Key Sites for Salinity Hydrology and Model Validation

Executive Summary

The 2000 NSW Salinity Strategy recognised there was very little data available to support either the salinity forecasts or the land use options to manage salinity. As a result the Key Sites project was commissioned to collect credible, comprehensive long term data.

The Key Sites project measured a range of bio-physical and eco-hydrological data at eight representative upland dryland catchments across the NSW. The sites represent a range of typical agricultural systems and landscapes. The sites represent in time a range of typical interventions that are recommended for improvement in NRM. The length of monitoring at the sites ranges from five to sixteen years with the earliest data collected in 1991 (Boorowa) while most of the data collection at the other sites started between 2002 and 2003.

Previously it was conceptualised that groundwater would drain from root zones and mobilise salts and then discharge these salts further down the catchment. Result from the Key Sites shows that salt stores in the landscape are highly variable and that groundwater and salt move slowly. Additionally results shows that at the farm and field scale the majority of salt is transported by surface processes from small zones in the landscape.

Since 2005 research conducted by the Key Sites team has produced over 40 scientific publications including 14 journal papers and 25 conference papers and conducted over 16 field days, 23 meetings and seminars with other DPI/ I&I NSW staff for CMAs, producers, private advisors, scientists and NRM practitioners. It is collecting, analysing and reporting data for one of the only comprehensive and scientifically credible studies in Australia that is validating conceptual and computer models of how water and salt moves under a range of common landuses. The research is challenging much of the commonly held conceptual understanding of hydrology processes that are used as the basis for investment of public funds and natural resource policy development.

Key messages

Manage the salt stores directly and not always assume recharge is the dominant process that mobilises salt

Manage salinity by appropriate land use options include interception planting where recharge is the dominant salt transport process and fencing and revegetating saline scalds where overland flow is the dominant salt transport process.

We have significantly improved the understanding and context of salinity in the landscape by the improved capacity to model and to ‘upscale’.

Implications

The major implication of the findings is that large landscape scale intervention may not be the most effective method to manage salinity. In fact the most efficient response to salinity should occur at the farm /paddock scale where overland flow appears to dominate the salt transport process.

How to use this report

This report describes the major outcomes of the National Action Plan for Salinity and Water Quality funded project Key Sites for Salinity Hydrology and Model Validation project. The project was funded from July 2005 until June 2009.

The Key Sites project studied eight representative upland dry land catchments to monitor and analyse the range of eco-hydrological processes occurring on site. This research activity allowed detailed understanding of the site specific processes as well allowing for generic processes to be compared across a range of geographical locations.

In this report the broader generic processes are reported and while specific examples from the sites are referred to detailed explanations are not included in the main body of the report. Individual site reports are included as appendices to the main report at the back of the main report. Additionally scientific and conference papers arising the research are listed at the rear of the report.

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Context

Background

The Key Sites project was initiated in response to a recognised need to provide sound long term data to improve the scientific understanding of salinity and hydrology processes and subsequent conceptual and computer modelling tools. Officially the Key sites project started in 1st July 2005. However the origins of the project reside back in to the NSW Salinity Strategy and research activities that commenced between 2001 and 2004 under that strategy. In late 2003 applications to the NAP SWQ from then three state agencies (DLWC, NSW Agriculture, and State Forests NSW) were received to undertake hydrological research to better understand the effect of landuse on water and salt flow. Feedback during early stages of the assessment process indicated that one comprehensive multi-agency project focused on the hydrology needs of NSW was an appropriate means for this activity to be conducted. To that end a joint proposal was submitted with NSW DPI as the lead agency of a highly collaborative project that was jointly implemented with DIPNR. The subsequent project was independently reviewed (Webb 2005) and found to "*form a critical asset for generation of scientific knowledge required to underpin the ability of Government and the CMAs to evaluate salinity management options across NSW*."

What is the Key Sites Project

It is a research project with eight sites across upland fractured rock aquifers in local and intermediate groundwater flow systems. These areas have been identified as being major salinity sources for NSW. Each site addresses a different and locally relevant gap in hydrology knowledge. The sites are not simply eight replicates of a single methodology. The effect of all major land on sub catchment hydrology is being investigated, including: annual cropping, improved annual and perennial pasture, native pasture, native forestry, planted forestry and rehabilitated open cut coal mine.

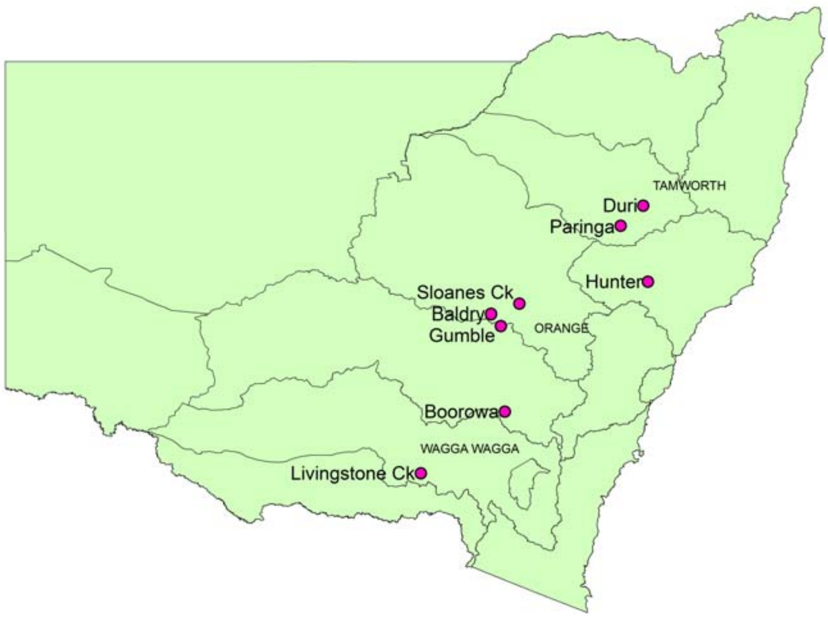

Figure 1 Location and name of the Key Sites

Contracted Project outcomes and outputs

Outcomes	Outputs
• Understanding of the processes that control and mitigate the expression of dryland salinity in the landscape • Understanding of key data required to parameterise and validate hydrological and salt mobilisation models • Knowledge to quantify the effect of land uses *viz*. cropping, herbaceous and woody perennials on the expression of salinity in the landscape • Improved confidence and reliability in models and decision support tools for catchment planning • Identify knowledge gaps and enhance existing models.	• Enterprise water balances for cropping, herbaceous and woody perennials • Sub catchment scale water balances for farming systems based on cropping, herbaceous and woody perennials • Data used for model validation which will be unsaturated soil, processes, unsaturated zone shallow aquifer, shallow aquifer, stream interactions • Validated models • A range of natural resource management options for current landuse

Summary statement of Key Project Outcomes

The Key Sites project has produced many significant outcomes in terms of new knowledge and understanding of the hydrological functioning of upland dryland landscapes. These include challenging the accepted paradigm that recharge management is the most appropriate method to limit salt mobilisation and transport. Results from the Key Sites project clearly show that the most effective and efficient way of reducing salt mobilisation and transport to streams is to manage the saline discharge site first then if need be undertake measures that control recharge of the groundwater.

The project has also delivered outcomes that may have wider implications than discussed above, these included the establishment, conceptualisation and documentation of eight sites that can be used to monitor evaluate and report on natural resource condition using high spatial and temporal resolution data. As these sites have been well studied and understood they can function as eco-hydrological laboratories to enable better understanding of the effect of a variable and changing climate and landuse on a arrange of biophysical and eco-hydrological processes.

Additional to these outcomes has been the collaboration and training that has occurred on and because of the Key Sites project. It has been estimated that over seven hundred and fifty people have either visited the sites to observe the activities have participated in natural resource training at the sites, or attended seminars about the sites over the last 5 years. The presence of the sites has facilitated ongoing collaboration with numerous universities, CRC's, state agencies, CMA's, private companies and individuals. As part of the collaboration increased understanding of the natural processes has occurred as well as increased technical capacity for the staff on the project as well as the people that have subsequently been trained or visited the sites.

Outcomes

Some of the important outcomes from the Key Sites project include:

- Provision of crucial dryland hydrology data and knowledge at the scale management intervention takes place – the paddock and farm scale
- Development and maintenance of a range of well conceptualised highly instrumented eco hydrological sites across representative upland dryland landscapes that are highly suitable for monitoring evaluating and reporting on a range of resource condition indicators
- Providing a focus point for significant collaboration and technical exchange between agencies, universities, CMA's and landholders. This includes
    - Three Divisions of NSW DPI with DECC and DWE
    - CMAs, Landcare and community groups
    - Future Farm Industries CRC, CRC Salinity and eWater CRC,
    - Universities of NSW, Melbourne, Sydney and ANU,
    - the National Airborne Field Experiment including NASA
    - Rio Tinto and Macquarie Generation
- Providing evidence based recommendations to support saline site discharge management as compared to groundwater recharge zone management.
- Validation of numerous computer models including 3PG, LUOS, 2CSalt, catchment level models of Future Farm Industries CRC and now informing the NSW TOOLS2 project
- Providing a significant resource of data that is reported in the scientific press and meets the needs of the state wide standard and targets established by the NRC for collaborative Monitoring Evaluation and Reporting activity
- Informing the processes that form the basis of the NSW Salinity Audit 2006 and the revision of salinity priorities in NSW
- Being recognised as a key achievement of NSW by the Independent Audit Group for the Implementation of the MDBC Salinity Strategy
- Contributing to the development of a framework for landuse recommendations that will complement the Australian Groundwater Flow Systems framework

Key Sites clearly addresses the standard and targets set out by the NRC and Priority E4 Targets 5, 6 and 11 and E1 Targets 1, 3 and 4 in the NSW State Plan.

Summary statement of Key Project Outputs

Since 2005 the Key Sites research has produced over 40 scientific publications including 14 journal papers and 25 conference papers and conducted over 16 field days, 23 meetings and seminars with other DPI staff for CMAs, producers, private advisors, scientists and NRM practitioners. One of the major outputs of the Key Sites project has been the products that enabled capacity building within natural resource management agencies. An example of this is the process to develop a paddock based robust and defendable management strategies (Fig 2).

Outputs

Some of the important outputs from the Key Sites project include:

- Establishment long term monitoring sites that can be considered national natural resource assets
- Documented changes to natural resource condition (groundwater depth and EC, streamflow and EC) over the period of measurement from the all Key sites that is consistent with the Australian Government's Land Salinity Resource Condition Indicator
- Over thirty scientific publications arising from the Key sites project or activities associated with the project.
- Individual case studies for all sites documenting the increase in knowledge generated from each site
- Project web site containing information and documentation relating to the project
- Four research forums delivering up to date techniques for catchment managers (Nov 2007)
- Series of harvest and delivery workshops presenting new research findings to farmers (2006 -2007)
- A range of field days showing latest research findings and implications (2005-2007)

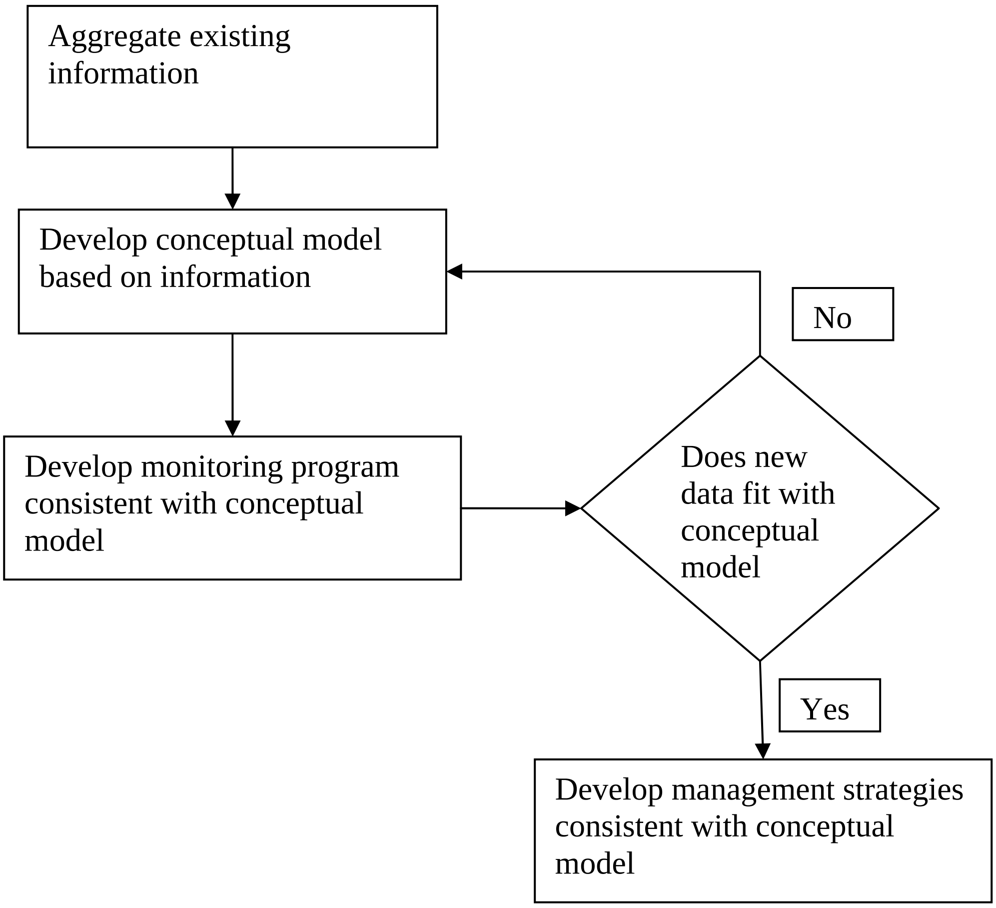

Figure 2 Example of the applied output from the Key Sites research

A method was developed to determine the investment options in terms of the type and the scope of investment a CMA should undertake at individual sites. Given that the research from the Key Sites project has demonstrated that investment needs to be developed from site specific data a logic framework based on a flow chart was developed. The process was to aggregate existing all the available information which also includes landholder observations and use that suite of information to develop an understanding of how water and salt move (conceptual model) at that site. Then use the conceptual model to construct a monitoring program, such as measure groundwater or stream flow. If the conceptual model is correct then the observations should support the model and then the appropriate investment could take place. If however the observations do not support the conceptual model it could be wrong and needs to be redeveloped. This is an important step as inappropriate investment could have taken place if it was based on a wrong understanding.

This approach was tested with Central West CMA staff on a small salinity site south of Dubbo. The method showed the value of aggregating existing knowledge from local experts, landholders and spatial data into a single understanding on which sound natural resource investment decisions could be made.

Project Conclusions
Natural resource issues such as dryland salinity have and will continue to have a significant effect on soil, land and water quality. Over the last 10 to 15 years dryland salinity was perceived to be an intractable natural resource issue with no ready solution. Research from the Key Sites project and elsewhere shows that while managing natural resources issues such as dryland salinity is complex it is no more difficult than other major natural resource issues. As with all these natural resource management issues improving understanding of the processes and providing appropriate management responses to these issues is the most efficient method to manage these problems.

One of the key conclusions from the Key Sites project is that there is no one size fits all solution to manage natural resources issues such as dryland salinity. Appropriate management responses must be based on site specific information and tailored to the economic, environmental and social drivers of the landholder. Additionally the management response that is decided on may not be a “win-win” solution but may be trade offs between competing demands. For instance establishing perennial pastures can reduce salt export but also at the expense of water. As with most things defining the balance between ranges of competing demands for the natural resources will be an ongoing challenge.

The Key Site project has developed long term monitoring sites that are ideal for reporting on land salinity resource condition indicators. The sites are hydrologically well conceptualised and processes well understood. Ongoing monitoring of these sites would provide an long term insight into the effect of climate and land use on natural resource condition.

Central to the success of the Key Sites project has been the ongoing collaboration between state agencies (DPI, DECC, DWE), universities (UNSW, ANU, U of Melb) CRC’s (Salinity, eWater, Spatial Information, Future Farm Industries), public companies (Macquarie Generation, Rio Tinto), CMA’s and landholders. This interaction has allowed a whole host of skills and perspectives to be brought issues that may have been outside the expertise of the individuals. This collaboration has allowed informal and formal training, capacity building and technical transfer of skills to a wide range of people.

Implications from project outcomes outputs and conclusions
The major implications arising from the project is that individuals, companies or agencies that manage land must be engaged in the development of land management actions from the beginning. These people should be supported by technical expertise but not to provide the answer but to provide advice to allow the land managers to develop actions that meet their economic, environmental and social goals.

Wise management of natural resources needs to be based on firm scientific understanding of the physical processes however it is not practical to develop the intimate knowledge as was done in this project. This project provides detailed understanding of eight typical upland landscapes, however the process from here is to use that understanding to design appropriate responses based on site specific data.

On-going public NRM investment will benefit from a better conceptual and predictive understanding of how the hydrological processes respond to landuse change and climate change. Thus without ongoing research into water and salt movement it would be difficult to provide accurate advice for either land management or public policy in terms of catchment management and land use under a variable and changing climate.

Detailed hydrology investigations such as Key Sites are quite rare and to a large degree a developing field of science (at least in Australian context). While it is providing answers, the fact that it is a discipline that to date is 'under researched' it often poses new questions that need to be answered and challenges current process of targeting investment. This can be unpalatable, especially when we face pressure to deliver improvement quickly. The Key Sites project has developed a unique set of sites that if continued will provide a invaluable way of monitoring resource condition at the field and farm scale now and in to the long term. This current knowledge and the knowledge that potentially can be gained from the data generated will allow a better targeting of public and private investment for broader catchment outcomes.

Detailed outcomes

Understanding of the processes that control and mitigate the expression of dryland salinity in the landscape.

Key Sites project has led to a greater understanding of salt and water movement in typical upland dryland catchments. It has led to better conceptualisation and simulation of these processes and a better understanding of the effect of landuse on water movement and salt mobilisation.

One of the underlying assumptions of salinity management is that groundwater elevation mimics surface topography. Of the eight sites in the present study this assumption held only for two of the sites, Boorowa and Sloanes Ck. It was shown explicitly that at a number of the sites that groundwater does not follow the surface topography; this finding suggests that it is risky to undertake land use change based on the assumption that surface topography is indicative of groundwater elevation. This assumption underlies the National Catchment Classification System (Groundwater Flow Systems) and results in six of the eight Key Sites explicitly show this is not always the case. Basing the investment of scarce funds on the National Catchment Classification alone and without greater consideration of local hydrology is unlikely to deliver positive results.

At the two sites that do conform to this assumption additional analysis have shown only one (Boorowa) would respond to wide spread replanting of perennials. Analysis using HARTT (Ferdowsian *et al.* 2001) technique at the Sloanes Creek site shows explicitly that time and not rainfall has been found to contribute significantly to groundwater dynamics (McCulloch *et al.* 2006). This means in terms of the analysis that the groundwater at Sloanes Creek is not controlled by climate but by other factors including a large geological constriction down slope from the scald. The implication is that any upslope planting to manage the groundwater would have little effect and the area that would require planting to minimise the scald would be far costly than directly managing the saline scald. The other implication of this finding is that even if the groundwater is found to be a subdued analogue of the surface topography widespread perennial plantings may not provide a ready solution to manage saline outbreaks. Of the eight sites investigated, only the Boorowa site has shown that wide spread perennial plantings of trees and pastures have a positive effect on saline outbreaks (Crosbie *et al.* 2007).

The Livingstone Creek site has shown that the pathways of salt from the landscape to the steams are complicated and if simplistic solutions that are based on incomplete knowledge are implemented then increased degradation of the natural resource may be the result. At the Livingstone Creek site a series of groundwater flow systems deliver both salt and water from contrasting landscape elements to the stream and to the land lower in the catchment. It is how these processes operate that make simplistic solutions to minimising salinity export risky. Broadly the upper catchment is delivering saline water to the alluvial plains and then subsequent leaching of the alluvial plains is transporting the salt to the nearby stream (O'Brien's Ck) (Summerell *et al.* 2006). Previously to manage the salt export it would have been recommended to reduce or stop the flow coming from the alluvial landscape however this would not stop the flow of saline groundwater from the upper catchment and if implemented could have risked the encroachment and discharge of saline groundwater at the soil surface and creating a saline scald next to the creek. Such a result would only be likely to further degrade water quality.

It was an accepted notion within the natural resource management community that the most effective method to control the mobilisation and transport of salt within the landscape and from the landscape to the stream was undertaking large scale plantings of deep rooted perennials to control excess recharge. Research conducted by the Key Sites project has shown explicitly that this is not the case, the research shows that managing and stabilising saline scalds will have the lowest risk and be the most efficient method to limit the amount of salt entering the waterways. Management responses to salinity should be focused on controlling or mitigating the movement of salt in the landscape and to streams. This can be partially completed by revegetation of saline scalds, which has been shown to reduce runoff and increase the use of groundwater. Current research suggests that while establishing vegetation on saline scald is difficult it is inherently less risky than attempting to identify recharge zones to minimise recharge by establishment of perennial vegetation. On scalded areas salt is transported by surface wash off and there needs to be discharge site management, however where there are areas of saline baseflow there needs to be recharge management.

Research undertaken by the Key Sites project and other research projects in the Hunter Valley has shown that the majority of the salt in the overburden of open cut coal mines will stay within the original mined area, leaching downwards until it reaches the final void. However the rate at which it travels is unknown as is the concentration and the mass of salt moving. Therefore this implies that to effectively manage the final void post mine closure rates of salt water movement need to be known to effectively design spoil heaps to minimise adverse salt and water outcomes. This may mean that if the water level and salinity of the final void is not within the range of pre mining activity additional salt may be exported to nearby streams and waterways or water from the nearby streams and waterways may drain towards the final void decreasing the flow of the natural streams. Therefore understanding of the movement of salt and water into, within and off these rehabilitated mining landscapes will assist in natural resource management at both the mine scale and at a larger regional scale.

However even after significant research has been undertaken due to the complexity of the landscape and the variability of the climate in which the eight sites are located (slopes and tablelands of NSW which has highly folded and faulted geology) the specifics of water movement and salt mobilisation in these catchments are still not fully understood.

Knowledge to quantify the effect of land uses viz. cropping, herbaceous and woody perennials on the expression of salinity in the landscape

The Key Sites project has enabled collection of high spatial and temporal resolution eco-hydrological data which when analysed has provided a unique insight into the effect of climate and current landuse on the hydrological processes. This data set presents a unique overview of landscape processes at a farm and field scale over the last 5-15 years.

The data collected by the Key Site project can directly used to report against the Australian Government's Land Salinity resource condition indicator. The project directly measures depth to groundwater, groundwater salinity/baseflow salinity and location, size and intensity of salt-affected areas.

At the eight sites data for all of these indictors are collected, stored, and analysed in terms of asset condition and trend. These data form the fundamental asset of the Key Site project and can be reported on if required.

A significant finding from the Boorowa Site is that if widespread plantings of perennial vegetation is undertaken and if the landscape responded in a similar fashion to the Boorowa site then increasingly the streams and rivers would be run less water and become more saline. Analysis conducted at the Boorowa site shows explicitly the effect of climate and landuse, particularly the effects of the wet 1990's on groundwater dynamics under annual cropping and rotational grazing. This data set shows the effect of increased perenniality on both groundwater response and salt export from a typical small dryland catchment in the Boorowa area. The analysis shows that both climate and land use has affected the dynamics of the groundwater, the groundwater responded less rapidly to rainfall after the catchment was planted to perennial pastures and trees and the analysis showed that while climate (less rain) had an impact more important was that landuse was a significant factor in the groundwater response. The data measured from the Boorowa site demonstrates that the change in landuse and climate has also reduced the amount of salt being exported by reducing the amount of water draining from the site. Key Sites project has confirmed that the changing landuse has decreased salt export but increased the amount of salt exported per mm of rainfall. The flow weighted mean EC of the runoff under an annual cropping system decreased with the increasing rainfall however when land use changed to a perennial system the flow weighted EC of the runoff increased with increasing rainfall. This provides some interesting implications for recommendations for landuse.

One of the "best bet' options for controlling saline discharge sites have been to establish perennial pastures and or trees. It was found that from a land management point of view, the establishment of more trees on the discharge sites would have the biggest impact on reducing saline discharge and the least impact on the agricultural operations. When the Key Sites project commenced little was known about the effect of landuse on groundwater particularly on scald areas. Research completed by the Key Sites project found that the tree belts and pasture sites used very similar amounts of water when planted in water limiting environments however if tree belts were established on scalds (locations that are not water limited) then these belts used double the water of pastures planted on the same scald. The tree belt on the scald operated in an energy-limited environment that is to say water was not limiting the growth of the trees and they were transpiring at a rate equivalent to atmospheric demand.

Planting trees in the 500-800 mm zone has been found to be sub economic by forestry standards however the effects of this landuse on water use have been found to be profound. Trees planted on a residual sandstone ridge effectively mined the stored soil water which appears to have been recharged from many years earlier when this ridge was used for annual cropping thus creating a buffer in terms of the soil water and stopping recharge of the alluvial plains. However the plantation may be compromised and this source and rate of water use may in the longer term effect survival of the plantation.

It was found in northern NSW that a plantation forest only requires a rainfall of 5 mm to increase water use as compared to 20 mm for a stand of native vegetation (Morgan and Barton 2008; Zeppel *et al.* 2006). It was found that in the planted forest, which was planted on a residual sandstone ridge, under extended drought transpired between 0.6-1 mm of water per day and this water was sourced from the shallow aquifers or the fissured bedrock. This source and rate of water use may in the longer term effect survival of the plantation as this water appears to have been recharged from many years earlier when this ridge was used for annual cropping. The rate of water use under the neighbouring native vegetation was between 1.5 mm per day in summer and 0.8 mm in winter. The long term water balance for the plantation trees shows that in the drier years, specifically 2002 and 2006 the trees transpired more water than fell. In 2002 the measured tree water use was 396 mm while only 276 mm of rain fell, however in the wetter years such as 2004 when over 1100 mm of rain was recorded at the site the measured tree water use was 629 mm.

At the commencement of the project the effect of climate on salinity expression was poorly understood, however both research completed by this project and elsewhere has shown explicitly the link between climate and salinity expression particularly in the response to groundwater. At the Livingstone Creek site the depth and pressure of groundwater in the 15 observation wells at the site has declined since monitoring commenced in the beginning of 2002. The groundwater in the main salinity generating landform at the site, the meta sediments, and the colluvium landform show groundwater fell 2.6 m over the observation period (Jan 2002 to Apr 2008), while the bores measuring the alluvial groundwater show a decrease of between 0.8 and 0.9 m over the same monitoring period. This period of falling groundwater coincides with the extended dry period with an accumulated deficit in rainfall of over 1000 mm since 2002.

To better understand the connection between surface and groundwater systems data groundwater data was collected at the Duri site and subsequent analysis showed that the calculated lag time between the rainfall event and the subsequent watertable response was between 10 and 22 days, while the average standing water level in the piezometers was 21 to 29 m below ground surface. This rapid response of groundwater suggest that despite the relatively thick layer of soil (21-29 m) and low hydraulic conductivity of the surface soil, either groundwater recharge must be via preferential flow through possibly fractured rock or the groundwater is responding to a pressure response as a piston displacement flow. The type of recharge occurring at the Duri Key site could be characterised as translatory flow (Hewlett and Hibbert 1967). This type of flow allows for rapid subsurface response as the groundwater responds to piston displacement or preferential flow through larger non capillary pores (Sophocleous 2002). If the described characteristics of this groundwater flow system are correct then the observed aquifer has a high hydraulic conductivity, medium transmissivity and low specific yield. These characteristics then suggest that although water can be transmitted very rapidly through the aquifer due to the limited pores space (low specific yield) then not a lot of water is required to change the groundwater elevation and this additional water would then slowly dissipate and discharge. The analysis of the groundwater hydrograph shows that there is direct evidence of recharge is occurring at the Duri site, and that this recharge is episodic that is in response to rainfall events but the actual processes of recharge and the location of the recharge zone is unknown. However the landuse directly above the piezometers appear not to have effect on the groundwater dynamics. As the range of land use activities is from native remnant vegetation to annual cropping and pastures yet the same groundwater response was observed in four piezometers. The implication is that even though there is a direct and rapid link between the surface water and groundwater systems there is no effect of landuse.

It is expected that climate change will overall decrease rainfall but may increase the variability of rainfall, then this begs the question how these factors interact with possible new landuse options (perennial pastures/ crops, and trees), then how will these factors interplay in terms of water quantity and quality? If we do not have sufficient data to determine a trend or change in resource condition then again we cannot provide advice for either land management or public policy

For example from our current understanding the soil water store plays a significant role in the both the generation of runoff and salt and this store has been depleted due to the below average rainfall. If or when this store fills we expect changes to how salt and water moves in the landscape and only long term monitoring can capture these processes.

Improved confidence and reliability in models and decision support tools for catchment planning

Computer models are widely used within natural resource management to identify the trends in resource condition from past interventions (hindcasting), fill gaps in monitoring stations to understand current resource condition (nowcasting) and predicting the effect of changes to land management and or climate on resource condition (forecasting). All these models rely on measured data to validate their output and additionally to provide confidence for the model users that the models are providing accurate results.

Key Sites is one of the few research studies that is collecting eco-hydrological data at the paddock and farm scale (the scale at which land is managed) that can be used to verify the output of these models at the scale of land use intervention. This data set is vital to validate models outputs for land management and policy formulation.

The data from the Key Sites project has enabled been used to refine, reconfigure and validate a range of models. Data from the project was used to determine the amount of water transpired by trees growing in the 500-800 mm rainfall zone. A tree growth model (3PG) was parameterised from data from the Paringa and Baldry site. Results from the Livingstone Creek site have been shown to be applicable at the larger scale through landform modelling. The project has led directly to improved insights into the complex influence of alluvial areas on stream salinity which in turn can be used to better target interventions in the landscape.

Outside of the Key Sites project, measured data to validate models is scarce, insufficient or not scientifically based. However this does not prevent models providing output that may have perceived credibility and result in altered land use and investment. Key Sites is providing the only source of scientifically credible information to validate models at the management intervention scale [paddock and farm scale] and the value of this data being collected over the long term and over a period of climate change can not be understated.

Understanding of key data required to parameterise and validate hydrological and salt mobilisation models

Determining the key data sets for models is an ongoing challenge as the required data is dependant on the model used, and the model used is dependant on the question that the modeller is aiming to answer.

However the range and extent of the data being measured by the Key Sites project has enabled a better understanding of the range, type and quality of information that is required to parameterise and validate hydrological and salt mobilisation models.

An example of this is the widely used bio-economic model MIDAS that was developed to understand the economics of dryland farming systems with the biological constraints built into the model. Using data derived from the Boorowa, Gumble and Baldry Key Sites MIDAS was able to simulate the effect of a range of different landuses from annual cropping, perennial pasture, and trees on farm profitability and catchment salt export. The modelling showed the potential for perennials to contribute to profitable and robust farm systems and to reduce degradation to land from salt scalds and to streams arising with elevated discharge and wash-off. However, increased adoption of perennials is likely to be associated with reduced stream flows. The economic farm surplus tending to increase with the area of perennial pasture to a maximum of $275/ha at approximately 60% land coverage after which it declined.

Additional outcomes

Improved agency and community skills, knowledge and collaboration to allow informed landuse decision making

Over recent years the KS team has initiated field days with participation of approximately 450 people and seminars with participation of approximately 330 people. The people who participated at these events include CMA staff, public and private advisors, researchers, natural resource professionals, university students and senior lecturers and leading farmers. Some of the feedback from people who participated in these activities includes:

"Extremely valuable for targeting on ground work"

"This allows management activities to address recharge and discharge issues"

"Essential information to base modelling on"

"This research is of huge benefit for management at a catchment scale"

"Provides fundamental understanding to allow successful management of water and salt"

"We can use this information to design interventions and reduce recharge problems"

"This information is important for the development of public policy"

Key Sites have provided considerable resources to train and maintain field based hydrological monitoring skills within NSW DPI and as such NSW DPI has developed considerable skills in establishing and maintaining a range of eco-physiological and eco-hydrological field based instrumentation. This included measurement of transpiration and evapotranspiration via sap flow and Bowen ratio, hydrometric skill for measuring stream flow, and groundwater and a broad range of telemeted instrumentation. Additionally there is considerable skill developed to analyse the hydrological and hydro-chemical processes that are occurring at the sites including detailed Bayesian end member mixed modelling. This skill set as allowed development of the above mentioned scientific knowledge, and this skill set will continue to be able to deliver the knowledge needed to better monitor and manage natural resource condition.

The Key Sites project has provided the avenue to facilitate closer collaboration between state agencies particularly NSW DPI, NSW DECC, and NSW DWE. Also the project has developed strong linkages with University of NSW and Australian National University.

The comprehensive technical base within the Key Sites project has allowed other divisions within in DPI to use and benefit from training and knowledge generated by the sites, leading to close cooperation between extension, economics and research disciplines. This in turn has led to highly valued training for CMA's and private agribusiness that have benefited from the skills within the Key Sites team. The close cooperation between the research and extension provides a valuable adoption pathway for improved monitoring and management of natural resources.

Publications
Journal

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Barton, C, Littleboy, M Mitchell, D. 2009 "Quantifying sub-catchment impacts of tree planting on water yield and quality – Little River". Knowledge transfer workshop NSW State Level Activity Sydney, May 2009

Mitchell D 2009 Development of the Australian Dryland Salinity Paradigm Salinity Exchange Conference Feb 2009 Albury

Mitchell D 2009 Development of the NSW Dryland Salinity Paradigm Mudgee Australian Soil Science Society regional update

Field days Workshops Forums Press releases

Workshops and Forums	Date	Contributors
CRC Salinity Harvest and Delivery Workshop	Aug 2006	D Mitchell, R Crosbie J Hughes
CRC Salinity Catchment Water Use Factors and Salinity	28-29 March 07	J Hughes D Mitchell R Crosbie
Central CMA Forum	November 2007	J Hughes D Mitchell
Northern CMA Forum	November 2007	D Mitchell T Bernardi
Southern CMA Forum	November 2007	V Shoemark G Summerrell
Eastern CMA Forum	November 2007	J Hughes T Bernardi
Press		
$3.3 million for key sites salinity research.	Ag Today May 2005	David Mitchell
Perennials reverse dryland salinity at Boorowa.	Ag Today February 2006	Russell Crosbie
Salinity drainage meters installed at Baldry.	Ag Today March 2006	Tony Bernardi
Salinity research challenging old theories.	Ag Today June 2006	David Mitchell
Livingston Creek Key Salinity Site.	Ag Today June 2006	Vic Shoemark
Researchers face new challenges	Ag Today June 2006	Peta Derham
Clever device samples falling water	Ag Today June 2006	Chris McCulloch
Hydrological impact of land use change	Focus on Salt 2007	Russell Crosbie
Clean mine site runoff	Ag Today June 2008	Tony Bernardi
Climate affects salt, water movement	Ag Today June 2008	David Mitchell

Key Sites Reports

Title	Contributors	Audience and Date
NSW Salinity Strategy Action 2.4 Interim report	Barton C, Roberts S, Walsh P, Montagu K, Cowie A	NSW Cabinet Office, July 2003
NSW Salinity Strategy Action 7.3 Interim Report	Friend J, Gallagher P, Hughes J, Derham P	NSW Cabinet Office, July 2003
Research into land management practices and establishing model farms	Friend, J Regan P	NSW Salinity Strategy Annual Report 2003/04 [final report]
Key Sites for salinity, hydrology and model validation	Friend J, Littleboy M, Barton C	Independent Review, commissioned by JSC, Feb 2005
Hydrogeological study of the	Ian Acworth	Site investigation report

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Baldry site		
Bowen ratio report	R Crosbie J Hughes	
Engineers Australia. 2006 National Salinity Prize. The Falling Stage Sampler	Chris McCulloch	Engineers Australia
Understanding the Processes of salt movement from the landscape to the stream in dryland catchments.	Summerell GK (2004)	PhD Thesis, The University of Melbourne.
December 2005- Update on "Keys sites for Salinity hydrology and model validation" SL 0017 SS	D Mitchell and KS staff	JSC Dec 2005
Key sites update	D Mitchell and KS staff	JSC Jan 2006
Steering Committee update	D Mitchell and KS staff	JSC Feb 2006
Steering Committee update	D Mitchell and KS staff	JSC Aug 2007

Seminars/presentations

Title	**Contributors**	**Audience and Date**
State wide hydrology research project	Peter Regan, John Friend	Senior managers of TCO, NSW Ag and DIPNR, February 2004
State wide hydrology research project	Peter Regan, John Friend	Senior managers of AG NRM Team, February 2004
State wide hydrology research project	Peter Regan, John Friend	Senior staff of MDBC, February 2004
Preliminary results - Hydrological impact of land use change	Russell Crosbie, John Friend	Boorowa Community Landcare Group, March 2004
A catchment study of salt and water movement	Peta Derham, John Friend	Timbumburri Landcare Group, May 2004
State wide hydrology research project	Peter Regan	Board of Lachlan CMA, June 2004
Independent review of Key Sites	John Friend, Mark Littleboy, Peter Regan	CMA Chairs and Managers Central West and Hunter, Jan and Feb 2005
Tamworth Key Sites Seminar	Peta Derham, David Mitchell, Ian Daniells	CMA, farmers, DNR, DPI. May 2006
Briefing - Hydrological impact of land use change	Russell Crosbie, David Mitchell, Peter Regan	Boorowa farmers, February 2006
Hydrological impact of land use change	Russell Crosbie, Peter Regan	SGSL NSW Producer Network Committee meeting, Yass June 2006
Hydrological impact of land use change	Russell Crosbie, David Mitchell	CRC Salinity, CMA, DPI extension staff, farmers, private agronomists, August 2006
Runoff and solute mobilisation	Justin Hughes	CRC Salinity, CMA, DPI extension staff, farmers, private agronomists, August 2006
Salinity Management	Training led by NSW	Public and private

Title	Contributors	Audience and Date
Training Courses	DPI Salinity advisory staff with contributions from many Key Sites staff	advisors, CMA staff, local government
	David Mitchell	Joint Standing Committee 19 October 2006
Development of the NSW Dryland Salinity Paradigm	Mitchell D	Soil Science Society regional update 2009
Key Sites for Hydrology and Salinity Measurement and Model Validation	David Mitchell	Knowledge transfer Workshop 2009
Note: Presentations on Key Sites research have taken place at all team meetings of DPI salinity research, extension and economics staff		

Key Sites Field Days

Title	Contributors	Audience and Date	Site
CRC Salinity Governing Board field tour	John Friend, Justin Hughes, Peter Regan	CRC Salinity Governing Board, local farmers, CMA – October 2003	Sloanes Ck
CRC Salinity NSW Node field tour	John Friend, Peter Regan, Peta Derham	Members of NSW Node of CRC, Salt Teams, local farmers - November 2003	Duri
CRC Salinity NSW Node field tour	Peter Regan, Justin Hughes, Russell Crosbie	Members of NSW Node of CRC, Salt Teams, local farmers – March 2005	Gumble
State Forests NSW field tour	Peter Walsh, Kelvin Montagu, Craig Barton	State Forest managers-Feb 2004	Baldry, Paringa
Field tour of State Forests plantings in Liverpool plains region	Craig Barton, Sandra Roberts, Peter Walsh	Local landowners, CMA's, other interested parties	Paringa
University NSW agriculture student field tour	Tony Bernardi	University staff and students, March 2005	Baldry
NSW DPI Resources Research Board of Mgt field tour	Vic Shoemark, Greg Summerell, David Mitchell	DPI managers, December 2005	Livingston Ck
NSW DPI Resources Research Board of Mgt field tour	Peta Derham, David Mitchell, Lisa Nies, Mirella Blasi, Tony Bernardi	DPI managers, March 2005	Duri and Paringa
NSW DPI Resources Research Board of Mgt field tour	Tony Bernardi, David Mitchell, Brett Wilson	DPI managers, September 2006	Baldry

Title	Contributors	Audience and Date	Site
PUR$L Conference, NSW	David Mitchell	PUR$L participants, salinity research and extension staff, October 2005	Gumble, Baldry
SGSL annual field day	David Mitchell, Russell Crosbie, Justin Hughes, Chris McCulloch	Local farmers, CMA staff, agency staff, private advisors	Gumble
CRC Salinity Harvest and Delivery field tour	David Mitchell, Russell Crosbie, Justin Hughes	CRC Salinity, CMA, DPI extension staff, farmers, private agronomists	Boorowa
Ground water field tour, Lachlan and Central West Catchments	David Mitchell, Russell Crosbie, Justin Hughes	CMA staff, August 2006	Gumble
Livingston Ck field tour	Vic Shoemark, Greg Summerell, David Mitchell	Murray and Murrumbidgee CMA, DPI,	Livingstone Ck
Salinity Management Training field studies	Training led by NSW DPI Salinity advisory staff with contributions from many Key Sites staff	Public and private advisors, CMA staff,	All