Smart Systems and System Harmonisation

Scoping Study for NPSI by the Co-Operative Research Centre Irrigation Futures

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15th March 2005

NATIONAL PROGRAM FOR Sustainable Irrigation

Cooperative Research Centre for IRRIGATION FUTURES

Submitted to the National Program for Sustainable Irrigation in March 2005 by the Cooperative Research Centre for Irrigation Futures, Toowoomba.

This document should be cited as follows:

Durack, M., Malana, H., Schmidt, E., Khan, S., Thompson, C., Steele, A., Standen, A.,(2005). Smart Systems and System Harmonisation – Scoping Study. Report to the National Program for Sustainable Irrigation. Cooperative Research Centre for Irrigation Futures, Toowoomba.

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Document Review and Authorisation

Version	Date Printed	Job Number	Checked	Release Approved	Issued to	Comments
1(e)	23/2/05	6-C-20	Charles Thompson	Charles Thompson	CRCIF Project Team	To insert track change comments
2(e)	28/2/05	6-C-20	Charles Thompson	Charles Thompson	Matthew Durrack	Circulate For comment after CRC IF comments included from HM, SR, ES, MKD, RS
3(e)	1/3/05	6-C-20	Charles Thompson	Charles Thompson	Murray Chapman, NPSI and CRCIF Project Team	Incorporate new MKD research programs. Circulate for NPSI comments
4(e)	7/3/05	6-C-20	Charles Thompson	Charles Thompson	CRCIF Project Team	Incorporate Murray Chapman's comments
5(e)	15/3/05	6-C-20	Charles Thompson	Charles Thompson	Murray Chapman, NPSI, CRCIF Project Team	Incorporate new MKD programs & ES & HM comments. Reformat

Final Copy Distribution

Number	Date Printed	Issued to

Note: (e) after number indicates electronic distribution

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1 Background, Introduction and Recommendations

1.1 Background To This Study

In February 2005 the Land and Water Australia National Program for Sustainable irrigation (NPSI) engaged a team from the Co-operative Research Centre for Irrigation Futures (CRC IF) to undertake a scoping study for:

"Smart Systems and System Harmonisation"

This was one of four scoping studies also commissioned by NPSI. The other Scoping Studies were:

- Three dimensional Water Flow and Salt Storage including root zone salinity
- Improving plants water use efficiency and potential impacts from soil structure change
- Common hydrological features in Australia Irrigation area.

The purpose of these studies is to provide the NPSI Board with advice on research priorities within this topic.

1.2 Terms of Reference

The Terms of Reference provided by NPSI are included in Appendix 1.

1.3 Study Approach

Due to the short timelines for this project the following method was used:

Table 1-1 Study Approach and Timelines

Date	Task
8th February	Teleconference to confirm report structure, content and responsibilities.
9th February	Circulate – Chapter headings and outline of content to team members and also NPSI Co-Coordinator (Murray Chapman).
10th February	Incorporate comments from Murray Chapman into document.
11th February – 16th February	Team members work on their chapters.
16th February	Circulation of draft chapters to team and teleconference.
16th – 21st February	Team members work on chapters.
21st – 23rd February	Integration of chapters into this report.
23rd February	Circulation of draft report for comment to CRC IF team members.

Date	Task
28th February – 1st March	Comment on report for CRC IF team incorporated into draft report
1st March	Provide draft report to NPSI for comment
4th March	NPSI provide comment on draft report.
4th – 11th March	CRC IF revisions to report.
15th March	Final report due.

1.4 Study Team

The study team for the CRC IF was:-

Matthew Durack – Total System Harmonisation Productive and Environment Opportunities.

Hector Malano – Off Farm System Technology and Hydraulic Modelling.

Eric Schmidt (with Steve Raine) – On-Farm System Technology.

Shahbaz Khan – Demand Management Modelling and Alteration Farming Systems.

RM Consulting Group (Charles Thompson and Andrea Steele) – Value Chain Impacts

RM Consulting Group (Roger Standen) – Institutional Issues and Water Service Provider Relationships.

Plus support from post graduate students. Armgard Elmahdi (seasonal flow modelling) and Matthew Berrisford (hydraulic modelling). Project management work undertaken by RMCG (Charles Thompson).

1.5 Introduction to Harmonisation

Harmonisation is a term increasingly used in both government and business circles both nationally and internationally to discuss a process of optimisation which requires cross-organisational collaboration.

Reference can be found to the term in the following context:

- International Trade Law "Harmonisation" – a key feature of current WTO discussions;
- Harmonisation of cross state legislative procedures – the National Water Initiative recognises this need but does not utilise the term itself;
- Supply Chain Harmonisation – major corporations such as McDonalds and Woolworths seeking to cut costs from linked commodity supply arrangements.

A search of the grey literature on the use of the term with specific reference to Water Service Provider commercial or pubic good service capacity does not reveal any evidence of its use. This is despite the fact that as a term it was probably first defined in some early research request proposals from the National Program for Irrigation Research and Development in the early 1990's (Derek Poulton February 2005 Pers Com.).

The concept has been explored by a number of researchers since this time with the topic being explored in some detail at a CRC IF Workshop (April 2004) and subsequently developed into a targeted research investment proposal by the University of Melbourne and STI Victoria (2004).

The focus of "Harmonisation Research" has until now, been based around improving the Hydraulic Performance of the system and its responsiveness to end user and environmental demands.

The Expression of Interest Document provided by NPSI in February 2005 expanded the concept considerably with the use of the term:

> Total System Harmonisation - *How do you achieve an irrigation system within a region that is absolutely resource efficient (resources = natural, human, economic)?*

This section of the document seeks to define the effective boundaries of this research field and critically evaluate the value of grouping independent research activities within the context of this research collective.

Figure 1-1 explores the elements required to achieve Total System Harmonisation (TSH) and demonstrates the holistic nature of the approach required to achieve a truly effective outcome. Starting with a clear definition of the regions goals and vision and the establishment of performance criterion for each element of the system, the process needs to incorporate the views, values and ultimately enthusiasm of all those captured within the water management cycle.

A research approach incorporating this broad concept of TSH runs the risk of being confused with a range of planning and resource management processes currently being undertaken by catchment management organisations and state planning authorities.

If on the other hand the focus is narrowed to incorporate only those processes subject to some form of "Corporate Control" leaving the broader community perception and planning frameworks to inform the operating environment, a clearer picture of research opportunities arises.

This definition does not reduce the exposure of the research activities to environmental objectives given the increasing 'corporatisation" of catchment based environmental objectives within the business plans of water service providers and their customers and the increasing use of market based instruments to achieve change. It does allow the research to focus on a set of stakeholders with increasingly aligned business processes and objectives.

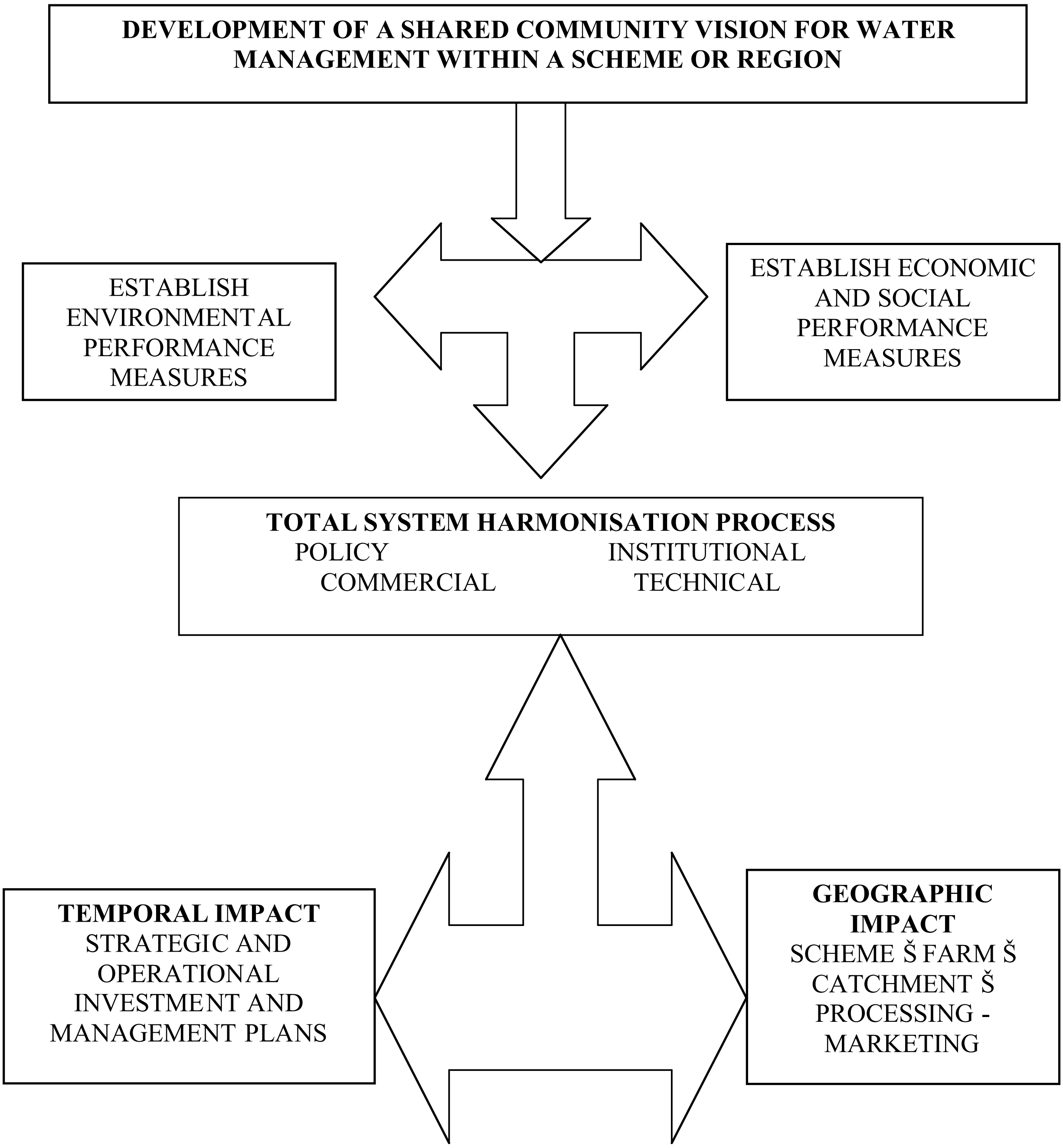
This concept of the process allows the work of Porter (1985) and others on Value Chains – and the importance of embedding a continuous value adding process into all segments of the chain to be used in defining our objectives. Chapter 3.1 builds on this linkage and recognises the inherent difficulty in working along chains with shared private and public investment.

In order to provide focus to the discussion and retain the value of using these terms as "research collectives" we have proposed the following boundaries be placed around terms within this paper:

– **System Harmonisation** – *focuses heavily on the Water Service Provider – End User relationships and the opportunities for collaborative strategic, seasonal and operational decision making, targeting optimised productive and environmental water use outcomes;*

– **Total System Harmonisation** – *confined to the corporate or privatised elements of the system but broadly targeting opportunities for collaborative decision making at all points in the value chain both within the water management cycle and external to it in order to optimise the performance of all irrigation related activities in the region.*

Figure 1-1 Total System Harmonisation – a holistic process incorporating input from all sectors of community and business.



Even using these definitions the terms threaten to become so all encompassing they lose value as a "Research Collective". As noted within the brief the benefits of Total System Harmonisation accrue up and down the irrigation industry's value chains not only within the water management sector but outside it in areas such as energy management, input logistics and transport. In addition it can relate to management or investment decisions at a range of temporal and geographic scales.

Table 1-2 sets out two dimensions of the system with decisions points being temporally defined as strategic or operational and the geographic limits of the system ranging from farm to catchment scale. There are strong opportunities to add value through "Collaborative Decision Making" at all points in this matrix. The table helps to define subsets of these activities within this framework.

Table 1-2 Total System Harmonisation – The extent of collaborative decision making opportunities across a range of temporal and spatial scales.

TIME SCALE	GEOGRAPHIC SCALE				
	CATCHMENT	SCHEME	FARM	PROCESSING	MARKET
STRATEGIC	*Allocation Decisions*	*Organisational Structure*	*Farm Management Plans*	*Organisational Structure and Risk Management*	*Image and Branding*
	Resource Operating Plans	**Product and Service Specification**	**Farm Management System**	*Production Planning*	*Market Definition*
	On Ground Works	Infrastructure Investment	Cropping Mix Selection	*Infrastructure Investment*	*Promotion*
	Monitoring	Communication s Protocols	Agronomic Program	*Processing Schedule*	*Order Collection*
OPERATIONAL	**Enviro Flow Management**	Service Delivery	Scheduling	*Dispatch*	*Distribution*

Light Grey cells – *Smart Systems – physical and technical aids to improve infrastructure and agronomic performance*

Light Grey + **Dark grey**– *System Harmonisation – incorporating broader range of cooperative decisions aimed at optimising the water management cycle.*

Light Grey + **Dark Grey** + *Clear – Total System Harmonisation – optimising all elements of the system within and external to the water management cycle.*

A critical element of the following chapters will be an attempt to define where the greatest opportunities lie – and where the leverage available through collaborative decision making outweighs the complexity of system wide thinking.

Although the term System Harmonisation may be relatively new in the context of irrigation there is clear evidence of its application in many of our current rural water service providers including:

- Central Irrigation Trust – Water Use Efficiency Reporting and attempts at predictive demand anticipation;
- Goulburn-Murray Water and Coleambally Irrigation Trust – trial installation of Total Channel Control Systems and the desire to use these systems for improved customer service as well as internal leakage management and control optimisation; and

- Harvey Water Ltd – installation of on demand pressurized system to encourage shift from surface irrigation to Large Mobile Irrigators such as pivots and lateral moves.

An examination of developments in other utility providers over the past 10 years provides some clues as to the future developments in this area:

- The energy sector now supports a thriving private sector consultancy industry which seeks to optimise on site demand with system supply characteristics with the aim of reducing overall energy costs – this is supported by a range of market based incentives including differential pricing strategies based on supply timing and maximum current loading;
- Telecommunication companies now offer the most bewildering array of services which are primarily aimed at providing improved customer service as well as optimised infrastructure utilisation.

The water industry is yet to develop the sophisticated array of product and service offer packages available in these sectors, innovation in our industry in this context is just beginning. The opportunity to learn from the alternative futures developed by other utility organisations may provide a powerful guide as to the nature of the water service provider customer service community of the future.

Summary of "Harmonisation" research opportunities

- "Harmonisation" – in terms of cross organization collaboration to make total resource use more productive is increasingly recognised as a key opportunity.
- "Total System Harmonisation" across the entire value chain is a broad concept, which runs the risk of lacking focus as a research area and will need a tight focus in order to achieve positive outcomes for the irrigation industry.
- "Harmonisation" – in terms of hydrology and hydraulics has long been recognised as important within the irrigation industry and is being addressed with new technology development and should be encouraged.
- Other utility providers have responded to the system harmonisation challenge by recognising the variability in irrigator demands and providing a wide range of new products and services. This is likely to be applicable to the irrigation industry.

More detailed analysis of the specific research opportunities are provided in Chapters 2, 3 and 4. Section1.6 below provides the recommended research program that has been constructed as a result of this detailed analysis.

1.6 Recommended Research Programs

This section summarises the research priorities referenced throughout the proceeding analysis in response to the key question posed by the NPSI brief (outlined below):

> *What should be the focus of research by the Sustainable Irrigation Program to achieve the tools that will guide and enable Total System Harmonisation (TSH)?*

Given the lack of evidence of specific research in this area there is a need for extensive capacity development. This also means that identification of appropriate research proponents at this stage is difficult given the general lack of activity in the area.

The strongly applied nature of research required would dictate the following principles:

- All research projects should be done in close association with appropriate private sector or industry partners;
- Early stage research projects and work of a generic nature will need to be supported by non-industry funding in order to promote the value of further industry investment;
- Industry investment in the applied stage of research projects should be relatively high in order to confirm the relevance of the research work;
- The holistic nature of the research effort does require a multi-disciplinary approach to any activity in this area and as such it is unlikely that anyone research provider in their own right would have the skills necessary to achieve significant success within any of the program areas described below;
- Although there is little evidence of similarly termed research in the international arena it is clearly a research area whose time has come and as such one would expect significant international activity to be underway fairly quickly. The industry as a whole needs to ensure that appropriate linkages are in place to benefit from this work.

The assembled research team believes the overall objective of a research program built around this topic area should be to:

> *To develop the skills, capacity, tools and technologies within the Australian Irrigation Community to optimise the performance of our current and future irrigation investments both on and off farm through improved cross organisational communication and system wide management in order to maximise productive returns and minimise environmental impacts.*

Based on earlier characterisation of the overall research portfolio and the detailed analysis of existing work and future opportunities we have proposed the following Research Programs and have set out more detailed objectives for each in the tables below:

- Smart Systems and Infrastructure Development Research program – at a Scheme Scale (where a Scheme can vary from being a district, with many managers, to a scheme made up of single manager, who is a private diverter with their own distribution system. It should be noted that in Australia most irrigation water is used by private diverters)
- System Harmonisation Research program – at a Catchment Scale; and
- Total System Harmonisation Research Program – at a Value Chain Scale.

The focus for research broadens from technical at a scheme level to more institutional at the catchment and value chain levels. The cross disciplinary and multi-partner basis for most of the work will require NPSI to be a co-investor with others in a broader research program. There do appear to be a number of critical roles which are better suited to the structure and resources of the NPSI program:

1). Case Studies and Demonstration Sites:

Reference is made to the need for active demonstration of System Harmonisation Concepts at a range of scales in the detailed research proposal analysis undertaken below for all program areas. NPSI partner organisations represent ideal locations for these events. One or a few good “integrated case studies” would provide more value than a large number of more limiting ones.

Research organisations such as CRC IF and Water can provide support in terms of case study establishment and evaluation and importantly use these sites as ground truthing opportunities for their more theoretical or blue sky research efforts.

There would be obvious synergies in ensuring that scheme, catchment and value chain scale case studies were linked in some way – although distribution of your efforts in this regard also broadens the extent of engagement.

2). Research Coordination:

As noted research activity in this area requires an extremely broad range of disciplines and partners – broader than the traditional boundaries of our existing CRC's. NPSI investment in a process involving at the very least a number of national and international workshops/conferences on the topic would help greatly in these early formative stages.

Currently the research area lacks obvious senior research champions with a mandate to commit significant time and energy to help consolidate existing disparate research efforts and drive appropriate new research initiatives. Joint investment with research providers and industry in a collaborative research program that links the key research providers (eg. CRC IF, eWater, etc.) would prove to be a very effective stimulus. For example, by creating a senior position in Water System Harmonisation Studies.

3). Specific Research Investment:

The tables below identify a range of specific research investment opportunities. The authors of this document believe that prioritisation of critical NPSI investment at this level is best left to the Program Management Committee.

Table 1-3 Smart Systems and Infrastructure Research and Development Program

	Description	Rationale link back to Chapter 4	Priority and for whom	Possible Areas of Collaboration
OVERALL OBJECTIVE	Development of new hardware and software and incorporation of existing products in to an integrated monitoring and control system which maximises synergies between channel automation and on-farm operations at a scheme level.	Recommendations 1,2,3,4		
KEY RESEARCH OBJECTIVES	a). Confirmation of the most appropriate **communications protocol** for use between elements of the system and promotion of this system industry wide. The ultimate goal being development and adoption of a "CANBUS" like protocol similar to that used in equipment automation for the irrigation industry. This may utilise existing SCADA protocols or other existing regulatory standards	Recommendations 2,3,4	CRC IF in conjunction with the appropriate industry bodies such as ANCID, AWA and IAA. Although CRC IF has not confirmed its own Stage II Investment Plan this is a critical issue of industry-research collaboration which falls squarely within its area of responsibility. This may represent a good area for CRC IF – NPSI co-investment – at least in supporting the nation wide forums which would be required to initiate such a process.	Direct linkage with proposed work headed up by John Langford and the STI Victoria and the University of Melbourne as well as all other case study sites.
	b). Continued **demonstration** of the water saving and productive value of these systems in highly regulated schemes as well as their potential in unregulated systems or single farm operations. A series of **linked case studies** Australia wide all assessed against a complete set of TBL indicators and building on the work underway in most states in this general area.	Recommendation 9	**NPSI – Key area for investment – identification of key sites could be based on competitive bid by Water Service Providers and end users in the first instance followed by assessment of an appropriate research partner**.	DPI Victoria in conjunction with Goulburn-Murray Water have initiated a major project in this area – with the primary focus being the demonstration of the on farm value of channel automation. Matthew Berrisford as a PhD through the CRC IF will be developing a model for Murray Irrigation on the value of off stream storage development. Sun Water have done some initial investigations and investment in channel automation in Emerald. Harvey Water – the experience here could provide an interesting basis for comparison as would work in other piped schemes.

	Description	Rationale link back to Chapter 4	Priority and for whom	Possible Areas of Collaboration
	c). Development of a single or broader range of **decision support systems** capable of incorporating both channel supply and on farm demand monitoring & prediction into the one software environment. Targeted end use would be to support initial feasibility studies in given systems as well as system design and ultimately creating the potential for automated decision support management systems.	Recommendations 1,2,3,4	CRC IF and eWater at least should attempt to build a collaborative research base in this area. Specific investment by NPSI at this stage may be pre-emptive with small scale projects running the risk of being over run by system or technology changes. The key role for NPSI in this context may be to support efforts to bring the parties together and facilitate effective co-investment.	CRC IF Scoping study projects on software for best use of water on-farm provides an initial compilation of on-farm tools. There is also obvious strengths in the private sector with AWM and Rubicon as well as some of the more generic packages used by WSP's based on SCADA control systems.
	d). Understanding the critical gaps in our current **sensor and control system hardware and software** and associated communication networks through practical experience and an understanding of the modelled environment. This information can be used to focus public and private sector research programs already involved in this area.	Recommendations 2,3,4	CRC IF through its existing work will be highlighting some of the gaps in the system – this along with continued gap analysis work to be carried out in conjunction with the case study sites needs to be effectively directed to the private sector with sufficient details of the market opportunity to support their direct investment in R&D to meet these market needs. A key role for NPSI could be coordinating co-investment by private sector	CRC IF Tools and Techniques Scoping studies will identify major gaps in this market. Any case study style work such as that being undertaken in Victoria both by DPI Vic and Melbourne University will identify further gaps in this market. Collaboration with private sector suppliers to evaluate current technologies available in this area.
Indicative Costing	a). $50,000 b). Site Specific c). $150-$200 K d) $50,000		Key investments: a). National Forum and consultant driven consensus process. b). Co-investment with case study partner in opportunity assessment and performance assessment c). Primarily software development – but with a strong endures interface investment d). Needs to be an ongoing process say every 3 years	
Indicative Time Frame	a). 6-12 mths – with ongoing industry support b). On Going c). 5 Years			

	Description	Rationale link back to Chapter 4	Priority and for whom	Possible Areas of Collaboration
	d). 6-12mths – repeated every 3 years			

Table 1-4 System Harmonisation Research and Development Program

	Description	Rationale link back to section 6	Priority and for whom	Possible Areas of Collaboration
OVERALL OBJECTIVE	To achieve optimisation within the storage, supply and on farm demand system for productive and environmental gain at a Catchment Scale.	Recommendations 1,2,3,4,5,6		
KEY RESEARCH OBJECTIVES	a). To establish a network of "Harmonised" supply/demand **demonstration sites** throughout Australia using existing technology and modelling experience. This would require utilisation of the modelling tools to demonstrate potential opportunities and to establish agreed alternative management regimes in order to achieve a set of shared environmental and productive outcomes and allow economic assessment of costs and benefits. Practical implementation of the concept using existing technology would starkly highlight the limitations of our existing knowledge and drive more focused research.	Recommendations 1,2,3,4,5,6	Key investment for NPSI – along similar lines to the Smart System Case Studies but involving either a more complex system or a more holistic approach to system management. This represents a significant evolutionary step in the commitment of the organisations involved – particularly with respect to incorporating environmental flow performance issues into the equation.	The holistic nature of these investigations would require a more cross disciplinary research team incorporating social, institutional and ecological research as well as the required engineering inputs. Potential case study partners would include managed scheme operators as well as subcatchment wide collections of private diverters. The New CRC for Cotton Catchments and Communities has a direct interest in this area. Similar support maybe available from other regional or commodity groups.

	Description	Rationale link back to section 6	Priority and for whom	Possible Areas of Collaboration
	b). To develop effective **demand predication tools** suitable for use industry wide which provide not only short term (7-10day) but also allows seasonal predications of total water crop water demand based on standard climate predication models. This work would build on ETO work underway within the CRC IF as well as demand prediction models developed by a number of water service providers	Recommendations 2 & 3	NPSI may have indirectly invested in this type of research in some of the previously suggested case studies. The CRC IF and eWater along with appropriate industry and research partners need to work at creating a generic modelling environment which supports this process nation wide. NPSI investment in the development/commercialisation stage of these processes may be appropriate.	There are a large number of supply prediction models in existence. There are fewer robust demand prediction models although at least GMW, MI and CIT are active in this area. Catchment Hydrology's Tool Kit material provides a review of hydraulic models, and proposed work by eWater CRC on Software for River System Management will all need to be combined to support at least a common software platform and interface. CRC IF in conjunction with the NRM SILO project has developed the capacity to provide ETo prediction and will be building on this to provide regional ETc prediction capacity. NSW DPI also has developed a catchment scale ETc prediction capacity.
	c). To integrate existing stream flow and system **supply prediction models** with newly developed irrigation demand prediction models to optimise the operation of river systems for productive and environmental objectives.	Recommendation 2, 5	Again the critical issue here is effective collaboration between the primary research providers in eWater, CRC IF and the WSP's themselves to ensure integration. NPSI investment in supporting this cross organisational collaboration may be useful.	Attempts are being made by some WSP's such as River Murray Water, Murray Irrigation Limited and Goulburn -Murray Water to achieve this in some areas.

	Description	Rationale link back to section 6	Priority and for whom	Possible Areas of Collaboration
	d). To incorporate system wide environmental flow demands into the modelling environment in order to examine system wide options for environmental and productive synergy with respect to supply options and productive and environmental demand management in the short term (intra seasonal) and the long term (interseasonal). This may not be possible in a generic sense and may need to be site specific.	Recommendation 2, 5	NPSI investment in appropriate case studies could provide a sound basis for a more theoretical approach to this issue through CRC IF – eWater and others	eWater and associated organisations involved in Fresh Water Ecological research units throughout Australia.
	e). To identify **the institutional and personal barriers to, and opportunities for adoption** of a harmonised approach to demand and supply management in our irrigation districts and catchments, including assessment of harmonisation models developed in other utilities. This would build on some of the work already undertaken by water service providers on sharing delivery capacity, carryover provisions and trade out exit fees with at least one aim being the development of a broader range of market based and consumer targeted water service provider product and service options which deliver improved outcomes across the catchment.	Recommendation 9	Key opportunity for NPSI to build on its existing links with ANCID through the "Know the Flow" process to examine some of these new opportunities.	A recent consultancy call by DAFF on third party access to water service infrastructure along with similar work undertaken in the commission would be useful. Existing survey work being undertaken by Jennifer McKay in the CRC IF will provide a useful background to this area. Partnerships need to be formed with research organisations who have worked in other utility corporations in order to explore the full gamut of opportunity in this regard.
Indicative Budget	a). Site Specific b). $150,000 c & d). $25,000 e). $300,000		Key Investments: a). Co-investment in case study b). Possible product development/ commercialisation c &d) Coordination role – national works etc e). Industry lead cooperative project	

	Description	Rationale link back to section 6	Priority and for whom	Possible Areas of Collaboration
Indicative Time Frame	a). On Going b). 12mths c & d). Annual event e). 3 years			

Table 1-5 Total System Harmonisation Research Program

	Description	**Rationale link back to section 6**	**Priority and for whom**	**Possible Areas of Collaboration**
OVERALL OBJECTIVE	To explore the opportunity of establishing a planning and operational framework designed to optimise all elements of an irrigation district both within the water cycle and external to it at a whole of value chain scale.	Recommendations 7,8,9		
KEY RESEARCH OBJECTIVES	a). **Scenario Analysis** targeting a particular district aimed at **demonstrating the potential value** of this approach. This could be undertaken in one of the existing NPSI research areas. It would involve a much more objective analysis of particular options than the current community engagement processes underway.	Recommendations 7, 8	NPSI is well placed to build on previous experience through the GBF to commission this work.	The strong linkages between this work and work carried out in the corporate sector on value chain analysis – may suggest that use of a non-traditional research team from the business disciplines or private consulting practice may be most appropriate.
	b). Review the potential value of this approach in terms of improving infrastructure investments and regional development plans more broadly. The key research question being “Does water represent the critical element of a regional development strategy and as such should optimised water management be the driver to all other investment in a region.	Recommendations 7,8,9	Work in this area would require a truly whole of government and community approach. As such significant cross investment would be required. The results of the scenario analysis would be helpful in supporting this investment.	A strongly cross disciplinary team would be required including elements of all of the research disciplines identified in the previous two program areas.
Indicative Budget	a). $100,000 b). $250,000		Key NPSI Investments: a). Focused consultancy report b). Partner in a much larger research effort.	
Indicative Time Frame	a). 12 mths b). 2yrs			

2 Detailed Analysis of System Harmonisation – Irrigation Schemes, Farms and Catchments

2.1 Irrigation schemes –managing water supply from storage to farm

2.1.1 Vision

A perfectly harmonised supply system is one in which flow management is optimised to meet productivity and environmental outcomes.

More specifically, maximising productivity entails a system that can supply water at the highest level of service in the most cost-effective way while meeting agreed environmental objectives.

2.1.2 Scope

There are two types of systems requiring different harmonisation approaches regulated and unregulated systems

- In regulated systems, harmonisation involves flow management from reservoir releases to the farm
- In unregulated systems, harmonisation involves flow management from stream diversions to the farm.

System harmonisation can only be achieved by a combination of appropriate technical, structural and institutional options. This section deals with the main structural and technical options. Section 3.2 discusses institutional options needed to achieve harmonisation outcomes.

Main structural and technical options for system harmonisation are:

- Channel automation (See Appendix 2)
- on-farm/off-farm storages. (See Appendix 2)
- Conjunctive surface groundwater management (See Section2.3)
- Change of crop mix (See Section 2.3)
- Intelligent systems (sensors, communication & decision support) to collect and integrate on-farm and off-farm monitoring data.

2.1.3 Take home messages for NPSI on Irrigation Scheme (Storage to Farm) research

Integration of on-farm and off-farm monitoring data in real time

At present, on farm and off farm systems are not integrated and the level of economic benefits needed to justify channel infrastructure upgrades can in most cases only be achieved if sufficient benefits accrue on the farm. The response time needed to supply water on-demand or near on-demand varies with the distance from reservoir to farm. Travel time in some systems on the Murray can be in excess of 10 days. Real-time operation of the system can be greatly improved by using DSS support systems that can forecast short and medium term demand based on soil monitoring, weather forecast and other factors. Whilst sensors are available to monitor on-farm soil moisture, they are still expensive and do not have wireless capability. Moreover, sensor collected data at present is only available to the grower but cannot be accessed and integrated by irrigation providers.

There are no DSS systems available for service providers to mine monitoring data and integrate it with weather forecasts to anticipate short and medium term demand (similar to existing robust DSS systems developed by the power industry). A proposed University of Melbourne-STI Victoria proposal aims to develop a wireless sensor network which would enable low-cost soil monitoring and enable integration with canal flow information and link water demand with operation of the channel system and reservoir releases.

The main research gaps in this area are: **Low-cost-wireless soil monitoring sensors and DSS to integrate on-farm monitoring and off-farm canal operation and control.** This should be addressed by the Melbourne STI proposal.

Selection of optimal mix of harmonisation technologies

Process and criteria to optimise a portfolio of harmonisation tools including on-farm and off farm storage, channel automation, crop mix changes, infrastructure mix (channel & pumps) are not available. Optimisation should occur at system and catchment levels. For instance, MIL on-farm storage policy (land and water management plan) focuses mainly on storage size to accommodate the first flush of rainfall runoff and 100% of irrigation runoff. However, there are additional benefits and options that may accrue from this technology such as improved level of service to irrigators. On-going research by CRC-IF aims to study the use of the storage option to raise the level of service delivery and reduce the impact of the order rejectionon river flows, and options for altering prevailing flow demand patterns.

However a **comprehensive framework for evaluation of best mix of tools for achieving system harmonisation** including automation vs storages; canal infrastructure vs pumps (river diversion) is lacking. With increasing attention being paid to carbon emissions, such a model should deal with the **energy implications of the alternative options**, in particular those involving pumping options.

Alternative canal and pipeline materials

In recent years, there has been significant progress in the development of new canal lining and pipeline materials. Experience in the application of geosynthetics in several countries has amply proved their superiority in quality, cost and speed of construction over the traditional hard rigid lining materials such as concrete.

Similarly, there is an array of new pipe materials which can provide cost-effective alternative to conventional techniques, in particular for use as short-term infrastructure.

Comprehensive field testing of alternative canal lining and pipe technologies for prevailing Australian conditions is lacking at this stage.

2.2 Irrigation Farms - managing water demand on the farm

2.2.1 Background and context

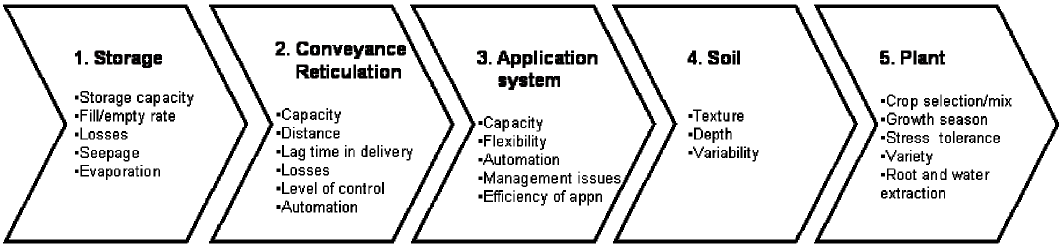
On farm total system harmonisation in its broadest sense implies integration across all elements of the farm production resource base (social, economic, technical, environmental) to achieve an optimum return on all resources. The focus of this section is on tools and systems (technologies) that will guide and enable on-farm harmonisation of all elements of the irrigation system. On-farm elements have to be synchronised with the off farm water supply.

Perfect on-farm irrigation harmonisation implies the irrigation requirement of the crop can be met by all elements of the on farm delivery system and that there is a balance of the flow across all elements. Imbalance in any element with respect to another requires a “buffer”.

The smaller the number of links and shorter (in terms of time lag) delivery chain; the better capacities are matched; the better the communication and control across links, the smaller will be the "buffer" required. The buffer typically takes the form of storage, but may also be excess capacity (eg to convey and supply water).

Providing "buffer" to compensate for an unbalanced system is not a bad default strategy and is used widely by farmers (eg who build storage). The soil is also an important buffer storage. A good soil is generally one with the highest storage (buffer). Open hydroponic systems which effectively remove or greatly reduce the soil storage available have a significant impact on the water demand profile and level of service required from the water provider (See appendix 3). Problems occur when the buffer results in increased losses such as evaporation or seepage from the storage or requires excessive capital (eg to oversize an irrigation application system). Other strategies can be used to correct system inefficiencies such as tailwater recycling although this comes with economic inefficiency (eg double pumping).

The elements making up the delivery system (from farm gate to crop) are diverse and thus constraints and opportunities for managing irrigation water demand/supply (and hence scope for harmonisation) are varied as indicated in the figure below. Opportunities to provide a "buffer" occur in each element of the system:



Any one or combination of the above elements can be managed to achieve on farm harmonisation. On-farm elements have to be synchronised with the off farm water supply which can vary from regulated supply from a water supply authority (e.g. via canal/pipeline), to uncontrolled water from a river, groundwater or overland flow. When supply is via a water supply authority, failure to adequately link off-farm water supply schedules to on-farm demand will limit incentive to implement on-farm improvements. Typically in larger schemes the control of water supply has been in the hands of the water supply authority and this has limited the incentive for the farmer to invest in and manage on-farm water supply e.g. adoption of drip irrigation when water availability for highly frequent applications cannot be reliably provided by the water supplier.

An example of perfectly harmonised on-farm system is a single field Centre Pivot with adequate capacity and operating off a bore at the field edge with no water supply constraints. A simple system does not therefore need many smart technologies for harmonisation.

As the system becomes more complex (Multiple fields, multiple crops, multiple soils, variability within fields, multiple application systems served by a range of water conveyance systems (canals and pipelines) the ability to balance the flows becomes more difficult. This increasesthe need for technology to assess current and future crop water demand and automation to optimise water supply to the crop. These are discussed in Appendix 3.

There are many challenges in achieving on-farm harmonised systems. An unfortunate trend has been the adoption of improved technology only to then move backwards to simpler systems which do not support harmonisation (eg move from Capacitance probe to gypsum blocks; move from Drip system to overhead systems). Relevant issues on adoption of irrigation system harmonisation technologies are discussed in Appendix 4.

2.2.2 Benefits of on farm harmonised systems

Harmonisation implies that field automation can be linked with the farm supply point which is in turn linked with the channel supply system. By integrating these components of the supply system there is greater efficiency and flexibility to meet delivery requirements and reduce losses. Water ordering becomes more predictable and opportunities for upgrading systems and adapting management strategies become evident.

The benefits of on-farm harmonised systems will relate to production, profitability and the environment. A deterrent will be the initial capital outlay and the management inputs required for system change and operation.

Production

- Improved yield and crop quality
- Increased area under crop by capturing water savings

Profitability

- Reduced operating costs through water savings and pumping costs
- Better product quality, time to market and price
- Better matching and rationalised infrastructure costs
- Management of cash flows through and across seasons.
- Water trading opportunities
- Access to funding from upstream/downstream links in value chain.

Environment

- Reduced water wastage
- Limited water table impacts
- Improved riverine flow regime
- Reduced off site water quality impacts (soil, nutrient, chemical wash off)

2.2.3 31Take home messages for NPSI for farm research

There are many technologies available to measure soil moisture, crop water requirement and flow rates in the delivery system. Cost is however prohibitive and communication between sensors is a problem. A missing link is integrating information across fields and the farm, communicating this (cost effectively) and having a decision support system (DSS) to optimise the solution based on a range of competing demand sectors.

More specifically research opportunities include:

Sensor Systems

- Development of affordable, reliable, easy-to-calibrate methods, sensors and/or techniques to conduct wide-area (i.e. not point specific) measurement of crop water requirement.
- Development and validation of affordable sensors and related technology to measure water flows and storage levels across the water supply system, particularly in open channel systems and on-farm storages.

Control Systems for Irrigation Application

- Automated control of irrigation supply to the field, particularly into furrow, basin, border and bed systems. Irrigators generally have no way of controlling variable inflow from the supply channel. This limits ability to manage infield water distribution. In mechanised systems (eg Centre Pivots) precision irrigation application technologies are already in place and the gap is related more to integration of information from field sensors to provide real time signals to emitter flow control.

Communication Systems

- Affordable communication networks to link multiple sensors for reporting to a base station. (Note that current technology is available, but generally is not at a cost low enough to justify investment for lower value broad-scale irrigation and it's management systems). The cost of communication networks, reliability and coverage is currently a problem and system harmonisation will require a greater array of sensors and communication requirements.
- Adoption of an irrigation industry standard communication protocol to be used across all sensor, control and DSS packages, similar to the standard communications protocols now in place for guidance systems (NMEA) and vehicle control (CANBUS).

Decision Support Systems (DSS)

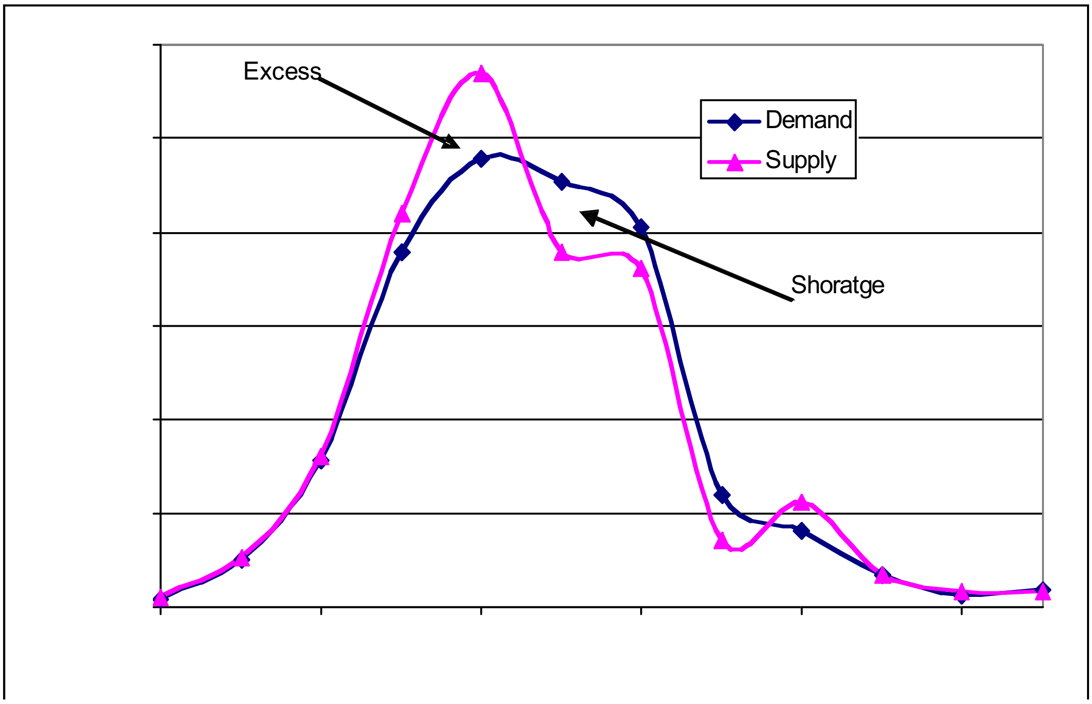
- Development of DSS's to integrate on-farm information from a range of field sensors to calculate current and future **water demand at field scale** and simulate alternative water management strategies and scenarios. Integration of soil moisture and crop data with field water balance simulations (based on historical and future weather data) would allow better field scale water planning strategies. Visualisation tools would help significantly in making management decisions.
- Development of DSS's to integrate information on **water demand at field scale (above) with water supply constraints, at critical points in the system** to optimise water supply across all fields and supply systems. This information is essential to inform decision makers and control irrigation application and supply/storage systems. The information needs to be distilled into a single point of information transfer from the farm to the water supply authority. Consideration needs to be given to the appropriate level of automation and need for the farmer to understand and approve the "order".

2.3 Catchments - matching water supply and water demand within a catchment

2.3.1 System harmonisation at the Catchment Level

The harmonised water demand management at a catchment level would:

1. Adjust for differences or inconsistencies between water demand and supply. This can be presented by the following figure



2. Make resources more productive i.e.:
   - increase agricultural production and profitability;
   - maximize net benefits from rivers, surface and groundwater resources;
   - use surface and ground water as a single resource;
   - implement new technology where effective.
3. Have the ability to attract and/or retain resources and investment funds.
4. Meet environmental performance standards for water, soil and species protection.
5. Meet food safety and other standards for crop production.
6. Have appropriate data and information management systems that can be readily accessed and compiled, and classified in a compatible way. Achieving this is the basic aim of harmonisation of demand management.
7. Achieve competitiveness not only on natural comparative advantage, but also on environmental policies within Australia and abroad.
8. Have operating rules for dams and groundwater storages to meet the environmental and consumptive water demand.

2.3.2 Changing Crop mix for Better Demand Management

Many water supply catchments in South East Australia are over-allocated and cannot meet peak demand. Therefore catchments are having to adjust to lower water availability. One option is to change crop mix.

The issues related to changing crop mix in order to achieve demand that is within the catchment ability to supply are:

- Reduction in crop area and farm viability
- Changing crop mix to give the best economic return.
- Increasing efficiency of water use for irrigation and harmonize it with the climatic situation.
- Changing irrigation technique (form of irrigation) to improve efficiency and interactions with crop mix.
- Scheduling plant demand using sowing date.

2.3.3 Key challenges to Catchment Harmonisation

The key challenges to catchment harmonisation are:

- rainfall rejection. Where there is a large reduction in irrigation demand over a large area and the supply system must discharge back to the river system.
- the coincidence of demand that results in peak demands across the whole area.
- the relationship between water reliability, water yield and how this is conveyed in price and other signals between irrigators and system provided.
- Matching crop mix with water quality available.
- Drought management strategies when irrigation water is in short supply. e.g. minimising losses by strategic shut downs of the system. e.g. knowledge of critical growth stages of crop.
- Integrating consumptive (e.g. irrigation) demands with environmental flows. For example with environmental flows. For example releasing an environmental flow that can be subsequently captured and used for irrigation i.e. achieve two objectives. This may require storages downstream of the environmental target.
- Trade off analysis of managing seasonal demand through en-route storage eg. reduction in irrigation peaks and enhanced water security and reduced rainfall rejection, versus increased risks of blue-green algae bloom, increased seepage and evaporation and possible deterioration of river water quality due to increased salinity.
- Harmonising surface and ground water storages with water policy e.g. water trading
- Opportunities for seasonal demand management through transfer of water between irrigation and environmental management activities– this needs to integrate crop science, demand management and ecological sciences

2.3.4 Crop Diversification Issues at the Catchment Level

The issues associated with crop diversification at a catchment level are presented in Appendix 5 Crop diversification will have a significant change in water demand for the areas under considerations. Modelling of such issue should consider many variables such as new crop intensity, new crop water requirements, economic aspects, production, yield, and long term impact of the new system on the soil quality for future long term impact. Also, modelling of such issues will require field experiments for model calibration and verification.

The key issue is how water yield and water reliability is most efficiently communicated to irrigators so that they can make crop diversification decisions with full knowledge of risks, so that crop diversification is optimised to catchment water availability and reliability.

2.3.5 Key Lessons from the Pratt Water Study

The Pratt Water study has concluded that en-route storages offer potential to harvest more water for productive use and for environmental flows. The storages offer a sustainable and potentially viable option to address the possible shortfall of water supply and the damage to restricted flow capacity reaches (e.g. Tumut River) resulting from the constant high flow rates during periods of peak demand.

Main lessons learnt from the Pratt report are:

1. **Better Pricing**: Need for market demand for water to meet productive use requirements, particularly during peak summer periods, and with that, an acknowledgement that the additional price paid reflects the additional security and environmental quality. For example *"attaching a more realistic charging regime and revenue recovery processes for the delivery and supply of water, effectively adopting a user pays model"*. There is a need for market based mechanisms for valuing enhanced environmental flow patterns.
2. **Institutional Issues**: Clarification of the roles of State Water and the Department of Infrastructure, Planning and Natural Resources, particularly as they relate to water allocations, and the potential for attenuation of water entitlements under certain circumstances There is a need for explicit and predictable coordination of regulated and unregulated river management and accurate measurement and monitoring of water flows Greater clarity on the conditions under which the limits set by the Murray Darling Basin Commission Cap may be adjusted. There is a need to determine ownership of water access and rights through a certification system and/or Concession Deed.

2.3.6 Take home messages for NPSI regarding catchment research

Research areas recommended include:-

- ❑ A cost/benefit analysis of downstream storages to enable flows to meet both environmental and irrigation demand profiles, this is of major interest and requires economic, environmental and water quality aspects to be considered. This type of work is being done by the Murray Darling Basin Commission and others as part of the Living Murray Program, but at a site specific level. The role for NPSI would be to provide some overarching generic principles for this type of analysis.
- ❑ Pricing signals and water allocation signals to reflect both water yield and water reliability to irrigators and the impact this has on crop mix. This is becoming increasingly important to understand in an environment where new water products are developing, water trade expands, system capacity trading develops, carryover, and water product tagging becomes more commonplace.
- ❑ Institutional clarification (see Chapter 3.2)

3 Analysis of Total System Harmonisation -Beyond the Water Cycle

3.1 The Value Chain

3.1.1 Definition

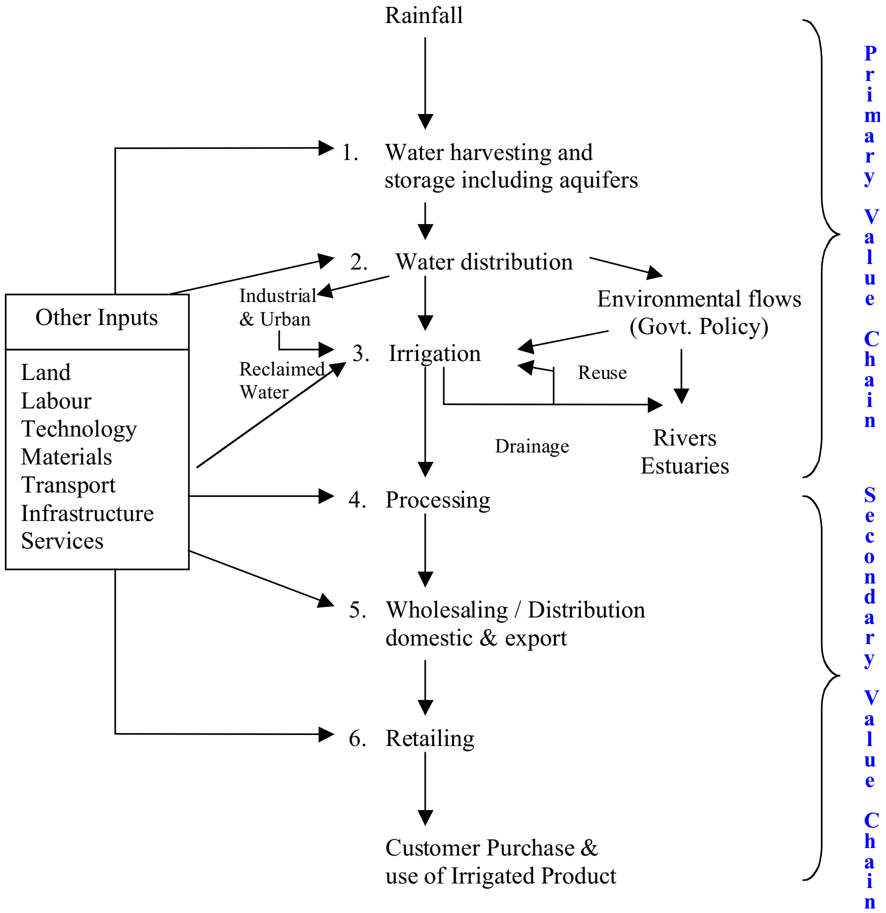
The term value chain was first used by Michael Porter in his book “Competitive Advantage: Creating and Sustaining Superior Performance (1985). The value chain analysis describes the activities of an organization and links them to the organisation’s competitive position.

The value chain can be defined as: “A series of linked business processes that create value in both products and services, which are delivered to the customer.”

The key linked business processes can be defined as the primary and secondary value chains according to the diagram below. In this case the farm gate is the boundary between primary and secondary value chains.

The ability to influence the value chain of irrigated produce beyond the farm gate is limited as the complexity and number of stakeholders increases enormously. The coordination of systems beyond the farm gate is generally market driven and coordination efforts can be seen as compromising competition, which may be counter to national competition policy or international agreements covering free trade. Having said this some industries such as the rice industry have been very successful at coordinating vertical integration of processing, distribution and marketing. The same has also been achieved in the wine industry using a mix of large corporate companies, which are vertically integrated to serve large markets, and smaller companies serving niche markets.

The Value Chain ➔ ŅLinked Business Processes that create value in products and services to the customerÓ



Each of the six business processes identified above could be split into a number of processes, butfor the purpose of this report the six processes are adequate. **The fundamental issue is that success in the value chain requires adequate feedback and response to the needs and wants of the next step in the value chain.**

Therefore "Total System Harmonisation" is the design and implementation of business practices which both communicate and respond to the needs and wants of the next step in the value chain This is for the purpose of achieving efficient resource utilisation across the total system (energy, water, land, people, infrastructure, environment etc.)

An explanation of the issues that limit the value chain's effectiveness and the opportunities to increase harmony along the value chain are included in Appendix 6.

3.1.2 Take Home messages for NPSI regarding Value Chain Research

As described in Appendix 6 the most appropriate role for NPSI would be to focus on improving businesses processes within the primary value chain. The key needs for each of these processes are:

Table 3-1 Research Areas for NPSI along the Value Chain

Business process	Information Needs	Research Role for NPSI
1) Storage	❑ feedback and integration of water demand from multiple water distributors	Yes
	❑ weather forecasting informing storage management	Yes
	❑ evaporation losses from storage	No, Already done by NPSI
	❑ storage cost and affordability of improved systems	No, is site specific
	❑ dam safety – community standards	No, lots of work done by ANCID/ANCOLD
	❑ seepage losses –affordable loss detection and prevention	No, lots of work done by ANCID
	❑ providing advice and forecasts to water distributors	No, is site specific
2) Water Distribution	❑ feedback and integration of water demand from multiple users	Yes
	❑ evaporation losses from distribution systems	No, lots of work done by ANCID
	❑ distribution system costs and affordability of technology	Yes
	❑ seepage losses –affordable loss detection and prevention	No, lots of work done by ANCID
	❑ providing advice & forecasts to water users	No, is site specific
	❑ re-engineering of supply systems to meet changing irrigation demand (flexible, low cost, supply infrastructure).	No, is site specific
	❑ energy use	Yes
	❑ price, water yield and water reliability signals between storage and irrigator.	Yes, links with NPIRD irrigation risk kit
3) Irrigation	❑ feedback and integration of agricultural market demands to identify optimum crop mix, within the available resources water and other constraints	No, is market driven decision, outside scope of NPSI
	❑ efficiency of conveyance and application of water to meet crop water demand	Yes, note lots of work already done
	❑ crop water demand assessment	Yes, note lots of work already done
	❑ water ordering procedures	No, is site specific
	❑ alternative water sources	No is site specific
	❑ integration of water demand assessment with water distribution	Yes, note lots of work already done
	❑ affordability of technology	Yes
	❑ energy use	Yes

3.2 Implications for Institutional Arrangements

3.2.1 Institutional arrangements and system harmonisation

An institution refers to an organisation founded for a specific purpose. There are a number of different institutions involved in total system harmonisation.

The most relevant areas for NPSI are those related to the functions of water harvesting, water distribution and water use (the primary value chain). Institutional arrangement along the secondary value chain are generally outside the sphere of control and influence of NPSI.

The diagram below illustrates those components where institutional arrangements influence the primary value chain. Appendix 7 looks at the implications of each component on total system harmonisation.

1.	Water harvesting	a)	Allocation Policy	Primary Value Chain
		b)	Environmental flows	
		c)	Annual allocation policies	
2.	Water distribution	a)	Water trade	
		b)	Tariff	
		c)	Flexibility	
		d)	Service levels	
		e)	Medium term demand change	
		f)	Land use planning	
		g)	Obligation to supply	
		h)	Information	
		i)	Capacity to change	
		j)	Conjunctive use	
		k)	Alternative technologies	
		l)	Business Structures	
3.	Water Use (irrigators and other customers)			
4.	Processing			Secondary Value Chain
5.	Wholesaling/Distribution domestic and export			
6.	Retailing			

3.2.2 Take home messages for NPSI on Institutional Issues Research

There is a range of institutional arrangements in place across Australia. Many of these are changing rapidly and are relatively new. The influence these are having on the adoption of harmonisation of systems is unclear and in some cases unknown.

Within the CRC IF Jennifer McKay is undertaking a review of institutional structures in the Irrigation Water Service Provider industry and their impact on adoption of sustainable practices. This is likely to have synergies with regard to the capacity to adopt System Harmonisation Technologies. The Murray-Darling Basin Commission Watermark Projects also have some key lessons to institutional capacity to improve irrigation sustainability.

A major issue that inevitably affects any research into institutional issues is that the implementation of water reform is at different stages within different jurisdictions. This means that the issues vary widely and it is difficult to come up with specific recommendations that will apply to all. Therefore NPSI should focus on those issues which are likely to be common and of wide application to most forms of irrigation. Examples of this are institutional frameworks to govern conjunctive use of surface water and groundwater. And also the fact that new institutional arrangements for upper catchment water management are now becoming critical as caps or water use limits to extractions are being applied catchment wide.

Research in institutional arrangements that are more specific to each jurisdiction and are covered in water policy development programs at a government level, rather than within the scope of NPSI, have been scored at a lower priority below.

There is a clear research need is to conduct an audit of institutional arrangements and assess their impact on system harmonisation in terms of:

- ownership structures - low priority
- scale of cross-subsidisation – low priority
- available tools to manage temporal and spatial ebb and flow of demand – high priority
- tariffs and the investment messages they convey – low priority
- cross jurisdictional barriers to conjunctive use of surface and sub-surface water use, -high priority
- suitable tools and processes to monitor farm and off farm systems against triple bottom line – high priority
- determine processes to track and monitor changes to these arrangements to ensure their impacts (many unintended/unforeseen) are assessed. – low priority

4 Priorities for Research- summarised from analysis

4.1 Detailed Recommendations

This section summarises the research priorities identifiedby the analysis undertaken in the scoping study.

This scoping paper provides the following recommendationsfor research areas:

Irrigation Scheme-Water Distribution/Supply

1. New water supply and drainage products for irrigators. This is core business of water authorities/suppliers and should be done in partnership with these organisations.
2. Hydraulic harmonisation with regard to:
   – water storage (on-farm) integration into the system
   – channel control and automation
   – pipeline control and automation
   – low cost, low pressure highly flexible supply infrastructure
   – sensor monitoring – inform irrigation demand scheduling. Integration of on-farm and off-farm systems eg. low cost wireless soil monitoring sensors and DSS to integrate on-farm monitoring and off-farm canal operation and control.
   – a comprehensive framework to evaluate the best mix of tools (DSS) for improving system harmonisation to optimise productivity and further development of appropriate DSS tools to integrate on-farm water demand with supply constraintsand environmental objectives.

On-Farm Irrigation

3. The development of inexpensive, reliable, easy to calibrate sensors of crop water requirement which communicates via the irrigator (or farm manager) to the supply system.
4. Technology to lift the uniformity of flow and application to the field through both off-farm and on-farm systems.

Catchment

5. A cost/benefit analysis of downstream storages to enable flows to meet both environmental and irrigation demand profiles,
6. Pricing signals and water allocation signals to reflect both water yield and water reliability to irrigators and the impact this has on crop mix.

Value Chain

7. Focus on improving primary value chain. Secondary value chain is market driven and is beyond the influence of NPSI. NPSI should look at reducing input costs of primary value chain with new technology, see recommendations above.
8. Improving feedback and communication along the entire primary and secondary chains is essential. NPSI can focus on the primary chain, but can help facilitate this in the secondary chain. For example;

infrastructure planning, energy use, skill requirement, training, quality assurance, environmental management systems can all be developed by a partnership of organisations in the value chain for mutual benefit.

Institutional arrangements

9. Conduct an audit of institutional arrangements and assess their impact on system harmonisation in terms of:

   - available tools to manage temporal and spatial ebb and flow ofwater demand
   - cross jurisdictional barriers to conjunctive use of surface and sub-surface water use, and
   - suitable tools and processes to monitor farm and off farm systems against triple bottom line

4.2 Integrated research programs

By definition, research into total system harmonisation must be integrated across components of the total system. Therefore, it is important that research efforts referred to above be combined within single projects to ensure maximum benefit.

Therefore the following three programs are recommended

- Smart System and Infrastructure Development Research Program – for Irrigation Schemes
- System Harmonisation Research Program- for Catchments
- Total System Harmonisation Research Program - for the entire value chain

These programs have been detailed in Chapter 1.

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6 Appendix 1 NPSI Brief for Smart Systems and System Harmonisation

Harmonisation: The adaptation of parts to each other in any system or combination of things intended to form a connected whole.

How do you achieve an irrigation system within a region that is absolutely resource efficient (resources = natural, human, economic)?

Today with the pressures on wise use of water, falling commodity values, and a need to work towards a sustainable environment there is a need to achieve a better return on the resources deployed. This means a total systems approach that evaluates both water and energy efficiency.

Research investment is expected to provide environmental benefit through more effective use of water and less risk to the environment. It will also inform the Goulburn Broken Futures and Northern Australia Irrigation Futures projects

The Sustainable Irrigation Program requests the following question be scoped:

What should be the focus of research by the Sustainable Irrigation Program to achieve the tools that will guide and enable Total System Harmonisation (TSH)?

TSH will require the use of smart systems that may operate independently but are able to be incorporated into a total irrigation system where water authorities, farms, manufacturers, energy suppliers, weather forecasters, and environmental agencies achieve a seemless irrigation production system that minimises resources per unit of production and risk to the aquatic environment.

As part of answering the question it is expected that the paper will cover:

1. Smart system technologies that may be used and currently available; new technologies being investigated; and types of systems that need inventing. (for example the current research results from investigations into Open Hydroponic Systems would be summarised and discussed).
2. The need for distributing demand for water through the irrigation season via strategic crop diversification and possibly multiple crops plantings in the one paddock. This would mean in some instances limiting the types and location of crops to be grown. How closely is this likely to align to value adding opportunities?
3. Micro industry intensification and identification of primary and secondary industry chains that could offer resource efficiencies. How will this help with the current free market approach towards water ownership?
4. What technologies are missing so that all irrigation systems within a catchment can be linked into the one TSH.
5. The change process for existing irrigation districts – what are the priorities to ensure that existing districts can move towards TSH. For example, consideration is required of the current irrigated agriculture regimes and whether there are specific barriers to commencing implementation of TSH
6. What are the human (individual, community, economic) issues that need to be addressed to build and implement such systems?
7. Who would be the main beneficiaries and what is the most appropriate framework for evaluating benefits?

The paper should also include reference to potential researchers or groups of researchers (both public and private) who could undertake the research either as a single entity or as part of a team.

The research to be developed and implemented as a result of this scoping study will inform the broader subject area of "Sharing Landscapes" which is also having a scoping study undertaken. Background information on the "Sharing Landscapes" project is available on request.

A draft report of about 20 pages (appendices additional) is required by February 28, 2005.

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7 Appendix 2 Storage to Farm Hydraulic Harmonisation

7.1.1 Channel automation

Channel control technology in Australian systems

Most irrigation systems developed worldwide over the last century systems use upstream controlled system technology by placing gate undershot or overshot structures in the canals to control discharge and water level. The simple use of these structures operated on an "on/off" basis improved the efficient use of water in many cases. Subsequently, the introduction of water measurement structures with gates allowed the systematic distribution of water by irrigation providers.

Since the introduction of the downstream control concept in the 1930s, rapid reaction of the system to irrigator's demands is possible. These systems react to changes in water demand automatically often without human intervention.

Since the 1980s, telemetry (SCADA)[1] technology allows operators to centrally control the individual canal reaches and the computerised control on the main system as-a-whole allows a further optimisation of the distribution of irrigation water.

Channel control technology used in Australian systems: Most (if not all) Australian systems were designed to operate as upstream control systems, e.g. channel operation to effect operational changes progresses in the downstream direction. In the early days systems were all manually operated but increasingly the main control structures have become SCADA centrally controlled.

Automated channel control in Australia: This technology involves the use of intelligent control logic to respond to changes in water level in the canal pools that result from changing flow rate and depth. Rubicon Systems has developed and tested this technology which can achieve near-on-demand deliveries. The control logic is based on a System Identification which models the behaviour of the system based on system observation data and can adjust it to maintain near constant water levels despite fluctuations in demand and supply. This technology allows service providers to retrofit existing canals designed for downstream control to deliver a higher level of service. An alternative approach to achieve a similar level of service would be to redesign the canal system to operate in downstream control mode. Such a conversion is very expensive since it requires dead-level canal pools.

There are two main companies providing these products with slightly different features: Rubicon Systems have designed and tested a hardware-software system based on integrated control of cross regulators and farm off takes using a purpose designed control logic based on system identification. AWMA supplies hardware for control of cross regulators and farm off takes which can be fitted with SCADA control.

Close systems (pipelines): Pipe systems can provide on-demand delivery within the restrictions imposed by their design capacity. Existing closed systems in Australiaand worldwide make use of advanced flow control technology which was primarily developed for chemical and industrial processes. The main opportunities for enhancing performance in these systems is by improved interlinks between farm monitoring and irrigation providers.

Low pressure pipe systems can potentially provide greater flexibility for changing and adapting the delivery infrastructure to changes in the agricultural systems. Traditional infrastructure life cycles usually span

[1] SCADA: supervisory control and data acquisition

between 50 and 100 years while agricultural markets, cropping mix and water markets can induce changes on a much shorter time scale. New low cost materials such as PE and layflat are easier to install and have lower construction costs. A complete evaluation of materials and criteria for use of various low pressure pipe technologies is lacking at present.

System upgrade: Most irrigation distribution systems in Australia require significant upgrade to achieve system harmonisation objectives either by implementing channel automation or pipeline technology together with appropriate intelligent monitoring and control systems. These technologies, however, have not been widely adopted to date. The high cost involved with any of the technologies often can only be justified if significant benefits accrue at the farm level in addition to improved level of service by irrigation providers. This can only be achieved by improving the integration between the on-farm and off-farm water control systems through the use of extensive on-farm monitoring and communication systems.

Systems modelling

There are two main modelling approaches to canal operation:

- Hydrodynamic modelling (or traditional hydraulic)
- System identification modelling

Traditional hydraulic modelling is based on first principles (St Venant flow equations). This approach is used for system design and training but has limited application in control logic. A large number of models have been developed in the past based on different computer algorithms. (See Appendix 2). These models, however, are data intensive and require specialised knowledge of hydraulics and fluid mechanics, and more importantly are not suited for real time control and use in PLCs[2] because of their computational complexity.

System Identification models are constructed from observed system data. The main advantage is that they are much simpler than models derived from first principles. Data rather than fundamental equations define the system. Unlike hydraulic models, these models cannot be generalised but can only be applied to the system behaviour explored by the model. These models are well suited for use in PLCs and thus offer greater opportunities for future real-time flow control on farm and off farm. It forms the basis for the control logic used by Rubicon Systems' Total Channel Control™.

A number of pipeline models are also used to schedule irrigation supply and demand patterns. However, real-time control of pipeline systems relies primarily on advanced pressure and flow sensor technology integrated with purpose built control logic.

7.1.2 Buffer storages: On-farm, Off-farm and groundwater

The use of buffer storages can result in improved channel delivery and distribution of seasonal demand. Buffer storages provide service providers and farmers with additional flexibility to store off peak season flows for use during periods of peak demand. A trade off exists, however, in that buffer storages incur additional evaporation losses.

There are a number of examples in which buffer storages are currently in use or can potentially be used. A distinction must be made between the use of buffer storages in canal supplied systems such as those in the southern MDBC (e.g. Murray, Murrumbidgee, Coleambally) and river diversion systems. The use of buffer

[2] PLC: Programmable Logic Controller

storages in these systems is still limited, although in some cases (e.g. Murray Irrigation Ltd) they have been in used for prevention of farm effluents.

On-farm storages are widely used in the cotton industry to store water directly diverted from river carriers These systems are either unregulated (run-of-the-river) systems where growers must rely on narrow window opportunities to abstract water, or regulated systems in which diversions are based on water orders (e.g. Gwydir).

Buffer storages can also be used in the implementation of new irrigation technology such as open hydroponics to match the low-flow demand with high-flow water supply prevailing in existing channel systems.

Water storage in aquifers presents distinct advantages and disadvantages. The main advantage is avoidance of evaporation losses. From a basin-wide perspective artificial recharge can have very high levels (>75%) of recovery. The main limitations are slow recharge rate, risk of groundwater contamination and greater extraction costs. Catchments with high connectivity between groundwater and surface water are more suitable to implement this storage option. Tradeable entitlements between surface and groundwater are necessary to achieve the benefits of this option.

Storage impacts on the delivery system and catchment performance depend on the local physical and agricultural features of the system. The degree to which storages can be used for system harmonisation and the optimal combination with other options such as smart channel control must be evaluated on a case by case basis.

The use of on-farm and off farm storages to date has been largely for a single purpose, e.g.tail water runoff capture, rainfall capture, capture of off-allocation flows, etc. However, very rarely buffer storages have been viewed as part of an integrated water management system designed to optimise the use of alternative resources (surface, groundwater, reclaimed water) and other system components (canal controland farm water control).

At present, there are no general criteria or model to evaluate trade offs between storages and other technologies and the best distribution and size of storages.

7.1.3 Harmonisation benefits

Benefits from harmonised systems will accrue at various levels:

- Water providers
- Irrigators
- The environment

Table 7-1 Water providers benefits from improved system harmonisation

Technology	Benefit
Storages, channel automation and farm monitoring technology	Ability to optimise delivery services
Storages	Reduction in peak design capacity and cost arising from less concentrated flow demand
Storages/pipelines	Ability to provide a higher level of service with lower infrastructure investment. On-farm and off farm reservoirs as an alternative to full canal automation- Reduced losses due to rain rejections and other short term system adjustments
Storages/channel control/pipelines	More options available to satisfy irrigators desire for higher level of service
Storages	Enhance ability to manage conjunctive flows (surface, groundwater, & reclaimed water)

Work by Graeme Dandy and others at University South Australia on optimising urban pipe networks to meet consumer needs. May provide lessons for irrigation systems. This technology has not been applied directly to rural supply systems and could represent a critical opportunity.

Table 7-2 Irrigator benefits from improved system harmonisation

Technology	Benefit
Storages/channel automation/pipelines	Faster and more flexible response to crop and on-farm management needs. In particular, better capacity to irrigate high value crops, e.g. horticulture
Storages	Storage of unused allocated water from rainfall rejection flows, off season flows and off allocation flows
Storages	Taking advantage of differential pricing between peak and off peak season
Sensor monitoring technology/DSSs	Improved ability to monitor and make informed irrigation management decisions, e.g. irrigation scheduling and applications; resulting in improved irrigation efficiency and productivity
Storages	Greater opportunity to capture runoff and recycle tailwater
Storages	A management option for water quality

Table 7-3 Environmental benefits from improved system harmonisation

Technology	Benefit
Storages/changed crop mix	Improved flow regime in rivers from changes in seasonal flow distribution to meet downstream environmental flow demand
Storages/channel automation	Reduced environmental impacts (land & water) from better on-farm application
Storages/ channel automation	Reduction in undesirable peak flows from rainfall rejection, e.g. Murray Irrigation and the Barmah Choke

System Models for Canal Operation and their Application

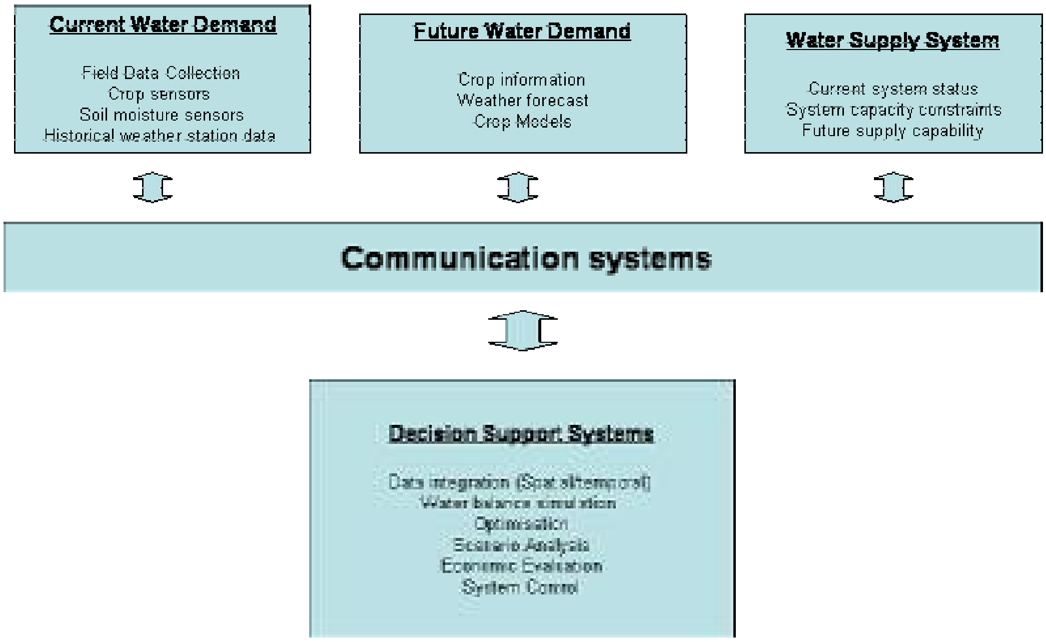
Model	Authors	Article Year	Developers	Application	Uses
CANAL	Merkley and Rogers	1993	Utah State University (1987)	10 pools of the Central Arizona Project	Modeling daily canal operations
CARIMA	Forrest and Parrish III	1993	Consulting engineering group SOGREACH (1976-78)	Cal Poly model canal (California Polytechnic Irrigation and Training Research Center, San Luis Obispo, California); canal systems in Iraq; the Rhone River hydropower cascades; the Imperical Irrigation District, Imperial, California; Texas Farms Inc., Alvin, Tex.	Unsteady flow problems
CanalCAD					
DUFLOW	Clemmens and Holly	1993	The public works department (Rijkswaterstaat) in The Netherlands, Delft University of Technology, the International Institute for Hydraulic and Environmental Engineering (1989)	Cal Poly model canal (California Polytechnic Irrigation and Training Research Center, San Luis Obispo, California);	Simple networks of channels with simple structures
	Mutua and Malano	2001		Pyramid Hill No 1 Channel, Victoria	
MIKE 11	Mishra et al.	2001	Danish Hydraulic Institute (1988)	Right Bank Main Canal system of the Kangsabati project, West Bengal, India	Developed as a river flood model
MIKE 11 HD	De Bievre	2003		Patococha Irrigation Scheme, Ecuador	Unsteady flow in open channels or rivers
MODIS	Schuurmans	1993	Deft University of Technology (1990)		Hydraulic performance of controlled irrigation canals
USM	Rogers and Merkley	1993	U.S. Bureau of Reclamation	Central Arizona Project canal system	Unsteady -flow conditions in canals
IMSOP	Malano et al.	2004	University of Melbourne	Irrigation Systems in Vietnam and China	Steady-state hydraulic model
SIC	Van Waijjen	1997	Irrigation Division of Cemagref, the French research center for agricultural and environmental engineering, Montpellier, France	Pakistan's Punjab	
OASIS	Roost and Musy	(In press)	Roost, Swiss Federal Institute of Technology, Lausanne, Switzerland (2002)	Lower Yellow River basin	Manage irrigation water within a broader context of basin water resources

Model	Authors	Article Year	Developers	Application	Uses
MIKE-11	Kinhill	1998	Danish Hydraulic Institute (1988)	Mulwala Canal, Murray Irrigation Limited, Deniliquin, NSW, Australia	
Water balance	URS	2004	URS	Murrumbidgee Irrigation Area	

8 Appendix 3 On- Farm system Harmonisation

8.1.1 Technological Solutions

Technological solutions for on-farm system harmonisation can be conceptualised in a number of areas (See figure below) and are addressed briefly:



8.1.2 Technology for assessing current crop water requirement

There is a vast range of technologies to measure current water requirement of the crop and forecast future water needs. Current requirement is based on the prevailing status of crop and soil water and usually obtained through direct measurement or a water balance model linked to historical weather data and appropriate crop/soil descriptions.

Charlesworth (2004) has reviewed soil water monitoring technology which includes tensiometers, gypsum blocks, neutron and capacitance probes, wetting front detectors and gravimetric soil sampling.CRC IF have commissioned a scoping study on measuring and monitoring tools and technologies for precision irrigation (CRCIF 2005a).) which forms part of CRC IF Project 3.07 "Tools and technologies for improving the precision of irrigation". In addition to soil moisture measurement this studyidentifies research opportunities for plant water use monitoring and measuring systems such as heat balance sensors, crop growth sensors, spectral imagery and crop water balance models.

Major constraints in these technologies appear to be

- Point measurement and representation across a field scale.
- Reliability and maintenance issues
- Communications and transfer of data
- Cost and affordability

- Time and skill requirements
- Calibration needs
- Provision of simple information for decision making.

8.1.3 Technology for predicting future crop water requirement

Predicting future crop water need typically requires weather forecasts and a crop model to predict soil water deficit. Both short term <10 days and longer term seasonal forecasts are required for operational and strategic decisions.

CRC IF (2005b) have commissioned a review of software for best use of on farm water (Project 3.08). The project is reviewing models to support tactical and strategic decisions regarding the timing of water applications, limitations of the technology and barriers to adoption.

Major constraints in these models is ease of access and use, need for professional support, input data requirements and limitations in region of application. While irrigation scheduling typically looks at decisions at a point, there is a need to assess scheduling decisions in the context of the whole farm operation. Scaling up the implications of decisions on irrigation timing and volume applied is thus important.

There has typically not been widespread adoption of these forecasting tools in irrigation operations and research into the adoption of these emerging technologies will be important.

8.1.4 Technology to automate and optimise water supply to the crop

Meeting crop water requirement is as much dependent on the irrigation system and supply constraints as on the soil/plant water status. Both on farm storage, distribution systems and the irrigation application system itself are integral to optimising water supply.

There are some examples of linking crop water requirement information with the irrigation application system (eg linking capacitance probe to field control and variable speed pump for drip irrigation or emitter flow controller for centre pivot system). These examples are however not widespread.

Furthermore control of the broader water supply system is generally not linked to the application system and crop water requirement. A significant technological gap is thus our ability to integrate/communicate and control across all elements of the delivery network.

8.1.5 Storage Management

Where demand and supply elements of any system are not matched, storage is required. Typically on-farm storage systems are not accurately sized or managed in accordance with their current and future demand and supply constraints. Automation of storage management and flow control is also not widely adopted.

Some remote activation has been installed on pump sets (both inflow and outflow to storage) but automated control of flows is often limited to pump station timers.

Real time information of available water in storage is critical for system management and harmonisation but is seldom available. Systems comprising accurate water depth sensors linked to loggers and weather stations show potential for both determining evaporation and seepage losses from storage and providing ongoing water level accounts. When combined with accurate depth: storage relationships (determined from conventional GPS surveys or depth sounder/GPS instrumentation, this allows continuous monitoring of water volume and provides the basis for an on farm water balance. This technology requires further development and testing.

8.1.6 Distribution Systems Management

Automation and monitoring of distribution systems is more of a problem for channel systems than for pressurised systems. The issues are similar to off-farm channel automationdiscussed in section previously, but there are few systems currently being used in the on-farm situation. Control is generally limited to pump timer at the storage/inflow point.

Typically there is no use of downstream control structures to maintain head and channel conditions. Little use is made of variable rate pumps except for high end pressurised drip systems controlled from in-field zone sensors. Uptake of both variable pumps and downstream structures would benefit many situations.

8.1.7 Application Systems Management

Technologies to automate and control irrigation application systems are generally available for pressurised systems (eg. Using automated valves) but there is a dearth of technologies for inflow control into surface systems. The main difficulty is in accurately measuring inflow into bay/border systems and this is a high research priority. Systems have been developed (Irrimate™) for measuring inflow in siphons using flow meters and software (eg SIRMOD/INFILT) is used to optimise flow management strategies. Some surge irrigation is practiced (eg in sugarcane production) using surge valves and there is some on/off control in dairy border check/bay irrigation based on air tube pressure sensors located near the end of the bay. There is however no control in siphon systems and poor technologies for control in layflat systems.

While automation and control is available for pressurised systems (drip and centre pivot), costs are prohibitive and generally adoption is only in high end cropping systems and there has been poor uptake in lower value crops. CRC IF Project (3.07) "Tools and technologies for improving the precision of irrigation" is scoping priorities for development of new and improved application systems for precision irrigation.

The Rubicon system being tested in Victoria will see state-of-the-art technology employed to improve irrigators' water use efficiency. It is a new technology for controlling water distribution through irrigation channels based on electronically controlled channel gates, linked together through radio telemetry and computer software to enable the whole channel network to be operated remotely and in a dynamic manner. However the cost of the system is high and low cost field level controllers are required.

8.1.8 Communication Systems Management

Main devices at present are radio (VHF) or telephony based systems. Many are application specific and do not interface easily with other systems while costs are high and systems lack robustness. Many irrigation areas are not covered by nationally telephony systems (eg. Telstra) and hence are forced to put in own infrastructure. Even in areas where there is telephony cover, the costs of network access can be prohibitive for a large number of devices ($10-15/mth for access under most plans). Data speed can also be a problem for downloading some systems.

A research need is to develop low cost, robust communication devices with standard interfacing and inter-operability. A proposed University of Melbourne-STI Victoria proposal aims to develop a wireless sensor network, which would enable integration of water demand and supply systems.

8.1.9 Decision support systems

There are a range of decision support systems ranging from field level irrigation scheduling, improved water use efficiency, system optimisation to strategic decision making on storage and system management.

Whole farm water balance systems are also important and various software is availabletypically in the form of in-house consultant software.

CRC IF (2005b) have commissioned a review of software for best use of on farm water (Project 3.08). Many of these models allow prediction of future water requirement. A listing of some of the models being reviewed is given below:

Model	Application
Flowcast	*Forecasting streamflow*
AgWISE	*Irrigation and salt management*
IrrMAX	*Irrigation and salt management*
SWAGMAN	*Assess farm cropping options*
Maizeman	*Risk analysis and scheduling*
HydroLOGIC	*Scheduling and improved WUE*
DamEa$y	*Investment in onfarm storage and irrigation*
WaterSupply	*Assess water supply options*
Waterbalance	*Irrigation scheduling*
Caneoptimiser	*Irrigation scheduling*
SIRMOD/INFILT	*Surface Irrigation optimisation*
TravGun	*Travelling gun irrigator optimisation.*
MBoss	*Centre Pivot performance optimisation.*
IRRIBAL	*On-farm water balance*
Aquatech	*On-farm water balance*

A missing link seems to be integration of DSS's to deliver total on-farm water management requirements. Many models are task specific, difficult to use and have stringent input data requirements and professional support is generally required.

Primary research opportunities would appear to lie in development of DSS's to:

- integrate on-farm information from a range of field sensors to calculate current and future water demand at field scale
- integrate information on field scale water demand (above) with water supply constraints in order to optimise water supply across all fields and supply systems and deliver relevant water orders to the water supply authority.

8.1.10 Challenges in Managing Irrigation

Harmonisation on the farm goes beyond the technical issues around crop water requirement and water supply. Management of the crop and irrigation will vary with:

- Crop selection. Crop selection decisions are more driven by product markets and prices and processing capacity in the region.

- Area to be planted (water availability, equipment available)
- Cultural practices – for example in a dairy farm irrigation may be a set rotation according to grazing needs or wine grapes may be held at different soil water deficits according to variety and quality required.
- Climate control – e.g. irrigation for cooling of crops (e.g. lettuce) or frost prevention.
- Disease control.

This raises the point that even the best on-farm monitoring and communication link back to the water supply system will be inadequate to achieve significant improvement in system harmonisation. There are simply too many variables.

The data flow from soil water sensors and future crop demand models must be via the irrigator before being used by the supply system model for providing future demand. A range of factors will affect the farmers adoption of these systems. These are discussed in Appendix 4.

Irrigations can be brought forward or delayed for a large number of reasons that are not related to crop water demand.

Another major issue that will constrain the use of more sophisticated on-farm monitoring is high variability.

Soil moisture variability and crops water use varies enormously even with high uniform water application and uniform crops. This then requires a large number of sensors to achieve a picture of average demand.

Irrigators can generally develop a picture of average demand with their knowledge of crop performance for each sensor. This would be a major challenge to automate. It may well be that ET predictions combined with knowledge of historic demand will provide the most reliable prediction of future water demand rather than smart sensors.

Open/Field Hydroponic Systems and Implications for System Harmonisation

Open Hydroponics (OH) are being trialled and adopted in horticultural field crops eg. citrus in Sunraysia, Riverland and Riverina. Also in avocados and wine grapes. Some proponents claim a doubling of water use efficiency in t/ML when compared to conventional irrigation. Most of this is through increased yield rather than reduced water use per ha.

While hydroponic systems have been used for many years in greenhouse situations, there is limited experience in open or field hydroponic systems in Australia. There is even less knowledge about what this could mean for future irrigation service needs for irrigation authorities.

New hydroponic technology requires a continuous supply of water, with minimum water storage in the soil. Nutrients are also supplied on a continuous basis. Drip irrigation technology can also be managed in a similar way and there are various levels of reliance on soil water storage.

At the extreme, it means that the peak demand cannot be met by drawing on soil moisture reserves and so will require a higher supply flow to match the demand. There is no buffering of peak demand by soil storage as in conventional irrigation.

The issues are:-

- to determine what the peak flow demand will be with the new technology/management system;
- and what this means for the design criteria to be used in the rehabilitation of horticultural districts and new developments;
- environmental sustainability. Drainage needs, nutrient and salt implications are uncertain.

If the current design of district systems is inadequate for future technology, this may lead to:

- growers not adopting technology, and a ceiling placed on potential water use efficiency improvements;
- district rules applied to growers which limit access to peak flows and limit adoption of technology; there are implications for trades in infrastructure capacity sharing;
- replacement of soil water buffer with dam water store. On-farm storage dams to provide for fluctuations in demand (remove peaks) could reduce water use efficiency through evaporation and seepage losses. There is loss of productive ground and liners may be required.

There may be a trade off needed between on-farm storage costs versus delivery capacity costs.

Open hydroponics represents the extreme case of no soil water storage, and therefore enables scoping of peak requirements across a range of technologies according to amount of soil water storage.

NPSI have funded a CRC if project managed by NSW Agriculture for investigate open hydroponics.

Initial results from CRC IF project are:

This project investigated the issue of supply system constraints. Preliminary results (not yet published) are:

Open Hydroponics Requirements	Water suppliers Responses
❑ 13 hour/day access to water everyday during peak demand (crops have reduced root zone and low buffering ability – i.e. (cannot stand waiting for water)	❑ cannot guarantee supply ❑ access to water is treated equally. Distribution capacity shares being investigated and may be able to be traded to increase access. ❑ irrigators are responsible for assessing their own level of risk. (eg lower risk on main channels, and higher risk on minor spurs) ❑ providers can supply water between 75% and 99% of the time. Depending on system/district. Most reliable is supply through private diversion districts.
❑ Peak requirement of 6.5 mm/d for citrus in 13 hours at 0.005 ML/ha/hr to 0.007 ML/ha/hr (0.5 to 0.7 mm/hr) eg. 10 ha orchard for 13 hours = 10 X 0.0065 ML/ha/hr X 13 hrs = 0.085 ML in 13 hours of daylight	❑ will vary from supply system to supply system ❑ currently daytime demand is low as irrigators prefer cheaper off peak night time and weekend pumping electricity. Therefore, there is generally some spare capacity during average summer days, although this can become over committed during peak demand eg. after rain shut down. Therefore, there will be some opportunity for meeting OHS demand while there is limited adoption during average demand periods. But there would be potential problems during peak demand periods, especially on tight lights. ❑ More modern pressurised on demand services, generally have higher supply capacity and risks are lower. However, these would struggle to meet demand if there was 100% adoption, without on-farm storage.
Crops requiring irrigation all year round	❑ This issue is not specific to over-hydroponics systems ❑ Access between May to August inclusive will vary between systems. Some have no access, while others have scheduled 'winter runs' ❑ This is dictated by maintenance requirements.
On-farm storage	❑ Various approvals are required
Premium water access service – delivery capacity	❑ Being explored in water reform process in Victoria

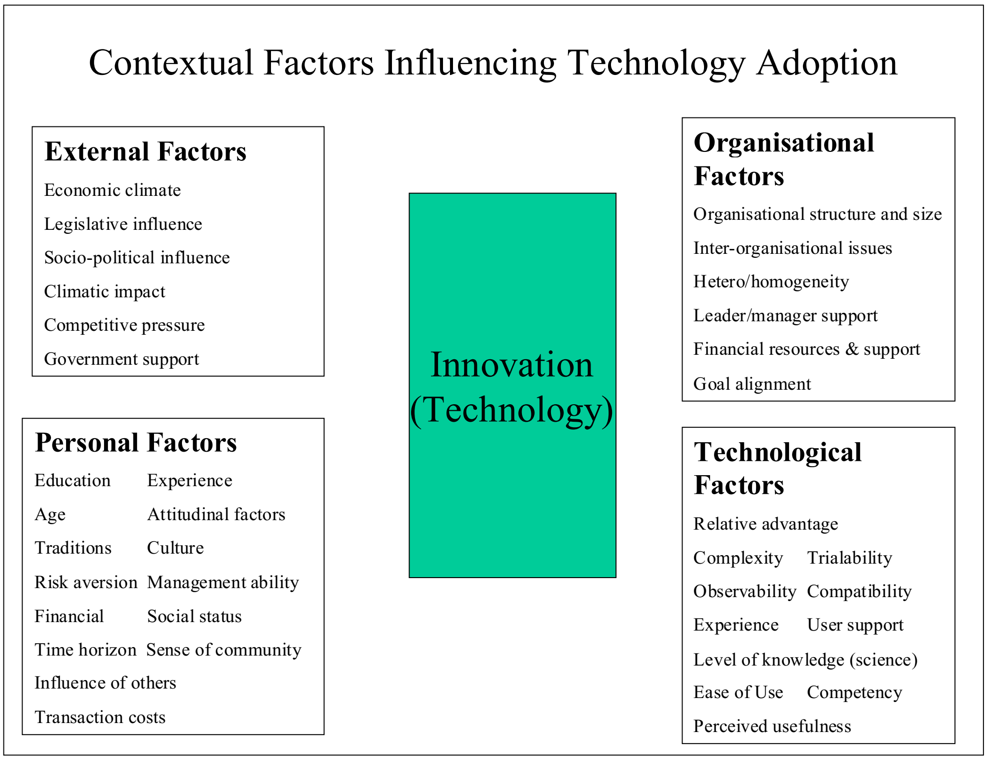
In summary for OHS:

- ❑ Supply risk assessment of OHS is needed in the planning and approval process
- ❑ Most risks to supply are site specific, but with increasing adoption of OHS within a supply district the risk increases (as system peak capacity is approached or exceeded)
- ❑ Some will require on-farm buffer storages to offset the lack of soil water storage.

9 Appendix 4- Adoption Of On Farm System Harmonisation Technologies

There are many "adoption studies" that are relevant to technology transfer and harmonisation of irrigation water management. Some pertinent models are included below. Combinations of external, personal, organisational and technological factors are likely to influence adoption of systems for system harmonisation.

Figure 1 Contextual factors influencing technology adoption



Some key issues have been raised in the context of lack of adoption of harmonised irrigation systems:

- Automation and skills levels of farmer
- Repair and maintenance issues
- Cost of communication systems
- Perception on profitability
- Accuracy of measurement
- Robustness of technology
- Simplicity of technology
- User skill
- Training and support

As part of the current CRC IF project Tools and technologies for improving the precision of irrigation (CRC IF (2005a)) a scoping study is being undertaken on improved promotion of existing precision irrigation measurement technologies and identifies seven obstacles to adoption.

- Entrenched culture
- Not seeing importance of water management
- Investment not paying
- Difficulty in getting started
- Complexity and uncertainty
- Science vs farmer perspectives
- Poor extension models.

Other key issues that will affect this adoption even if these integration and communication systems were available, such as

- The unstable irrigation environment
- Uncertainty irrigators operate in (risks imposed throughHarmonisation)
- Broad focus of decisions (not just technicali.e. how much water do I need), but social (how is my management affected, how complex is this, how does it fit with my culture/traditions; financial (impact on investment and cash flows)
- Cross - organisational impact
- Also important is who drives the Harmonisation process, the need for clear and transparent procedures and quantifying who pays and who benefits how much.

10 Appendix 5 Concept of Crop Diversification

Crop diversification can be a useful means to increase crop output under different situations. Crop diversification can be approached in two ways. The main form and the commonly understood concept is the addition of more crops to the existing cropping system, which could be referred to as horizontal diversification. For instance, cultivation of field crops in rice fields or growing various types of other crops in uplands have been defined as crop diversification. However, this type of crop diversification means the broadening of the base of the system, simply by adding more crops to the existing cropping system utilizing techniques such as multiple cropping techniques coupled with other efficient management practices.

The other type of crop diversification is vertical crop diversification, in which various other downstream activities are undertaken. This could be illustrated by using any crop species, which could be refined to manufactured products, such as fruits, which are canned or manufactured into juices or syrups as the case may be. Vertical crop diversification will reflect the extent and stage of industrialization of the crop.

It has to be noted that crop diversification takes into account the economic returns from different crops. This is very different to the concept of multiple cropping in which the cropping in a given piece of land in a given period is taken into account.

Besides the above, some other terminologies are also used to define crop diversification. There are terms such as “crop substitution” and “crop adjustment”. It is necessary to indicate here that crop substitution and adjustment are linked to the main concept of crop diversification and are strategies often used to maximize profit of growing varieties of crops. The level of diversification will also be different in various countries. Diversification at farm level will involve growing of several crops for achieving self-sufficiency, but it may be a totally different approach at the national level. Crop diversification at national level will demand more resources and require selection and management of a specific crop or a group of crops sold freshly or value added to achieve higher profits.

There are several advantages of crop diversification, which could be listed as follows:

- Comparatively high net return from crops
- Higher net returns per unit of labour.
- Optimisation of resource use.
- Higher land utilisation efficiency.
- Increased job opportunities.

In order to achieve the above benefits the process of diversification should be changed from very simple forms of crop rotations, to intensive systems such as relay cropping and intercropping or specialization by diversifying into various crops, where the output and processing etc., could be different. This process could be similar at farm level and national level.

Therefore, the main concept implied in farm diversification (crops, livestock and fisheries) and crop diversification programmes should be placed in a proper perspective in order to

- respond to the objectives and goals of the farmers such as consumption, household utilities, income etc;
- increase farm income and provide a continuous income for farm families;
- reduce farmers' risk and encourage them to make their own farm plans;

- promote various farm enterprises to avoid any risk and uncertainties from natural disasters and marketing setbacks;
- encourage the farmers to recycle farm wastes and integrate farm activities such as crops, livestock and fisheries;
- minimise the use of external inputs; and
- conserve the natural resources and balance the agro-ecosystems at the farm level.

Crop Diversification within Different Countries:

In Vietnam: Crop diversification as understood is defined as the strategy of shifting from less profitable to more profitable crops, changing of variety and cropping system, increasing exports and competitiveness in both domestic and international markets, protecting the environment, and making conditions favourable for combining Agriculture-Fishery-Forestry-Livestock.

In Malaysia: horizontal diversification or the cultivation of an increasing number of crops as opposed to one or two major crops is the practice. Oil palm, rubber, cocoa and rice have been and continue to be the major crops grown by the private and public sectors. However, other crops such as coconut, tropical fruits, vegetables, flowers, annual crops etc., are being grown by the smallholders and the private sector.

Vertical diversification is usually occurs when a government or compony diversifies into a new area which is one step removed from its traditional area. Vertical diversification in agriculture area starts from primary production (farm products) goes through primary and secondary processing and finally the finished products. The vertical variant gives increasing emphasis to intra and inter-sector linkages thereby developing the relevant value chain in order to be competitive

In Nepal: Crop diversification represents the growing of a variety of agricultural commodities that are commercially viable and locally acceptable. The farmer has limited land where he wants to grow everything possible for home consumption. Whatever may be the crop intensity, this type of approach is not commercially viable. These days the farmer has to be commercialised for sustained livelihood. Commodities having higher comparative advantage and higher marketability should be grown on a commercial basis. In order to encourage commercialisation, the production pocket concept and farmers group approach as encouraged by the Agriculture Prospective Plan (APP) should be fully implemented.

In Philippines: The government has adopted crop diversification as a strategy to promote and hasten agricultural development. Crop diversification has two perspectives: one aspect is planting a cash crop after the main crop and the other is planting intercrops (permanent or cash crops) in-between the main crop, usually a permanent crop. This strategy helps attain the goal of the Department in increasing productivity and farm income notwithstanding the benefit of environmental conservation

11 Appendix 6 Issues and opportunities along the Value Chain

11.1 Issues in the irrigation value chain that limits its effectiveness

11.1.1 Number of entities

In some cases all six business processes are done by the same entity and the issues are internal eg. an irrigator harvesting rainfall and retailing at the farm gate.

In most cases the six steps are managed by separate entities. The issues in achieving harmonisation of the value chain are far more complex and more challenging.

Physically reducing the number of entities reduces the number of organisations involved by this only leads to improvement if communications are improved internally.

11.1.2 Distance

The physical distance between each of the six steps increases the complexity in communication and understanding of needs and wants.

11.1.3 Timescale

Long lag times for delivery and use of product often means that needs and wants are not matched and communications between organisations are out of date.

11.1.4 Role of Government & ability of governments to respond to market signals

The secondary value chains is generally market driven and is continually improved by commercial drivers, with a limited role for Government.

Although, in the early days of irrigation government was much more actively involved in actively encouraging and funding these parts of the supply chain.

In recent times, and as a result on national competition policy (COAG reforms) government involvement in the secondary chain is generally limited to improving infrastructure such as roads, power, gas etc and in export market development (e.g. trade missions).

Water harvesting and distribution are still the domain of government (to a greater and lesser extent), but COAG water reform is increasingly exposing this sector to market forces eg. water trade and full cost recovery pricing.

Despite this government ownership and management may make these entities less responsive to market signals.

On the other hand, it can also be argued that the long asset life and large fixed costs that are a feature of water storage and water distribution which means that the ability to respond to rapidly changing market forces will always be limited, irrespective of government involvement.

However, the interface between private and publicly managed parts of the supply chain can be an area where the ability to communicate and respond breaks down. This is the communication between irrigators and the water supplier and sometimes between the water supplier and government.

11.1.5 Compounding system disharmony

Examples of system disharmony issues that can compound and lead to inappropriate investment mix across the supply chain are illustrated below.

Examples of system disharmony are:

11.1.6 Relative market power of different sectors in the value chain

Where an entire business process (steps 1 to 6) in concentrated in the hands of a single entity then the relative market power is much higher and this can result in increasing pressure on other sectors.

This is a major issue for irrigators as they see their numbers of direct customers (e.g. food processors) being reduced and their input water costs are often supplied by a monopoly.

Where irrigators have ownership or management input into the monopoly this issue is much reduced.

11.1.7 How big are the multipliers along the value chain?

Primary irrigation activity connects with the rest of the economy in three basic ways (CIE 2004):

- purchasing goods and services from other industries
- irrigation expenditure on consumptive goods
- transport, processing, marketing, exporting of primary irrigated products

CIE (2004) estimated that in 1996/97 irrigated production generated $9,096 million gross value of production plus $5,036 million of other value added from above.

ACIL in Sept 2002 in its "Economic Impacts of Draft Water Sharing Plans" suggest a regional and state multiplier of 2 is relevant (SKM 2003) (quoted in SKM 2003 – The Living Murray Murrumbidgee Water Recovery regional Study October 2003).

This contrasts with earlier work where:-

- In 1986 Powell Report on Rice indicated that for every $1 of rice production $6 is generated in associated activity.
- In 1985 NSW Agriculture estimated multipliers of 5 for irrigation.
- The main difference seems to be that more recent economic modelling takes into account the opportunity cost of irrigation (eg lost dryland production) while earlier studies did not.

11.2 Opportunities to Increase Harmony within the Value Chain

11.2.1 Reduce input costs with new technology

This could occur at any stage in the value chain, but in terms of NPSI interests the main focus should be within the primary chain. The secondary chain is generally outside of NPSI sphere of influence.

11.2.2 Improve feedback and communication links between the six steps

This is fundamental. Again for NPSI and its interests this should be in the primary chain in a single co-ordinated system.

However, a regional value chain could benefit from a much wider program that links through to brand at a retail level. This would be a commercial investment decision for a region, rather, than be a role for NPSI.

11.2.3 Integrate business processes

Vertical integration occurs when one business process along the value chain combines with it's upstream or downstream neighbour in order to capture the profit margin of both steps.

The classic example in the irrigation industry is the rice industry. SunRice is a grower owned cooperative that purchases all rice and is responsible for it's processing, distribution and marketing.

Another example, would be if a dairy processor negotiates a bulk water purchaser for its milk suppliers/irrigators.

However, this could be interpreted as a market signal failure. Ideally the dairy factory should be able to achieve the same security of supply by offering a fixed price for a contracted volume of milk so that its farmers can purchase water with confidence.

Horizontal integration is where individual businesses carrying out the same process combine for the purpose of achieving economies of scale and market power. This involves the consolidation/rationalisation of market suppliers at one level (s) of the supply chain e.g. production or distribution/logistics generally.

The table below illustrates the relative advantages and disadvantages of integration.

Table 11-1 Features of Integration in the value chain

Level of Integration	Generalised Advantages	Generalised Disadvantages
High -Vertical integration	❑ Strong R&D investment ❑ Strong brand. High marketing and advertising investment ❑ Excellent for high volume markets ❑ Can invest in high overhead market development (eg. Exports) ❑ Strong logistics ❑ High market power ❑ Stronger understanding of the entire supply chain from production distribution ❑ Market position should also be stronger. ❑ Pooled resources - $ and people	❑ Requires large scale to achieve advantages ❑ Transfer prices and internal costs can be lost unless good internal accounting ❑ Cannot quickly respond to low volume niche markets ❑ Subject to scrutiny for anti-competitive behaviour from National Competition Policy and may threaten free trade provisions for market access
High – horizontal integration	❑ Co-operative approach ❑ Economies of scale eg. purchasing power and marketing. ❑ Lower cost of production ❑ Co-operative approach to achieving reduced cost outcomes e.g. market co-ops ❑ Innovation may be derived from being focused on one part of the value chain.	❑ Requires considerable effort in maintaining good relationships and achieving agreed business strategies ❑ May be a small step in the whole value chain process e.g. benefits may be small vs benefit derived from vertical integration
No Integration/regular market players	❑ Good for low volume niche markets ❑ Transfer prices subject to competition which forces costs down ❑ High range of products/choice ❑ Good level of competition – keeps prices in line – supply & demand theory ❑ Good for players which do not need a complicated/sophisticated distribution, marketing channel	❑ Low market power ❑ Higher risk of low profile brands ❑ Overhead costs are duplicated in every business ❑ Low R&D investment ❑ Low marketing & advertising budgets ❑ Poor penetration in high cost markets ❑ Low logistics investment

Level of Integration	Generalised Advantages	Generalised Disadvantages
	etc.	❑ Price & profit erosion due to high competition. ❑ Overhead & distribution costs are duplicated in every business. ❑ May result in over-serviced/supply market ❑ Ability to invest in R&D and marketing/advertising is lower. ❑ Access to export markets more limited

11.2.4 Strengthen retail profile/brand

For example the Coca Cola Amatil purchase of SPC/Ardmona may provide an opportunity to lift the irrigated fruit exposure to more customers and provide for greater value from the whole irrigated value chain.

Establishing regional or catchment brands (eg. Goulburn valley) for a range of products within the same value chain may add value to the total irrigated supply chain.

Another example is the "paddock to plate" value added by environmental management systems, Regional Catchment Strategies, food safety, and quality assurance schemes.

11.2.5 Increase understanding of the value chain

An example of this to increase irrigator ownership and management of supply systems. Although it is important that this is supported by a high level of executive and technical support and with some government safe guards.

11.2.6 Address common business processes needs within the value chain

For example improve road and power networks and provide programs that skill development can achieve cost savings throughout the value chain.

11.2.7 Implement collaborative decision making with players along the value chain

This requires a partnership of key players along the value chain to develop a common vision and business plan. For example the Goulburn-Broken Irrigation Futures Project.

11.2.8 Move to higher value products

Shifting water to higher value enterprises can justify increased investment and improvement throughout the value chain.

12 Appendix 7 Institutional Arrangements and their Components

12.1 Water harvesting

a) Allocation Policy

There is a need for a process to determine bulk entitlements for water held in storage and rules for times of spill and restrictions. This is generally covered by State Government processes and investment by NPSI is unlikely to add value; except for exploring how long term water reliability is best communicated with irrigators.

b) Environmental flows

How does co-ordinating the management of releases for hydroelectricity, consumptive use and environmental flows occur? This becomes a more critical question when a range of jurisdictions are involved.

This is generally done by State Governments and in the care of the Murray Darling and partnership of governments. investment by NPSI is unlikely to add value.

c) Annual allocation policies

Is it clear who determines the rules for what the normal allocation will be?

Generally this is responsible of governments and the water harvesting organisation. NPSI are unlikely to be able to add value to this component of the system. Except for identifying how best to communicate seasonal yield and reliability forecasts to irrigators.

12.2 Water Distribution

a) Water trade

Water trade needs to be a complete package to give the right signals to users eg. lack of exit fees makes it too easy to sell water and retain access to the system while leaving an unfair burden on the remaining irrigators. There is a disincentive to invest in parts of the system where water is transferring out. An incomplete trade package distorts the messages to investors. For example trade does not consider total infrastructure investments; only farm investment.

Research: review trading rules to identify where market signals are distorted and this can be overcome.

b) Water Charges & Tariff

Setting water charges and tariffs to reflect the true cost structure is needed to give the right signals to the customer and delivery authority.

e.g. including channel replacement costs in renewals annuities distorts the cost (good maintenance on channels means they may never need replacing, unlike most structures) that can impair good investment decisions.

The scale of any transparent cross-subsidies (shouldn't be any hidden ones) needs to match a sensible management unit where responses can be managed.

Where different security water products are available, tariffs need to be tailored to maintaining the viability of both farm and off-farm infrastructure. For example in systems that may only be used in high allocation years.

Research: determine what the impacts are of having no low/medium users in a system, determine what circumstances need to exist for them to be retained/encouraged for system viability and review tariffs to ensure they encourage sensible investment.

c) Flexibility

Early irrigation systems were designed to last 60 – 100 years. With the changing nature of irrigated industries, technology, continued pressure on efficiency and competing uses, it is reasonable in some areas to plan for 10 – 20 years. This will impact on the type of infrastructure installed in refurbishing a supply system.

Research: what replacement or maintenance strategies exist to meet a 10 – 20 year planning horizon?

d) Service levels

Traditionally service levels were set by the water supply Authority. Often this was a strict roster. Over time this has changed to water on order, and on demand systems, with much greater flexibility.

This has been a major benefit to the industry and its water use efficiency and needs to continue to improve.

Increased customer involvement in decisions on service levels reduces the risk of getting the system wrong.

There are difficult situations where a mixture of low volume/frequent irrigation needs of horticulturalists and high volume/less frequent irrigation needs of dairy farmers when on the one system make it difficult to optimise that system. Flexibility in tariffs to encourage customers to set their own service levels may be needed.

Service providers need to be receptive to and have the capability of doing innovative things to meet customer demand.

eg. where the dairy/horticulture mix exits, rather than try and pick a winner (the loser becomes uncompetitive), or do nothing (and both customer groups get frustrated or both become uncompetitive), a solution may be to offer reduced tariff to horticulturalists to take water when others don't (and eliminate outfalls), put it into their own storage to provide the service they need and makes the supply system very efficient.

Other examples include 'picking the winner' of horticulture at Woorinen that resulted in mixed farmers changing enterprise, selling out or in a couple of cases, opting out of the irrigation system. This area was predominantly horticulture and needed a system refurbishment.

Also rural residential growth and "take over" of irrigation infrastructure can affect service levels and tariffs.

Research: investigate what the options and implications are for a range of irrigation products to service enterprise mixes within a system to optimise the viability.

e) Medium term demand change

The shift in acknowledgement of climate change has been significant over the past 10 years.

How real is the 25% reduced rainfall in south west WA?

What legislation changes may be needed to enable agencies (CMAs, water authorities) to adapt to stream flow changes and crop demands as a result of climate change?

Research: Modelling of future irrigation demand from existing land use under a range of scenarios. Identify what changes in legislation could be required to manage the implications of the changes.

f) Land use planning

Few areas in Australia have institutional systems in place that guide investment in irrigation to the most sustainable places. There are a number of exceptions, but these tend to be where there are serious issues already apparent (eg lower Murray salinity and development zones to protect the river from more salt).

The Murray Darling Basin Commission Watermark project investigated land use suitability and capability guidelines for irrigation development. (SKM for MDBC in 2004).

Changes in enterprise viability will see an ebb and flow of demand for water between industries that can occur over seasons (eg. high prices for lambs resulting in demand for water) or decades (eg. expansion in wine grape plantings that create an over supply of the industry with a consequence of reduced production).

What are the options to have supply “put on hold” for variable periods to accommodate these changes (temporary water trade is one clear option) that may have variable levels of formality?

Research: investigate whether temporary trade and permanent trade is sufficient in terms of tools to manage the ebb and flow of demand on a system.

g) Obligation to supply

Most water authorities have an obligation to supply all properties within the irrigation system.

What mechanisms are needed to enable supply to be discontinued if it is deemed necessary to harmonise the system?

Victoria’s White Paper implementation process is exploring this issue with compulsory purchase provisions.

Research: Investigate what legislative changes may be required to enable withdrawal of supply across different jurisdictions.

h) Information

The better informed the decision makers, the better decisions that are likely to be made. Examples of the need for good information are with:

- implications of trade (eg. not knowing the impact of trading without exit fees has distorted the decisions to trade out)
- probability of seasonal allocation to enable informed decisions about crop mix by farmers

How complete is the information around system operation, supply, tariffs etc across the country?

Research: Best practice information systems across the total system.

i) Capacity to Change

The human factor in change is potentially larger than the technical with some new technology. Staff in water distribution agencies can become nervous when efficiencies are the aim eg. phone ordering, automation and remote monitoring of channel structures.

Irrigators are equally suspicious of new technology where there isn't a clear demonstration that they will not be adversely affected (eg. replace metering devices with more accurate meters that mean farmers get less water for the unit measurement) or where reliability is unclear (eg. automate a regulator and farmers find their head level drops in the middle of the first watering – they won't trust it for a long time).

Sufficient resources need to be put into social implications of change as well as the technology effectiveness.

Research: identify gaps in the available tools and processes (training) to equip people to participate in change.

j) Conjunctive Use

Surface and groundwater systems are interdependent. In some cases there is a clear recognition (eg. north Burdekin Water Board recharging the groundwater supplies in the Burdekin delta with surface flows from the Burdekin River).

Where this recognition is not so clear, how are the institutional arrangements made to protect beneficial use of both supplies?

Research: Determine the institutional arrangements that are needed to protect beneficial use of both surface and sub-surface supplies.

k) Business Structures

Private companies that own the water they deliver on behalf of shareholders can face complex challenges as they are obliged by law to continue servicing the needs of existing shareholders, but their overall survival may require servicing a particular group of their shareholders or possibly new customers.

Where these situations exist, there can be barriers to change as it can adversely affect many.

Research: There will be pros and cons to every business model, identifying these may be useful but ultimately the business models selected will be dictated by government policy.

12.3 Water Use (irrigators and other customers)

Farm Planning (or irrigation and Drainage Management Planning) is the most widely used tool to integrate the water demand/supply system on farm and much has been done to refine the development of these plans. However, their remains a gap that is being looked at from many areas in relation to how a farmer demonstrates that the plan is well implemented and managed.

How do the resource "guardians" gain confidence in how the resource is being used? Does feedback to the supplier of water from the users of water about the impacts of using the water occur?

From an institutional perspective, the monitoring of water use and any impacts of that in terms of environment, economics and society/community is the area needing more research. Many people are pinning their hopes on EMS[3] related systems or water use licence obligations to deliver the answers from an environmental point, but nowhere are the economic or social impacts monitored as a matter of course.

In 2003 Marsden Jacob completed an investigation of the policy, legal and other institutional factors which influence the extent to which irrigation water providers promote or impede water use efficiency on-farm. They identified a range of principles and strategic options which could be used to promote sustainable water use. In particular, it is recommended that institutional measures should target beneficial savings, not savings per se. Water Use efficiency policies, plans, incentives and licensing should be aimed at the farm situation, not the regional level. Furthermore, water use efficiency framework should build on past achievements. Reforms should not be bound by incremental thinking but incorporate lateral solutions. Broader dissemination of positive policies and practices could also be encourage greater uptake.

Research: Investigation of what are suitable tools and processes monitor against triple bottom line.

[3] Environmental Management System