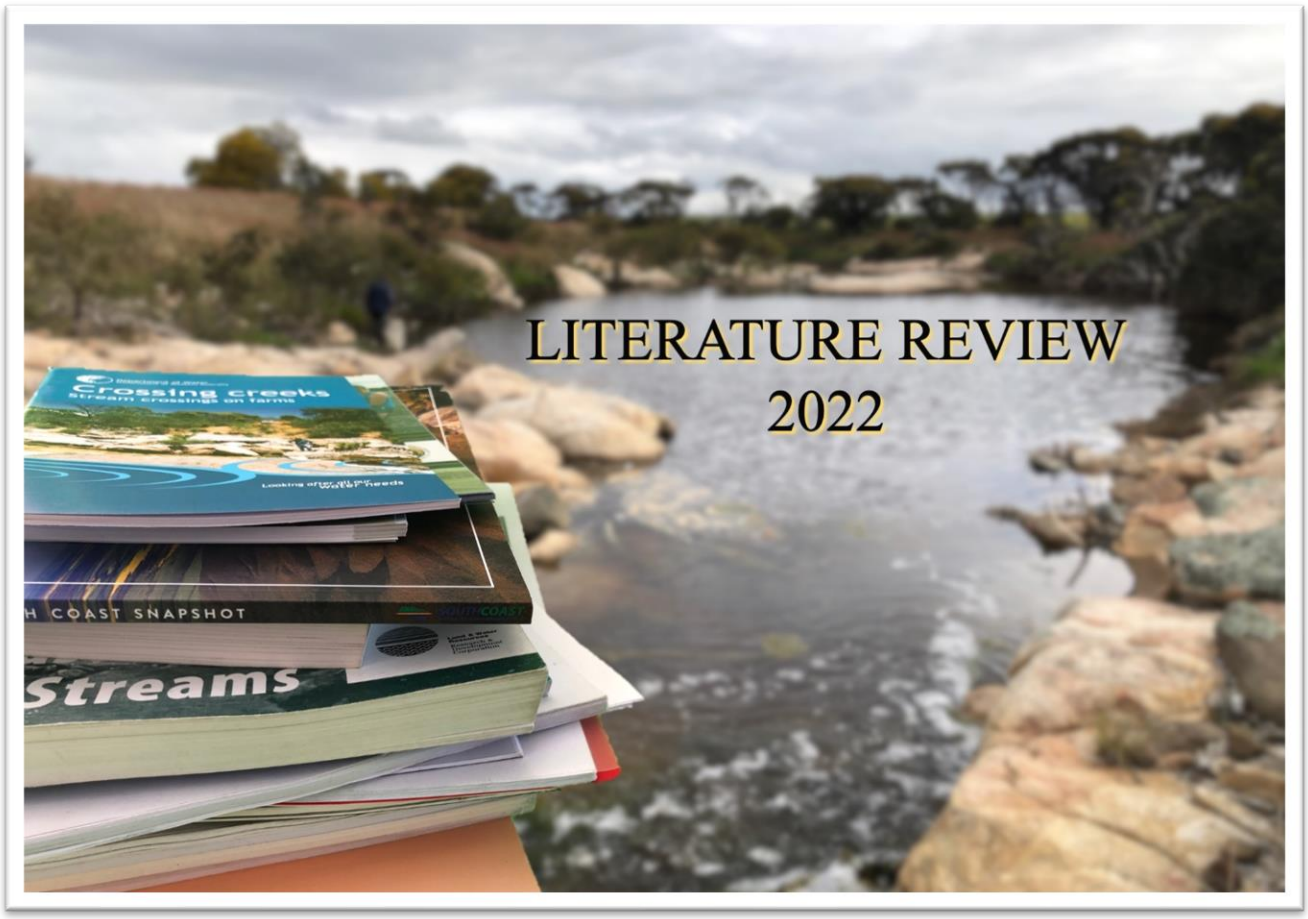
Warperup Creek Improvement Plan

Feasibility Study 2022

Supplement 2



Prepared for

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GOVERNMENT OF WESTERN AUSTRALIA

natural resource management program

NORTH STIRLINGS PALLINUP NATURAL RESOURCES

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Warperup Creek Improvement Plan
Feasibility Study 2022: Supplement 2
Literature Review

Prepared by Steve and Geraldine Janicke for North Stirlings Pallinup Natural Resources Inc as part of their Waterways Restoration Project (CSGL19013)

This project was supported by funding from the Western Australian Government's State NRM Program.

Cover Graphic: Warperup Creek.

Disclaimer: The authors have in good faith, made every effort to ensure the accuracy of the information presented in this review and to acknowledge the sources, subject to the limitations of the methods used and take no responsibility for how this information is used subsequently by others, including implied notions, comments and conclusions drawn. *Management implications* are not recommendations, but present options for consideration and discussion.

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OVERVIEW

This literature review supports the report titled *Warperup Creek Improvement Plan: Feasibility Study 2022*. It focuses on past and current waterways management issues and practitioner views relevant to the waterways of the Pallinup River catchment. The experiences of people in similar environments and with similar issues provides important reality checks when planning long term environmental maintenance and rehabilitation projects.

Intermittent projects sit best within an overall water condition improvement plan for a catchment. The plan put together by most landholders within a catchment for the purpose of ensuring a consistent approach to stream management practices with the goal of long-term benefits to both the natural environment and agricultural enterprises. Knowledge of the nature of the catchment waterways and the history of landscape development is essential for steering environmental maintenance towards successful outcomes. Gaining understanding of how conditions are changing will be a vital component. The subjects included in the literature review are assessed for relevance to Warperup Creek as follows:

- Knowledge of the landscape and hydrological processes influencing the waterways.
- People's experiences and views with respect to the waterways.
- Material useful for the ongoing development of better management practices applicable to Warperup Creek, which includes information about other catchments.

Successful Natural Resource Management rests on the willingness of landholders to be actively involved and for this reason the review includes several quite relevant documents dealing with the ups and downs of community engagement in land care.

A general assessment of the available information is that environmental data for the streams of the Warperup catchment is sparse and fragmented in time and space. Nevertheless, various studies have shed some light on the general character of the landscape and the various environmental processes taking place. One important conclusion is that detailed information and insight is essential for developing a comprehensive management plan for the Warperup waterways, a plan fully owned and endorsed by individual landholders.

The authors of the literature review do not necessarily endorse all views or relevant principles, expressed in the literature or that all the information will prove to be relevant to the Warperup Creek catchment, but nevertheless consider the information is mostly relevant to the feasibility study and should be considered if the development of the proposed Water Condition Improvement Plan is to go ahead.

The format of the review for each document consists of three sections:

- Document information
- Extracts of interest
- Comments on the relevance to Warperup Creek

HISTORY, PERSONAL PERSPECTIVES AND COMMUNITY ENGAGEMENT

The Bush Comes to the City - Fitzgerald Biosphere Project (1989)

Author: Fitzgerald Biosphere Project January 1989

Publication: Papers from a seminar held at Murdoch University 25th of September 1987 Perth, Western Australia. Printed by Picton Pt Ltd.

Type: Book

Extracts - Insights, principles, and perspectives

COMMENTS BY BOB TWIGG (farmer, Fitzgerald Biosphere)

"What I've done to the land and what it has done to me"

p15

The first attitude and motivation for development and land ownership that I had brought with me was a belief that the land is the greatest asset. That was an ideal that I grew up with, and it was passed on to me, no doubt, from four generations of farming families.

p21

I now understand that it is not really people separate from the environment that we're talking about. What we're really talking about is that people are actually part of the environment. Barry Hodge (MLA) mentioned the same sort of thing this morning, that people are doing something to the environment and the environment is certainly doing something to the people. The interaction is both ways.

p22

Question: knowing what you now know if you had the chance to develop your land again do you think you could have developed it to agricultural use on a more ecological basis?

Answer: Oh, I'm sure. Yes, I'm sure no doubt about it. But the first essential would be to go and look at what was there, before I worked out what to do. That would be the first real principle.

The second one would be not to clear the land totally, to leave at least the major gullies within the areas even though it is more expensive and more difficult to carry out the clearing. To do it that way in the long term is much more beneficial. So, I think I would have a much better long-term view than what I've had in the past.

COMMENTS BY IAN PEACOCK (farmer Fitzgerald Biosphere)

A community approach to salt problems

p25

It is a self-help community. The community, since I've been in it anyway, doesn't expect government handouts.

p26

Most farmers are at their individual best when they are inside their four boundary fences on their piece of land and they will rarely tolerate anybody else from outside coming in and telling them how to go about running that piece of land unless they have particularly employed people in some way, to do it: to give the sort of advice offered by farm consultants, the accountant or, in some cases advises from the Department of Agriculture or other such bodies.

p27

Cooperation I believe comes in four different forms within the community, cooperation through necessity; cooperation for community needs; cooperation with friends and neighbours; and cooperation with the environment in which the community has to exist.

p29

Not to cooperate with the environment and to try and farm in my opinion is just not on any more. A farmer who does not cooperate with the environment is probably doomed to failure these days. Probably a reason why a lot of people have disappeared in the past years because they tried to fight the environment. Farming to me now probably more than in 1969, means using the environment wherever I can to enhance my production.

p31

Every time I've done something on my property with regard to salt or drainage or whatever, I have always asked and got the neighbours to come and have a look or pass an opinion and it has got them involved and it has got things ticking along.

One thing became very apparent in those early days. It is no good telling your neighbour, or any other individual for that matter, how to run his farm. You simply get booted out the gate and nobody is going to listen. So, I took the approach of asking questions. Instead of going and telling somebody something, go and ask him a question. Once you've asked him a question and you get an answer, then it gives you an opportunity to tell him what you think, rather than going and saying I think you want to do this or that.

p34

We've got to realise that salt reclamation work is a between seasons job. It is not going to happen quickly. It is one of those jobs that will be done between harvest and between shearing and between seeding. It is not like I thought when I first thought of getting this thing going: "Well six months up the track we are going to have this you-beaut group, and everything is going to be running smoothly. In a couple of years, we will have it all solved". Well, we are three and half to four years down the track now, and we are nowhere near getting it solved and we are still virtually in the planning stage.

p34-35

What advice would I give to others?

Well first don't come to heavy if you want to get something done there is no good going on with jack boots, you just won't get any cooperation. Lead by example, ask questions, listen to the people that you're trying to help and win them over that way, give people time to see the ideas after you've asked and those questions, give them time to think and don't be discouraged by people who are negative in their attitude.

COMMENTS BY REX EDMONSON (farmer at Jerramungup)

p39

I arrive to Jerramungup at the point where Kay Vaux left off.

Farmers are a pretty proud and individual people. They are proud of their own little patch and also fiercely independent of how and what they do on that patch. Most farmers get a great deal of satisfaction out of what they do.

p42

The wind drift in this case has not covered the fences. It just destroys them as it takes all the galvanising off the wire. It would probably reduce the life of the ring lock fence down to 10 years instead of 30 or 40 years.

P45

And of course, in amongst all this the farmer's pride was getting pretty hurt by what he saw as bad publicity. For instance, we had come to Perth, and we got:

"Where are you from?"

"Jerramungup?", "Oh! That is the place that has all the wind erosion".

"Yeah, that's right".

And so, it really started to hurt the farmer's pride.

p47

Whether you like the chemicals or not, they play a big part in applying that minimum tillage technique.

Probably the superpowers could learn a bit off us, the way we negotiated backwards and forwards between the Party.

One of the other things we found: once the committee was formed, we were able to get personal contact with the farmers that had the problems.

We felt timid for a while, it is not quite as bad as it sounds when she get into it. It's not very pleasant when you have to front up to your neighbour with a problem that you know he's been feeling a bit hurt about and try to get some action.

p49

I will make a few profound statements just to sum up.

Firstly, I don't think there will be any more major wind erosion, I'm quite positive of that. There will certainly be small pockets that will break out from time to time. I'm extremely confident that we now know how to deal with wind erosion and that the farmers recognise the signs as they come.

Secondly salt is a major problem. I'm quite certain this state doesn't realise how major a problem it is. I probably don't even realise it myself, but what I have seen of it, it is enormous.

If salt breaks out along the south coast at the speed that country was clear, I'm certain that this State will never foot the bill.

It will be enormous so much more money is needed for research on salt problems. But we need to know exactly what we will use research money for. There is not much point getting the money just for the sake of having it. There are preps too many small projects around. With all of these soil conservation districts there are perhaps too many small projects around. Sure, they need those small projects to get the catalyst to work but there are too many small ones, that is my opinion.

Thirdly, we are tending to shift onto extension now rather than aiming at research. We are wanting to get the message across to a few people and to other farmers and to that effect of course the Fitzgerald Biosphere Project is very necessary.

Relevance to the Warperup Creek catchment waterways

The range of views expressed in these testimonials from the Jerramungup area are likely well reflected amongst farmers in the Warperup Creek catchment. The development of a workable and long-term Water Condition Improvement Plan will rest firmly on these values and should provide the foundation for designing the catchment landscape to best suit changing times, volatile markets and uncertain climatic conditions. Important points are:

Look at was and is there before working out what to do.

Farming communities are self-help communities willing to cooperate on various levels but not willing to tolerate outsiders telling them what they should be doing.

Salt reclamation work and waterways protection and enhancement are between seasons jobs and need a long-term view.

Farmers get great satisfaction out of what they do.

Pallinup Pioneers - The Whites of Whiteworth

Author: Unknown

Publication: Shire of Gnowangerup library document

Type: Locally produced, spiral binding

Extracts - Insights, principles, and perspectives:

Salt gradually encroached on the land. Various causes are given for this, one of the main issues was the proximity to a river which was described as '*always salty*' (Mick Mouritz) or *'fresh water in those days*' (John White). Another is the farming practices. ". (Reg Gillespie, A concise history of Pallinup). Others said that ploughing to deep could introduce salt from affected areas. In any event, for Arthur and the other settlers at Pallinup the encroachment of salt made a huge impact on their farming income. "*Salt is constantly creeping up leaving the acreage less each year" John Baxter, Sept 1935). "The landholder has to constantly curtail the area of cultivation adjacent to the watercourse on account of salt and requests revaluation on the basis of 100 acres has gone salt out of a total of 677 acres*" (Frank Norris).

Relevance to the Warperup Creek catchment waterways

Although the property 'Whiteworth' is west of Gnowangerup, the comments reveal a feature of the Pallinup catchment, including the Warperup, which was not understood in the early days of clearing – namely the massive amounts of salt hidden below ground and easily moved to the surface through ground water pathways and processes.

Fruit of the Country. A history of the Shire of Gnowangerup Western Australia. (1977)

Authors: Merle Bignell

Publication: University of Western Australia Press. 1977

Type: Book

Extracts - Insights, principles, and perspectives:

p133

This couple (John and Jean Moir) chose the rich pastures undulating on either side of the Warperup and Peerup-Meenup creeks for a property they named Warperup. This vicinity was first surveyed in 1854 by Surveyor Gregory when he pegged the watering point location 72, which had been granted to Lieutenant G.E. Warburton.

p163

In the vanguard were the Stone brothers, Joe and Alec. They were Victorians who had come to Bunbury in 1902. During 1905 they inspected land east of Broomehill and though some of the residents of that town told them: 'Don't go further east; that is the end of the earth', the Stones had minds of their own. They chose a site of fresh soakage around the junction of the Warperup and Pallinup River. They were never to regret their choice. The water persisted even in the heart of a drought. Other settlers had not such a high regard for a reliable water supply and were come close to perishing. They are said to have gone begging to one of the old homesteads for some of their meagre supply.

At first the Stones built a house close to the river but after the 1914 floods they moved to higher ground.

p164

By 1905 George Wickham, then about forty years of age, owned 405 hectares near the Warperup Creek.

p165

He (George) wrote in July 1906 (to his brother Peter) 'If there is any water on the land don't let Cobham know or he will immediately make a reserve…'

Ducks – When they do come along shoot them on your neighbour's property and don't disturb them on our pools'.

Mercenary though these comments may seem they were typical of the time: the rush for grazing land, in some quarters, was as fierce almost as the previous fever for gold, in the state and George Wickham was well aware, that it would not be allowed forever.

p178

By 1910 would be farmers were moving through Gnowangerup to the newly surveyed land in the vicinity of the Warperup and Ongerup Creeks, both of which drained into the southerly Pallinup River.

p202

At a meeting held in a weatherboard building used by the Agricultural Bank at Ongerup, Toby Carpenter forcefully told the representatives 'that Ongerup would come to grow wheat and wool equal to any area in the state'.

But for a long time, the government bodies were unconvinced and would not advance credit. As a result, many settlers faced untold hardships and distress.

p231

Undoubtedly, they (A.B. Stone family and friends) had learnt to swim somewhere because in March 1920 an annual sports day was held “by the lovely Warperup River, amidst rocks, trees and shrubs”.

Relevance to the Warperup Creek catchment

The relevance of Merle Bignall’s detailed and engaging history of settlement in the Gnowangerup – Ongerup - Borden area to management of the Warperup Creek may seem obscure however, natural resource management is more than just about solving technical problems in the landscape. It is fundamentally a socio-economic endeavour and the personalities and attitudes of landowners and the values which have been forged over the generations hold the keys to the future of these rural communities and therefore, the quality of care afforded the natural aspects of the environment.

The descendants of various settlers who moved to the district 120 years ago, remain and are actively working properties in the area. This reveals two important features of the community, first many landholders have inherited a rich, detailed understanding of the Pallinup landscape and how it has responded to the massive changes brought about by clearing for agriculture. Secondly the landscape itself is appreciated, environmentally as well as economically, and is attractive enough to hold people to the area. This point was affirmed by many participants in the 2022 landholder survey.

It is this appreciation of the Warperup landscape which provides justification for encouraging independent minded landholders to continue to take a broad view of land and waterways management outside the boundaries of their own properties and to work cooperatively, as much as is feasible, to achieve a catchment-wide improvement in water condition along the Warperup Creek and its extensive network of tributary streams. Such a management approach must in turn, contribute considerably to the water health of the Pallinup River and the final destination for its waters at Beaufort Inlet.

Green Gems: Stories of the Alcoa Landcare Project 1989 – 2003. (2015)

Author: Pilgrim, Alan T.

Publication: Black Swan Press. 2015

Type: Book

Extracts - Insights, principles, and perspectives

Alan Pilgrim's history of Alcoa's involvement in the Decade of Landcare is recorded in great detail and provides valuable insight into the company's engagement with rural communities and government agencies regarding what worked and what did not work as the Landcare movement was developed.

The term Landcare did not appear until 1986 when it was introduced by Joan Kirner, then Minister for Conservation in the Victorian State Government.

In December 1991 it was noted that the Select Committee into Land Conservation had been shocked to learn of the extent and severity of the deterioration of W.A.'s environment, its soils, water resources, and flora and fauna.

p20

Alcoa Identify two types of conservation projects for the company to support. These were the reclamation of salt land and or natural habitat restoration.

p22

The Avon Valley proposal identified nine objectives which in the years to come would provide a virtual checklist of the major projects included in the Alcoa Landcare project.

At the top of the list of objectives, was involving the community in a major Landcare demonstration. Other objectives included improve the stability and environmental values of the river and adjacent lands.

p27

Wider context desirable

Recognising the merits of linking any proposal with government initiatives that have a national focus.

p57

For the project to succeed everyone would have to find common ground. This meant strongly, independent landholders would need to work collaboratively, agencies would need to share knowledge with Landowners and with each other, and Alcoa would need to be clear in their expectations.

Strategic partnerships

p82

The development of strategic partnerships is one of the most important and successful elements of the Alcoa Landcare Project. The Landcare project enabled the company to develop a diverse range of partnerships with environmental and other non-government organisations, for example Greening Australia in W.A.

p85 Whose projects?

The assets farmers brought to the table were huge and they needed to be recognised as the dominant partner.

Grants and Sponsorships

p88

The group processes used in many of the projects highlight the difference between the giving of donations or grants and a sponsorship partnership. The emphasis in a sponsorship partnership is on providing assistance through direct funding, sharing of expertise and empowering community-based groups to build their capacity to make decisions.

p90

A low level of bureaucracy

The work has been undertaken without strategic workshops and without the development of inch thick documents. Decisions on funding are almost all made at the one meeting. Decisions are conveyed immediately, and unsuccessful applications are given space to become eligible. There is no over auditing process but rather a higher level of trust between Alcoa and the Landcare groups. I have seen no other process that delivers so well per dollar invested. I've seen lots that do not - Keith Bradby former coordinator community catchment centre Pinjarra commenting in 1997

Catchment and Group Processes

p93

Undertaking Landcare on a catchment or landscape scale makes sense. Regardless of size and complexity, catchments constitute natural hydrological and other ecological systems within our landscape. Property boundaries and fences, other than creating social or temporary physical barriers are no impediment to the flow of water, loss of sediment, accumulation of salt or any other land, water or biodiversity management issue. As a consequence, DPaW land management in the area of a catchment has the potential to have not just onsite impacts but also offsite impacts lower in the catchment. Adopting a catchment management approach enables farmers and other land manages to take a whole of catchment or landscape view to natural resource management. The discussion in this and many of the subsequent chapters highlights the role of farmers as land managers, as they develop more sustainable farming enterprises, embracing both production and conservation outcomes. The terms farmer, landholder and land management are used interchangeably in this context.

While there were many notable projects undertaken in both states, the six Avon demonstration catchments in the W.A, Wheatbelt and the Woady Yaloak catchments south of Ballarat in the Western District of Victoria were for many people the flag ships of the Alcoa Landcare project. Both were judged to be highly successful by those closest to the process, the participating farmers and other land Managers.

Farm productivity increased over a 10-year period and significant landscape changes were achieved in relationship to land, water and biodiversity protection and enhancement. There were major social benefits and attitudinal change in relation to farming systems and natural resource management.

p99

The philosophy and approach of the Avon Landcare program was aimed at improved financial and production outcomes with conservation, consistent with ecologically sustainable development. - Darrel Brewin, manager, Avon Task Force group (1989 - 1999) W.A. Department of agriculture commenting in 2006.

p104

> We knew that landscape scale change is mostly about changing people, their attitudes and beliefs and values about landscapes and natural assets. Ted Rowley, Landcare Consultant to Alcoa of Australia 1998 - 2003, commenting in 2007.

p106

> Prior to Landcare most farmers had not worked together and unless they were mates many had not set foot on their neighbour's farms.
>
> One of the earliest activities undertaken by each of the catchment groups was to jump onto the back of several of the farm utes, and over a period of several days drive around each of the properties within the catchment. The farmers shared their successes and failures, their hopes and aspirations. This started the process of building a cohesive group who shared a common sense of purpose and a strategic direction.

p107

Fundamental to the success of this catchment scale planning process was the ability of, and acceptance by, all landholders to look beyond their own boundaries.

p108

The ability of landholders to make unselfish decisions based on the best interest of the community or catchment when allocating external funds came as an absolute revelation to some senior offices within the Department of Agriculture.

Ground water bores

p111

The report concluded that the network of bores were of limited value in assessing catchment wide trends in groundwater movement. With the majority of bores located low in the landscape and therefore in discharge zones such as valley floors, fluctuations in groundwater level were more likely to be reflecting seasonal rather than long-term variations.

p112

By 1996 there were more than 400 local catchment groups across W.A., most of them within the wheat belt.

The State Salinity Action Plan was launched in 1996.

Yeelanna Catchment Group

p119

Our greatest achievement was to realign the fence lines on the farm. These along with tree lines, we are placed on the contour. As a result, no water run-off so water and wind erosion had been arrested, salinity controlled, pasture has improved and cropping yields are certainly better. An added advantage was that the landscape improved aesthetically. - Ron and Anita Foord, former members of the Yeelanna catchment group commenting in 2005.

Brian and Pam Caporn at South Yoring have noticed that as a result of the tree planting floodwaters move much more slowly through the landscape, and they lose very little soil off their farm. They noted dust storms also caused less damage.

p123

We are very proud of what we have achieved. We are going to have a lot more productive land because we have controlled water on the property. During floods, water now moves more slowly through the landscape. There is land here that my father had to stop cropping in the mid-1950s. That land is now in better shape and was cropped for the first time in 50 years in 2004. - Brian and Pam Caporn, members of the South Yoting catchment group, commenting in 2005.

In terms of investment in Landcare, the 2002 benchmark survey showed that on average most farmers were spending between $13,000 and $18,000 a year on Landcare.

p131

The development of neighbourhood groups was of fundamental importance to the development of true cross boundary projects. To receive funding Landowners had to work collectively. - Cam Nicholson, project officer 1992 to 2012, Woady Yaloak catchment project, commenting in 2003.

p172

One of the preconditions for sponsorship imposed by Alcoa was that Landowners work together as a catchment group to ensure a focus on the rehabilitation of Lake Toolibin.

p214

In 2005 WWF commissioned a social impacts evaluation of Woodland Watch. The evaluation revealed that farmers, Landcare and NRM coordinators, and local government officers had developed higher levels of awareness and knowledge about bushland values. In addition, they had acquired new skills and capacity to plan and share knowledge about bushland conservation.

p225

Within the first two years of the Alcoa Landcare project, the company has sponsored the printing and distribution of dedicated teacher resource kits for all primary, secondary and agricultural schools within W.A.

p231

It was recognised early in Alcoa's Landcare project that education is a key element in making lasting change. - Wayne Osborn, Managing Director (2002-2008), Alcoa of Australia (extract from speech notes for the TALEC 15th Anniversary Dinner, April 2005).

p277

If you want groups to be decision makers, you have to trust that they can do it and you have to release the reigns by giving them responsibility. Alcoa displayed a great degree of trust. - Neil Guise, District Manager, W.A. Department of Agriculture and Food, Waroona district office, commenting in 2005.

The most obvious and immediate benefit from the rivers, wetlands and habitats project was the opportunity for local Landcare groups to gain access to funds for on-ground work, through a remarkably simple, community driven and empowering process. This was in marked contrast to the NHT (Federal Government) funding process, which, as already noted was both complex and restrictive.

Site inspection audits were never undertaken. The groups were told, "your neighbours will be the auditors and they will let us know if you do not do the work".

p279

> A more worrying trend is the anecdotal evidence suggesting that as land ownership changes, not all new Landowners understand and appreciate the importance and value of the work that has been undertaken.

p280

Fox baiting programs did not qualify for funding under NHT guidelines. This presented a challenge for the groups as their revegetation work was undertaken for multiple benefits, including encouraging the return of wildlife but with so many foxes it was proving to be an impossible task.

As farmers observed improvements on their neighbour's properties their outlook grew beyond the local area to a catchment scale understanding and appreciation of the impact of individual properties on the total catchment. Networking through the Landcare groups also meant that farmers and other land managers had contact with many more scientists than would normally be the case. As a result, group members had the opportunity to learn much more about the impact of their farming activity on the land and gained a better understanding of the physical landscape.

p281

During the mid-1990s, when the level of activity was at its peak, most groups would meet once a month at someone's house, with everyone bringing along some supper.

Many of the farmers involved in the project acknowledge there have been economic benefits from the shade and shelter provided by their revegetation efforts. The shelter belts offered protection for cows during the cold winter months, especially important for cows carving in winter, as well as providing shade from the summer heat.

p317

> Initially we saw Landcare as primarily a technical challenge, transferring some of our mining rehabilitation technology to help repair degraded agricultural land, with the social and capacity building aspects as almost a by-product. In the end it was a social and capacity building skills that became the key. This is the real value of the model – it goes to the heart of sustainability and to the heart of functional communities. And this is why it works so well in the broader sense when you extend it beyond Landcare. What a fantastic decision it was for us to embark down this path - Wayne Osborn, Managing Director (2002-2008), Alcoa of Australia commenting in 2007.

Relevance to the Warperup Creek catchment

The relevant objective of the program was "to foster community interest and involvement in Landcare restoration project and education programs." This objective is also relevant to developing a Water Condition Improvement Plan for the Warperup Creek catchment.

The insights presented in the book provide practical lessons in community engagement with the development of large-scale landscape rehabilitation projects. The principles, continue to be relevant to the future management of waterways large and small.

North Stirlings Pallinup Natural Resource have employed many of the principles presented effectively in the Middle and Upper Pallinup and Pilgrim's account provides a valuable educational tool for future NRM officers, future landholders and future projects which will become larger and larger as time passes.

Ongerup Rocks Vegetation and Flora Survey. (2006)

Author: Anne (Coates) Rick

Publication: Report commissioned by landholder Judy O'Neill. 2006.

Type: Detailed environmental report

Extracts - Insights, principles, and perspectives

p3

Ongerup Rocks and the surrounding remnant vegetation is a significant site for the conservation of flora and fauna in the Ongerup area. The site includes a granite rock area and a section of the Ongerup creek which connects with the Warperup Creek and Pallinup River. The area is fenced and has not been grazed since the 1960's. Jam posts and sandalwood have previously been removed from the area. Weeds including wild oats have invaded most of the bush and pose the greatest management problem at the site. Plant health is good apart from fringing vegetation along the Ongerup creek which shows signs of stress from waterlogging and salinity.

The study area is an area of remnant vegetation on privately owned land approximately 12 kms Northwest of Ongerup on Location 6505 in the Shire of Gnowangerup. The remnant is approximately 24 hectares in size and includes a creek line, the Ongerup Creek, and a granite area known as Ongerup Rocks. The Ongerup Creek connects with the Warperup Creek main channel a short distance upstream of the Hart Road crossing

The area is fenced and has not been grazed since the 1960's. Jam posts and sandalwood have previously been removed from the area.

The object of the flora and vegetation survey at Ongerup Rocks is to gain an understanding of the vegetation associations and plant species present (including native and weed species) in the remnant. No formal survey has previously been carried out at the site. The survey will provide direction for revegetation and weed control work designed to restore the ecosystem and manage salinity. Flora surveys are also important in providing baseline data on the condition of the site prior to the commencement of the restoration activities in order to assess the success of these activities and monitor the ongoing condition of the bush. This final report describes the vegetation and flora of the Ongerup Rocks site and includes a plant species list, vegetation descriptions and a vegetation map of the area.

Relevance to the Warperup Creek catchment

Given that this isolated reserve had not been directly impacted by grazing for more than forty years, the site provides information about how native plant species have coped with initial impacts and with ongoing external pressures such as weed colonisation. The site offers some insight and a benchmark into what might be expected of rehabilitation efforts along other reaches of the upper Warperup tributaries. This site could be included as an addition to the 10 sites established as part of the Warperup water condition and quality monitoring project.

Duncan Family of Boroondara, Ongerup.

Author: Duncan family, Ongerup

Publication: Photographs taken in and around the property "Boroondara" with descriptions. Copyright SLWA 2013

Type: Index of photographs with notes

Extracts - Insights, principles, and perspectives:

Acc #56-57 Views west towards homestead from top of Front Paddock c 1935

Acc #94 View looking north on Peerup Road toward Boroondara front gate. The floods of February. 1955 delivered seven inches (175 mm) of rain.

Acc #100 Elaine, Ian, Sandy and Carolyn Duncan - picnic lunch by a creek. 1961-62

The photographs provide rare glimpses of the landscape and waterways in the early days following land clearing.

Relevance to the Warperup Creek catchment

One photograph corresponds to reference reach PAL509 and enables a comparison of the state of the riparian condition after an interval of more than 85 years.

Groundwater Monitoring 1998-2016 - Yebwen

Author: Steve Newbey

Type: Unpublished monitoring notes 2016

Extracts - Insights, principles, and perspectives:

2003

2003 annual rainfall was 138.7mm above average (135.81% of average). The annual rainfall 1998-2003 was on average 23.67mm above average. 14 bores were lower than 1998 on average by 70.71cm (13cm - 172cm). 1 bore was the same as 1998.

4 bores were higher on average by 28.25cm. (10cm – 49 cm).

12 bores were dry since installation at 330cm - 660cm.

Overall, 19 bores were on average 58.47cm lower than 1998.

Conclusion: 74% of bores had lower water levels, on average 70.71cm, this was despite rainfall in 2003 being 138.7mm above average (135.81% of average) and the average yearly rainfall 1998-2003 being 23.67mm above average.

2016

2016 annual rainfall was 117.9mm above average (130.44% of average). The annual rainfall 1997-2016 was on average 5.87mm above average. 10 bores were lower than 1998 on average by 87.8cm (35cm – 119cm). 1 bore was the same as 1998.

2 bores were higher than 1998 on average by 33.5cm (17cm and 50 cm).

7 bores could not be located (broken off) and therefore could not be read.

Overall, 12 bores were on average 67.58cm lower than 1998.

Conclusion: 83% of bores had lower water levels, on average 87.8cm. lower. This was despite rainfall in 2016 being 117.9mm above average (130.44% of average) and the average yearly rainfall 1998-2003 being 5.87mm above average.

Annual rainfall 2004-2016 - 1.15mm. below average

6 bores were lower than 2003 on average by 90.67cm. (10cm. – 164 cm.)

1 bore was the same as 2003.

6 bores were higher than 2003 on average by 51.5cm. (2cm. – 135cm.)

Overall, 12 bores were on average 19.58cm lower than 1998.

Conclusion: 50% of bores had lower water levels, on average 90.67cm and 50% of bores had higher water levels, on average 51.5cm. Annual rainfall for the period 2004-2016 was 1.15mm below average.

NOTE: Unfortunately, seven wet bores could not be located and had been broken off. These bores were located adjacent to contour drains that have since been filled in. Six of these bores were also away from the immediate influence of revegetation works and were therefore valuable as control bores.

Relevance to the Warperup Creek catchment

Steve farmed the property “Yebwen” which is a short distance north-west of the town of Ongerup. He was actively involved with protecting the streams on his property and adopting recommended farming

practices to reduce secondary salinity. This included monitoring groundwater bores even after the property had been sold.

His report summarises his findings and matches bore water levels with rainfall, but not with farming practices in adjacent paddocks.

The variation in water levels across the property and over nearly two decades, suggests that bore depth readings are sensitive to local factors and for this reason can provide a useful meter for tracking changes and guiding management in the long term.

The loss of a number of bores, for various reasons, highlights the requirement for clear identification of bore sites and ongoing maintenance if they are to be reinstated in a monitoring program to reveal long term trends.

It is suggested that bore data be matched with paddock history data as well as annual rainfall.

INVESTIGATIONS, RESEARCH AND REPORTS INVOLVING WARPERUP CREEK CATCHMENT

Rethinking the externality issue for dryland salinity in Western Australia. (2001)

Authors: Pannell, D.J., MacFarlane, D.J., and Ferdowsian, R. 2001,

Publishers: The Australian Journal of Agricultural and Resource Economics, 45:3, pp. 459-475

Type: Research paper

Extracts - Insights, principles, and perspectives:

Introduction

The fundamental underlying causes of dryland salinity is that the full impact of changed water balance is generally not experienced by those responsible for the imbalance and the resulting recharge of groundwater. (Hayes 1997, p10)

Hayes comment reflects a widespread belief about why dryland salinity has developed to such an extent in Australia and why farmers are still not adopting farming practices that would prevent its ongoing spread. One farmer's management or non-management of salinity has impacts on others through movements of salt in groundwater and or saline discharge into waterways.

Economists use the term 'externalities' to describe (financial) impacts of one economic agent on others.

The message of this article is that externalities have been greatly over emphasised in the shaping of salinity policy and extension in Western Australia and that this has had some important negative consequences.

We are claiming that farmers can, in many circumstances, a) act to prevent salinity within their own farms without requiring cooperation from neighbours; and b) an approach relying solely on internalisation of externalities will not substantially reduce the level of salinity occurring in the future.

For a large portion of the landscape, little groundwater moves across farm boundaries.

<u>Flow (groundwater) systems (Figure 1 below)</u>

Local flow systems are structured such that water that recharges within the catchment will discharge within the same farm (say, one to three kilometres between recharge and discharge). Local flow systems tend to occur in relatively undulating landscapes where there are many discharge sites separating the areas of recharge.

Regional flow systems - Extend for large areas (tens of kilometres)

Intermediate flow systems – in which ground water is likely to cross a single farm boundary before discharging.

Typically, common soils in the large wheatbelt valleys of Western Australia, which are archetype regional systems, have low transmissibility, meaning low potential for water to pass through them. This combined with the very low slopes typical of these large valley systems, means that lateral water movement is very slow indeed and transmission of pressure is low.

Indeed, hydrologists recommend that the most important effective treatment for preventing salinity damage within town site is reducing recharge within the town site (Ferdowsian and Ryder 1997, 1998).

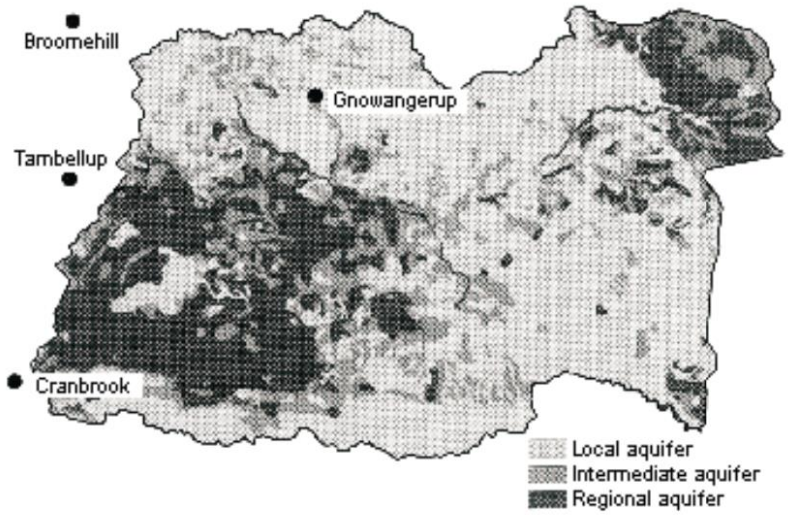


Figure 1 Distribution of local, intermediate and regional flow systems in Upper Pallinup Catchment

For some towns in Western Australia e.g., Cranbrook, Tambellup, imported water and run-off from roofs and roads account for a substantial part of the groundwater rise within the town.

This positive aspect of low transmissivity is matched by a negative; the distance that positive effects may extend away from land on which treatments are implemented is also likely to be very small.

A recently published review of field measurements of impacts of trees concluded that measurable impacts at a distance greater than a few tens of metres away from the trees, are very rare (George et al 1999).

Similarly, deep open drains that have been installed by some farmers to enhance discharge have been found to reduce ground water levels within only a few metres of the drain on high clay soils and rarely more than 40 m on the most favourable soils (George 1985; George and Nulsen 1985; speed and Simons 1992; Ferdowsian et al. 1997).

At least in Western Australia, it appears that it is rarely possible to implement treatments that protect much more than the land on which they are situated. This information requires us to fundamentally rethink the nature of the salinity abatement problem.

Unfortunately, it appears that at least in Western Australia current river salinity is highly unresponsive to revegetation of the surrounding catchment (e.g., Bari 1998).

As with land salinity, local treatments of an engineering nature are likely to be more effective against river salinity then remote treatments higher in the catchment.

The primary method available to farmers for prevention of salinity off-farm is the establishment of perennial vegetation.

Perennial vegetation in most situations mainly protects the land on which it is located, with little benefit for surrounding land.

Establishment of perennial vegetation is expensive. We have already noted that for at least some rivers, revegetation of the catchment can be affective at salinity prevention in the long term. If such rivers have sufficiently high value e.g., ecological or for human water consumption, then the incentives provided by internalisation of these values into the farmer decision-making may be

sufficient to prompt radical changes in farm management. Similarly high-value public or environmental assets on threaten land made, in some circumstances, clear the necessary double hurdle: sufficiently high value of the assets under threat, and sufficiently high impacts of on-farm treatments on offsite assets.

It would require current generations to be willing to provide farmers with sufficiently strong incentives to act in ways that promote the interests of future generations.

Even in the very long-term, the hydrogeological evidence and modelling seems to indicate that on-site engineering works are often more cost-effective method of protecting public assets from salinity than large-scale revegetation on farmland.

Many members of the community both agricultural and non-agricultural subscribe to a land conservation ethic, overriding mere financial considerations. They grieve at the prospect of millions of hectares of land being more or less permanently lost to salinity and would be willing to see public funds spent to prevent this, even if strictly financial calculations did not support it.

Further declines in rural prosperity due to salinisation of agricultural land will have negative consequences for the social fabric of rural W.A. Consequences for mental and physical health, welfare, employment, and rural infrastructure both social and physical can easily be anticipated.

The national Landcare program has been widely criticised for failing to deliver substantial improvements to dryland salinity (e.g., Lockie and Vanclay 1997). Given the technical and economic nature of the salinity problem in Western Australia, its failure in this regard is not at all surprising in that state.

Criticism should not be directed at those implementing the program, but at those who conceived the program based mainly on extension and social processes could make significant impacts on salinity in W.A.

Conclusion

We emphasise that we are not attempting to claim that salt and groundwaters never cross farm boundaries. (Indeed, where large faults and shear zones are important, ground water movement can even transcend surface water catchment boundaries (Clarke 1998). Instead, our objective is to move general perceptions towards a more balanced and realistic view of the importance of externalities from salinity. Externalities are not the essence or the defining characteristics of the salinity problem in Western Australia.

Relevance to the Warperup Creek catchment:

This paper holds some important considerations for the Warperup Creek catchment in terms of rehabilitation projects with soil and waterway salinity abatement objectives.

It should be appreciated that the focus of the paper is the movement of groundwater and questions whether revegetation works have off-farm benefits for reducing land salinisation. The key conclusion is that where local groundwater systems dominate, rehabilitation of salt affected land is a local farm management issue.

The map in Figure 1 implies that saline groundwater issues in the Warperup catchment (intermediate flow systems) have the potential to cross farm boundaries to some extent. This lends support to the idea of a catchment wide coordinated approach to salinity management.

Once ground water is discharged it becomes surface water and for this reason the structure of the stream channels would seem to be the main concern regarding off-farm impacts of saline waters on the riparian and aquatic environments. Thus, the paper implies, but does not elaborate, that an understanding of the influences of farm activities on the streamlines is best investigated through surface water pathways not groundwater movement at a regional scale.

Evaluation of deep, open drains in the North Stirling area. (1997)

Authors: Ferdowsian, R, Ryder, A T, and Kelly, J. (1997),

Publisher: Department of Agriculture and Food, Western Australia, Perth. Report 161.

Type: Research paper

Extracts - Insights, principles, and perspectives:

p1

In April 1995, Agriculture WA undertook a stock-quality drilling program in the North Stirling area. Three of the selected sites were on Mr. Ken Pech's farms which form the headwaters of the Six Mile Creek. Ken showed us the deep drains he had constructed more than ten years earlier. His photos showed that there was an apparent reduction in salinity in an area between 100 and 200 m away from the drains. The improvements were unusual because similarly constructed drains in other landforms have had little or no effect on the salinity status of their surrounding areas (Speed and Simons, 1992). We decided to evaluate these drains and present the results for the benefit of other landholders that may want to construct deep drains. This report is the result of that study.

p6 Discussion and recommendation

The valleys in this area have sandy lenses in their Tertiary sediments. The existence of sand has made this area one of the most suitable areas for constructing deep drains in the district. The drain has therefore reduced the extent of salt-affected land in some nearby areas, but it has not been a cost-effective exercise.

The area required to break even, with the lowest level of discount rate (6%), is four times the reclaimed land. These limited gains are unlikely to happen in other areas, particularly if the soil profiles are less permeable. Most areas that are already, or are becoming, salt- affected have tight clays that restrict the movement of groundwater. Thus, the effect of deep drains in those areas would be localised and confined to the immediate vicinity of the drains (e.g., within 10 m; Speed and Simons)

Deep drains are costly, $2500 to 8000 $/km (1997) to construct and to maintain. Therefore, a feasibility study should be done before they are constructed. In most cases, the money is better spent on other conservation work, such as shallow surface drains ($500 to $1000/km). These are more cost-effective than deep drains. In addition, shallow surface drains should always be tried first, before embarking on ambitious deep drains. Fencing off the potentially saline areas and planting salt tolerant species such as *Melaleuca thyoides* which has an impressive, large canopy (5 m in diameter) and seems to be more salt tolerant than *Acacia saligna* and saltbush, is also recommended.

The environmental consequences of the deep drains must also be considered before any deep drain is constructed. Some of these consequences include:

- disposal of saline water into properties and creek lines further downstream. This saline water may kill the riparian vegetation and increase soil and creek salinity. A good example of these off-site effects is a deep drain at the Esperance Downs Research Station (EDRS). In 1981, a deep drain was constructed at the EDRS that went through a remnant vegetation before discharging into the Dalyup River. By 1988, a 10ha patch of remnant vegetation at the end of the drain had been affected by salinity (Rod Short, Max Crowhurst and Grant Lubcke, Agriculture WA; personal communication). Salinity of this 10 ha was mostly the result of the saline water from deep drains in EDRS.
- gully erosion due to storm water dropping into the drain channel;
- siltation and movement of sediments due to the collapse of banks and gully erosion;

- siltation of inlets and also pools along the rivers; As an example, many pools along the Pallinup River have been filled by sediments.
- eutrophication of closed pools and inlets due to nutrient in the runoff; and
- saline water collected by deep drains, may recharge the aquifer further downstream.

These problems may be seen in almost all deep drains that have been constructed in the district. Almost all of the deep drains that we have observed were designed poorly and constructed poorly. Proper design of deep drains needs technical knowledge. Issues such as: side slope, longitudinal slope, erodibility of the material, erosive velocity, free board, drop structures, culverts, headwater protection, excluding storm water and disposal of saline water should be addressed.

Relevance to the Warperup Creek catchment:

Engineering solutions to water problems are popular and periodically, at least in the past, some innovative version has been found to help in some local areas and is touted to do the same elsewhere. Later the limitations become apparent and the initial cost and supposed benefits questioned. Logically, the construction and value of engineering solutions should be preceded by a detailed review of experiences in similar environments elsewhere, and be followed by experimentation in various local situations, which of course takes time.

Wetlands on tertiary sandplains need to be managed to reduce secondary salinity (1996)

Authors: R. Ferdowsian, D.J. McFarlane, and A.T. Ryder. Agriculture Western Australia.

Publication: 4th National Conference and Workshop on the Productive Use and Rehabilitation of Saline Lands. Albany 25-30 March 1996.

Type: Research paper

Extracts - Insights, principles, and perspectives:

Introduction

The 700,000 ha of Tertiary sandplains on the western South Coast of Western Australia are located in three distinct zones (Figure l):

- Between the coast and the Stirling Range. This belt starts from north of Albany (800 mm annual rainfall) and extends eastwards from Chester Pass Road through Wellstead (550 mm) to Bremer Bay (500 mm)"
- The North Stirling Basin (370 to 450 mm).
- The Mill's Lake area, about 10 km northeast of Ongerup (350 mm).

These closed depressions may be classed into three categories based on size, depth and water quality:

- Broad and shallow, seasonal freshwater depressions or deep sumps that are perched high in the landscape,
- Brackish sumps that are close to regional groundwater levels and are becoming saline, and
- Saline lakes and sumps that are in the lowest part of the area.

This study was carried out to improve our understanding of the hydrology of the sandplain and to recommend solutions to the waterlogging, inundation and salinity problems.

p212

General management options that limit the extent of salinity

There are management options for all agricultural areas on the sandplain that reduce recharge. These options include:

1. Strip revegetation of the long slopes and plains. Although these areas have low annual rainfalls (470 mm/year rainfall), some farmers have successfully grown strips of blue gums which intercept fresh waters. After six years these trees are doing as well as blue gum plantations in the > 600 mm rainfall zones. lronbark is another possibility.
2. Timber belt on alluvial fans.
3. Strip planting of the foot slopes.
4. Phase cropping of selected areas by introducing a few years of lucerne into the crop rotation Introduction of perennial pastures.
5. Any management that increases crop and pasture growth such as the high yield crop package.
6. Use of the stock-quality groundwater.
7. Interceptor drains wherever possible to remove excess water during very wet periods. It is better to continue the drains to a regional drainage line if possible. In the absence of these natural drainage lines, salt lakes, brackish lakes and deep freshwater lakes could be used to discharge the runoff. If these lakes are not existing, it is better to store water in constructed dams rather than dumping them in leaky depressions.
8. Well-designed surface drains may be an effective option for valley floor and flat areas;

9. A few deep drains in this region have reduced or held salinity while salinity has encroached along nearby drainage lines. These deep drains had worked because the permeable Tertiary and Quaternary sediments in the depressions help the movement of groundwater to sections of the drain. While deep drains may be effective in a few cases, they are usually not cost-effective. Before deep drainage is considered, the environmental effect, maintenance problems as well as cost-benefit of that should be carefully considered. There are also drainage regulations which farmers and operators need to meet.
10. Fencing off creek lines and salt-affected areas and revegetating these areas and their fringes. A Geonics Em38 should be used to mark the areas that are in immediate danger of salinity before fencing.

Any treatment to control salinity is better if it is catchment based. There are decision aids that help with planning including landform pattern and hydrological system maps which identify the potentials and limitations of different areas.

Relevance to the Warperup Creek catchment

The Warperup Creek catchment lies within or adjacent to the study area and the recommendations are relevant in various areas. However, it is 26 years (as of 2022) since the land management options outlined in this document were recommended**.**

Have landholders implemented any or all of the 10 options since 1996 and if so, how effective have they been from a cost and functionality perspective?

If they have not been implemented, it would be worthwhile discussing with landholders what the limitations or obstacles were.

A review of actual outcomes, drawn from the experiences of landholders would provide extremely useful insight into the nature of the hydrological processes taking place as a response to farm management.

A review would also assist with refining future NRM project goals and developing better management practices.

<u>Some specific questions of interest are:</u>

- What are the noticeable results of fencing off creek lines or planting strip revegetation?
- Have the recommendations for crops and stock been practical?
- How have surface water drains performed?
- Is ground water suitable for stock being replenished or diminishing?
- How are farm dams performing?

Report card on sustainable natural resource use in agriculture. Status and trend in the agricultural areas of the south-west of Western Australia (2013)

Authors: John Simons (DAFWA), Richard George (DAFWA) and Paul Raper (DAFWA) with support from members of the DAFWA water science group, including Don Bennett, Adele Kendle, Adam Lillicrap, Paul Raper, Arjen Ryder, Rosemary Smith, Russell Speed and Grant Stainer.

Publication: Section 2.7 Dryland salinity. Department of Agriculture and Food WA (DAFWA 2013).

Type: Department Bulletin

Extracts - Insights, principles, and perspectives:

Section 2.7 of the Report Card (122 pages) presents a broad summary of the state of dryland salinity in the SW of WA in 2013.

25 spatial 'hydrozones' are defined, and groundwater risks and trends estimated.

The report aims to identify trends and make predictions in short, medium and long term timeframes.

Relevance to the Warperup Creek catchment:

The hydrozone of most relevance to the Warperup Creek catchment is #21 Pallinup

Table 2.7.1 Resource status and trends summary for dryland salinity (cont.)

Hydrozone	Summary	Risk and groundwater trends: Very high / High / Mod / Low / Very low	Confidence: In condition	Confidence: In trend
16 Donnybrook–Leeuwin	Extent of salinity very minor and future development is unlikely because the zone is at hydrological equilibrium.	Very low (?)	Limited evidence or limited consensus	Limited evidence or limited consensus
17 Scott Coastal Plain	Extent of salinity very minor. Future development is unlikely because the zone is at hydrological equilibrium.	Very low (?)	Limited evidence or limited consensus	Limited evidence or limited consensus
18 Warren–Denmark	Extent of salinity minor with variable trends in groundwater levels. Salinity risk is moderate and extent will depend on future land use.	Mod (▪)	Adequate high-quality evidence and high level of consensus	Limited evidence or limited consensus
19 Albany Sandplain	Extent of salinity minor. Groundwater levels are currently deep with variable trends.	Low (~)	Limited evidence or limited consensus	Adequate high-quality evidence and high level of consensus
20 Stirling Range	Salinity is extensive and groundwater trends are variable and equilibrium will be reached in the short term.	Low (~)	Adequate high-quality evidence and high level of consensus	Adequate high-quality evidence and high level of consensus
21 Pallinup	Extent of salinity moderate; expansion is likely but extent restricted. Variable trends in groundwater levels.	Mod (~)	Adequate high-quality evidence and high level of consensus	Adequate high-quality evidence and high level of consensus
22 Jerramungup Plain	Extent of salinity moderate, expanding slowly and likely to continue. Mostly rising trends in groundwater levels.	Mod (↙)	Adequate high-quality evidence and high level of consensus	Adequate high-quality evidence and high level of consensus
23 Ravensthorpe	Extent of salinity minor; expansion is likely but extent restricted. Mostly rising trends in groundwater levels.	Mod (↙)	Limited evidence or limited consensus	Limited evidence or limited consensus
24 Esperance Sandplain	Extent of salinity moderate but will almost certainly continue to expand because groundwater levels are mostly rising.	High (↙)	Adequate high-quality evidence and high level of consensus	Adequate high-quality evidence and high level of consensus
25 Salmon Gums Mallee	Extent of salinity moderate; expansion is possible because groundwater levels are mostly rising.	Mod (↙)	Limited evidence or limited consensus	Limited evidence or limited consensus

Salinity risk grades

- Very low
- Low
- Moderate
- High
- Very high

Salinity risk grades matrix

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Moderate	Moderate	High	High	Very high
Likely	Low	Moderate	Moderate	High	High
Possible	Low	Low	Moderate	Moderate	High
Unlikely	Very low	Low	Low	Moderate	Moderate
Rare	Very low	Very low	Low	Low	Moderate

Recent trends

- Improving (↗)
- Deteriorating (↙)
- Stable (▪)
- Unclear (?)
- Variable (~)

Confidence

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

The prognosis for the Pallinup hydrozone is, moderate risk but deteriorating with rising trends in groundwater. The evidence is rated as 'adequate high quality' with a 'high level of consensus' amongst researchers for both condition and trend.

The predictions suggest that ongoing data systematic collection is important rather than adopting a 'suck it and see' approach.

The approach to modelling the situation and trends is at a SW agricultural regional level and for this reason local nuances at the sub-catchment level are not addressed. There is a case for empowering

farmer groups to take on systematic monitoring, with support from agencies and other researchers to verify trends.

An important component of developing a Water Condition Improvement Plan is a subplan for ongoing monitoring of ground and surface water salinity. An important benefit of implementing a well-designed long-term monitoring plan is that it builds confidence in funders that land managers know what they are doing and are worth supporting in their efforts.

The overall tenor of the report is somewhat pessimistic while supporting efforts to undertake better management and offset risks to agricultural production.

Salinity and Hydrology of Mills Lake Catchment (1997)

Authors: Ruhi Ferdowsian and Arjen Ryder

Publication: Resource Management Technical Report 166, 1997 (Agriculture Western Australia)

Type: Technical report

Extracts - Insights, principles, and perspectives:

The report gives a comprehensive overview of the topography and hydrogeology of the Mills Lake area which covers approximately 38,800 Ha.

P2

Groundwater level contours show that the study area is a closed basin and there is no water flow out of this catchment

The crests and the upper part of the very gentle to level plains have local aquifers that are separated by the granitic highs (near crests).

In areas with local aquifers, the salinity and rising groundwater is an on-site issue. Therefore, the management of land outside the influence of the local aquifer, will have little or no effect on that aquifer. Salinity in areas with a regional groundwater aquifer will be affected by on-site as well as off-site management.

Groundwater salinities in the study area vary between 3900 mS/m (39 mS/cm) and 7400 mS/m (74 mS/cm).

Groundwater from the Werrillup formation was also very saline. This indicates that the aquifer in these coarse sands has been stagnant and very little, or no groundwater movement has occurred.

P3

More than 50% of agricultural land in some of the Landform patterns (LFP's) may eventually become salt affected.

June 1996: Mills Lake surface area was 18.5ha and its maximum depth was 1.5 m. The estimated volume was 90,000 cubic meters (9,000,000 L). The salinity was 283 mS/m (2.83 mS/cm) Note: Seawater salinity is approximately 5300 mS/m (53 mS/cm)

The present water level in Mills Lake is controlled by runoff as well as the regional groundwater levels.

A perched fresh groundwater mound is discharging into the eastern side of the lake.

The western part of the lake is recharging the regional aquifer.

p7

In the absence of detailed studies, the findings in this report may be applicable to other areas which have similar rainfall and similar hydrological systems. These include the Upper Warperup Catchment and the ancient Drainage Valleys that are north of the study area.

p9

The remainder of the report provides detail of the study method used and the data which was collected.

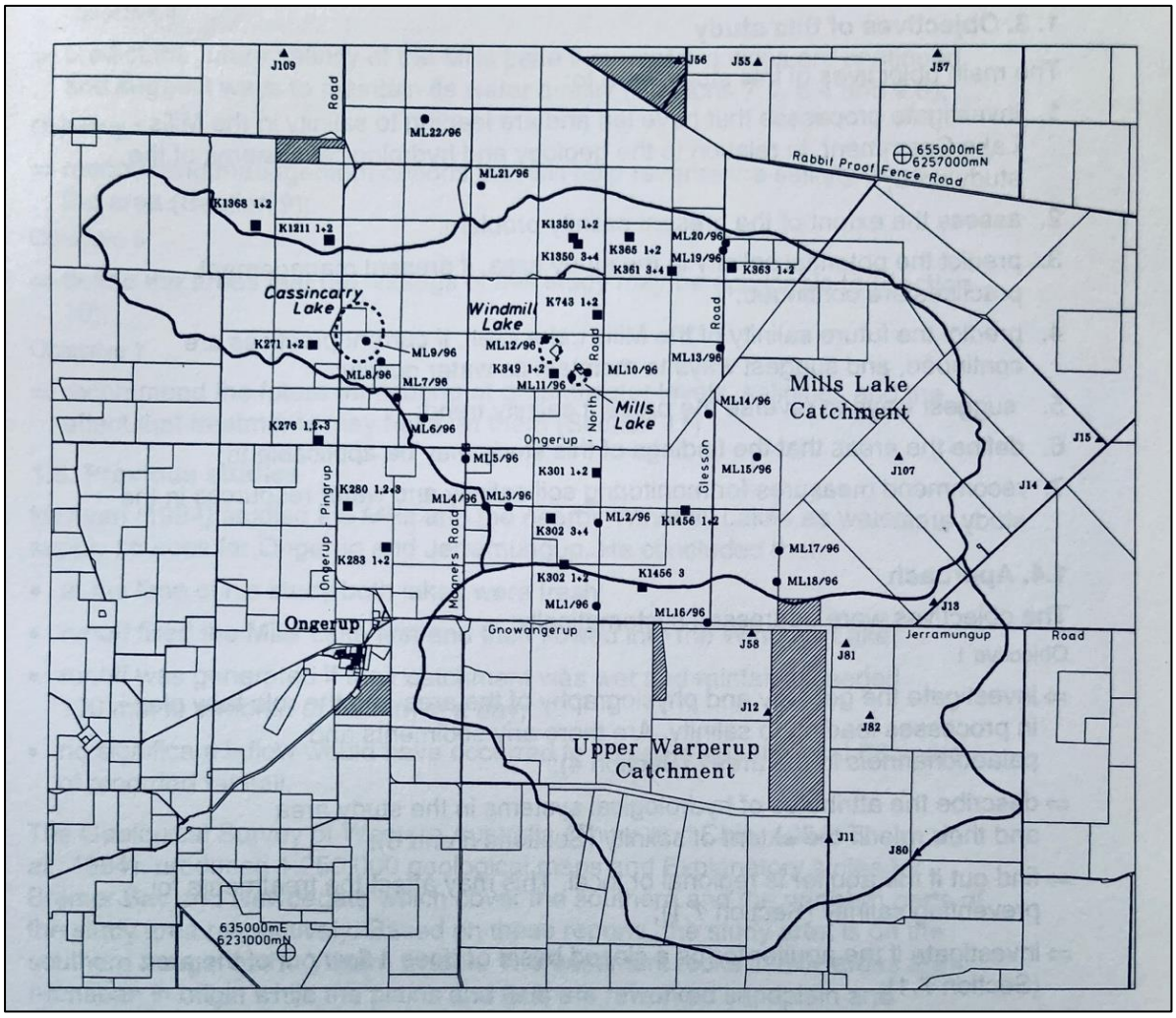


Figure 1: Study area with bore locations

p22, Figure 5

McAvan (1984) studied the Mills and nearby Windmill Lakes as water sources for Ongerup and Jerramungup. He concluded that:

- At the time of his study both lakes were fresh.
- Runoff filled the Mills Lake first then flowed into Windmill Lake;
- Runoff was generated if their catchment was wet, and rainfall exceeded 100 mm in a month or 50 mm in a day.
- No significant inflow would have occurred in 53 years out of a total of 68 years of recorded rainfall.

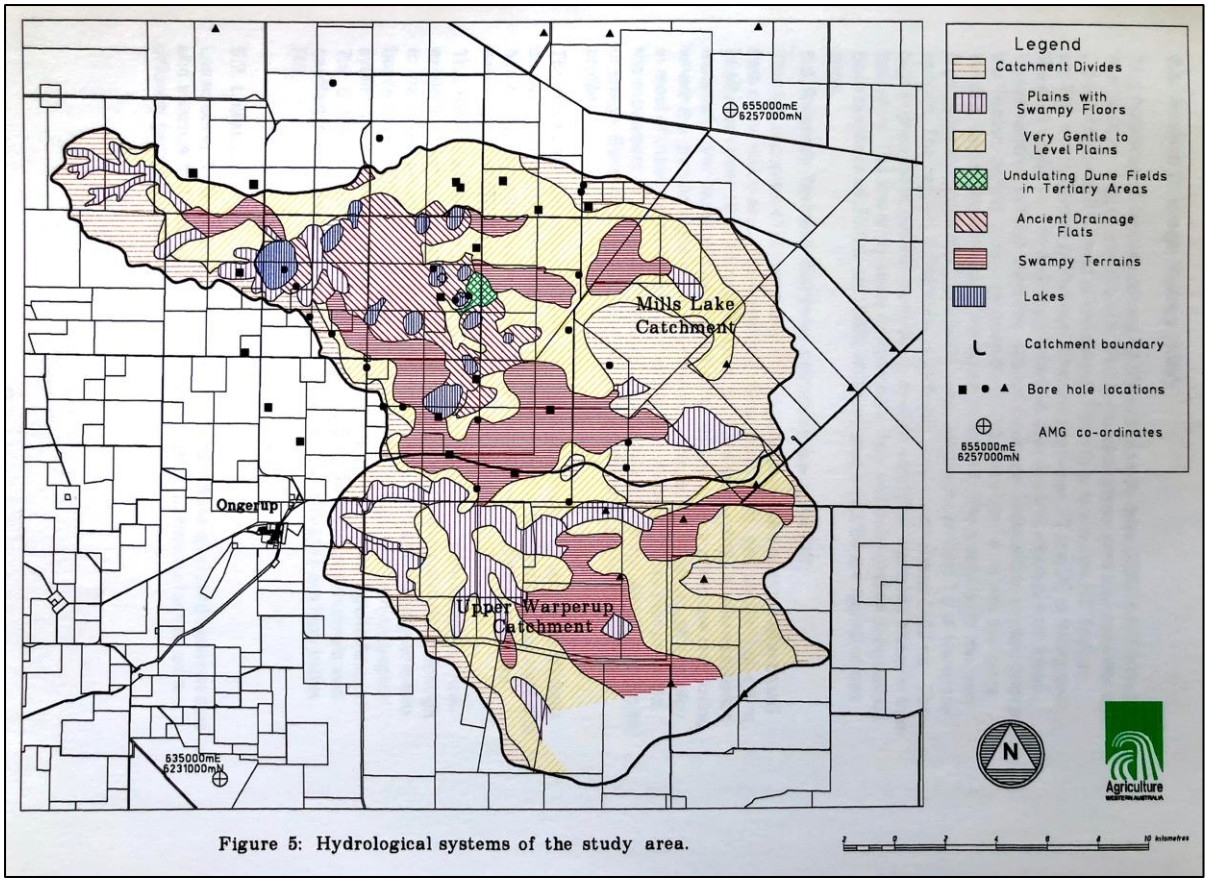


Figure 5: Hydrological systems of the study area.

Relevance to the Warperup Creek catchment

As of 2022 it is 25 years since the salinity study was undertaken. Management options (p6 – 7) were tabled in the study and this suggests that there would be value in assessing what management has taken place during the ensuing years and re-evaluating the state of the catchment and its salinity status.

The report tables sufficient data for a quantitative scientific study to be conducted to compare 'then and now'.

In addition, this would also provide information about the pros and cons of uptake of recommendations made by experts.

A discussion with former farmer Steve Newbey, highlighted the issue of changing land tenure and the transmission of information and management recommendations to new landholders who may not be familiar with the area.

State of the Pallinup River: changes in water quality and biodiversity values 2007 – 2017. (2018)

Authors: Ben Ford and Barbara Cook (2018)

Publication: Report No CENRM147. Centre of Excellence in Natural Resource Management, University of Western Australia.

Type: Report to NSPNR

Extracts - Insights, principles, and perspectives:

The report focusses on the evaluation of condition of the Pallinup River and used existing and new data to assess whether there has been a trend of improved water quality and biodiversity values associated with on-ground works in the river.

Although our results do not support the notion that NRM activities such as revegetation and fencing have resulted in significant improvement of the conditions of the Pallinup River within the last 20 years, they do suggest that the river system has not deteriorated during this period.

Relevance to the Warperup Creek catchment

The CENRM document is a technical report relying on relatively scanty data to determine whether there have been significant changes in the environmental condition of the Pallinup River. The paucity of water condition data led to inconclusive results regarding trends.

The discussion on p17 notes that, '*Future restoration efforts in the Pallinup River catchment would benefit from the adoption of a more systematic approach to restoring river function, such as that proposed by Woolsey et al (2007). These authors identified key elements needed to ensure successful restoration, including the need to establish baseline conditions*.'

This recommendation ratifies the initial establishment of ten monitoring sites in the Warperup catchment to represent water and floodway condition and to focus the gathering of baseline data to track changes into the future.

Tables 6 (p11-12) and 10 (p16) summarises aquatic macroinvertebrate species gathered intermittently in 1997, 2007 and 2017.

Water quality data for 2017 is tabled in Appendix 1 (p21)

The report does not deal specifically with the Warperup catchment for which data is sparse.

One site (PAL04- 118.4725 E -33.9519 S) on the Warperup main channel near Ongerup was sampled once in 2007

Upper Pallinup area: Catchment appraisal. (2007)

Author: S Sounness and B Whitfield

Publication: Dept of Agriculture and Food report No 277 (2007)

Type: Report

Extracts - Insights, principles, and perspectives:

The publication provides an agricultural perspective of 3194 sq km of the upper Pallinup River catchment. This includes overviews of the geology, climate, soils, and native vegetation. Land and water management are discussed.

Of particular relevance to the Warperup sub-catchment is a discussion of water and soil salinity and the implications for management. Pertinent comments are as follows:

4.2.1.1 Technical feasibility of salinity management in dissected landscape

Since the groundwater gradient is high, there is some drainage towards discharge areas. Under these conditions there is a good chance of recovering some saline land and excellent technical feasibility of preventing further spread. Deep-rooted perennials such as lucerne, that mimic the temporal and spatial distribution of leaf area that existed prior to clearing can effectively reduce land and water salinity. In dissected undulating landscapes with a local groundwater flow system, two years of cropping is possible for every year of lucerne.

4.2.1.2 Technical feasibility of salinity management in moderately dissected undulating areas

In moderately dissected areas, it is possible to contain salt-affected areas or even recover some areas. The best management option for recovery or containment is to grow deep- rooted perennials such as lucerne, and although research has shown that lucerne is not as effective as in the dissected landscapes, it will still reverse (in hilly areas) or halt (in lower slopes) the rising trend of groundwater. To contain salinity, one year of lucerne may be required to negate the effects of 1 to 1.5 years of cropping.

4.2.1.3 Technical feasibility of salinity management in very gently undulating areas with stagnant flats and swampy floors

Leakage of excess rainfall followed by evaporation from the soil surface causes saline water table to fluctuate and occasionally inundate the root zone of plants. Under these conditions there is a low technical feasibility of recovering saline land by growing perennials in stagnant flats. However, there is a moderate chance of containing salinity by reducing recharge with perennials, and an excellent opportunity to adapt to salinity using salt land agronomy techniques in conjunction with enhanced surface drainage.

Research results indicate that lucerne causes a limited groundwater level reduction in the broad stagnant flats and ancient drainage areas (Ferdowsian et al. 2002). The low rate of groundwater level reduction in these hydrological landscapes may be due to two factors:

- Limited lateral movement of groundwater
- Inability of lucerne to use saline groundwater.

In these landscapes, up to two years of lucerne may be required to negate the effects of one year of cropping. It is important to note that lucerne is likely to be more effective in reducing groundwater levels prior to levels reaching the soil surface.

Relevance to the Warperup Creek catchment

It is fifteen years since the appraisal and there is opportunity to review how management of salinity in the different landscape zones has progressed.

What approaches have landholders adopted and what has been learnt?

Reviews of surface water management and native vegetation management can also be made although these are discussed more generally in the report and more particularly discussed in the feasibility study.

State of the Pallinup River and the Beaufort Inlet (2003)

Author: Water and Rivers Commission

Publication: Water Resource Management Series Report No WRM 37 March 2003

Type: Agency state of the environment report to NSPNR

Relevance to the Warperup Creek catchment

This publication was a first pass at producing an environmental overview of the Pallinup River, describing its regional context and the general characteristics of the river system. The report outlines the broad environmental issues but is not suitable for detailed planning of waterway restoration projects.

Tambellup-Borden land resources survey (2009)

Authors: Angela Stuart-Street, Rohan Marold

Publication: Department of Agriculture and Food, Western Australia, Perth. Report 21 (2009).

Type: Detailed technical report

Extracts - Insights, principles, and perspectives:

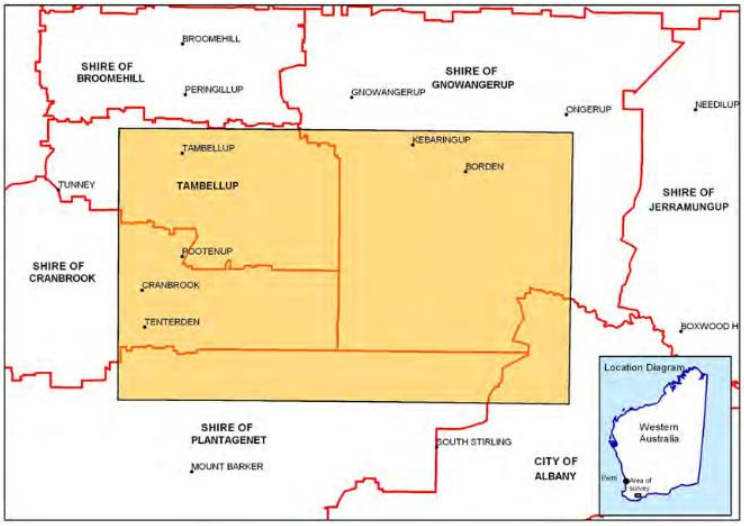


Figure 1 **Location of the survey in relation to the region and to the rest of Western Australia**

A general Geological and physiological overview is given for the landscape, followed by quite detailed descriptions of zones and sub-systems within the survey area.

p21 Previous surveys are identified

- CSIRO Division of soils large scale survey in the 1940's. Surveys conducted were
- Reconnaissance soil surveys in the South and South-east Stirling Areas (Smith 1950)
- Preliminary Report on the Soils of the North Stirlings Area (Hare, cited in Poutsma 1953)
- Soil Reconnaissance in the North Stirling Range Area (Burvill 1949)
- The North Stirling Soil and Salinity Survey (Poutsma 1953)

The most widely used soil information for the area to date has been Sheet 5 of the Atlas of Australian Soils (Northcote et al. 1967) and the associated Factual Key (Northcote 1979). It is published at a scale of 1:2,000,000 and provides a broad indication of the major soil and landform associations.

Relevance to the Warperup Creek catchment

The survey area includes the lower half of the Warperup Creek catchment, Kebaringup and Borden, but not the Ongerup area.

The synopses provide summaries of what is known about the soils in various zones and subsystems in the area. This information provides landowners with a guide to better understanding their soil structure, but advice for managing the soils is general and probably already largely appreciated by landholders.

The North Stirlings System is described generally in 2 pages (pp56-57) but largely concerns the area immediately adjacent to the Stirling Ranges.

Soil mapping at the property scale is not addressed.

Mapping acid groundwater in Western Australia's wheatbelt. (2011)

Author: Holmes, Adam Lillicrap

Publication: Department of Primary Industries and Regional Development. Report 373 (2011)

Type: Report

Extracts - Insights, principles, and perspectives:

This study was supported by the 'Management of nutrient release and acid sulfate soils' project which was funded by the Australian Government through the Natural Heritage Trust II (NHT 2) regional competitive component, and the Centre of Excellence in Ecohydrology at the University of Western Australia

The mapping method combined conventional statistical and geostatistical methods within a geographic information system (GIS) to make a gridded map which includes information about the accuracy of prediction in each grid cell. The final map was constructed by identifying statistically significant relationships between groundwater pH measurements and environmental datasets (e.g., landform information, soil type, vegetation cover), and subsequently using these supporting environmental datasets to predict the likelihood of acidity occurring areas with no bores. The environmental datasets selected are consistent with recent research into wheatbelt acid groundwater formation (Lillicrap and George 2010).

This report describes development of a map of the likelihood of acid groundwater occurrence to support strategic decision making by state agencies, natural resource management groups, landholders, and community stakeholders. The intended impact use of the map is to minimise potential environmental harm related to acid groundwater management.

Relevance to the Warperup Creek catchment:

The study noted that the origin of acid groundwaters in the wheatbelt is not well understood and several different causes have been suggested and involve both soil and natural vegetation processes.

'It is now generally accepted that oxidation of sulfides is not the cause'. This means that the inland wheatbelt acidification processes are not the same as those associated with coastal acid sulphate soils (ASS)

An important point made is: "*the distribution of acid groundwater is controlled locally by vegetation type and regionally by controls on vegetation such as climate, geology and soil characteristics"*.

Clearing of native vegetation has caused the regional water table to rise in recent decades, increasing the hazard of encountering acid groundwater. Agricultural drains amplify the area impacted by acid groundwater by bringing it to the surface and directing it into natural waterways (Degens et al 2008b).

Three groundwater hazard levels or classes were mapped: High, Moderate and Low.

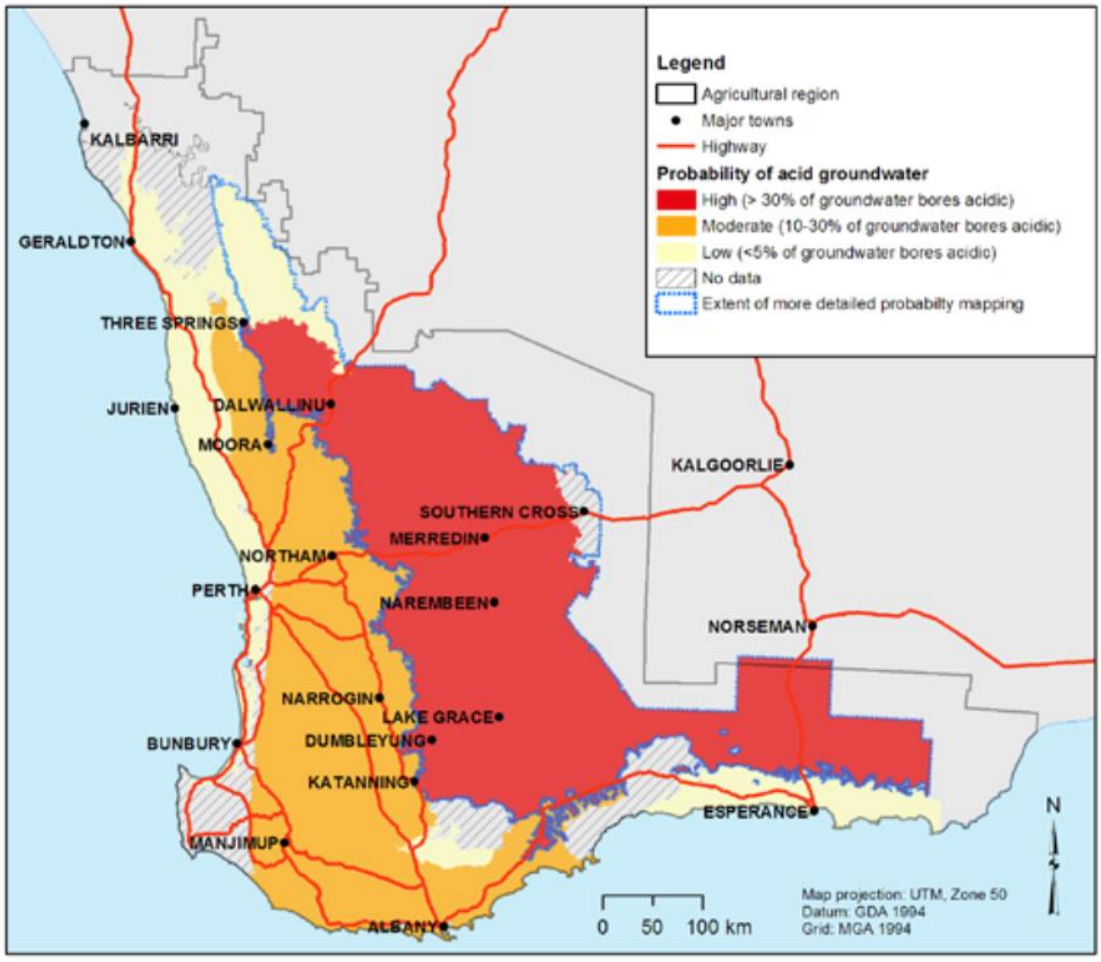


Figure 1 **Broad trends in ground groundwater acidity, determined using groundwater bore pH data summarized by soil landscape zone (Lillicrap and George 2010).**

The map indicates that data on acid groundwater in the Warperup Creek catchment is sparse or non-existent

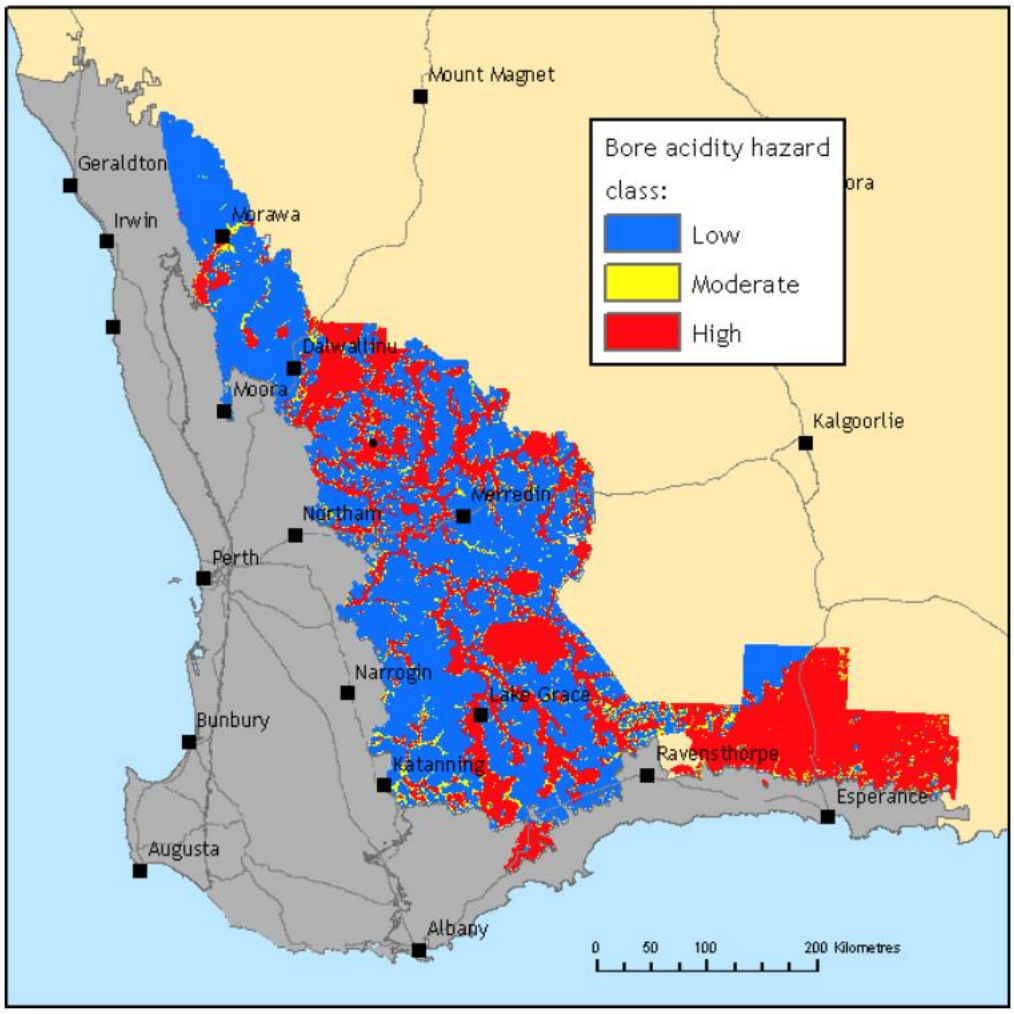


Figure 9 **Map simplified to three classes of hazard of finding acid groundwater**

Figure 9 in the study suggests there is a good case for extending acid groundwater investigations southward into the Warperup Creek catchment and adds to the case for rehabilitating existing ground water bores for this purpose as well as for tracking groundwater levels and salinity.

The distribution and origins of acid groundwaters in the South West Agricultural Area. (2010)

Author: Adam Lillicrap and Richard George

Publication: Resource Management Technical Report 362. May 2010. ISSN 1039-7205

Type: Agency report

Extracts - Insights, principles, and perspectives:

This study was supported by the 'Management of nutrient release and acid sulfate soils' project which was funded by the Australian Government through the Natural Heritage Trust II (NHT2) regional competitive component. This study was also conducted in cooperation with the Acid Groundwater projects, managed by the CRC Landscapes Environment and Mineral Exploration, which was co-funded by the National Action Plan for Salinity and Water Quality and operated by the Department of Water (WA) as part of the Engineering Evaluation Initiative.

Deep rooted plants, a common tool recommended for salinity management, have not been as successful as forecast in the drier areas. Therefore, land managers have looked to engineering solutions.

Groundwaters in the region are highly saline and commonly acidic, and therefore disposal of drainage waters can pose an environmental risk to receiving waterbodies.

Acidification can impact on aquatic systems in a number of ways. These can be grouped into three broad categories:

(i) the direct effects of acidity;
(ii) (ii) metal toxicity; and
(iii) (iii) sedimentation.

Acidification impacts on fringing vegetation. Acidification also impacts on infrastructure as it corrodes concrete and some metals such as aluminium and iron.

With the increased use of engineering options such as drainage or groundwater pumping to manage saline water tables, it is important to understand origins and extent of acid groundwaters so that adverse effects can be managed. This report details a methodology to map the extent of acidity and poses causal mechanisms to explain its distribution.

There was a regional trend in the occurrence of acidity, with acid groundwater least common in the steeper, higher rainfall areas of the Zone of Rejuvenated Drainage and more common in the drier, inland palaeo-drainages of the Zone of Ancient Drainage.

Within individual zones, the distribution was heterogeneous.

Vegetation was the strongest predictor of acidic groundwater occurrence, followed by geology.

Acidic groundwater had the highest occurrence under Eucalyptus woodlands and shrublands. Two of the most common species associated with acidic groundwaters were salmon gum (Eucalyptus salmonophloia) and sand mallee (Eucalyptus eremophila).

The probability map suggested that acid groundwaters are far more widespread than previously thought, though mainly confined to valley floors of palaeo-drainages.

The most extensive area of acid groundwater occurred in the south-east of the agricultural area.

A number of conceptual models have been proposed for the origins of acid groundwater. They involve processes in the saturated zone, where iron is mobilised and subsequently oxidises to generate acid. Based on the results of this study, an alternate conceptual model has been proposed whereby acid groundwaters are mainly the result of processes in the unsaturated zone. Evidence presented here suggests the distribution of acid groundwater is locally controlled by vegetation type (mainly Eucalyptus) and regionally by controls on vegetation such as climate, geology and regolith.

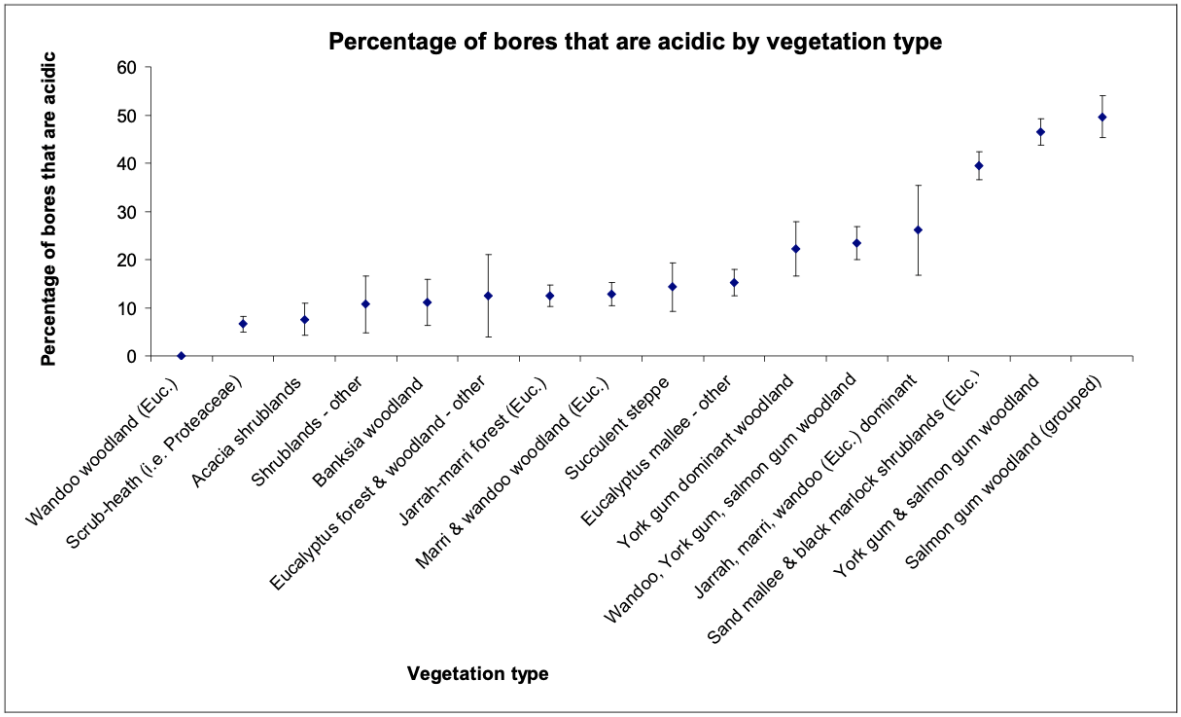


Figure 12 **The percentage of acid bores in different vegetation types**

Relevance to the Warperup Creek catchment:

The issue of soil acidification in the NSPNR Community Survey Report 2020 rated as moderately concerning across the wider NSPNR operational area. Farming practices are thought to account for the acidification.

During the NSPNR October 2020 and 2021 water quality monitoring, the pH readings at the Upper Warperup Creek sites were found to be slightly acidic compared with alkaline values at the other sites. pH may be a useful indicator of groundwater pressures from farming practices in the upper catchment and how this impacts on surface water condition and riparian health further down the creek system.

Landscape evolution in the south Yilgarn Craton and Albany-Fraser Orogen, Western Australia. (2018)

Author: Pernreiter, S., González-Álvarez, I., Klump, J., Smith, G., Ibrahimi, T., 2018.

Publication: Western Australia. CSIRO Internship Thesis, Mineral Resources, Discovery Internship Program, Australia, EP183453, 67pp.

Type: Research report

Extracts - Insights, principles, and perspectives:

P5 Valleys are one of the most important features to classify a landscape. Geology is important because faults might change river system directions (Magee, 2009). Associated with the variability of sediment and flow is the permanent adjustment of a river (Fryirs and Brierley, 2013). To read the landscape and interpret river diversity, four steps are suggested by Fryirs and Brierley (2013): step one includes the identification of individual landforms and process-form associations; step two examines the **river diversity**; step three clarifies the **controlling factors on river diversity**; and step four illustrates the effects on river diversity by catchment-scale relationships. Clarke (2009) introduced a terminology of palaeo-drainage (Table 2), used in this thesis.

P15

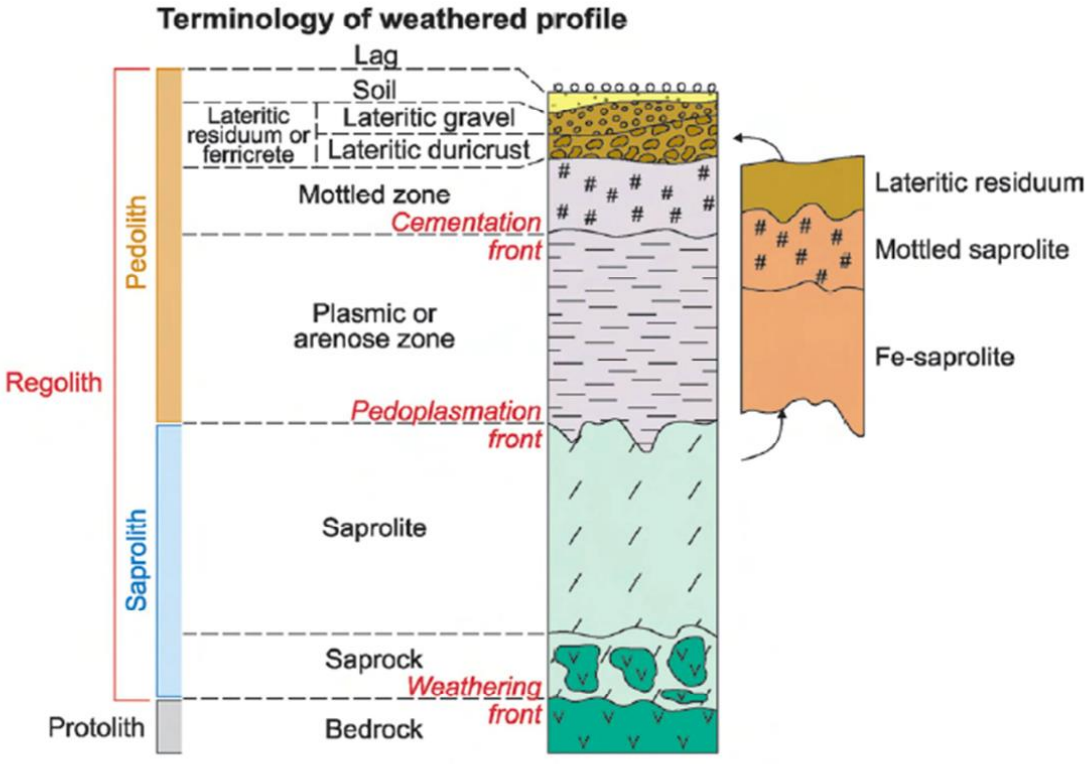


Figure 11. Terminology of a deeply weathered profile (Anand and Butt, 2010).

Relevance to the Warperup Creek catchment:

The publication presents a highly detailed, technical investigation of the superficial and underlying geological nature of the southern WA landscape, extending roughly from Denmark eastward to Cape Arid and northward as far as Coolgardie.

The publication would suit an enthusiastic reader with an interest in and basic knowledge of geology. Nevertheless, the descriptions of various landforms and landscape features provide valuable understanding of how the land was formed. This information in turn provides insight into matters which are important for farming activities, matters such as groundwater processes. For example, the diagram on p15 identifies various soil profile features that are relevant to the Warperup system.

The Warperup catchment is represented in the SW corner of the study area and is described as Landscape type 3 (p32).

The description best suiting the Warperup River can be found on p48 as follows: "*rivers in partly confined valley settings such as bedrock-controlled discontinuous floodplains*". The 10 monitoring sites in the Warperup catchment match this basic description well (Type 3 below).

Table 11. GIS-analyses, conceptual comparison of landscape types with: palaeodrainage, flatness map, hill shade and drainage, DEM, geology, regolith and vegetation cover.

	Type 1 Indian Red	Type 2 Gold	Type 3 Magenta	Type 4 Cobalt Blue	Type 5 Deep Sky Blue
Palaeodrainage	*Pronounced drainage valleys; Plain wide bottom areas*	*No drainage pattern; Sparely plain areas*	*Pronounced drainage valleys; Plain narrow bottom areas*	*Plain* *Flat*	*In the background: drainage system*
Hill shade and Drainage	*Waterlines/ -bodies*	*Elevation Outcropping*	*Rivers, valleys*	*No rivers and flat*	*Waterbodies*
DEM	*±250–550 m ±0-125 m (coast)*	*±0–1000 m*	*±125–375 m*	*±125 m*	*±125–200 m*
Geology	*YC (FR)*	*AR*	*YC*	*(FR) Oligocene deposits*	*FR*
Regolith	*Lacustrine Coastal Sandplain*	*Exposed Colluvium Sandplain*	*Colluvium Alluvium Sandplain*	*Sandplain Colluvium*	*Sandplain*

Using modern remote sensing data enabled researchers to define large-scale patterns but defining landscape features at a more local level proved problematic: '*Large-scale pattern changes were possible to map, whereas picking of landscape type boundaries and defining features per landscape type have been very challenging*.' It can be concluded that the structure of ground water features in the catchment remains unclear. This implies there is value in ongoing bore monitoring, however, interpretation of any data gathered requires specific hydro-geological expertise.

Climate Change: Whole of Landscape Analysis of the Impacts and Options for the South Coast region. (2009)

Author: Coffey Environments, in association with Marsden Jacobs Associates, MP Rogers and Associates and Gaia Resources,

Publication: Report prepared for SCNRM – 10 November 2009

Type: Report

Extracts - Insights, principles, and perspectives:

The executive summary notes the following points:

There has been a significant decrease in rainfall in the Southwest of Western Australia since the 1970s, with projections for a further drying of the climate. Annual average temperatures are also predicted to increase by approximately one degree Celsius (C) over southern Western Australia by 2030.

However, the scale and nature of the changes to the climate within the South Coast region is likely to vary significantly within the region. Modelling of climate change within the South Coast region undertaken by DAFWA is predicting significant differences in the extent of the reduction and changes in the timing of rainfall from west to east and north to south.

The scenarios confirm a drying climate with reducing rainfall and rising temperatures although these underlying changes are small relative to the inherent seasonal variability.

Current trends are clearly consistent with the scenarios (across thirty or more years) in the western part of the region but less clear in the eastern part of the South Coast region.

The projections for climate change in the South Coast region beyond 2030 are still not clear.

The impacts of climate change within the South Coast region are likely to be significant, particularly on water resources and biodiversity.

Climate change is likely to exacerbate stress on ecosystems with areas already under pressure from habitat loss, fragmentation, invasive species and changed fire regimes. Species are likely to experience changes to timing of their lifecycles such as flowering, fruiting, reproduction, egg laying, mating, spawning, emergence, and migration.

Water resources on the South Coast are already limited for both human and environmental use. The 10-20% decline in rainfall since 1970 has resulted in 40-50% reduction in stream flow in the south-west of Western Australia, with further reductions predicted as a result of climate change.

Groundwater and wetlands are likely to experience less recharge, water quality is likely to decline, rivers are likely to experience less flow and the salinity of estuaries may increase.

The risk of fire is likely to increase with drier conditions and longer fire seasons.

There is likely to be increased opportunity for range expansions of invasive species such as dieback, weeds and feral animals, and new species may become invasive.

The predicted changes are also likely to have significant impacts on primary production.

Although increasing carbon dioxide levels may increase plant growth, protein levels in cereals are likely to decline, and livestock is likely to experience increased stress during hot spells. Pasture growth may have a shorter growing season with less winter and spring rain.

Site selection is likely to be increasingly important in forestry. However, there are opportunities for forestry, agroforestry, and farming practices to take advantage of possible carbon credit schemes.

Reliable data to accurately predict climate change impacts at a local level is generally not yet available.

Relevance to the Warperup Creek catchment:

The report is a comprehensive risk assessment of climate change predictions up to the year 2030, as of 2009. The feasibility study supported by this literature review, while considering the implications of a changing climate for water management in the Warperup creek catchment, does not tackle the task of determining whether and how the predictions may be coming to pass with respect to the catchment. Nevertheless, some discussion regarding the potential influences on the stream network is undertaken.

Distribution and impacts of introduced freshwater fishes in Western Australia. (2004)

Authors: David L. Morgan Howard S. Gill Mark G. Maddern Stephen J. Beatty

Publication: New Zealand journal of Marine and Freshwater Research, 2004, Vol. 38: 511–523 © The Royal Society of New Zealand 2004.

Type: Research paper

Extracts - Insights, principles, and perspectives:

This paper presents comprehensive distributional data, from over 1300 sites, on introduced freshwater fishes in Western Australia. Currently, there are 10 species of introduced freshwater fish established in the inland waters of Western Australia.

Relevance to the Warperup Creek catchment:

The paper reveals the paucity of information on the distribution of native and non-native fish species in the South Coast region. A water condition study conducted by the Centre of Excellence in NRM in 2007-09 included fish monitoring and remains the most up to date assessment for South Coast rivers. Sites on the Pallinup and Warperup were part of this program and the two Warperup sites have been included for monitoring during the three years of the current project. The results are presented in the feasibility study report.

The pest fish Gambusia (Mosquito fish) are prolific in most Pallinup waterways. Gambusia prefer shallow, warm, saline waters.

The re-establishment of deep, well shaded river pools may provide benefits for native fish populations by increasing habitat water temperature diversity. Native fish have been observed but there is little doubt the Gambusia have compromised populations of these and made little dent on mosquito populations.

Surface Water Quality in the Beaufort Inlet - Pallinup River Catchment 1998 – 1999 – draft.

Authors: Steven Janicke with assistance from Robert Donohue

Publication: Unpublished part of an NHT funded project undertaken by the then Water and Rivers Commission and titled, Water Resources Assessment and Enhancement (WRAE).

Type: Project report

Extracts - Insights, principles, and perspectives:

2. Background

Actual data about water quality from rivers and streams draining catchments of the South Coast of Western Australia is not extensive. High quality data has been collected at various stream gauging sites, generally located in the lower parts of catchments.

Nevertheless, it is generally accepted that due to widespread clearing for agricultural water quality has been severely degraded. For example, extensive areas of the catchment are affected, and many waterways are highly saline with significant algae growth suggesting higher nutrient loads.

It is assumed through anecdotal evidence and experiences in other Western Australian catchments that sediment and nutrients carried by the region's rivers have increased dramatically. However, except for areas such as the Wilson Inlet and Albany Harbours catchments, the water condition of the waterways of the south coast is not well quantified. If management initiatives are to achieve improvements in water quality, a statistical definition of current water quality is a must and ongoing, systematic water quality monitoring should be a priority.

2.3.1. Overview of Surface Water Hydrology of the Pallinup River catchment.

For most of the year, the Pallinup River drainage is a series of permanent or semi-permanent pools. The catchment area is moderately large at approximately 4800 Km2. For a relatively brief period after good rains, the river and its tributaries experience significant flows.

The average annual rainfall for the catchment varies from about 600 mm /year in the south coastal areas to less than 400 mm /year in the extreme north. The northern side of the Stirling Ranges is in a rain-shadow which 'pulls' the 400 mm isohyet further south. Most rain falls in the cool winters although this is subject to unpredictable influences such as summer storms and the occasional cyclone. Rainfall becomes less and less seasonally predictable further inland.

The range of stream flows generally reflects the unpredictable rainfall patterns that occur in the climatic zone. Rains generally fall in winter but even then, they are unreliable. The Pallinup River catchment has one interesting and virtually unique feature for Western Australia in that it is occasionally the recipient of snow-melt waters from the Stirling ranges although this contribution is very small indeed. Both saline and fresh minor streams are known to flow from the Stirling Range National Park.

An analysis of the frequency of increasing discharges indicates that the Pallinup catchment does not store a great deal of water. Stored water is released slowly from the ground into the channels and is seen as the low base flow. Water moves relatively rapidly out of the landscape compared with some rivers on the South Coast, for example the Kalgan. The geology and 'heavy' (clay) nature of the soils on the Yilgarn block are probably responsible for this effect.

For example, the Kalgan River exceeds a discharge of 0.1 cubic metres per second for approximately 90% of the year, on average, whereas the Pallinup exceeds this discharge for 40% of the year although

it has about twice the catchment area. Chelgiup Creek, near Albany exceeds this flow rate for almost the entire year on average and it is only 1/90th of the catchment area of the Pallinup.

Relevance to the Warperup Creek catchment:

Water quality was measured at selected sites within the Pallinup River catchment during the period 2 September 1998 to 13 October 1999, by Shane Delury resident at Ongerup. This included one site on the Warperup Creek. Shane was trained in the use of equipment and provided with ongoing support for the duration of the project. Thirty-four (34) measurements were made and consisted of Electrical conductivity (salinity), pH, Oxygen levels, temperature, turbidity, Total Nitrogen and Phosphorus.

The 'flashy' nature of flow in the channels, particularly the low order channels, meant that weekly sampling was most unlikely to coincide with substantial flow.

Table 3 below illustrates this. Conditions would have been similar for the Warperup Creek site.

Flow conditions	Percentage of visits
Nil	45
Trickle	36
Moderate	19
Flood	0

It can be noted that water data can be used to track changes in quality over time provided there is sufficient data to account for the natural variations which occur, both seasonally and annually. This *baseline* data should be collected systematically and reliably. Occasional, ad hoc measurements do not qualify as reliable baseline data. The obvious should also be stated namely that, historical data can only be gathered once and for this reason it provides the tenuous connection with past waterway condition which is essential to answer the question; how have things changed and perhaps, why?

Evaluating perennial pastures, A case by case study of Perennial Pasture use in the South Coast Region of Western Australia. (2007)

Authors: Nicole Witham, Kira Buttler, Arjen Ryder, Harvey Jones, Kelly Hill

Publication: A joint Project by Department of Agriculture and Food (DAFWA) and South Coast Natural Resource Management (South Coast NRM Inc.) 2007

Type: Report

Extracts - Insights, principles, and perspectives:

This booklet gives a snapshot of how 17 farmers along Western Australia's South Coast have created profitable farming systems using perennial pastures to better utilise their available water resources throughout the year.

In all, four project officers collected information on 17 farms that operate perennial-based farming systems. Farms were selected with 8 – 50% of perennial pastures. While 8% of a property's arable area might not sound like it is a significant proportion of the farm, it is when you consider that they might be cropping 75% then we find that the 8% is one third of the total pasture area.

The farmer's normal practice was recorded.

it was obvious that a paddock demonstration was the only way to demonstrate the benefit of perennials to the whole farm. While research would have delivered accurate results, research is not capable of accounting for the multitude of variables operating in a whole farm.

It is all very well to ask farmers to adopt systems of management that incorporate the bigger environmental issues surrounding our natural resources. Not many farmers can justify any change unless it has an economic benefit – let's face it, farming is a business!

Case Study #7

Lucerne on Low Salt Prone Areas Stops Groundwater Recharge and Provides Year-Round Green Feed

Kingsley and Sandy Vaux - Wigboro, Ongerup

The Vaux family settled in Ongerup in 1913. Sandy and Kingsley Vaux are the fourth generation to farm the land located just to the north of the town and they are only too aware of the affect that clearing has had in the area.

Over the years they have seen many farmers around Ongerup leave, but the couple continues to invest in the future through the establishment of a whole farm system that has for more than 10 years addressed a rising water table and salinity issues. Their long-term commitment is evident through the planting of 70 acres to sandalwood – a crop that can't be harvested for around 25 years.

Piezometers dotted throughout the property show that they are winning the salinity battle; with the water table having dropped between 1 and 2 metres since 1997.

The property now has massive salt lakes; which were once intermittently filled with perched shallow fresh water. These have been fenced off but only a few decades ago some had fences running through the middle of them because when they were still fresh water, and on the years they dried out, they were occasionally cropped.

Thriving tree lines surround the paddocks which are now, depending on soil types and also their proximity to salt: put to lucerne; tagasaste; or still cropped. Salt bush is now established in many of the dry creek beds.

"The salt was at its worst in the early 80's when we were still practicing traditional farming methods. Then we got into legumes, trees, tagasaste, salt tolerant grasses and direct seeding," said Kingsley.

The lucerne is planted mostly in the lower areas of their landscape and adjacent to saltier areas. It has enabled year-round green feed and is especially beneficial in summer and autumn.

The best aspect of lucerne from an economic perspective was that it provides opportunistic feed in an area that receives around 30% of its rainfall outside of the growing season. Their average rainfall is 375mm. The sheep, 60% of which are merino, can be sold out of season as prime lambs which can bring a premium of between $10 and $15 a head.

Currently 18% of the arable landscape is sown to perennials, and the Vaux's would like to increase that to around 35%. Lucerne comprises most of the perennials planted.

The deep-rooted perennial has been popular in the region and controlled grazing has been an important management tool in order to avoid overgrazing.

The Vaux family have already dramatically changed their situation through the use of lucerne and trees on their property. Salinity has changed their landscape, but through the use of piezometers and the keeping of rainfall data, they can monitor their situation and now have a clear plan in place for the future.

The trial found that the soils in the paddock chosen had good nutrient levels and salinity was the constraint in most areas showing poor productivity. Through the continued increase of lucerne plantings higher in the landscape the family will be able to make further inroads into containment and reclamation of salt affected land and further increase their productivity and profitability.

Case Study #8

Lucerne Reduces Waterlogging and a Rising Water Table

Michael and Marie White Stirling Plains, Tambellup

Lucerne was planted on the White's picturesque Tambellup property which overlooks the Stirling Ranges, in 1999 to try and combat increasing salinity issues caused by a rising water table.

The lucerne is planted on the mostly flatter, wetter parts of the farm and most years Michael White estimates that he gets around six weeks extra grazing for about 1 to 2 sheep per hectare during summer and autumn. He says that two weeks of spring grazing for his cross- bred lambs can also be a bonus.

He was inspired to plant the perennial after reading about what lucerne pioneer; Geoff Bee was doing at Jerramungup.

The lucerne seed is sown in springtime on the valley floors and the recharge slopes are sown in autumn and winter.

In conclusion it would be fair to say that Michael and Marie White are heading for their goal of 25-30% perennials as they can see the benefit of growing lucerne for their stock enterprise.

Trials on the property have found that planting lucerne within the lower parts of the landscape has had an impact on soil moisture and ground water levels; however, these benefits can disappear 1-2 years after returning the paddock back to an annual system.

The Whites continue to find a system of management of lucerne that will enhance their cropping operation; will continue to provide an economic benefit to their livestock; while constraining salinity issues.

Relevance to the Warperup Creek catchment:

Case studies were drawn from six sub-regions of the South Coast Region; Esperance Sandplain, Esperance Mallee, North Stirlings Pallinup, Fitzgerald Biosphere, Albany Hinterland and Kent-Frankland.

Four of the case studies were in the Pallinup North Stirlings and the focus was:

- Lucerne Provides Flexibility on Shallow Duplex Soils in a Highly Variable Rainfall Zone
- Lucerne on Low Salt Prone Areas Stops Groundwater Recharge and Provides Year-Round Green Feed
- Lucerne Reduces Waterlogging and a Rising Water Table
- Mixed Perennial Plantings Work on Highly Variable Soil Types

Research by McFarlane, Pannell and Ferdowsian (2001) concluded that managing salinity at the farm scale with the primary objective of reducing impacts across the wider catchments was not likely to be effective in areas where groundwater movement away from the farm areas is minor. The benefits of salt land management in these systems would be local. The case studies provide practical information appropriate to the catchment areas of the Warperup given landscape commonalities with the case study sites.

A positive message is that some success was had in reducing the impacts of salinity in what is a highly susceptible area and that measures to deal with salinity can have benefits for the farm and the environment of the waterways.

Australian Farmland Values (2021)

Authors: Rural Bank, a division of Bendigo and Adelaide Bank Limited 2021

Type: Synopsis report

Extracts - Insights, principles, and perspectives:

The Australian Farmland Values report is based on actual farm sales using data collected by the official government agency in each state and territory, which is then compiled by PriceFinder.

The report is not intended for use as a farm valuation tool.

The median price per hectare for farmland in the South Coast region of Western Australia increased by 21.7 per cent in 2020 to $4,145 per hectare, with land values in most areas of this region trending higher. Low supply was a key driver of the solid growth in the median price per hectare for the region.

Albany and Plantagenet saw the largest growth at municipality level, with modest growth in Gnowangerup, Kent and Ravensthorpe also contributing to the stronger median price per hectare for the region. In contrast, Esperance and Jerramungup recorded a decline but only accounted for 18 per cent of transactions which was unable to offset the growth in other municipalities.

All municipalities had lower transaction volumes than 2019, Jerramungup recorded the largest decline in transaction volume, with ten fewer transactions year-on-year.

“Farmland in the South Coast region is tightly held as reliable rainfall makes it one of the safer places to farm within WA. Strong commodity prices and low interest rates in 2020 instilled confidence within the property market, which corresponded to strong competition for land when it came available. Prices have continued to trend higher in the region as when a seller markets their property, it is often a generational sell and nearby farming families compete to secure additional hectares close to existing holdings.” - Adam Powell, Rural Bank, Albany.

Relevance to the Warperup Creek catchment

Although the value of farmland is not based on the environmental values present on farmland, environmental issues will have an influence.

Regional trends to larger and often more geographically fragmented farming enterprises implies that specific landholders will have a proportionally greater influence on the future management of the waterways and hence riparian water condition.

How the market trends will influence Natural Resource Management (NRM) is uncertain. Will productivity concerns marginalise management of the remaining natural assets of the Warperup Creek catchment or are there opportunities to enhance the efficiency of land management to incorporate natural assets and to maintain or even increase farm values.

NRM goals are decade long compared with production goals which continually draw landholder attention to seasonal outcomes.

INVESTIGATIONS, RESEARCH AND REPORTS IN OTHER RELATED AREAS AND REGIONS

Riparian condition of the Salt River - Waterway assessment in the zone of ancient drainage (2008)

Author: Kate Gole

Publication: Department of Water. Report No WRM 46. 2008

Type: Department report

Extracts - Insights, principles, and perspectives:

The key management issues dealt with in the Salt River (Avon River catchment) floodplain are:

- increasing salinity and waterlogging in the valley floor
- loss of riparian vegetation fringing the Salt River and its tributaries
- management of flood flows
- impedance of flood flows by road crossings
- increased stream flow causing erosion and sedimentation in tributaries
- pest species degrading riparian vegetation
- lack of corridors linking areas of remnant vegetation
- fire risk
- dumping of rubbish in floodplain areas.

Section 2.2.3 Post-clearing changes to vegetation communities

While the Salt River is naturally saline, widespread clearing has fragmented remnant vegetation and increased waterlogging and salinity levels across the floodplain.

The native riparian vegetation is adapted to natural waterlogging and salinity levels; however, the increased salinity and frequency of inundation has led to a decline in vegetation condition and caused deaths in some areas. The overall result is a simplification of the vegetation communities, as the Melaleuca thickets and Eucalyptus woodlands that once covered the floodplain are replaced by salt-tolerant plants such as samphire (Halosarcia).

5.3.3 Recommendations for the management of salinity and waterlogging

Salinity and waterlogging are processes that need to be managed at a catchment scale. Given this, and the fact that salinity management needs to be tailored for different salinity impacts, the following general management recommendations are proposed:

- the detention of surface water, water quality permitting, higher in the catchment to slow recharge to valley floors
- revegetation of tributaries to slow movement of surface water on to valley floors without increasing flood risk
- evaluation of commercial revegetation options, including agroforestry and salt land pasture
- identification of recharge areas, such as sand lenses, suitable for revegetation for local water table control, with either local native or commercial species
- groundwater and surface water quality and quantity to continue to be monitored as part of Department of Water's ongoing water quality monitoring programs.

Relevance to the Warperup Creek catchment:

The management issues considered in this report on the Salt River in the Avon catchment are also common to the Warperup Creek catchment. Of most concern are salinity levels and waterlogging in the valley floor. The Warperup Creek differs slightly from the situation of the Salt River which features wide paleo-channel flats eventually reaching the Yenyenning Lakes system. The Warperup is a product of active headward development of the channels from the coast and inland to the plateau region.

The course of the Salt River is punctuated by salt lakes which store a lot of flood water, whereas the main storage areas along the Warperup are the numerous but now shallow, river pools. In other words, flood waters move more rapidly downstream in the Warperup creating many sand slugs which choke the pools. Nevertheless, both systems have features in common as well as their own unique management issues. There is value in understanding what management actions have been successful in other inland systems but also requires care in transferring management methods from one catchment to another without considering the differences in landscape structure.

The appropriateness of actions listed in Section 5.3.3 need to be tested in the Warperup catchment.

Appendix 4 provides an extensive list of plant species, both native and exotic, found in the Salt River catchment.

Appendix 5 gives examples of species suitable for salt land pasture.

Appendix 6 gives examples of local native species suitable for revegetation.

*During the past thirty years of Landcare there has been a preference for using local provenance species for revegetation, however a drying climate may require the definition of 'local' to be extended. Stream stability is about the physical structure and function of vegetation not so much a botanical biodiversity issue. This point would likely lead to controversy between landholders and botanists focused on trying to preserve the historical vegetation structure.

Principles, of Riparian Lands management. Chapter 5: Managing the effects of riparian vegetation on flooding. (2007)

Authors: Ian Rutherfurd, Brett Anderson, and Anthony Ladson

Publication: Land and Water Australia 2007

Type: Technical manual

Extracts - Insights, principles, and perspectives:

Chapter summary

The major effect of removing riparian vegetation and wood from streams has been the changes in channel form (widening, deepening and straightening) that have occurred.

It is important to consider that we are returning vegetation to a channel system that now has a much larger flow capacity.

The major hydrological effect of returning vegetation to streams is via its influence on roughness and flow resistance.

Revegetating riparian zones, or adding large wood to stream channels, increases the stage of floods at a cross-section and reach scale, although in many cases the effects are likely to be small. The effect will be greatest where the vegetation is planted across the full width of a floodplain.

Adding or removing large wood (snags) in streams has little effect on the height and duration of large floods.

At catchment scale, the cumulative effect of riparian revegetation is to increase flood stage and duration in headwater streams (where flooding is usually not a problem anyway), but decrease flood stage in larger streams, further downstream, where flooding may in the past have been a problem (local-scale versus network-scale effects).

Although the effect of riparian vegetation on flooding is modest in comparison to the effects of dams and river regulation, it should be considered in planning major revegetation works. The effect is largely positive for downstream catchments, where riparian vegetation will reduce the depth of flooding. The decreased flow depth comes at the cost of slightly longer flood durations.

Riparian revegetation should be seen as a catchment scale tool that can have a beneficial effect on flooding in lowland areas. Whilst flow regulation and land-use change affect the amount of water available in floods (magnitude and frequency), riparian vegetation affects the velocity of the flood wave delivered to the stream. All of these interacting aspects need to be considered together.

Rules of thumb for the effect of vegetation on floods levels

Flood levels at a cross-section

1. If vegetation does not block more than 10% of the cross-sectional area, it will probably have little effect on stage. This is why vegetation has more effect on small streams than large ones.
2. If the stream has a width/depth ratio greater than 17, vegetation is unlikely to have any effect on flooding because the cross-section is too wide and shallow (Masterman and Thorne 1992).
3. Vegetation in the bed has more influence on flow than does vegetation on the top of the bank.
4. If the vegetation lies down during a flood, then it probably has little effect on the flood stage.

Flood levels at catchment scale

In what sort of catchment types will flood stage be most affected by riparian revegetation? The answer is where the catchment:

- is long and thin in shape,
- has a high drainage density, and
- has a short, steep headwaters section, and then a long low-gradient section.

Relevance to the Warperup Creek catchment:

This chapter of the publication deals with the realities of managing streams and the issue of flooding. It provides an excellent technical overview of the dynamics of stream flow and the results of man-made changes over the past two centuries. The principles of water flow in rivers apply to South Coast streams.

On the South Coast floods which inundate houses in towns are not out of the question but tend to be local rather than widespread in their effect compared with many east coast towns and cities. The history of large floods here primarily concerns damage to infrastructure such as bridges, farm crossings, fences, roads, paddock scouring and the resulting inconvenience. From a waterways environmental perspective large floods have moved substantial amounts of soil from riverbanks, and floodplains leaving behind large scours and in some case stripping the topsoil horizons down to the clay base. The soil which has been eroded chokes the bed and infills the river pools and fine organic rich silts find their way into the numerous estuaries and lakes along the coast. This in turn fuels algal growth leading to putrid waters and fish kills.

An important conclusion from these studies is that, a*t the catchment scale, the cumulative effect of riparian revegetation is to increase flood stage and duration in headwater streams (where flooding is usually not a problem anyway), but decrease flood stage in larger streams, further downstream, where flooding has in the past often been a major problem*.

*In other words, storm flooding is not usually a critical problem in the many small upper catchment streams but riparian vegetation in these streams plays an important role in reducing the impact (the peak flood levels) downstream as waters feed into larger and larger channels. The minor streams can act as 'chokes' which govern the accumulation of flood waters downstream. The studies also show that vegetation across the bed of the stream has a significant slowing effect compared with vegetation on the banks. Thus, although the upper Warperup streams seem minor, taken together they can exert a powerful influence for reducing flood impacts in the river.

Principles, for riparian land management Chapter 6 -The influence of riparian management on stream erosion. (2007)

Authors: Ian Rutherfurd (edited by Phil Price)

Publication: Land and Water Australia 2007

Type: Technical manual

Extracts - Insights, principles, and perspectives:

All streams erode. Streambank erosion is a dominant source of sediment in many river systems.

Rutherford identifies the following stream types (p88):

Small upland tributaries (1st to 3rd order streams)

These are the small (mainly 1st and 2nd order), cleared, rural streams that dominate the Australian rural landscape. These are the type of streams that will be most affected by riparian revegetation, and by removing grazing.

Gullies

Gullies are strictly a product of stream network extension. They may be small enough to be heavily influenced by riparian vegetation, particularly in stabilising the channel floor.

Incised streams

Unlike gullies, these "valley-floor incised streams", developed by the incision of existing stream channels. They are typically tens of metres wide, and several metres deep. These streams pass through predictable stages of evolution, as they incise, then stabilise over decades. The main influence of vegetation on these streams is to stabilise the channel floor in later stages of their evolution.

Larger meandering streams

Occupying the larger valleys, these streams have often experienced bank erosion and widening. The streams may be too big for bank vegetation to have much influence on erosion rates.

Larger, meandering lowland, silt-clay streams with anabranches

Moving downstream, meandering gravel streams give way to these larger, sinuous channels, that are dominated by silt-clay banks. Bed material tends to be fine gravel or sand. Vegetation will interact in a completely different way with the resistant, cohesive bed and banks that are very different to the gravel bed of the up-valley stream.

p95: Masterman and Thorne (1992) suggest that at width/depth ratios greater than 30:1, it is unlikely that vegetation will have any influence on channel flow capacity, and very little influence when the ratio exceeds 16:1. Certainly, where the bank height exceeds the rooting depth of vegetation, and where vegetation does not grow on the bank face, trees are unlikely to have much effect on channel geophysical processes. In Australia, the root zone seldom extends below two metres in depth. Although some roots extend deeper than this, they tend to add little extra strength to the banks.

P103: Most of the discussion so far in this document, and in most riparian research, deals with woody vegetation. This ignores the fact that the most common vegetation type in streams is almost certainly grass.

This is an important question for gully management, for example. If grass can be established in the bed of a gully, will it stabilise the stream? How will grazing alter the resistance of grass in streams?

P104: The implications of this research are that grass is tremendously effective at stabilising stream beds if it is able to grow to maturity, and particularly if it is not grazed.

P112: The messages from this work are a) that a huge amount of money and effort can be wasted if revegetation is not done in the right part of a catchment, b) the amount of revegetation work that we are presently doing in Australia is of the scale that can achieve end-of-valley targets.

A consistent conclusion of the research is that about 80% of the sediment in a catchment in the Basin is generated from just 20% of the area of that catchment, be it from gullies, stream banks or steep lands. These sediment sources are called 'hotspots' of sediment production.

Targeting hotspots that are also well connected to the stream network dramatically reduces the cost of achieving catchment sediment yield targets. Taking the Goulburn River catchment as an example, with random works in the catchment (which is the type of model that is probably practiced now) it will cost over $150 million to reduce sediment yield to half. By targeting well-connected hotspots, this can be achieved for under $20 million dollars.

P113: Conclusions

Riparian management, particularly in the form of the very popular riparian revegetation, can influence and control stream bed and bank erosion. But the effectiveness of vegetation varies greatly depending upon the particular processes driving erosion, the position within the catchment, the type and location of the vegetation, and the scale of both the erosion and the revegetation. Time is the other important variable to consider.

There is little point attempting to understand the role of vegetation in bank erosion mechanisms if we do not understand bank erosion processes and rates, so this should be the first step taken by river managers. Once the processes and rates at a site or within a reach or catchment have been identified, then the most effective management options can be determined.

Relevance to the Warperup Creek catchment

The document provides technical insight into river processes in relation to riparian vegetation and although the source of information has been eastern states waterways, there are many issues in common with rivers on the South Coast.

Observations along the Middle Pallinup River and the 10 reference sites in the Warperup catchment suggest that the stream banks are indeed the dominant source of sediment along the Warperup waterways. This in turn suggests that future management of the riparian areas will be a critical factor determining the structure of the floodway, and in consequence, water condition. This is not to suggest that other sources of sediment, for example floodplain scours, loss of paddock topsoil, drains, general earthworks etc, are not important.

The stream types described on p88 have worldwide application and the physical characteristics apply in the Warperup catchment with some provisos based on the unique geological nature of the landscape and the types of soils and vegetation.

One of the issues discussed in Chapter 6 and one which warrants ongoing research along South Coast rivers, is the habit and role of native plant root systems in stabilising stream banks. Greater insight in this area would aid in guiding riparian replanting projects by including waterway stability factors in site design and not based solely on biodiversity goals.

An example of this is gaining a better understanding of the role of common plants such as sedges, Paperbarks, Samphire, Jam trees, Sheoak etc in mitigating flood impacts.

The role of grasses in mitigating flood erosion also warrants further investigation. Exotic grasses now tend to dominate the waterways but their beneficial role in stabilising stream channels and floodways has tended to be overlooked as a potentially useful rehabilitation tool. A biodiversity focus can lead to an 'eradication at all costs' mentality which apart from being impractical is at best a rear-guard action largely involving herbicides.

The comments on p112 suggests that identifying and targeting sediment source 'hot spots' in the Warperup catchment could be a means of achieving significant sediment control at a much lower cost than simply undertaking rehabilitation randomly across the catchment. This hypothesis could be tested using catchment process modelling simulations. A targeted rehabilitation process would engage individual landholders who are willing to contribute their part to an overall Water Condition Improvement Plan.

Defining and measuring river health. (1999)

Author: James R. Karr University of Washington, Box 357980, Seattle, WA 98195±7980, U.S.A.

Publication: Freshwater Biology (1999) 41, 221-224

Type: Research Journal

Extracts - Insights, principles, and perspectives:

Society benefits immeasurably from rivers. Yet over the past century, humans have changed rivers dramatically. Do those changes mean that people have degraded river health? The answer depends on whom you ask. To irrigators, rivers are healthy if there is enough water for their fields. For a power utility, rivers are healthy if there is enough water to turn the turbines. For a drinking-water utility, rivers are healthy if there is enough pure, or purifiable water throughout the year. To sport or commercial fishers, rivers are healthy if there are finfish and shellfish to harvest. For recreationists, rivers are healthy if swimming, water skiing, or boating do not make people ill. But every one of these perceptions is only part of the picture. Each trivializes the other uses of the river not to mention non-human aspects of the river itself while assigning value only to their own desires. To protect all river uses and values, should we not seek broader definitions of river health?

Applying the concept of health to rivers is a logical outgrowth of scientific principles, legal mandates, and changing societal values. Success in protecting the condition, or health, of rivers depends on realistic models of the interactions of landscapes, rivers, and human actions.

Communicating results of biological monitoring to citizens and political leaders is critical if biological monitoring is to influence environmental policies.

Biological monitoring is essential to identify biological responses to human actions. By using the results to describe the condition, or health, of rivers and their adjacent landscapes and to diagnose causes of degradation, we can develop restoration plans, estimate the ecological risks associated with land use plans in a watershed, or select among alternative development options to minimize river degradation.

Relevance to the Warperup Creek catchment:

This research paper presents a multi-use approach to defining what is an acceptable condition for our rivers and streams. The idea of river health can be applied to the Warperup Creek catchment and would include, as a minimum:

- The resilience of the floodway to the impacts of large flood events.
- The contribution to the overall appearance of farms
- Use of the riparian areas by stock.
- Recreational use of the stream.
- Economic value.
- The degree of erosion.
- The degree of sedimentation.
- The condition of river pools.
- The type and condition of vegetation fringing the floodway and within the floodway.
- The quality of native fauna habitat.
- The impacts of feral pests.

To develop a robust plan to improve river health will also require the following considerations.

- Landholder willingness to plan and act.
- Identifying sections of waterways most prone to erosion, salinisation, etc
- Optimising potential actions like further fencing, tactical revegetation, seasonal stock access control, carbon plantings etc.
- A strategic approach to implementing works.

Framework for prioritising waterways for management in Western Australia. (2011)

Authors: Macgregor, C., Cook, B., Farrell, C. and Mazzella

Publication: UWA Albany CENRM Report 120 (2011)

Type: Research paper

Extracts - Insights, principles, and perspectives:

The Framework for prioritising waterways for management in Western Australia was developed to assist regional natural resource management groups and state government agencies to choose management priorities for waterways.

The framework provides a relatively simple, quick, and objective approach. It is also transparent, enabling stakeholders to readily engage with the approach and provide input. In situations where there are already processes in place for setting priorities, it can be used to augment what has already been done. Where these types of decision-making processes are yet to be carried out, the framework can be used as the initial approach.

Use of the framework as a community engagement tool could also increase support for management decisions.

The framework commences with an assessment of the state of the waterway of interest and the focus is:

1. Identifying the values of the waterway units, and the criteria, indicators and measures to be used to assess them.
2. Identifying the threats to the waterway units and the indicators and measures to be used to assess them.
3. Identifying the appropriate management responses.

Relevance to the Warperup Creek catchment:

The framework provides a rational and systematic recipe for evaluating priorities for waterway management in WA based on various criteria. What it does not address is the feasibility of adopting the process, namely who will do it, how will it be done, and where the funding will come from. It therefore paints a somewhat idealistic and static 'agency' world view.

Each of the environmental, economic, and social elements is a complex world of investment and the components are not independent nor are they static, but constantly shifting. The framework does affirm numerous other similar frameworks aimed at delivering better management of Australian rivers and streams.

CENRM Report identifies 10 threatening processes with respect to degradation of SW waterways. These are:

- Riparian zone degradation
- Erosion and sedimentation
- Eutrophication and deoxygenation
- Inappropriate fire regimes
- Pollution
- Introduced animal and plant species
- Salinisation and waterlogging
- Acidification
- Flow alteration
- In-stream habitat destruction and fragmentation.

These processes agree with most other assessments regarding river management in WA although the order of priorities varies depending on the focus whether productivity or environmental concerns. Some of the processes will be more important than others depending on the situation although all are common to a greater or lesser extent.

1. Identifying the values of the waterway units, and the criteria, indicators and measures to be used to assess them.

The focus identified in point 1 is the basis for undertaking a GIS study of aerial images of the catchment. Then, having determined a complete set of waterways units these can be analysed regarding their place and contribution to the drainage network and used to develop suitable indicators for auditing environmental changes as well as the progress of future project work.

The framework promotes a logical assessment to provide both an overview of the state of a river system and importantly to determine ways to track changes and the impacts of management practices. The approach is to identify a number of indicators of the environmental, social and economic state of the waterways system. These in turn will point to the type and level of management required to sustain acceptable river condition.

Landcare finds hope in an ongoing battle. (2021)

Author: Interview with Ella Maesepp (Katanning Landcare)

Publication: Southerly magazine, Issue 37, December 2021

Type: Magazine article

Extracts - Insights, principles, and perspectives:

"Early on, in the 1990s, erosion was a huge driver in getting Landcare started in Katanning. People older than me talk about the dust storms that used to come in over the town, from the farmland, that was basically blowing away. It was an issue that was facing everybody, so Landcare really started to try and tackle it".

"And then as the dust storms were eventually brought under control, it evolved into salinity as the primary focus and major risk for Landcare". "Then as time has gone on, I think biodiversity has become more prevalent in people's minds". "Even just in the last four or five years the issue of climate change has now emerged".

"Many more people are aware of its impacts and that it's not something in the future, it's actually something we are facing now".

"The environment is a very, very interconnected thing. If you're planting a tree, you are helping (deal with) salinity, you're helping climate change, you're helping erosion, you're helping biodiversity - everything with that one tree".

"We've had an evolution of the major environmental issues that concern the community and with continuing Landcare, have been able to roll with that and adapt – even though the core of what you do with the environment is the same sort of activities, the focus and how you angle it and how you respond to people's concern has been able to change.

"We've got so many amazing farmers in Katanning who really value bushland and the health of the environment".

"I really feel that it is farmers stewardship driving it – they want to be caring for their land; it's not forced. I've had people say to me, how do you get farmers to plant trees? and my response is usually, we're just trying to keep up with their demands, you're actually wanting to do more than often we can support them to do".

"I don't think the story about farmers and agricultural gets out very well. I think there is this terrible public image that maybe farmers are some sort of environmental vandals, when the vast majority, and particularly those I work with around Katanning are actually the opposite".

"Climate change is going to be a significant impact on Katanning. We are already seeing a drying trend and the rain that we are getting is coming in different ways than it used to. We are not generally getting the steady soaking winter rains of the past – this year being the exception. We are now getting a lot more episodic events out of season. This is going to have major impacts on the way we farm. It's going to have major impacts on water security. And it's going to have major impacts for animals that rely on water in the landscape, such as through our lakes and our waterways".

"Salinity is still a major issue facing our agricultural land as well as our bushland. Our native vegetation on the lower slopes and on the lower country is being impacted by salinity and we have so many dead, bare trees that have been killed through waterlogging and salinity. That's going to continue with the change in the water regime around climate change as well. A drying climate actually slows down salinity, but these big, main wet rainfall events, they are filling up the landscape rapidly and quickly in a way that our groundwater doesn't cope with. And we are

seeing a lot more hillside break outs of salinity – places where salinity traditionally hasn't been, throwing us a management curveball.

Relevance to the Warperup Creek catchment:

The statements made in this article suggest there is an increasing awareness and willingness amongst landholders to take a whole of landscape view, as far as practical regarding how farm activities can contribute positively to the wider vision for the environment. The development of 'culture of Landcare' will be the lynchpin upon which best management practices for waterways should be based on.

PRACTICAL WATERWAYS MANAGEMENT APPLICABLE TO WARPERUP CREEK

Rivers of Carbon – Stream condition checklist. (2017)

Authors: Australian River Restoration Centre

Type: Fact sheet (2017)

Extracts - Insights, principles, and perspectives:

… by looking at six features we know in affect, whether a stream is healthy (in good condition).

1. Management of riparian areas
2. Bank erosion
3. Shade and shelter
4. Water quality
5. Wildlife
6. Weeds and pests

The stream condition checklist provides colour coded pictures that you can use to quickly assess the condition of your stream or creek against each of the six features.

Relevance to the Warperup Creek catchment

The fact sheet provides a broad brush, rapid assessment of the condition of a reach of a stream, but it is not sufficient for undertaking a formal, detailed assessment of streams.

It is suitable as an educational resource and prompts observers to be more objective in their assessment of riparian condition and what may or may not be done to better manage stream reaches.

Monitoring and evaluating river restoration works. (2002)

Authors: Text by André Taylor.

Publication: Water and Rivers Commission Water Note 28 2002.

Type: Guideline bulletin

Extracts - Insights, principles, and perspectives:

Monitoring and evaluation are important elements of river restoration projects because they help us understand why some projects succeed, why some fail and what can be done to improve the chances of success in the future.

Monitoring and evaluating river restoration works provides answers to the key questions being asked about the project (e.g.; did the project raise community awareness as expected?).

Monitoring:

- provides the stakeholders who are asking these questions with an appropriate level of confidence in the evaluation results; and
- matches the project's resources in terms of available funds, time, and skills.

Relevance to the Warperup Creek catchment:

Water Note 28 emphasises the value of monitoring environmental project works and provides a systematic approach to incorporating monitoring and evaluation into the project planning phase.

However, specific water monitoring methods are not described as they are dependent on the questions being asked.

The emphasis on the importance of monitoring comes with a requirement. Locally based NRM officers do well to develop a reasonable level of technical skills with respect to environmental monitoring. If consultants must be regularly engaged to inform the local NRM bodies of what the environmental state of the catchment is and how management and rehabilitation are progressing, it suggests there is a knowledge disconnect between local environmental planners and the environment they are dealing with. This is akin to running a business and having no accounting system in place and no accountant with a clear knowledge of the cash flow.

In addition to monitoring expertise, consistent methods for auditing aspects of the catchment wide landscape are required and this means routine spreadsheet and GIS skills are essential. With these tools, on-ground data can be gathered, added to, audited, summarised in real time (rather than simply during intermittent project funding events) and the information passed on to landholders to include in their decision making.

Treating a small erosion head-cut with rock flume (2017)

Publication: Rivers of Carbon Technical Note - Australian River Restoration Centre

Type: Information brochure (2017)

Extracts - Insights, principles, and perspectives:

Using rock to reduce soil loss from erosion is an adaptation used for over a century. It is a lower-cost alternative for treating smaller head-cuts instead with earthworks and other structures such as artificial channels (flumes) made of concrete. It is suitable for head-cuts less than 1 metre deep. If the head-cut is deeper than this, then design advice should be sought.

Relevance to the Warperup Creek catchment:

Small head-cuts are common erosion features along farm drainage lines and often indicate that stream channels are deepening and widening to accommodate more frequent storm runoff from cleared land. Destabilisation of the channel bed aggravates the tendency of storm flows to create head-cuts.

The three main ways of dealing with head-cuts are:

- Direct surface flows around the head-cut on a lesser slope.
- Stabilise the head-cut by converting it into a rocky chute
- Back flooding to drown the head-cut face.

The eroded material is mobilised and adds to the excess accumulation of sediment moving down the waterways. The massive amounts of sediment in the Warperup Creek waterways is visual evidence that erosion of stream banks and beds is a major factor in the degradation of water condition.

Low-cost engineering methods for reducing erosion are sometimes necessary, but differences in individual situations means that there will be a degree of experimentation required.

Perennial forage shrubs – from principles, to practice for Australian farms. (2014)

Authors: Dr Jason Emms (SARDI) and Dr Dean Revell (CSIRO)

Publication: Future farm Industries Inc (2014).

Type: Booklet

Extracts - Insights, principles, and perspectives:

This document considers the value of diversity in the grazing system. It profiles Bluebush, small leaved bluebush, Yanga bush, Nitre goosefoot, Old-man saltbush, Rhagodia, Mallee saltbush, River Murray saltbush, Ruby saltbush, Sandhill wattle, Tar bush and thorny saltbush.

The perennial nature of forage shrubs provides an opportunity to supply green feed at any time of the year.

This makes them a real option to manage the year-to-year variability experienced across our low rainfall agricultural zone.

Forage shrubs also provide shade and shelter.

Bio-economic modelling has indicated that converting 5 – 20% of a mixed farm to shrub-based systems could increase whole-farm profit up to 20%.

Relevance to the Warperup Creek catchment:

Riparian areas are often used to shelter livestock to mitigate seasonal pressures and in adverse weather conditions. The use of perennial shrubs for shade and shelter offers means to reduce adverse impacts to riparian vegetation.

In addition, the proximity of forage shrubs to riparian areas provides extended habitat for native fauna such as birds, reptiles, and predatory insects to reduce pest species.

It is suggested that synergies between forage shrubs areas and the riparian zone provide an opportunity to value add to both.

The implications of assertions in this publication could be reviewed periodically by NSPNR in the form of case studies relevant to the Warperup catchment and the results presented to landholders.

Swamp Sheoak (Casuarina obesa) use in Farm Forestry

Author: Tim Emmott, Greening Australia (WA)

Publication: Greening Australia, Natural Heritage Trust

Type: Information Bulletin

Extracts - Insights, principles, and perspectives:

Casuarina obesa is not a new 'miracle' species for farm forestry. Rather, it has strengths in particular situations on farms in Western Australia.

In Western Australia, Swamp Sheoak naturally occurs in the 275mm to 700mm per annum rainfall zone, growing around the margins of salt lakes and along saline creeks and rivers throughout the Wheatbelt and Goldfields. Swamp Sheoak is found on sand plains, flats, gently undulating land and, occasionally, on the slopes of low hills.

Site Preferences

Usually associated with drainage lines, floodways, river systems, edges of salt lakes and seasonally inundated fresh-water depressions. It has been recorded growing in a range of soil types including saline loams, red and yellow earthy sands, calcareous and sandy earths, and grey cracking clays.

The species is adaptable to most soils from sands to clays within its natural rainfall zone. Optimal growth will occur on moist clays and loams lower in the landscape where average rainfall is 400mm and above. The species will survive and grow well in areas receiving 350mm of rainfall per annum where the trees will have access to groundwater.

Swamp Sheoak can tolerate highly saline conditions and will grow in soil with electrical conductivities (EC) of greater than 1600 mS/m (equivalent to an EM38 reading of greater than 200 mS/m), however reduced growth can be expected between 800 and 1600 mS/m. In salt concentrations of greater than 800 mS/m (EC), long term survival is reduced, and establishment and growth of seedlings is also reduced.

It is tolerant of waterlogging and will survive in sites that are permanently waterlogged, however growth and survival will be affected in areas that are frequently inundated with saline water.

Swamp Sheoak can tolerate poor drainage, saline soils, frosts, exposed sites, and to a degree, drought. However, tough sites exhibiting all of the above features will restrict growth and hence commercial opportunities.

Soil benefits

Pasture grows better under Swamp Sheoak than it does under eucalypts. This may be due to increased sunlight available through the canopy, less root competition, and nodulation with Frankia bacterium. Frankia colonises

Other uses

In WA, Swamp Sheoak timber has been used for fence posts and tool handles. The timber of Swamp Sheoak and many other Casuarinas also produce excellent fuel woods.

Sheoak timber has been used Australia wide. The main commercial Sheoak species in Western Australia is *Allocasuarina fraseriana*, commonly known as West Australian Sheoak. This species occurs in the greater than 700 mm rainfall areas of south-western WA and is harvested from native stands.

In eastern Australia, *Casuarina cunninghamiana* (commonly known as River Sheoak), is a widely used species; cultivated in Australia and overseas for timber production. *Allocasuarina fraseriana* and *Casuarina cunninghamiana* are used to manufacture furniture, decorative woodware and turnery, roofing shingles, flooring, parquetry and panelling.

Casuarina species appear to have broadly similar wood characteristics, and therefore Swamp Sheoak may have similar applications.

Relevance to the Warperup Creek catchment:

This information bulletin focuses on farm forestry as a commercial venture; however, the characteristics of the Swamp Sheoak suggest they are a suitable option for rehabilitation of the water ways of the Warperup Creek catchment. This is supported by their presence along the Pallinup River floodway and elsewhere. While waterway stabilisation is not a commercial forestry enterprise the developing Carbon Farming industry has potential to derive economic benefits for farmers interested in stream rehabilitation on their properties.

'Managing riparian widths',

Author(s): Price, P., Lovett, S. and Lovett, J.

Publication: Land and Water Australia, Canberra (2004).

Type: Fact Sheet 13,

Extracts - Insights, principles, and perspectives:

The fact sheet provides information about the different management objectives landholders and river managers might want riparian areas to achieve and discusses how riparian areas function to meet those objectives.

Relevance to the Warperup Creek catchment:

The fact sheet provides an excellent overview of the factors influencing riparian condition and practical management objectives to enhance stream condition. It provides guidelines on how to determine an appropriate riparian buffer width for different sizes of streams. These are generally applicable to well-defined South Coast streams, but less so in broad paleo-channel areas. A key principle is that riparian buffer width and is dependent on the size and formation of the active channel and its associated terraces and floodplain. This implies that streams should be assessed to determine an appropriate minimum width rather than simply applying an arbitrary width measurement. An appropriate minimum buffer width will vary along the stream reaches.

A number of these 'fact sheets' (list below) were produced by Land and Water Australia, generally with an eastern state's emphasis. Given the commonalities of stream channels in general landscape settings, many of the principles presented are relevant to the Warperup Creek catchment, however, what principles may be most applicable will need to be determined. Other fact sheets (not reviewed) are:

- 1 Managing riparian land
- 2 Streambank stability
- 3 Improving water quality
- 4 Maintaining in-stream life
- 5 Riparian habitat for wildlife
- 6 Managing stock
- 7 Managing woody debris in rivers
- 8 Inland rivers and floodplains
- 9 Planning for river restoration
- 10 River flows and blue-green algae
- 11 Managing phosphorus in catchments
- 12 Riparian ecosystem services

Note: The River Landscapes website of Land and Water Australia is no longer available, but PDFs of the fact sheets may be located by searching for them individually.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Author: Australian Government (2019)

Type: Manual

Extracts - Insights, principles, and perspectives:

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality provides a detailed and consistent framework for assessing and managing water in the Australian landscape in a scientific manner.

To protect the community values of waterways, the Water Quality Management Framework logically encompasses key requirements for long-term management strategies:

- Good understanding of links between human activity and water/sediment quality
- Clearly defined community values or uses, including the setting of unambiguous goals
- Clearly identified and appropriate water/sediment quality objectives
- Adoption of cost-effective strategies to achieve water/sediment quality objectives

The framework defines 10 steps to implement the Water Quality Management. In order, these are:

- Examine current understanding
- Define Community values and management goals
- Define relevant indicators
- Determine water/sediment quality guideline values
- Define draft water/sediment quality objectives
- Assess if draft water/sediment quality objectives are met
- Consider additional indicators or refine water/sediment quality objectives
- Consider alternative management strategies
- Assess if water/sediment quality objectives are achievable
- Implement agreed management strategy

Relevance to the Warperup Creek catchment:

The ANZWQ Guidelines provides a useful resource for NRM activity around waterways in the Pallinup River catchment. Relevant sections for developing a WCIP for the Warperup Creek and tributaries should be incorporated in the plan, and this will require scrutiny of what is a large and apparently complex document due to its comprehensive coverage of all facets regarding water quality.

The section titled Chapter 3 – Aquatic ecosystems presents a table of water quality ‘trigger values’ that represent the highest levels of various nutrients that can be considered acceptable. These can be used as a comparative benchmark for measurements made in the field. However, the tabled values are guidelines only and real WQ data will begin to build a picture of the conditions which are common to the Warperup Waterways and what might be achievable in improving water quality.

It is suggested that the field data gathered over time will provide a realistic benchmark for auditing changes in water quality over time.

Ecological values of waterways in the south coast region, Western Australia

Author(s): Barbara Cook, Geraldine Janicke and Judy Maughan

Publication: Final report CENRM Report No CENRM079

Type: Investigative report prepared for the Department of Water.

Extracts - Insights, principles, and perspectives:

This publication summarises the findings of an extensive assessment of water quality in river systems across the South Coast, including the Pallinup River.

p3 The overall objective of this project was to conduct a comparative assessment of the ecological values of selected river systems in the South Coast region. To achieve this objective, an "ecological" snapshot of each river was undertaken and covered the diverse range of aquatic environments found along the South Coast.

Activities included:

(i) the collation of existing ecological information on South Coast rivers using both published and unpublished sources,
(ii) additional surveys of fauna and flora, habitat and water quality at 183 sites in 33 river catchments, covering a range of habitats, including river pools,
(iii) the delineation and description of interim 'aquatic bioregions' for the South Coast region using macroinvertebrate data,
(iv) the identification of 'hotspots' for species richness, and endemism using appropriate multivariate analyses,
(v) the assessment of 'ecological values' of selected rivers systems using a recently developed Framework of criteria, indicators and measures,
(vi) the exploration of the use of 'surrogate' taxa for tracking and mapping aquatic biodiversity in South Coast waterways, and,
(vii) mapping of the presence of biodiversity and endemism 'hotspots' using the GIS software package ArcView.

Relevance to the Warperup Creek catchment:

Eight water quality monitoring sites were selected in the Pallinup River catchment and sampling took place in August 2007. The sampling included water chemistry and aquatic macro-invertebrates.

The sites were designated PAL01 to PAL08.

PAL04 (6242199 N/ 636066 E Z50) was the only site visited on the Warperup Creek and this is at a different location approximately 2.2 Km upstream of site PAL09 monitored in the current feasibility study.

An earlier rapid assessment of key rivers had been undertaken as part of the national AUSRIVAS survey and this data was used to do an initial condition assessment but lacked detail sufficient to be used as baseline data.

Potential for vegetation-based river management in dryland, saline catchments.

Author: John Callow

Publication: The University of Queensland, School of Geography, Planning and Environmental Management Wiley, River Research and Applications. c 2008.

Type: Draft research paper

Extracts - Insights, principles, and perspectives:

p2

Hatton and Salama's paper "Is it feasible to restore the salt-affected rivers of the Western Australian wheatbelt?" concluded by stating (Hatton and Salama, 1999, p316):

"We may have to accept that some changes in the hydraulic and hydro-chemical characteristics of the system may be irreversible... [and while] ...there is an ethical compulsion...there may be little we can realistically do to control or reverse this process"

p3

River management in dryland saline landscapes is challenging. The largely non-strategic approach to funding, lack of scientific basis for planning (Hillman and Brierley, 2005), limited monitoring of intervention success, and the growing extent of salinity (National Land and Water Resources Audit, 2001), means that the potential for vegetation-based river management strategies to offer meaningful outcomes for saline landscapes appears limited (Hatton and Salama, 1999). Despite this, there is strong public and political pressure to pursue management goals of river "rehabilitation" (Possingham, 2001; Hobbs et al., 2003), in landscapes where human actions have fundamentally changed the flux of water, sediment and salt, and in settings recognised for the dearth of research (Tooth, 2000; Nanson et al., 2002).

p4

River management schemes based on a "remediation" philosophy need to work within the new limits on plant growth.

From a botanical perspective, field-based solutions and quantitative models to determine changes in species structure, diversity and dynamics along riparian corridors have been illusive, due to complexity and variability in factors affecting vegetation composition, distribution and growth (Hobbs and Norton, 1996; Cramer and Hobbs,

2002; Hobbs et al., 2003). Cramer and Hobbs (2002) identified the need to recognise zones of the river channel where management can succeed under the new regime.

p7

Following a large flood in February 2000, 259 photos were taken by the Water and Rivers Commission in May 2000 along 50km of river channels of the lower and middle Dalyup and West Dalyup Rivers. In June 2005, 99 sites were precisely located and re- photographed along 35kms of the lower Dalyup and West Dalyup Rivers (see Fig. 2 for location).

Repeat photography has been used extensively for analysis of landscapes, particularly for analysing change in gross vegetation patterns (e.g., Hart and Laycock, 1996; Lewis, 2001; Kull, 2005). Original photographs were used (in-field) to orientate repeat photography. Their positions were recorded with a GPS to allow location for future surveys, with brief vegetation survey at the sites also conducted to identify dominant species.

p8

Vegetation conditions (see Birkeland, 2002; Faustini and Jones, 2003; Stromberg et al, 2005; *Sable and Wohl, 2006). Repeat photography data (and in-field surveys) was used to build a* conceptual model of the types of vegetation that were colonising and growing on different areas of the channel, surfaces (i.e., sand or clay), and under different salinity conditions.

This work also stresses the importance of managing vegetation recovery pathways, such as the invasion of weeds over less competitive but more effective vegetation such as shrubs and trees, and how this has the potential for divergent river management outcomes. It also identifies that sufficient wide riparian zones are critical for managing erosive processes in this setting.

p18

Overall, this study identifies that vegetation-based river management has the potential to deliver meaningful management outcomes in dryland catchments affected by severe secondary salinity. The approach applied in this study provides the basis for assessing the spatial arrangement of channel management and remediation potential within the limits of salinity, microtopography and morphological characteristics of reaches, that affects the vegetation growth potential. Through investigation of the present limitations of stream salinity on vegetation growth, this study identifies that while framing river management goals of rehabilitation or restoration are ill-conceived in this environment, there are options for remediation based on understanding the limitations. Results of modelling changes in stream power for reach types in the context of limiting factors identified by this research, provides a framework to identify river management priorities. Through this approach, there is the potential to develop meaningful river management strategies in a dryland, saline landscape.

Relevance to the Warperup Creek catchment:

There are commonalities between the Dalyup River, which is west of Esperance, and Warperup Creek catchments. Both have headwaters on the uplands of the Yilgarn Plateau, both are in a saline environment, and both have rocky incised channels with high sediment loads. One critical difference is that land clearing occurred more recently in the Dalyup then for the Warperup.

The study implies that the concept of 'restoring' Warperup Creek is unrealistic and what future projects should aim for is to achieve what might be termed, *acceptable functioning condition*. This would apply to floodway stability, aquatic biodiversity and fringing vegetation diversity and condition.

The Dalyup River study effectively used repeat site photography to provide information about what changes were taking place and what is feasible or otherwise in terms of restoring and acceptable level of environmental condition for the erosion ravaged waterways.

Wetland Conservation at Ongerup WA – Recommendations for the Management of the Mills Lake wetlands - 2001

Authors: Kevin Hopkinson for Green Skills

Type: Report

Extracts - Insights, principles, and perspectives:

During 1997 the Mills Lake catchment was selected as a focus catchment under the State Salinity Action Plan and catchment planning activities began in 1998. An integrated catchment plan was released during 2000.

The Mills Lake area was targeted for assessment by Green Skills due to the wetlands of the area being locally outstanding and regionally significant and threatened or at risk of degradation.

Relevance to the Warperup Creek catchment

Mills Lake catchment is adjacent to the Upper Warperup catchment and potentially overflows into Ongerup Creek during extreme rainfall events. The direction of movement of groundwater out of the Mills Lake area is uncertain, but it is suggested that the catchment be included in management planning.

The wetlands report is one of many reconnaissance and planning level reports produced for South Coast catchments following the Decade of Landcare. They presented overviews of the nature and character of catchment bushland reserves, bush remnants and various waterways and delineated the problems facing the environment. Various recommendations for their protection and end enhancement were offered. The reports are in essence, state of the environment assessments at a local level.

Changes to government, agency roles, key players and community group participation have meant that follow up of specific recommendations have tended to be piecemeal and intermittent. A few basic principles have steered project funding namely, fencing riparian areas and remnant bush patches to exclude stock, weed control prior to revegetation or where possible and revegetating riparian verges. On this basis, there has been an overall continuance of natural resource management projects, and in this case in the Pallinup catchment.

The volatility of governance and funding opportunities has made it difficult to track progress towards the initial specific goals mentioned in reports. For this reason, there would be significant value in conducting longer term reviews of environmental outcomes of on-ground works and the effectiveness of recommendations which have been implemented. This information would greatly assist in defining and improving “best management practices”.

Casuarina obesa in the Avon Wheatbelt. Management of native stands and provenance trials

Author: Wheatbelt NRM

Type: Brochure (2013)

Extracts - Insights, principles, and perspectives:

The information brochure reports on trials to:

- Show how the benefits of thinning native colonised stands of *C. obesa* can assist landowners.
- Compare future growth rates of 3 stocking levels of thinned natural regenerated *C. obesa*
- Compare long term tree health with managed and unmanaged stands.

Relevance to the Warperup Creek catchment

The trials and findings have relevance for revegetation in the Warperup catchment.

Consider farm forestry, biodiversity plantings and potential for erosion control

Also see the document titled, *Swamp Sheoak (Casuarina obesa) use in Farm Forestry, b*y Tim Emmott, Greening Australia (WA)

Further information can be obtained from Wheatbelt NRM. PO Box 311 Northam WA 6401. Ph: 08 9670 3100. www.wheatbeltnrm.org.au

Warperup Creek Restoration and Protection – Michael Wright

Author: Michael Wright interview for the Water and Rivers Commission – South Coast Region

Type: Early website page

Relevance to the Warperup Creek catchment

The article is a summary case study of riparian rehabilitation along reaches of the Warperup Creek and highlights the benefits the landowner derived from project works. These illustrated the state of the art with respect to waterways rehabilitation in the area.

Revisiting such sites at intervals can provide valuable information about outcomes of riparian works and therefore fine-tune realistic goals to aim for in the future.

River History – Photo Auditing Rivers to Monitor Changes into the Future

Authors: Steve and Geraldine Janicke 2021

Type: Manual

Extracts - Insights, principles, and perspectives:

This manual considers the use of photography for evaluating the physical condition of rivers, creeks, and wetlands with a view to tracking changes over time.

Systematically gathered photos of waterways provide visual data that can be analysed, and conclusions drawn about changing riparian condition and function with a view to developing better river management practices and assisting with designing on-ground rehabilitation works.

The techniques described here have been found to be practicable for relatively open river floodway conditions common to South-West agricultural areas of WA and for any length of channel.

Photo-auditing provides a simple but powerful tool in the environmental monitoring toolbox and the monitoring can be carried out simply and effectively by community members and researchers.

Relevance to the Warperup Creek catchment

Two of the most difficult questions asked of natural resource managers regarding waterways are: First, how are the river and tributary streams changing and secondly, have management initiatives enhanced the environmental condition of the waterways?

Scientific investigations usually target specific issues in isolation, and this is because ecosystems are complex systems with many interdependent parts. In addition, scientific research is often expensive to do and excludes local community participation in the planning and evaluation process. The presentation of results and conclusions is often a 'show and tell' exercise. The development of what has been termed 'Citizen Science' has aimed to bridge the gap between scientific investigations and community appreciation of what is taking place in local catchments. It does this by engaging local people in the data gathering and interpretation process. The use of readily available technology and training offers a robust way to obtain reliable data and to increase community expertise in understanding natural processes.

Photo Auditing was initiated at ten representative waterway sites in the Warperup Catchment with the following goal in mind; to track structural and vegetation changes to the streams over the short-term (seasonal and post flood events), medium term (2 – 10 years), and long term (10 – 100 years).

The auditing (monitoring) techniques outlined in the manual were developed in part for the Pallinup River specifically and later for South Coast rivers in general.

North Stirlings and Pallinup River Catchments – Revegetation Guide

Authors: Wendy Bradshaw and Geoff Woodall 2009

Type: Booklet

Extracts - Insights, principles, and perspectives:

This practical manual provides plain information on site assessment and preparation, species selection, machinery and approach, planting design and other environmental issues relevant to revegetating areas of the landscape.

The revegetation guide is specifically tailored to the North Stirlings Pallinup area and provides a useful resource for designing riparian rehabilitation works.

Relevance to the Warperup Creek catchment to Warperup Creek and its tributaries

Riparian zones present specific rehabilitation design problems when it comes to revegetation; flooding, erosion, sediment deposition, weed management in difficult to access areas and feral animals. Nevertheless, establishment of local robust perennial plant species in these areas offers more than just increased biodiversity. Trees and shrubs in a floodway act physically to control water velocities and therefore erosion.

Reducing erosion is largely about controlling the velocity and focus of flowing water. Traditionally any slowing of flood waters has been viewed as a negative because slowing the flow tends to raise the water level. However, an all or nothing approach with respect to riparian vegetation is a somewhat clumsy management approach. A relatively small reduction in stream velocity and hence stream power, can significantly reduce erosion and its by-product, sedimentation.

Deep rooted perennials are well suited to the flood zone of waterways.

MAPS

Nyabing-Kukerin-Land Resource Map No 34

Author: H.M Percy and M.J Roberts

Publication: Department of Agriculture

Type: Map

Extracts - Insights, principles, and perspectives:

The lower part of the map shows the landscape units in the upper Warperup Creek and Gnowangerup area. The primary unit was classified as follows:

Upper Pallinup System: Gently undulating and undulating rises with upland plains. Grey shallow and deep sandy duplex soils, alkaline grey shallow sandy and loamy duplex soils with minor rock loamy duplex soils and gravels.

To the immediate north of the Warperup catchment is the Tie-line System. This is classified as:

Level to gently undulating plains and gently undulating rises. Grey sandy duplex soils, alkaline grey shallow duplex soils, saline wet soils, grey shallow loamy duplex soils and loamy earths.

Relevance to the Warperup Creek catchment:

The exact watershed of the Warperup Creek drainage network is not completely understood as evidenced by various comments by landholders. The low relief of the landscape in the Upper Warperup contributes to the uncertainty. The same may be true for the groundwater system which is a mixture of local and regional aquifers. Inputs to the lower creek system from the northern zones may or may not be significant. Some further hydrological insight may be useful but would realistically involve obtaining high resolution remote sensing data, namely LIDAR based DEM (less than 0.5 m altitude resolution) and ground penetration radar to define the basement geological structure. Relating surface soil types to basement rock topography would provide a much greater understanding of water management in the landscape.

AgBore locations

Authors: Department of Primary Industry and Biosecurity (Department of Agriculture)

Type: Map

Extracts - Insights, principles, and perspectives:

Relevance to the Warperup Creek catchment

The Agbore network is an array of bores located across the Wheatbelt and was designed to enable gathering data about groundwater salinity, both salt levels and depth. The data is related to soil and landform types and is the basis of efforts to understand how the extent of salinisation of landscape soils is progressing.

The upper Warperup Creek catchment is well represented, but the larger part of the catchment is not.

Knowledge of the extent and severity of soil and waterways salinisation is therefore predominantly held by individual landholders and extends within their properties.

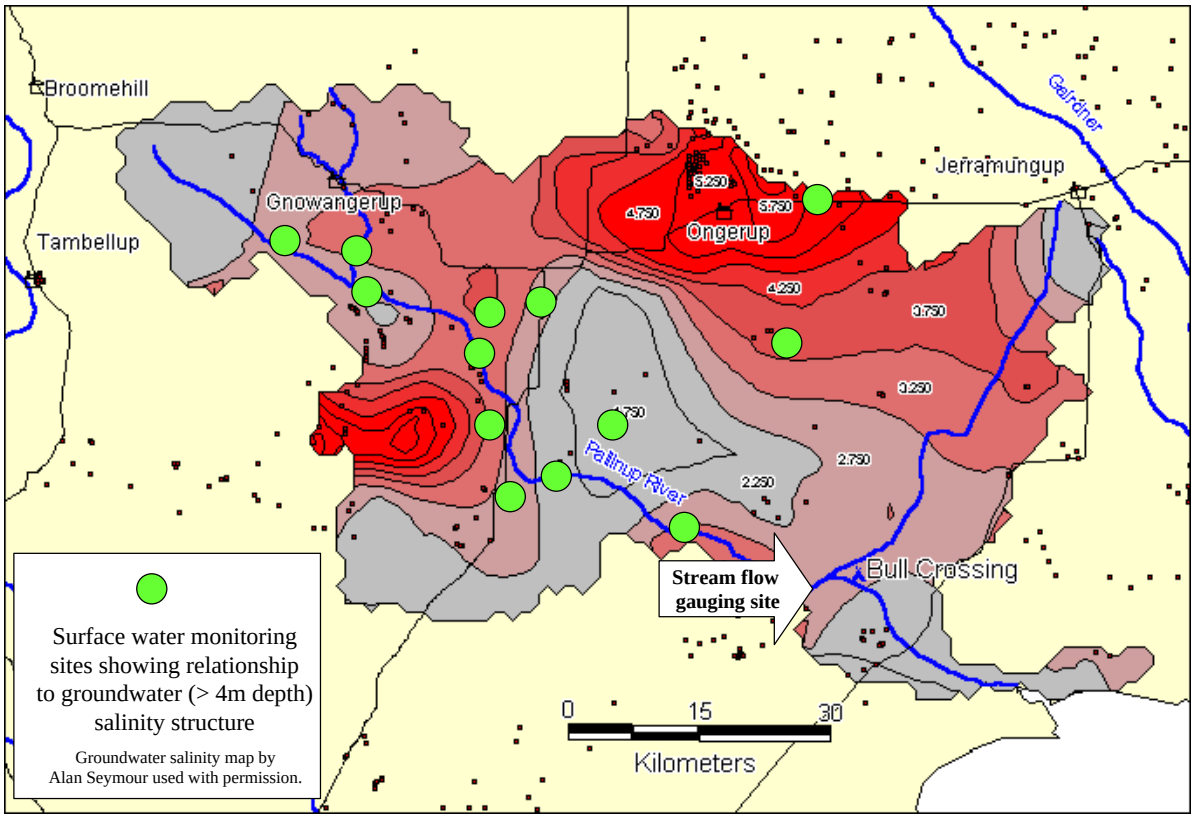
The Agbore focus was and is understandably farm productivity focused and the implications for surface waters in local waterways has been of peripheral concern although surface runoff modelling has been undertaken to better understand the hydrology of catchments.

Groundwater salinity map (> 4m depth) c 2000

Author: Department of Agriculture

Type: Map

Extracts - Insights, principles, and perspectives:



Relevance to the Warperup Creek catchment:

The map was constructed using data from an extensive network of groundwater monitoring bores. The surface monitoring sites (green dots) have been added, but these were part of a separate NHT funded water quality monitoring program during 1998 - 1999.

The feature of interest here is the distinct salinity 'hot spot' which underlies the upper reaches of Warperup Creek. Changes in groundwater levels in this area have important ramifications for future salinity levels in the creeks. The connection between groundwater levels and annual rainfall variability and long-term trends will continue to be important for assessing and understanding the hydrology of the sub-catchments.

Soil landscape map of the Tambellup – Borden area

Author: A. Stuart-Street and R. Marold, Department of Agriculture Western Australia

Type: Map

Extracts - Insights, principles, and perspectives:

The landscape unit map covers the North-Stirlings area from the Stirling Range to Keberingup.

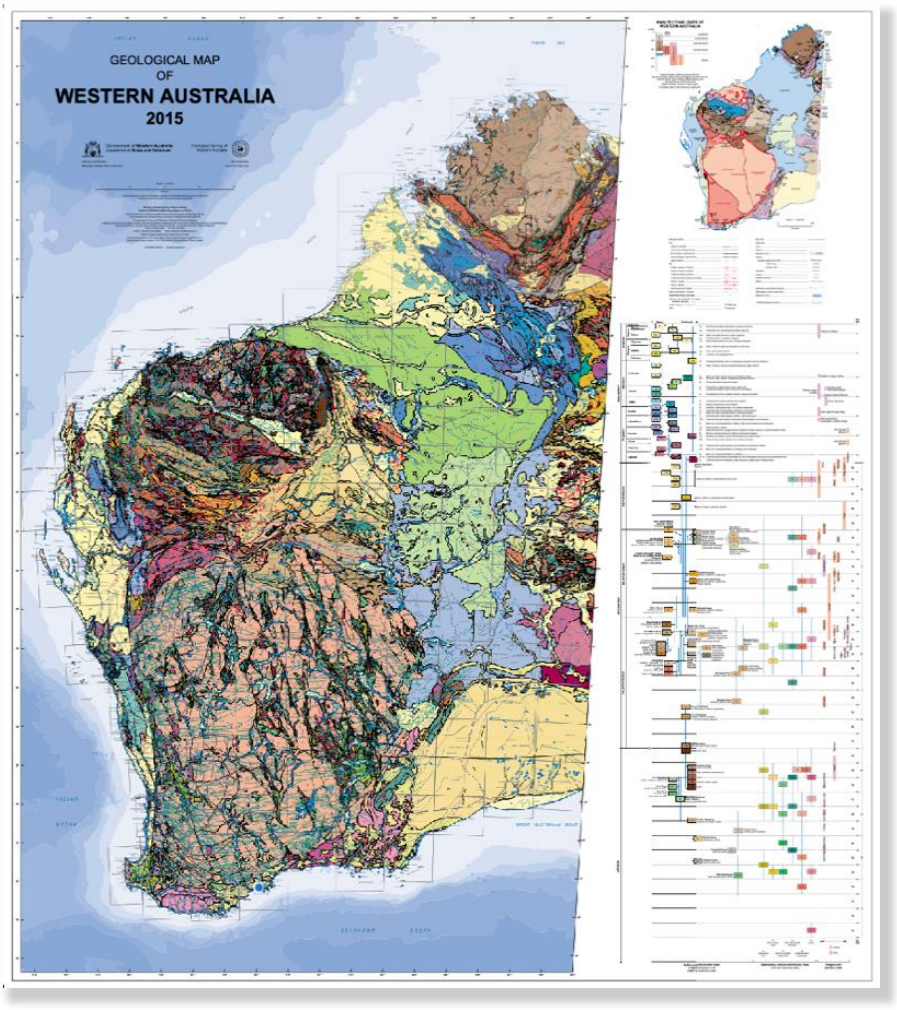
Relevance to the Warperup Creek catchment:

The Upper Pallinup landscape unit covers the lower Warperup Creek catchment. South of the Pallinup River the units are varied.

Geological Map of Western Australia 2015 Edition 14

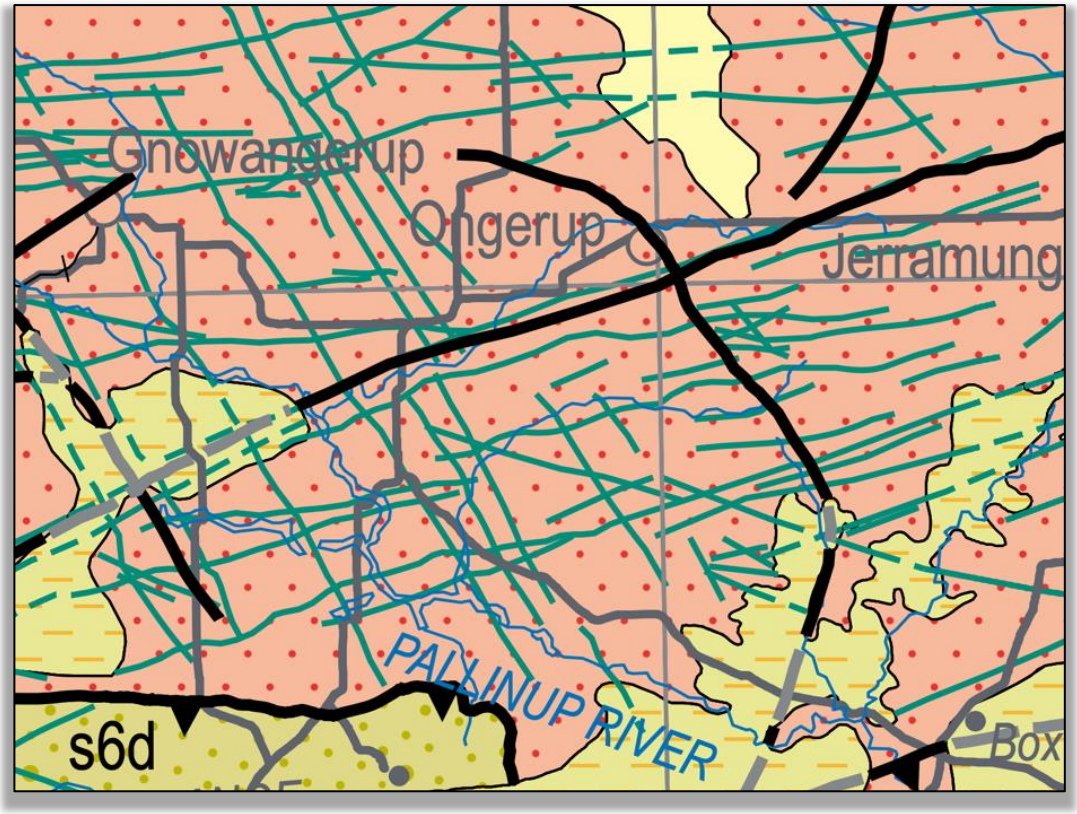
Publication: Martin, DMcB, Martin, Hocking, RM, Rignanti, A, and Tyler, IM 2015 Geological map of Western Australia, 1:2 500 00 (14th edition): Geological Survey of Western Australia.

Type: PDF



The geological map covers Western Australia but can be zoomed in to examine geological detail at a sub-regional scale (e.g., Warperup Creek catchment below).

Relevance to the Warperup Creek catchment



The enlargement allows general fault lines and dolerite dykes to be identified in the Warperup catchment and these could be loosely matched with individual properties at this scale. However, apart from identifying the presence of these features, how they relate to groundwater issues on properties would require detailed on-site assessment. It can be noted that the development of ground penetrating remote sensing technology would be useful for a) mapping the regolith topography and

b) building more accurate models of groundwater depth and movement within and across the catchment.

DATA SETS

Information about various environmental data sets relating to water condition in the Pallinup catchment have been included in this literature review.

Data sets are an essential source of information to justifies assessments and conclusions regarding the state of the environment and the scope of natural processes taking place. Unfortunately, raw data sets associated with specific projects are rarely systematically archived or consolidated into a single location, but are scattered amongst agencies, community groups and sometimes, individuals. Data may be in hard copy form or digital, it may be incomplete, mislaid or lost altogether. Meta-data (information about the data) is often absent or separated from the raw data. As a result, data is not easy to access.

An important component of any plan for a Water Condition Improvement Plan for the Warperup Creek catchment will be a system for gathering and storing water and channel condition data. The value of this as a resource for future projects should not be underestimated. It describes how things were and is the means of answering the important management questions: How has the environment changed and has what has been done achieved a positive improvement and therefore justifies the investment?

Historical data cannot be obtained again if it is lost and for this reason its usefulness increases with time.

Data set	Description	Custodian	Origin	Completeness
River flow gauging	River flows at Bull Crossing on the Lower Pallinup River near Chillinup have been measured since the mid 1970's.	DWER	Hydrography division of DWER	Ongoing
Bore data	25 bore holes drilled on 8 properties by landholders to determine water levels and groundwater salinity (1996)	Landholders and DPIRD	8 landholders in the Mills Lake catchment	Results tabled in appendix 2 of 'Salinity and Hydrology of the Mills Lake Catchment'. TR 166 Nov 1997
Bore data	22 bore holes drilled by Agriculture WA in 1996			Results tabled in 'Salinity and Hydrology of the Mills Lake Catchment'. TR 166 Nov 1997
Baseline water monitoring sites	Ten sites in the Warperup Catchment were established in 2020 to develop a baseline water quality data set. Each site was a reach of the waterway approximately 500 m long and the data includes a series of Photo Points for each.	NSPNR Inc	S and G Janicke	Can be added to in subsequent projects
Other water quality data	Data from a number of sites (one on the Warperup) collected between 1998 and 2000.	DWER	Water and Rivers Commission. An NHT funded project titled Water resources Assessment and Enhancement (WRAE), South Coast.	DWER appears to have restricted the access to the salinity data.