UniSA

USQ
AUSTRALIA

University of Western Sydney
Bringing knowledge to life

State Government Victoria
Department of Primary Industries

Cooperative Research Centre for
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