Yarra Yarra Catchment Management Group

Final Report on Feasibility Study

2003-2005

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and

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nacc
managing natural resources

Kalannie

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YARRA YARRA CATCHMENT MANAGEMENT GROUP

Summary

This report summarises work carried out by the Yarra Yarra Catchment Management Group (YYCMG) during the period September 2003 to September 2005. The work forms part of a longer-term study by YYCMG into the feasibility of landscape rehabilitation on a whole-of-catchment scale, involving groundwater drainage, surface water management, preserving remnant vegetation, constructing environmental corridors, and setting up a system of regional governance. Some of the earlier programs are described in appendices to this report, where results have not previously been presented. It is anticipated that, subject to further funding, feasibility studies and on-ground works will continue over coming years.

The current study, predominantly a program of soil pits, groundwater observation bores and detailed surveying, has focussed on the valley floors of 11 subcatchments in the Yarra Yarra basin. One of these subcatchments, Mongers 55, was selected for more-detailed investigation. We have identified that the most pressing need, both here and throughout the region, is for the relief of waterlogging and salinity from silted-up drainage lines. Saline groundwater has accumulated in the subsoil of valley floors, in places within 0.5 m of the surface, and now poses a threat to agricultural production, public infrastructure and remnant vegetation in much of the subcatchment, even in upland areas near the catchment divide. Tree-planting exercises and other plant-based attempts to deal with this problem have been unsuccessful because of the rising watertable.

It is the intention of YYCMG to drain the entire landscape, through a network of deep drains, both privately and publicly funded, into the salt-lake system, and to rehabilitate the drainage lines as vegetated corridors, similar to the highly successful Goodlands Environmental Link. Salinisation and waterlogging will be prevented from redeveloping by (i) maintaining the deep-drainage network in working order, (ii) managing groundwater recharge through surface-water management plans and by encouraging revegetation in the sandy, upland areas, and (iii) setting up a hydrological monitoring system of wells, piezometers and flow meters. Biodiversity values will be enhanced by draining threatened patches of remnant vegetation, increasing the total vegetated area of the landscape, and connecting isolated patches to each other by constructing environmental corridors.

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1. Introduction

1.1 The Yarra Yarra Catchment

The Yarra Yarra catchment in the Northern Agricultural Region (NAR) is centred about 350 km NNE of Perth and straddles the wheatbelt – rangelands boundary (Fig. 1). This report concerns only the agricultural portion -- an area of around one million hectares, including the towns of Carnamah, Kalannie, Morawa, Perenjori and Three Springs. The climate is Mediterranean, with hot, dry summers and cool, wet winters. Drainage is internal. Irregular surface flow is directed to a chain of several thousand ephemeral saltlakes, playas and samphire-covered claypans, approximately 300 km long and 250,000 ha in area. Some of these lakes rarely contain free water and there is no recorded instance of continuous flow from one end of the chain to the other. In most years (and this is the nub of the problem), surface water does not flow to the lake system at all. Instead, it ponds in waterlogged depressions or poorly defined drainage lines, and eventually drains away to the local groundwater table. The geology, landforms and soils of the Yarra Yarra catchment are described in McArthur (1991). A general description of the catchment, including aspects of hydrology and hydrogeology is given in Clarke (2001).

These drainage lines, as well as the broad valley floors that host them, are becoming progressively saltier, as groundwater builds up – often to within 1-2 m of the surface. Valley floors that once supported crops or diverse woodland communities, are now bare salt-scalds or samphire-covered flats (Fig. 2). Some small depressions high on the valley sides have also become afflicted by this combination of saline groundwater and waterlogging.

Gradients are extremely low throughout the region, and the distinction between valley floor and valley sides is not always obvious. There is only about 40 m fall 'downstream' along the saltlake chain from saline wetlands near Burakin to Yarra Yarra Lake near Carnamah.

The Yarra Yarra catchment basin is made up of about 60 primary subcatchments, each of which has a principal streamline, which either empties into the lake system or empties into another channel that eventually leads to a saltlake (Fig. 3). These subcatchments fall naturally into 11 higher-order catchments, which we recognise as 'zones' (Fig. 4). At the subcathment level, interfluve boundaries are subdued and can be difficult to identify. At the zone or catchment level, by contrast, the divides are clearly defined. The Yarra Yarra Catchment is a basin that is often rimmed with granitic outcrop.

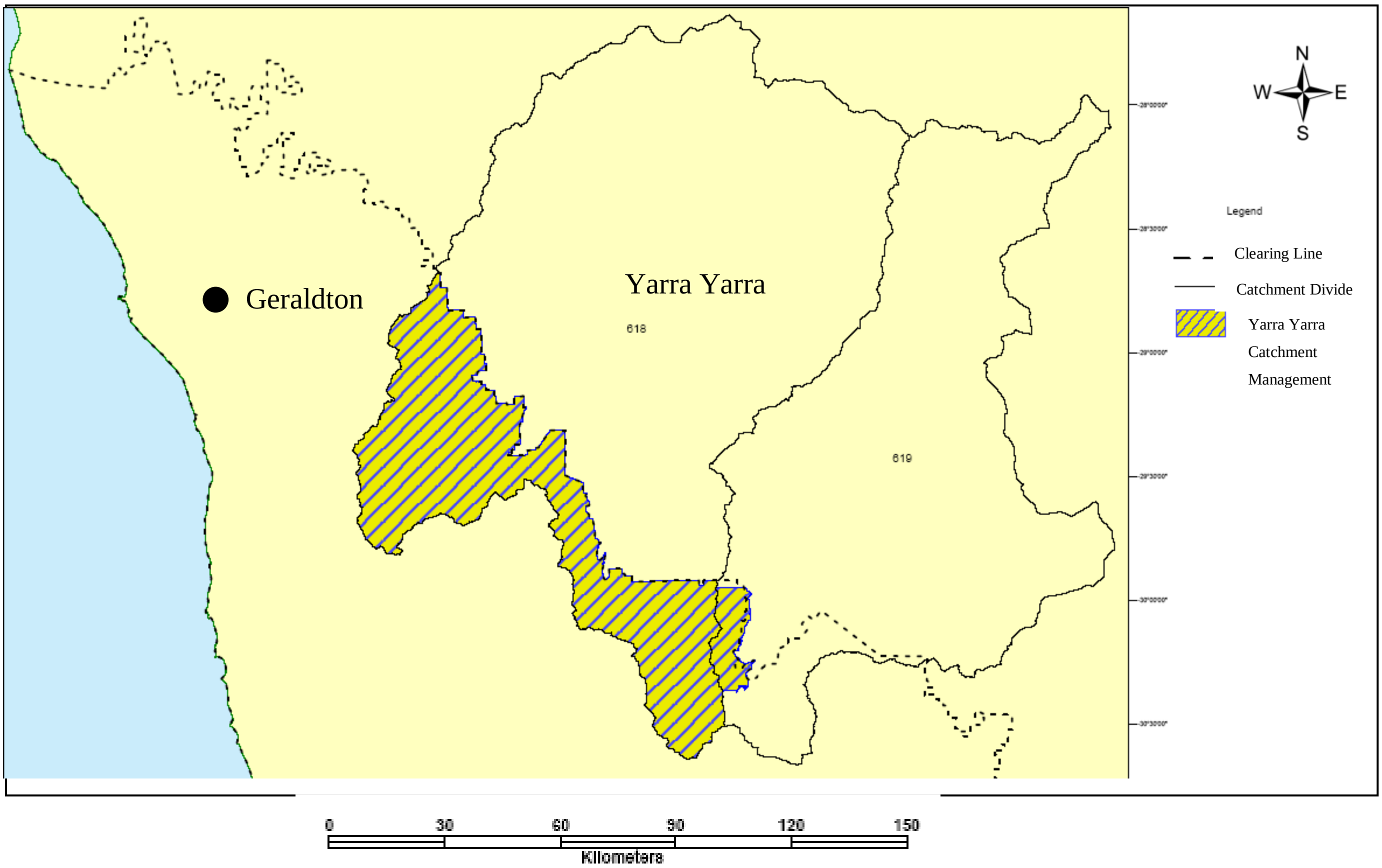


Fig.1. Location map, showing the Yarra Yarra catchment, the clearing line and the jurisdiction of the Yarra Yarra Catchment Management Group.

Fig. 2. A samphire-covered and salt-encrusted valley floor near Perenjori.

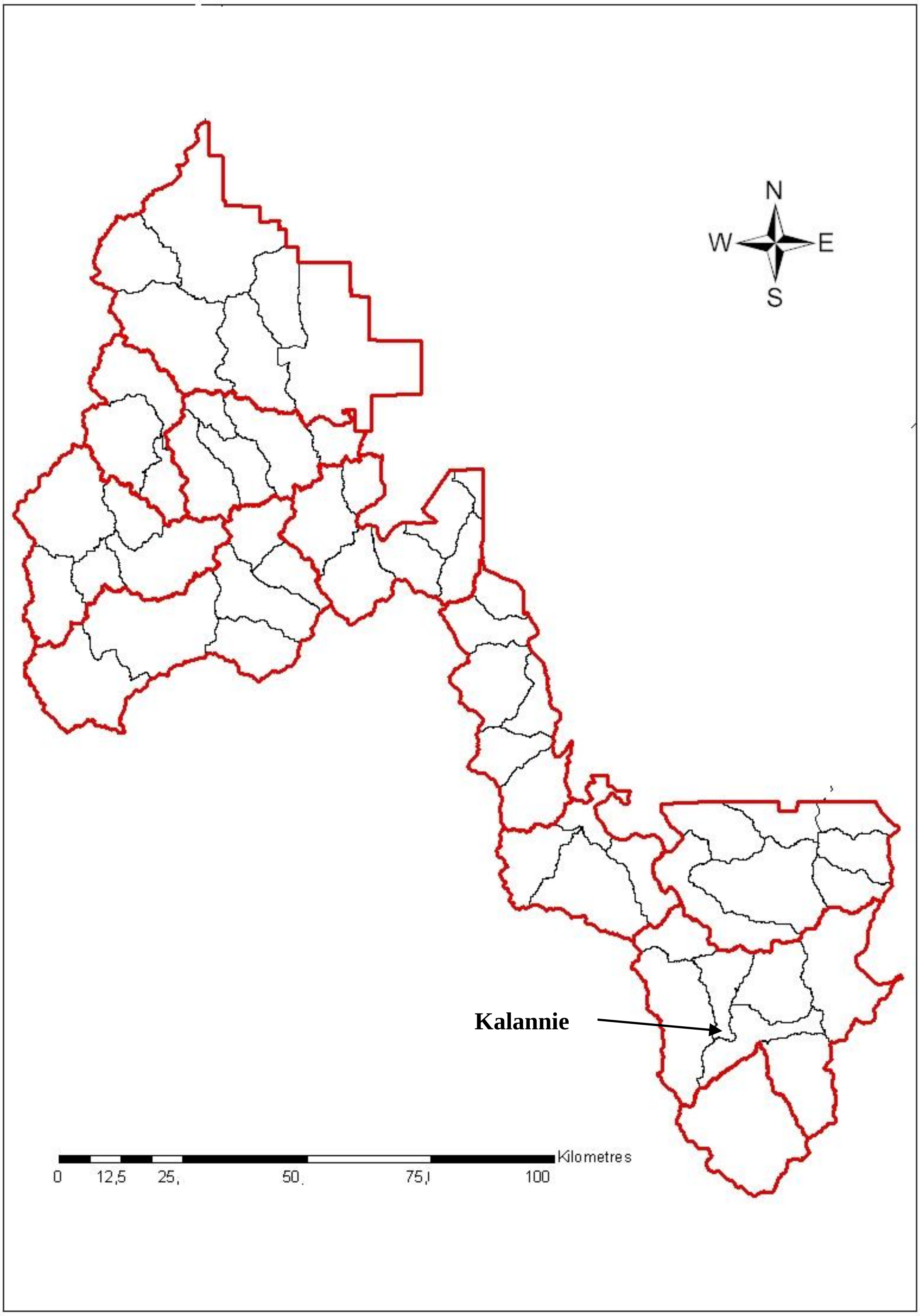


Fig. 3. The 60 subcatchments of the Yarra Yarra catchment.

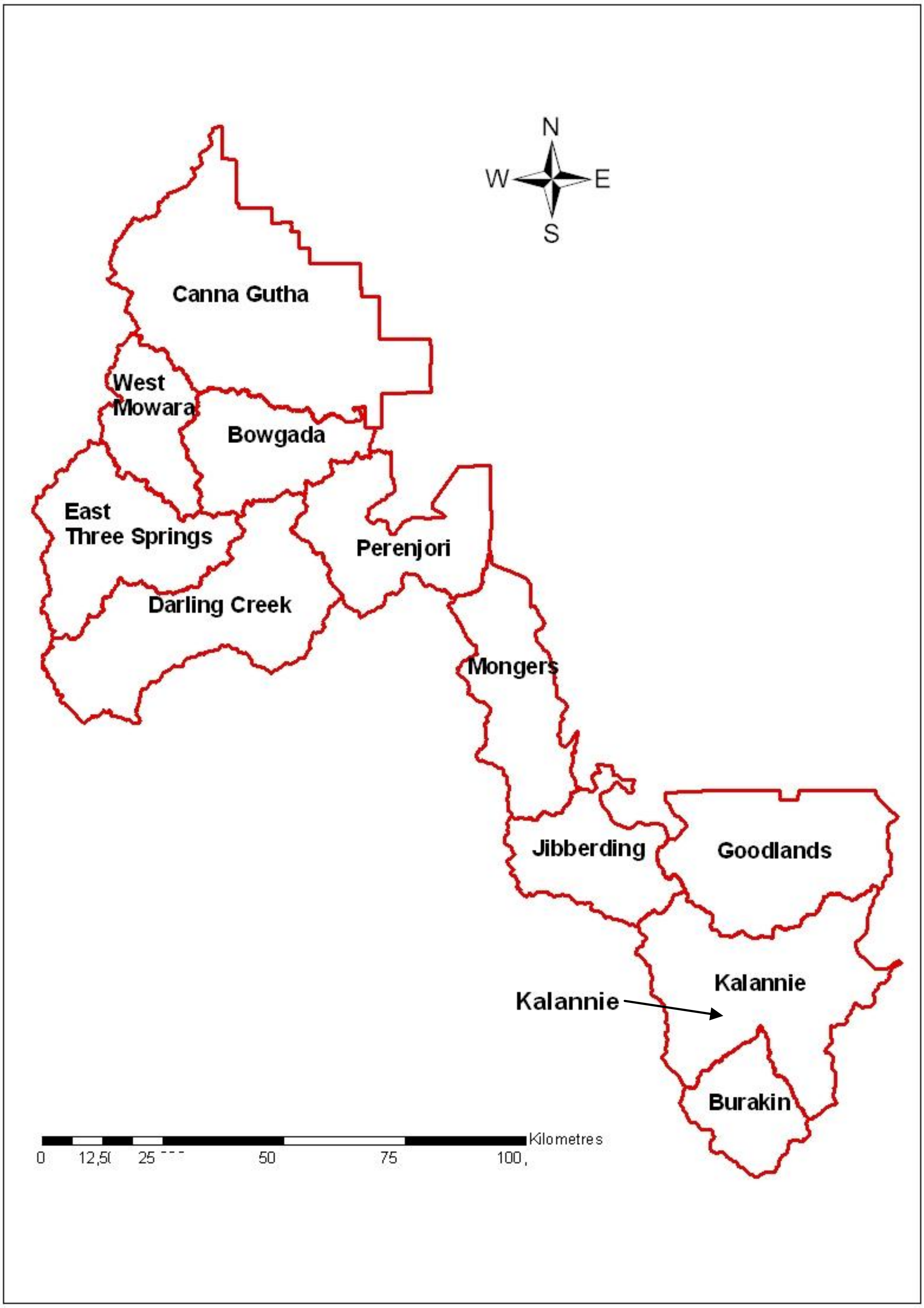


Fig. 4. The 11 zones of the Yarra Yarra catchment.

1.2 Yarra Yarra Catchment Management Group

The Yarra Yarra Catchment Management Group (YYCMG) was formed in 1997 to manage catchment projects on a regional scale. After an initial study identified that the principal concern of landholders was increasing salinity and waterlogging, YYCMG's main focus has been the rehabilitation of streamlines. We see the immediate treatment as an engineering one – the waterlogged (and increasingly saline) valley floors should be drained with a network of deep drains. These drains should remobilise the ponded groundwater and move it out of the catchment to an adjacent saltlake. We recognise that a longer-term solution requires rehabilitation of the drainage line, with reclamation and eventual revegetation of the samphire flats, as well as some revegetation in recharge areas, such as sandy hilltops.

YYCMG is primarily concerned with the Yarra Yarra catchment (Catchment Basin 618 of the South-west Drainage Division). However, it also has jurisdiction over a small part of the adjoining Ninghan catchment (Basin 619) on the western edge of Lake Moore.

The hydrological divisions – subcatchments and zones – described in the previous section, also serve as our basic management units. A representative from each zone serves on the YYCMG management committee and is able, in turn, to muster the landholders from relevant subcatchments.

There are typically around 5-10 landholders in a single subcatchment, 20-50 in a zone, and 480 in the entire Yarra Yarra catchment. Management is community-driven and more democratic than any other regional Natural Resource Management (NRM) body we are aware of. YYCMG is overseen by a management committee, which is made up of community representatives from each of the 11 zones and nominees from the seven shires with holdings in the Yarra Yarra catchment. The committee meets at two-monthly intervals.

There are two offices – a main office, attached to the shire hall at Perenjori (shire population 590), and a branch office at Kalannie (district population 380). Currently, there are two full-time staff at each of the offices, two part-time staff, and two periodically employed casuals. Funding is from a number of sources – projects, direct support from the Northern Agricultural Catchments Council (NACC), and a small but increasing contribution from YYCMG's fundraising enterprises. These enterprises include software sales, contract drilling, surveying and training.

In recent years, Yarra Yarra has been redefined as a 'subregion' of the Northern Agricultural Region; YYCMG has become a subsidiary of the NRM body NACC. All NRM funding from the federal government is now dispersed through regional bodies like NACC. Currently, YYCMG has no statutory status and there appears to be no official recognition of its existence, except as a subregional organ of NACC. This situation makes us extremely vulnerable to the partial or complete loss of funding, the loss of key personnel and data through possible changes in government policy, and the takeover of our community-based structure by a top-down, public-service-style system that we are convinced would be doomed to fail. To pre-empt possible problems of this nature, we are in the process of setting up a statutory council, the Yarra Yarra Catchment Regional Council (YYCRC) to replace YYCMG. This restructuring proposal is discussed in Appendix II.

1.3 Integrated Drain Design

Secondary salinisation is one problem in the catchments; waterlogging is another. Clearly, these problems are related. If drainage is impeded, then, once rainwater has wetted up the topsoil, it ponds in local depressions and eventually infiltrates through the subsoil and adds to the local groundwater pool (George & Conacher 1993). High in the catchment, surface waterlogging can be addressed as an independent problem, with spoon- or w-drains and various kinds of seepage-interceptor banks (Hunt & Gilkes 1992). On valley floors low in the catchment, however, the problem of disposing of excess surface water becomes an important part of the total water-management issue. Our design for integrated management of both groundwater and surface water is shown in Fig. 5.

In a double-leveed drain of the kind shown, we keep most of the surface water out of the deep central drain. This strategy has a number of advantages.

- Peak flows after storms are reduced, which means that there is less erosion and decreased maintenance requirements.
- Road crossings, which are an expensive component of drain construction, do not need to be so elaborate.
- Groundwater is likely to be hypersaline and might also become acidic and moderately toxic. If a requirement develops for pre-disposal treatment, then it would be easier to deal with a discrete and steady flow.
- Surface water, which is relatively fresh, can be redirected as required to revegetation plantings on the valley floor.

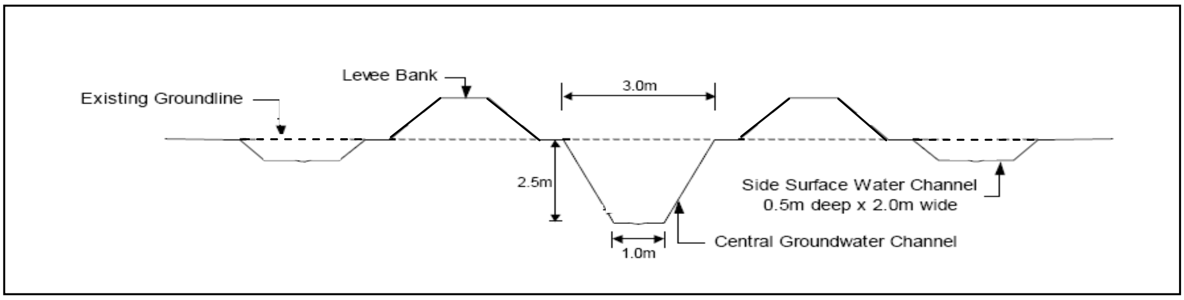


Fig. 5. Cross section of proposed drain, showing the separation of groundwater and surface water.

1.4. Our Vision – Green Corridors

In the century or so since clearing, there has been a widely documented decline in biodiversity throughout the wheatbelt (e.g. George *et al.* 1995; Cramer & Hobbs 2002; Keighery *et al.* 2004). This decline, and its apparent coincidence with increasing salinity, might have more to do with habitat loss *per se*, rather than with the loss of connectivity between populations. Nevertheless, it is generally accepted that vegetated corridors linking isolated patches of remnant vegetation, would improve the situation (Hussey *et al.* 1991; Lefroy *et al*. 1991; Saunders & Hobbs 1991). Our plan is to combine drainage with the revegetation of valley floors – a total waterway-rehabilitation package.

Draw-down, reported from drains across the entire wheatbelt, varies from substantially less than 100 m to several hundred metres (Ali *et al*. 2004a). Even in the Yarra Yarra itself, experiences vary widely (Robert Nixon, farmer near Kalannie, pers. comm.; John Battaglia, farmer near Goodlands, pers. comm.; Gary Mason, farmer near Perenjori, pers. comm.; Dave Mutter, farmer near Gutha, pers. comm.). The most important contributors to this variability are probably regolith permeability, topsoil depth and local groundwater pressure. However, predictions of draw-down, made before drain-construction, have rarely been successful, so it is apparent that there are unforeseen factors involved.

The minimum draw-down experienced in local drainage projects is about 100 m, and we are confident that, in most cases, we will do better than this. Even if, in a worst-case scenario, we achieve a local draw-down of only 50 m, then we can still expect to reclaim a 100 m-wide strip along the valley floor. If this strip is revegetated, then the central waterway would be stabilised. We would fence the entire area off to exclude stock, as shown in Fig. 6.

Our experience on the 'Goodlands Environmental Link' and elsewhere throughout the Yarra Yarra, is that groundstorey and understorey plants readily recolonise sites protected from grazing. Once an undergrowth has become established, then the revegetated strips will act as wildlife corridors.

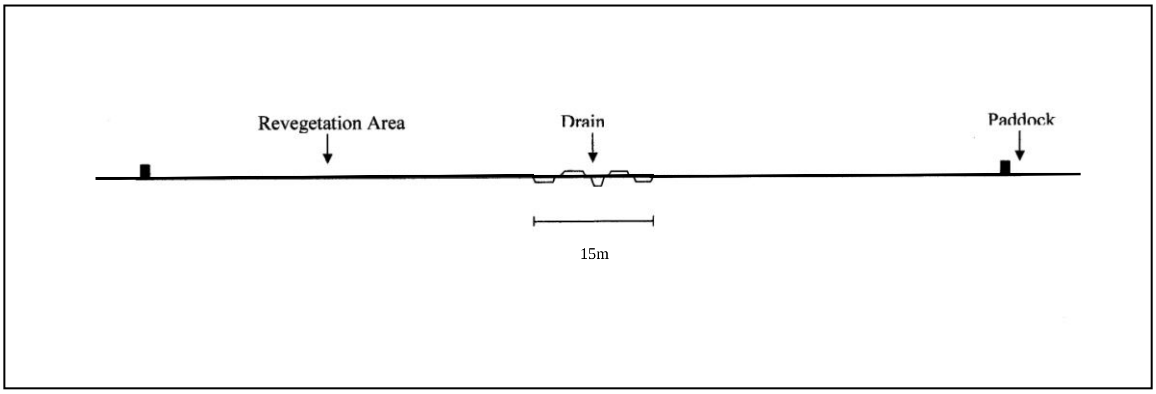


Fig. 6. Idealised cross section of a rehabilitated waterway.

2. Feasibility Study

2.1. Soil Pits

As part of the feasibility study, some 87 backhoe pits, 2-3 m deep, were dug in 11 subcatchments (eight zones) during March and April, 2005 (Fig. 7). The pits were designed to

- (i) determine the depth of the local groundwater table
- (ii) describe the soil profile and assess its suitability for drainage works
- (iii) measure the rate and nature of groundwater movement (approximated by inflow into the pit after 1 hour, 1 day and 1 week)
- (iv) identify hardpan layers and ground conditions that are likely to affect future earthmoving contracts
- (v) provide groundwater samples for chemical analysis

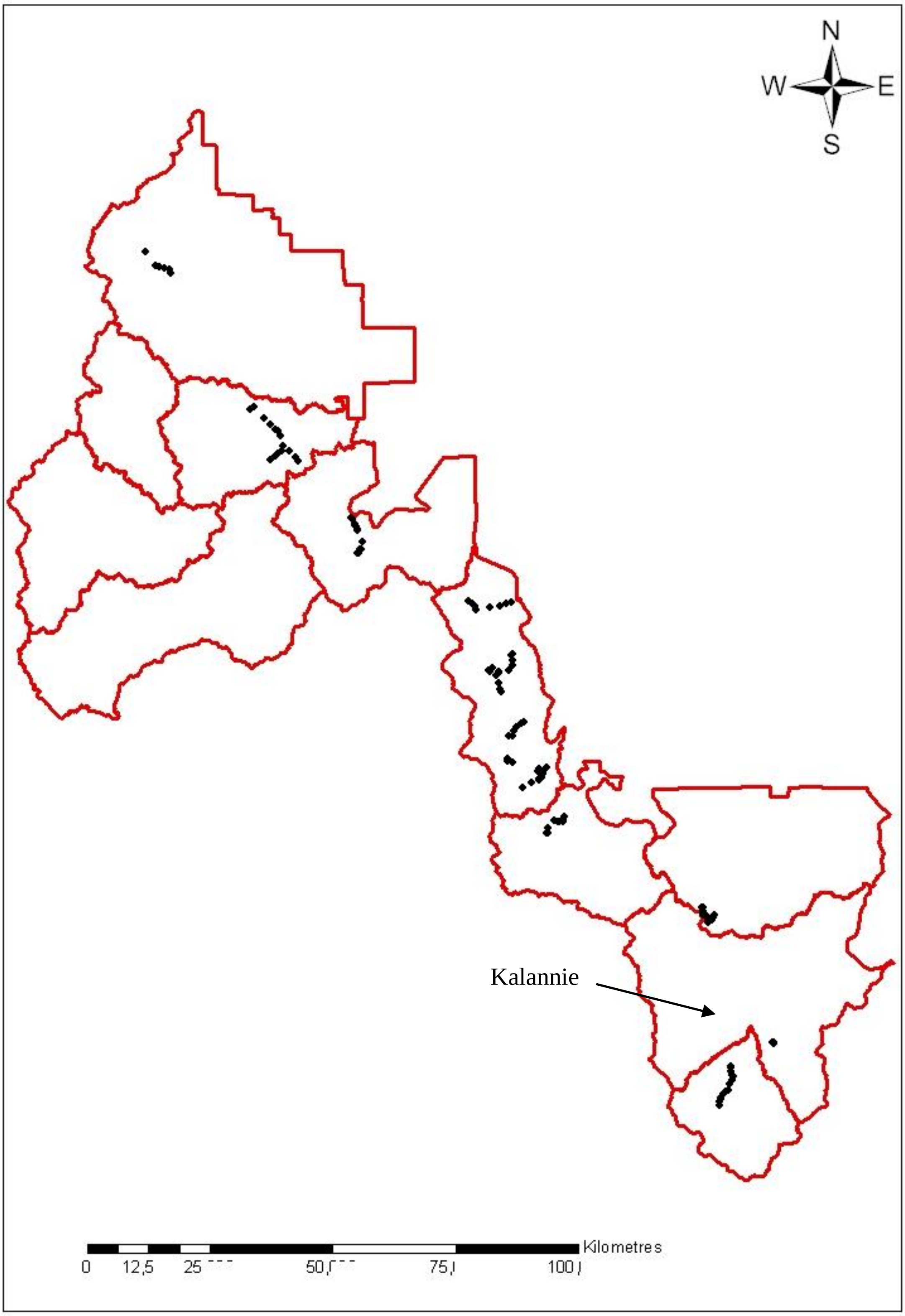


Fig. 7. Soil pits dug during the period September 2003 – September 2005.

In addition, a suite of soil samples was collected from some (but not all) of the pits. These samples will be used, as required, for more detailed tests of soil properties, such as particle-size distribution, lime content or water-holding capacity.

The pits were sited along first- and second-order drainage lines, which had probably been active streams in the pre-clearing landscape, but were now silted up and characterised by samphire shrubland or degraded pasture. Ideally, the pits were spaced at 1 km intervals, between existing, monitoring bores. Most pits have now been filled in (or will soon be backfilled), but a few have been kept open for chemical monitoring. Groundwater samples are collected periodically from these pits to test for gross changes in acidity and metal content.

Most pits intersected groundwater at depths between 1.0 and 1.8 m. Results so far show that there is no regional water table for the Yarra Yarra catchment as a whole; rather, almost each subcatchment is hydrologically isolated from its neighbours and has its own, individual water table. In most cases, there was very little variation in groundwater pH or salinity within each subcatchment. Similarly, valley-floor soils varied only slightly along a single drainage line, although, in places, there were substantial differences between subcatchments. Only two soil types were encountered on valley floors in this survey (Schoknecht 2002) —

- red-brown hardpan shallow loam: a reddish brown sandy loam with a shallow calcareous and/or ferruginous hardpan, underlain by mottled reddish and greenish clay
- yellow shallow loamy duplex: a yellow or yellowish brown sandy/loamy earth, underlain directly by mottled yellow or pale brown (occasionally olive) and grey clay.

In general, soils of the former type were associated with neutral or near-neutral groundwater, while subcatchments such as Burakin, with soils of the latter type, were associated with moderately to strongly acid groundwater.

2.2. Bores

During the two-year period 1/10/03 -30/9/05, 495 bores were drilled and cased as observation wells (Fig. 8). Several hundred wells had been established throughout the Yarra Yarra catchment in preceding years. For the current program, holes were drilled at approximately 1 km intervals along drainage lines, which were selected following zone workshops with local farmers and site inspections. Approximate hole locations were marked on maps and air-photos in a desktop study. The driller, often accompanied by the landowner, was responsible for final site selection.

Holes were drilled to depths of 4-6 m, using a truck-mounted auger rig (Edson MRA 260; Fig. 9) with a bit diameter of 50 mm. The driller recorded on a *pro forma* record sheet major soil changes, the depth at which groundwater was encountered, the presence and nature of any hardpans, and the ease of penetration. Each hole was cased with PVC (40 mm pipe), which was slotted for the bottom 2-3 m. Coarse sand was then packed around the slotted section, while drill-cuttings and clay were backfilled down the annulus to pack the upper section. Some of the collars, particularly those in seasonally wet areas, were sealed with a quick-setting cement, but this was not a consistent practice.

After a few days of drilling, the record sheets were passed on to the database manager (or to whoever was filling that role at the time). Bore details were then entered into the appropriate database and collar locations were incorporated in the GIS.

Ideally, each bore is inspected at least once a year, although such regular visits have not always been possible. Water level is recorded on yet another *pro forma*, the well is emptied as far as possible, using a custom-built, 600 mL hand-baler, then sampled on a return visit the following day. The two properties that are regularly measured are pH and EC, using waterproof sticks (Eutech Instruments, Malaysia). A few water samples have been submitted to a laboratory for analysis of major ions.

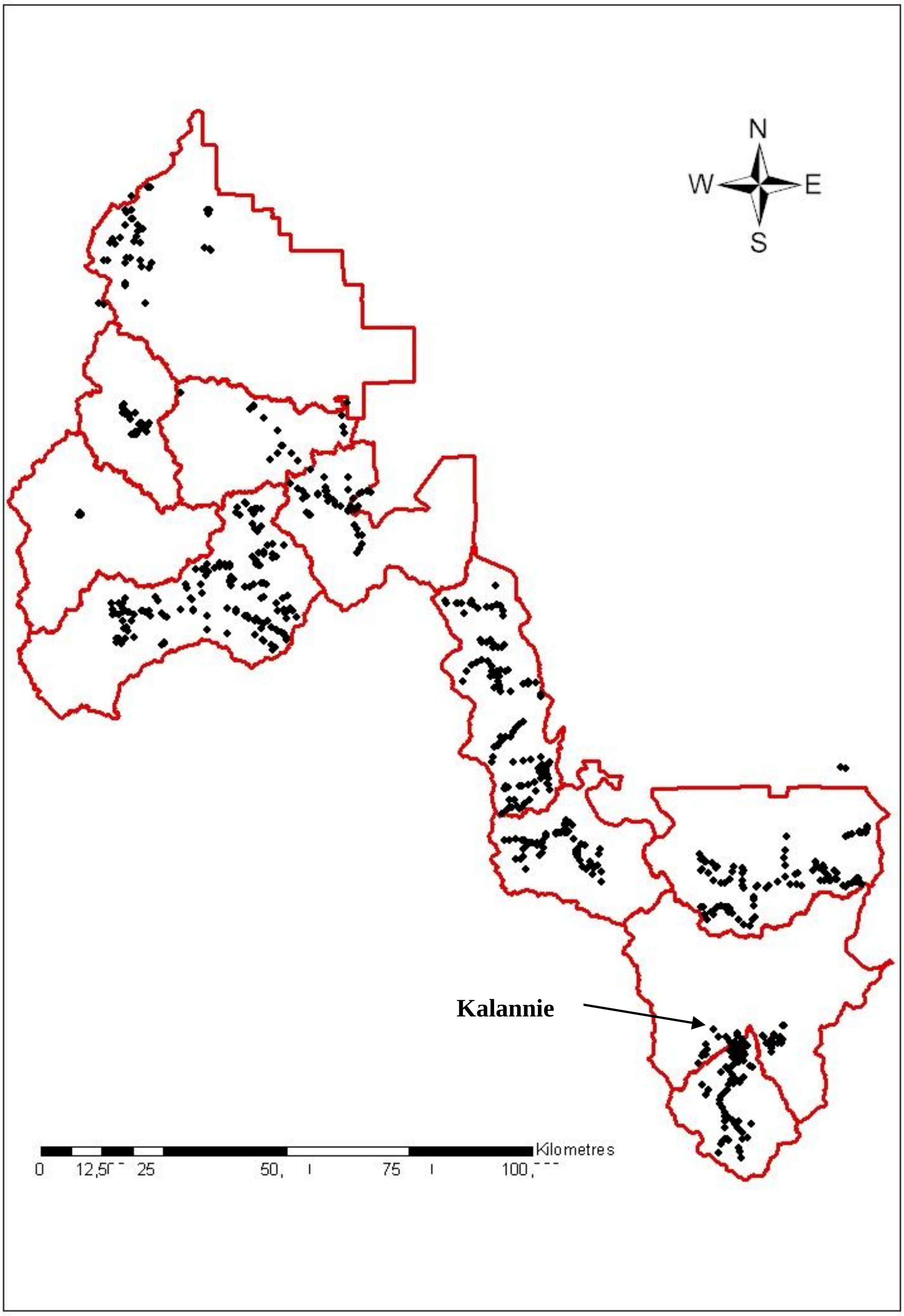


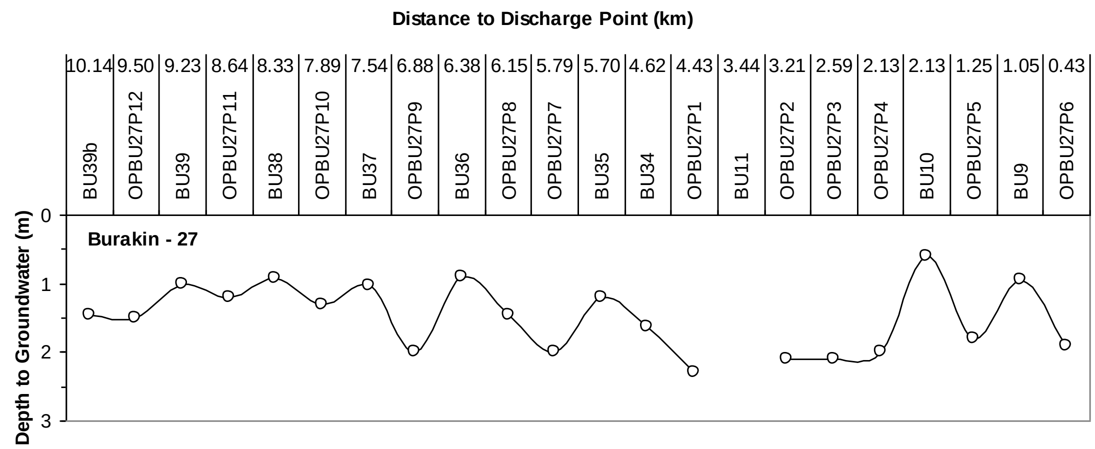
Fig. 8. Bores drilled and fitted as observation wells during the period September 2003 – September 2005.

Fig. 9. Drilling rig setting up observation well, Darling Creek.

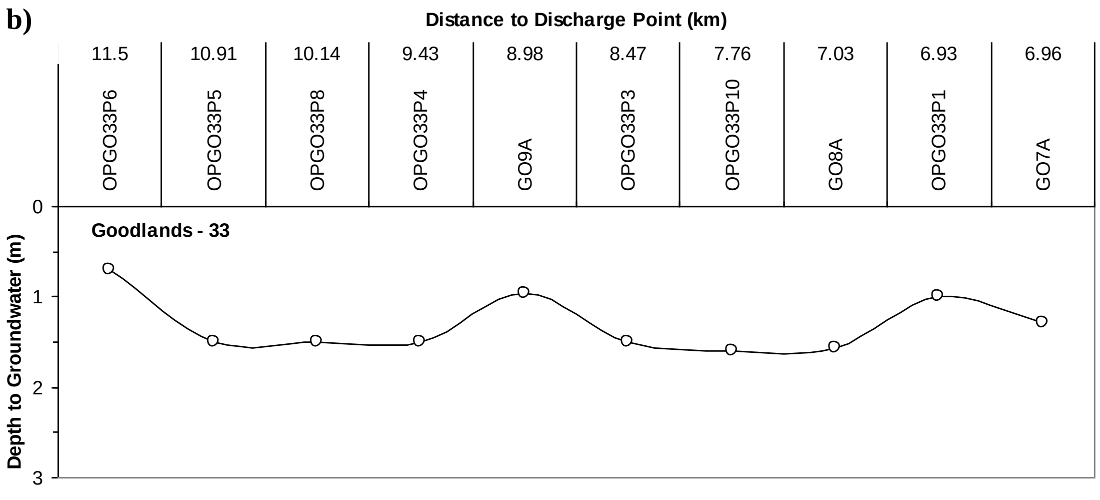
2.3. Depth to Groundwater

The accompanying graphs show the watertable depth, as reported in bores and pits along each of the subcatchment drainage lines in the first half of 2005 (Figs 10 a-j). Blanks in the graphed line are knowledge gaps – dry pits are often those that were abandoned short of target depth; bores are sometimes recorded as dry when they fail to refill satisfactorily after baling (probably because of blockages in the slotted casing). Although we have tried to show only those pits or bores that are aligned with the actual drainage line, the possibility remains that, without more-detailed work, some of the pits and bores have not been optimally sited.

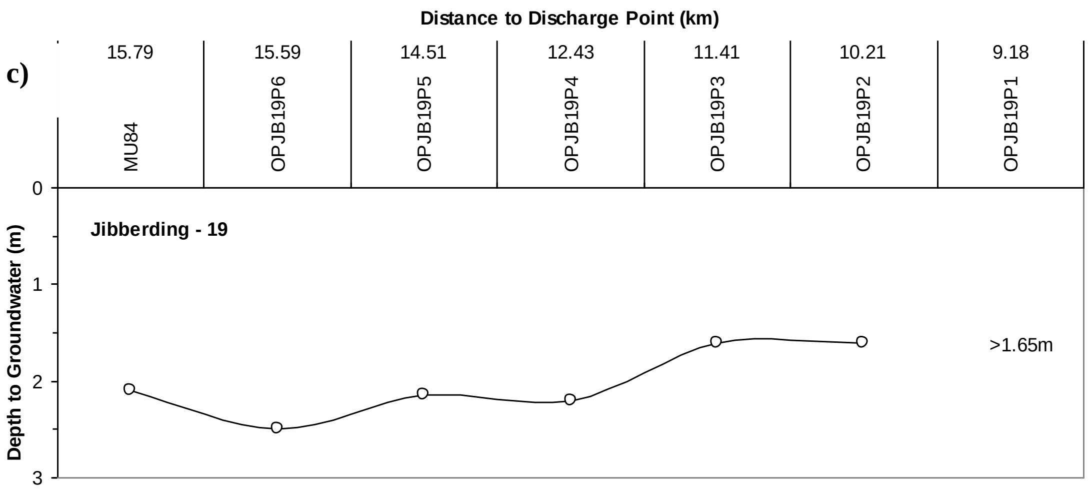
a)

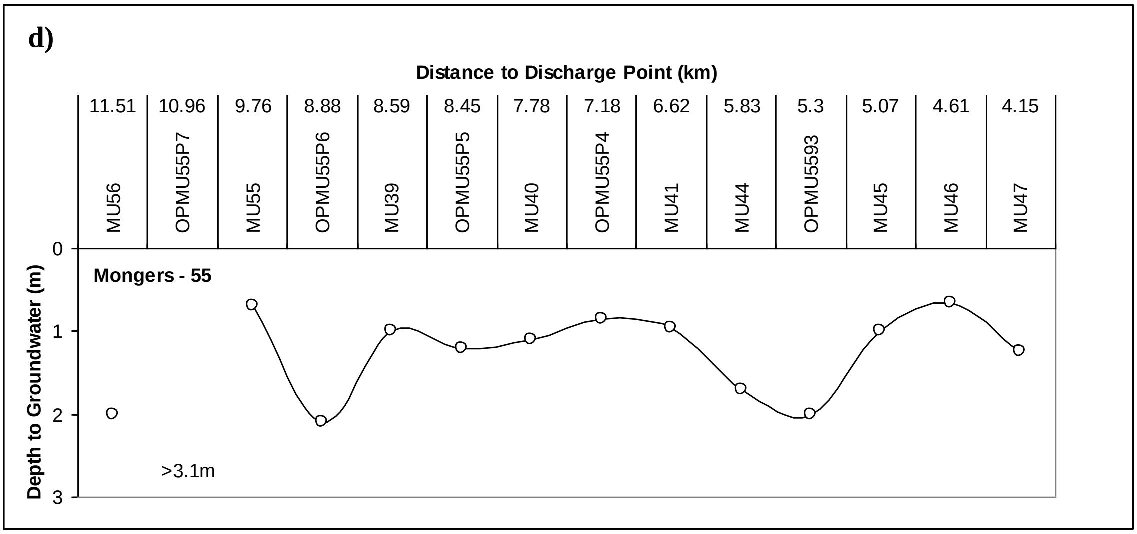

Distance to Discharge Point (km)
10.14 9.50 9.23 8.64 8.33 7.89 7.54 6.88 6.38 6.15 5.79 5.70 4.62 4.43 3.44 3.21 2.59 2.13 2.13 1.25 1.05 0.43
BU39b OPBU27P12 BU39 OPBU27P11 BU38 OPBU27P10 BU37 OPBU27P9 BU36 OPBU27P8 OPBU27P7 BU35 BU34 OPBU27P1 BU11 OPBU27P2 OPBU27P3 OPBU27P4 BU10 OPBU27P5 BU9 OPBU27P6
Burakin - 27
Depth to Groundwater (m)
0
1
2
3

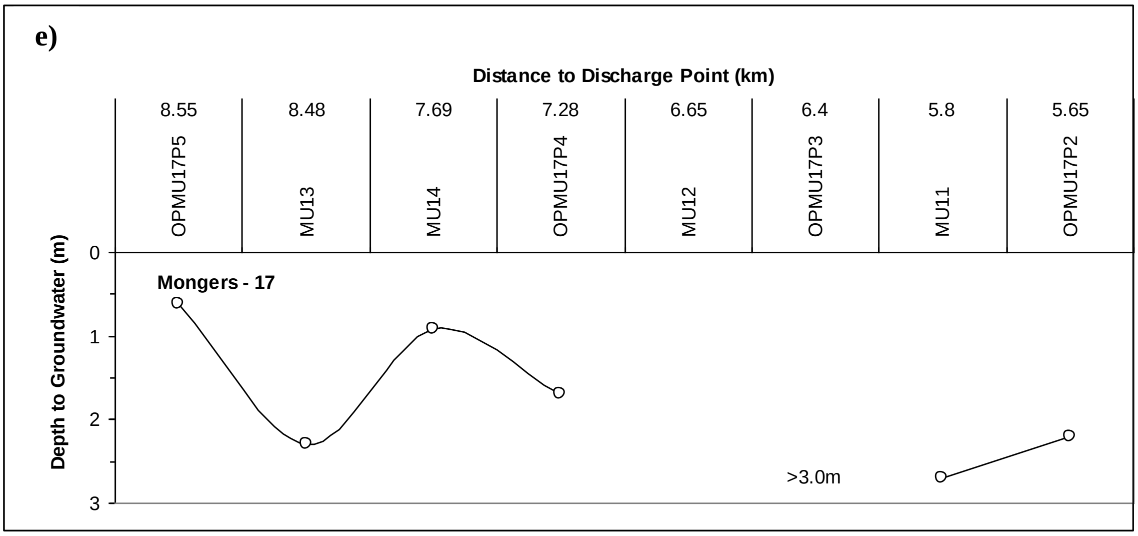
b)

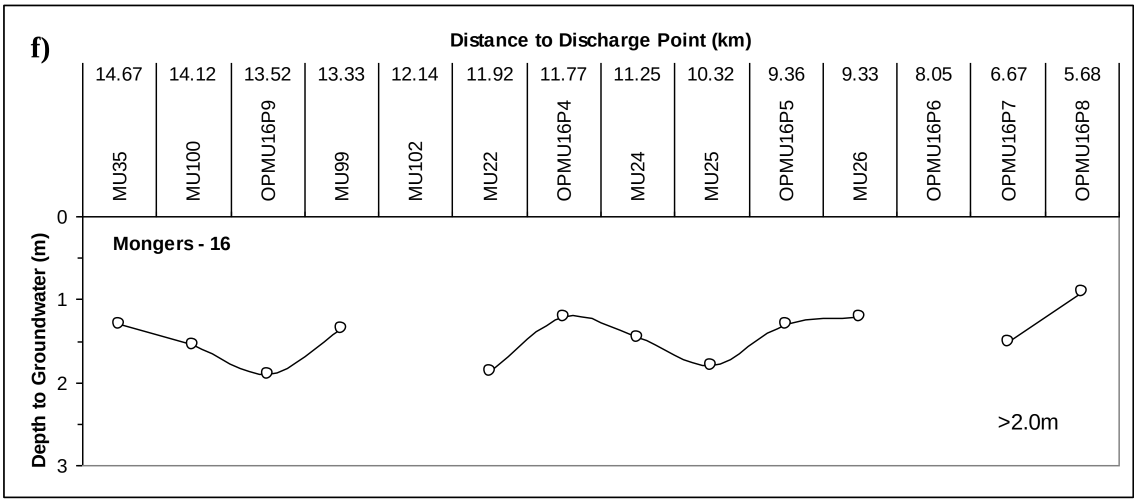

Distance to Discharge Point (km)
11.5 10.91 10.14 9.43 8.98 8.47 7.76 7.03 6.93 6.96
OPGO33P6 OPGO33P5 OPGO33P8 OPGO33P4 GO9A OPGO33P3 OPGO33P10 GO8A OPGO33P1 GO7A
Goodlands - 33
Depth to Groundwater (m)
0
1
2
3

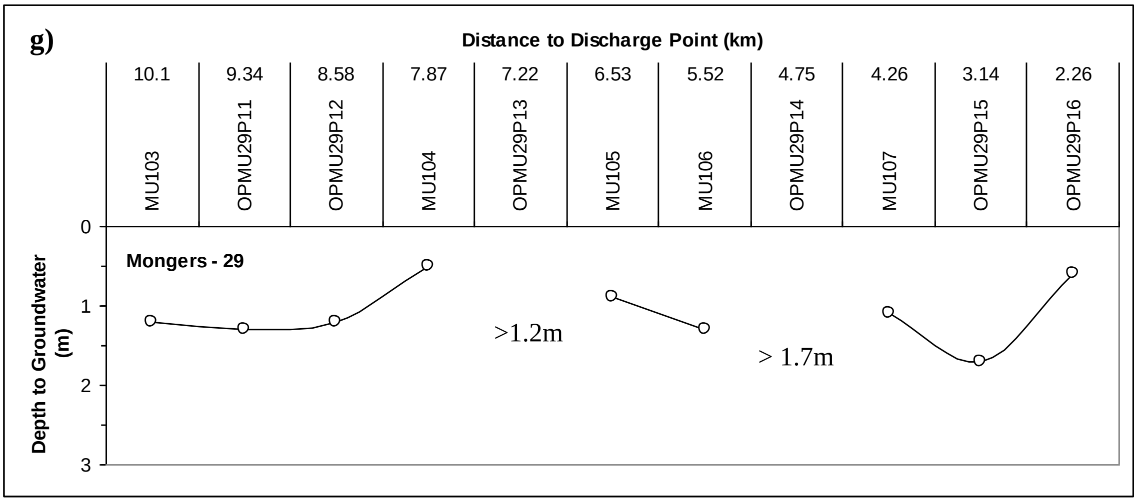
c)

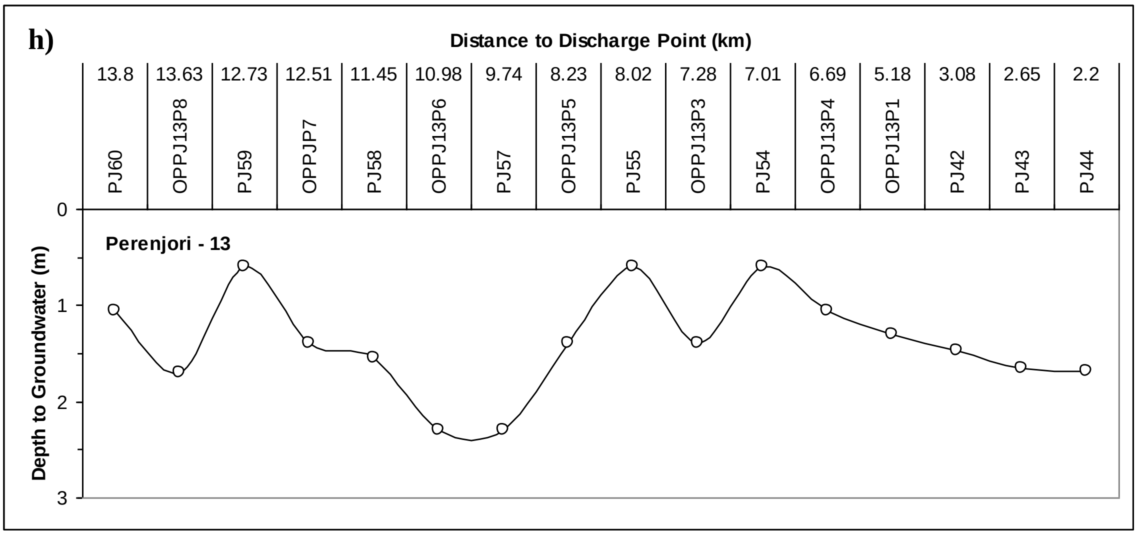

Distance to Discharge Point (km)
15.79 15.59 14.51 12.43 11.41 10.21 9.18
MU84 OPJB19P6 OPJB19P5 OPJB19P4 OPJB19P3 OPJB19P2 OPJB19P1
Jibberding - 19
>1.65m
Depth to Groundwater (m)
0
1
2
3

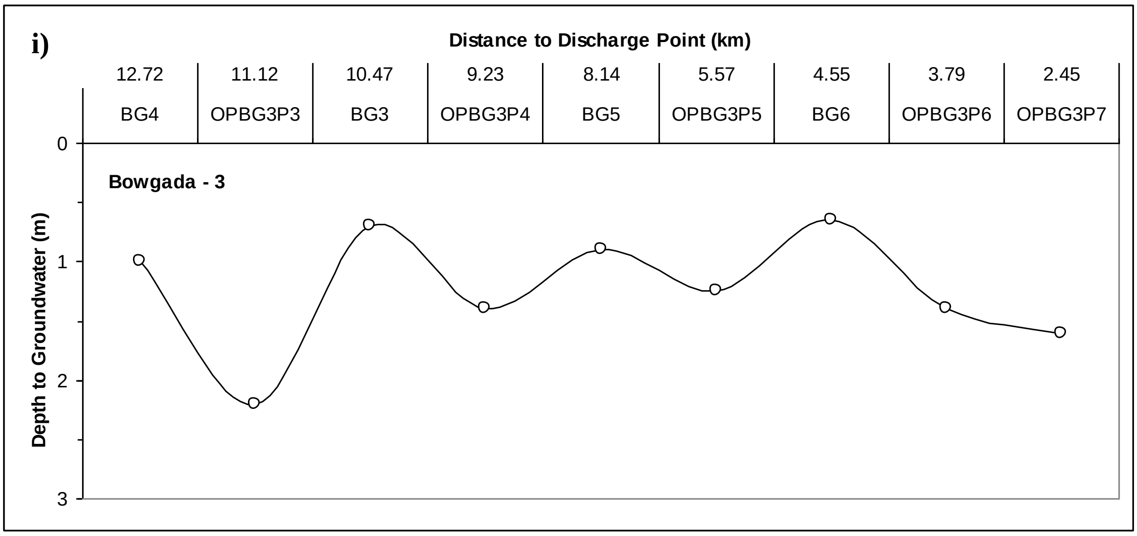

d)
Distance to Discharge Point (km)
11.51
10.96
9.76
8.88
8.59
8.45
7.78
7.18
6.62
5.83
5.3
5.07
4.61
4.15
MU56
OPMU55P7
MU55
OPMU55P6
MU39
OPMU55P5
MU40
OPMU55P4
MU41
MU44
OPMU5593
MU45
MU46
MU47
Depth to Groundwater (m)
0
1
2
3
Mongers - 55
>3.1m


e)
Distance to Discharge Point (km)
8.55
8.48
7.69
7.28
6.65
6.4
5.8
5.65
OPMU17P5
MU13
MU14
OPMU17P4
MU12
OPMU17P3
MU11
OPMU17P2
Depth to Groundwater (m)
0
1
2
3
Mongers - 17
>3.0m


f)
Distance to Discharge Point (km)
14.67
14.12
13.52
13.33
12.14
11.92
11.77
11.25
10.32
9.36
9.33
8.05
6.67
5.68
MU35
MU100
OPMU16P9
MU99
MU102
MU22
OPMU16P4
MU24
MU25
OPMU16P5
MU26
OPMU16P6
OPMU16P7
OPMU16P8
Depth to Groundwater (m)
0
1
2
3
Mongers - 16
>2.0m


g)
Distance to Discharge Point (km)
10.1
9.34
8.58
7.87
7.22
6.53
5.52
4.75
4.26
3.14
2.26
MU103
OPMU29P11
OPMU29P12
MU104
OPMU29P13
MU105
MU106
OPMU29P14
MU107
OPMU29P15
OPMU29P16
Mongers - 29
>1.2m
> 1.7m
Depth to Groundwater (m)
0
1
2
3


h)
Distance to Discharge Point (km)
13.8
13.63
12.73
12.51
11.45
10.98
9.74
8.23
8.02
7.28
7.01
6.69
5.18
3.08
2.65
2.2
PJ60
OPPJ13P8
PJ59
OPPJP7
PJ58
OPPJ13P6
PJ57
OPPJ13P5
PJ55
OPPJ13P3
PJ54
OPPJ13P4
OPPJ13P1
PJ42
PJ43
PJ44
Perenjori - 13
Depth to Groundwater (m)
0
1
2
3


i)
Distance to Discharge Point (km)
12.72
11.12
10.47
9.23
8.14
5.57
4.55
3.79
2.45
BG4
OPBG3P3
BG3
OPBG3P4
BG5
OPBG3P5
BG6
OPBG3P6
OPBG3P7
Bowgada - 3
Depth to Groundwater (m)
0
1
2
3

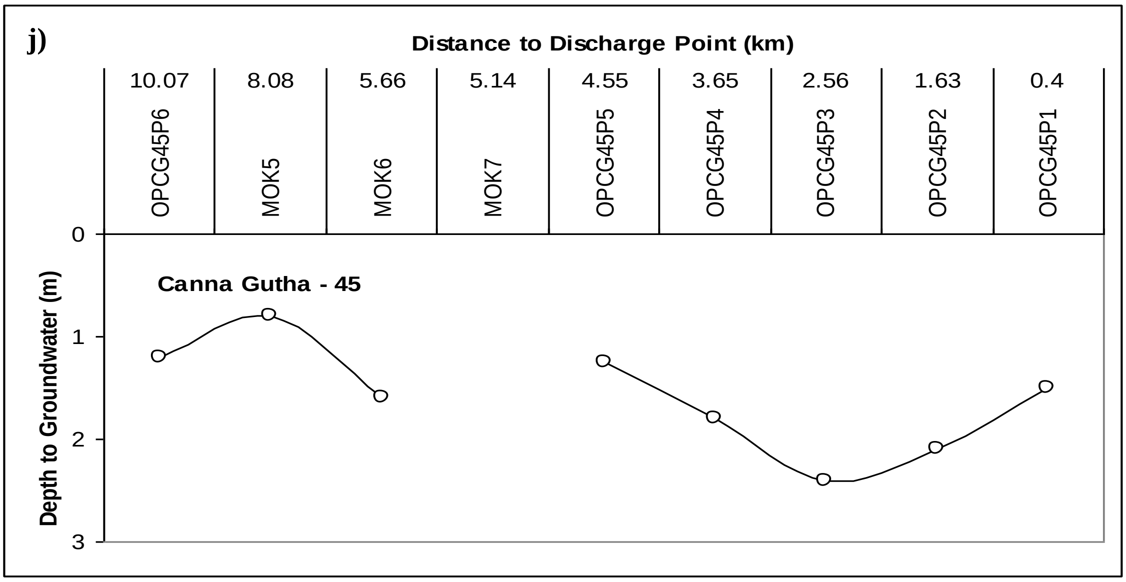


Fig. 10. Depth to watertable along drainage lines in 10 subcatchments

- **a) Burakin-27**
- **b) Goodlands-33**
- **c) Jibberding-19**
- **d) Mongers-55**
- **e) Mongers-17**
- **f) Mongers-16**
- **g) Mongers-29**
- **h) Perenjori-13**
- **i) Bowgada-3**
- **j) Canna Gutha-45**

2.4. Environmental Risk

2.4.1. Drain Precipitates

There are no published accounts about the geochemistry and mineralogy of precipitates in WA drains. However, there have been reports of high concentrations of heavy metals and rare earths in drain discharge (Ali *et al*. 2004b; Steve Rogers, CSIRO, pers. comm.), raising concerns about possible pollution in ‘downstream’ wetlands. This concern seems to have developed from the recent recognition that acid groundwater is widespread in the southwest of WA (Coleman & Meney 2003, Dogramaci & Degens 2003).

A group led by CRC LEME (Co-operative Research Centre for Landscape Environments and Mineral Exploration) and including the WA Department of Agriculture and the WA Department of Environment has been researching this heavy metal issue as part of the Engineering Evaluation Initiative (EEI). Although their study has focussed largely on the Avon Catchment, at YYCMG's request, the study has been extended to include parts of the Yarra Yarra Catchment. Much of the information we have collected from pits and bores over many years has been made available to the group and, in return, some of their findings are available to YYCMG.

The groundwater that flows into newly excavated pits is of especial interest, as it is likely to be fairly representative of drain water at that site – more so than bore water, at least. In the feasibility project, we collected water from pits (three pits in each of 10 subcatchments) on the day following excavation, and again after three months. Electrical conductivity and pH were measured at the site. Filtered samples were sent to the CSIRO, Land and Water laboratory in Adelaide for analysis of a comprehensive suite of metals, rare earths and radioactive elements, as well as standard cations and anions.

George & Rogers (2004) and Rogers & George (2005) reported that drains on the WA wheatbelt fall into two broad groups – those that are approximately neutral and those that are strongly acid – with very few intermediates. We observed a similar dichotomy in pits. Those in the north of the Yarra Yarra region (say, north of latitude 13^{o} 50' S, approximately Maya East Rd) had a pH value in the range 6.5-8.0. Most of those in the south were in the range 3.5-5.0. The northern pits, i.e. those with neutral or near-neutral groundwater, were associated with red-brown loams, with a distinct calcareous (calcrete), siliceous (silcrete), and/or ferruginous (ferricrete) hardpan (Fig. 11). Strongly acid groundwater, on the other hand, was associated with shallow duplex soils, where yellow sand was underlain directly (at depths of only 15-50 cm) by light brown or yellow clay (Fig. 12). The table below shows the subcatchments investigated in the current project, with the corresponding pH of groundwater encountered in pits.

Table . 1. Groundwater pH in pits excavated during Autumn, 2005. Subcatchments are listed from north to south. Each pH figure is the average (± standard error) from at least three pits along the main drainage line in each subcatchment.

Subcatchment	Groundwater pH
Canna-Gutha 45	7.4 ± 0.2
Bowgada 3	7.4 ± 0.3
Perenjori 13	6.7 ± 0.3
Mongers 29	7.9 ± 0.3
Mongers 16	nd
Mongers 17	6.5 ± 0.9
Mongers 55	3.8 ± 0.2
Jibberding 19	4.8 ± 1.1
Goodlands 33	6.7 ± 0.2
Burakin 27	4.9 ± 0.5

nd: not determined

In their preliminary survey of drains in the Avon Catchment, Rogers & George (2005) identified three broad types of precipitate as potential hosts for heavy metals, namely
red crusts and gels (iron oxyhydroxides) (Fig. 13a)
white films and gels (aluminosilicates) (Fig. 13b)
black ooze (monosulphides) (Fig. 13c).

We have recognised examples of each of these types in existing drains in the Yarra Yarra Catchment. In addition, some drain-wall crusts (Fig. 13d) of carbonate (e.g. lime), sulphate (e.g. gypsum) and halide (e.g. salt) are known from other areas to contain trace concentrations of metals as impurities (e.g. Kohut & Dudas, 1993).

Samples from Yarra Yarra, as well as other parts of the wheatbelt, are being examined by an independent group at the University of Western Australia in Perth. Although this research is at only an early stage, it is clear from mineralogical work completed so far that some of the hosts are in fact hydrous or amorphous species. That is, they have no well-defined crystalline structure, but have instead a temporary and precarious existence, which depends on immediate environmental conditions (such as temperature, humidity, acidity and/or exposure to air). Amorphous phases are unstable and can change chemically (releasing whatever trace elements they include) to form stable minerals. Many of these minerals, such as iron oxides, are relatively stable in rainwater, but become soluble (along with their cargo of metals) under strongly acid conditions.

A more-detailed knowledge of the chemistry of drain water and precipitates will allow us to devise effective management strategies and plan for any problems that might arise from the composition of drain sediments. For example, if a drain is blocked and allowed to dry out, black monosulphide muds will react with oxygen in the air to generate acid. When flow resumes, the water will become considerably more acidic and capable of carrying higher concentrations of most trace elements, including heavy metals such as copper and cadmium. Another research finding that has management implications is that many of the minerals that are known to carry metals have specific requirements for oxygen (or the lack of it). This means, for example, that solubility might be enhanced in strongly reducing conditions, such as those produced by decomposing matter (Fig. 14). For this reason alone, quite apart from hydraulic considerations like maintaining an unobstructed flow and scale (iron oxide) build-up on walls, it is important to clean drains periodically.

Geochemical and mineralogical work, begun during the current feasibility study, will continue in future years. We acknowledge the assistance of the WA Department of Agriculture in introducing YYCMG to recent research in this field and to some of the researchers.

Fig. 11. Soil profile in pit PJ13P1, Perenjori 13 subcatchment. Light brown sandy loam (0-35 cm) underlain by pale hardpan (30-80 cm), underlain by mottled red-brown/green-grey clay.

Fig. 12. Soil profile in pit JB19P3, Jibberding 19 subcatchment. Pink and red-yellow sandy loam (0-35 cm) underlain abruptly by pale yellow clay. Boundary highlighted by crowded roots.

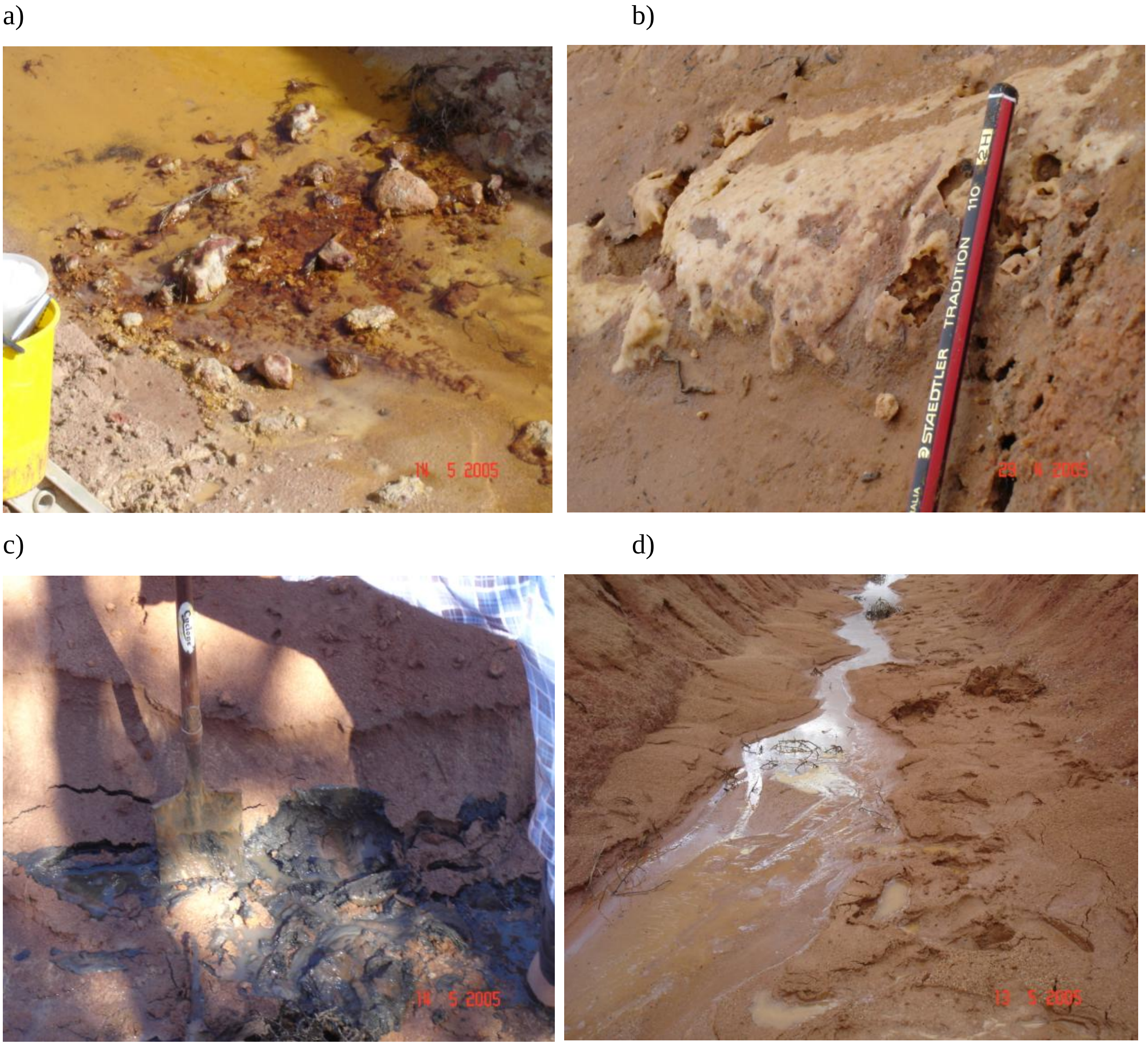


Fig. 13. Precipitates found in Yarra Yarra drains; a) iron oxyhydroxides; b) gypsum; c) monosulphides; d). aluminosilicates

Fig. 14. Drain precipitate; Note rust-coloured iron minerals on the drain floor are being dissolved close to the decomposing matter to form a black halo.

2.4.2. Downstream Effects

The most obvious and unavoidable effect of drainage on the downstream environment is the increased availability of water. The long-term consequences of continuous waterlogging on the ecology of wetland systems, accustomed to irregular and occasional soakings, is unknown. Since there have been no reports to date of environmental damage in the Yarra Yarra saltlake chain, despite discharge there from more than 20 drains, it is likely that any impacts will be subtle and difficult to detect. In an ecological study commissioned by YYCMG, the only environmental impact reported at the outfall area of the Youangarra drain, Goodlands, was a slight increase over an area of 11 ha in the succulence of samphire (Regeneration Technology 2003; Appendix VI).

A slightly more plausible concern is the possibility of downstream contamination. Even though a recent study found no significant increase in heavy-metal concentration in drain-mouth sediments, compared with sediments collected from distant parts of the same saltlake (Fordyce 2005; Appendix VII), YYCMG treats this as a serious, although remote, possibility. In any drain-construction work that YYCMG undertakes, there is provision for regular monitoring of metal, rare-earth and radio-element loads in groundwater, drain precipitates and outfall sediments. There will also be regular biological monitoring of communities in outfall wetlands. In addition, YYCMG will continue its relationship with the research community in this field. Our aim here is to develop best-practice management techniques from a genuine understanding of the situation

2.5. Prioritising the Subcatchments

YYCMG has examined 10 subcatchments in the current feasibility study (Fig. 15). Attributes are listed in the accompanying table. Most attributes are presented simply as values. For most of the subsurface attributes, such as pH or depth to groundwater, these values represent averages from all the bores and pits along the route of the proposed drain. For some attributes, such as inflow, where assigning a precise value would dishonestly exaggerate our understanding of the soil-water system, we have given relative terms like ‘slow’ and ‘fast’. For some attributes, such as ‘Cross-regional Significance’, the only possible entry is Yes or No. Shaded attributes are those considered critical. The subcatchments on the table are listed in order of latitude; there is no implication intended that subcatchments high in the order are ‘better’ than others.

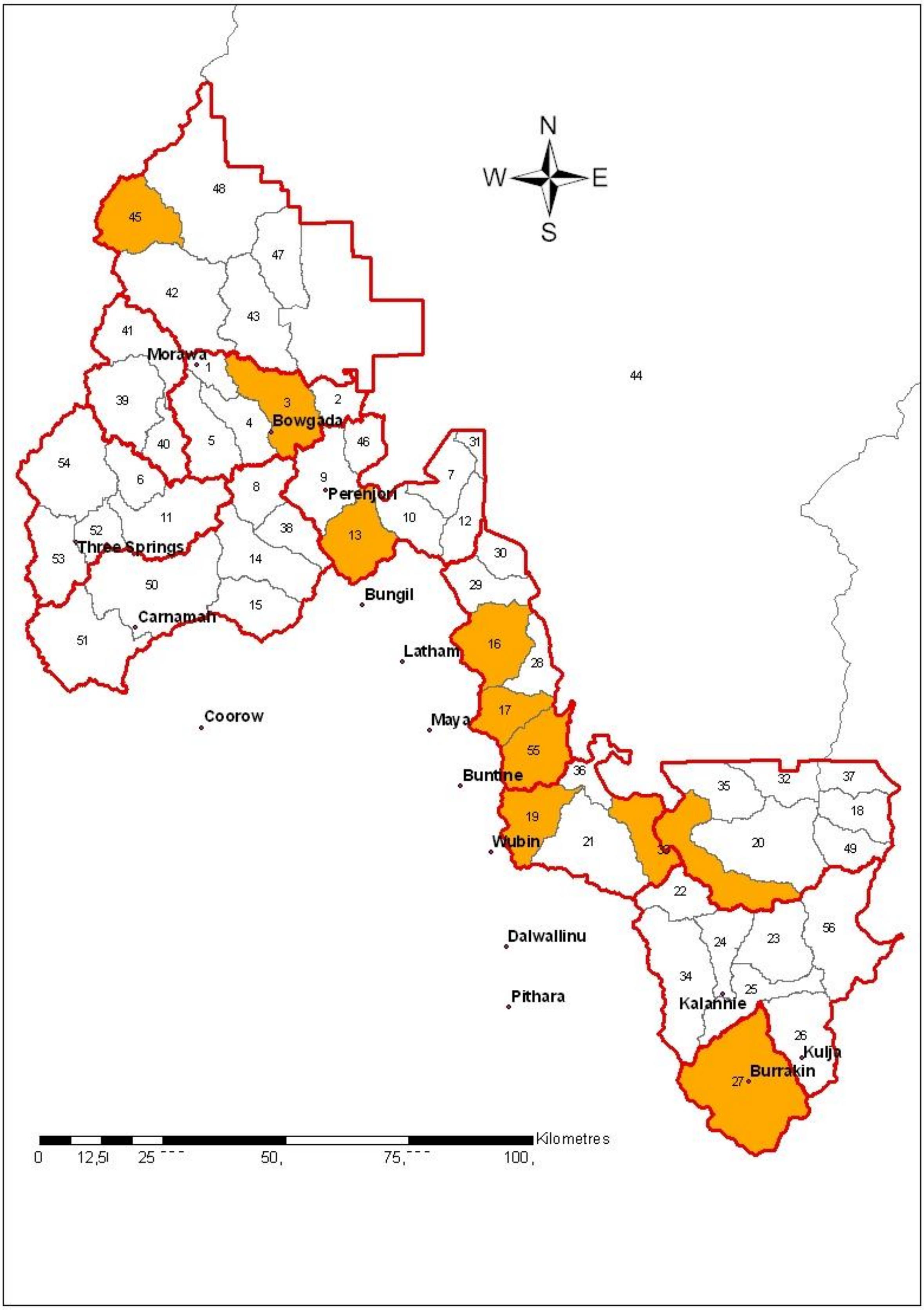


Fig. 15. The 10 subcatchments investigated in detail in the current study.

Table 2: Subcatchment attributes.

Subcatchment Number	**45**	**3**	**13**	**29**	**16**	**17**	**55**	**19**	**33**	**27**
Subcatchment Name	**Canna Gutha**	**Bowgada**	**Perenjori**	**Mongers-29**	**Mongers-16**	**Mongers-17**	**Mongers-55**	**Jibberding**	**Goodlands**	**Burakin**
Total Catchment Area (ha)	19 079		17 788	12 431	19 647	11 478	17 754	15 831	14 796	44 911
Average Gradient (%)	0		0.13	0.25	0.24	0.28	0.2	0.21	0.1	0.1
Workable Gradient for all Sections?							Yes			
Cross- Regional Possibilities?							Yes			
Whole-catchment Demo?	No						Yes			
Contributing Landholders (%)							100			
Private:Public Funding Ration							1.5			
Discharge Area	Large Saltlake	Claypan	Small Saltlake	Large Saltlake	Large Saltlake	Large Saltlake	Large Saltlake	Large Saltlake	Large Saltlake	Large Saltlake
Threatened Private Buildings										
Threatened Public Assests										
Threatened Arable Land										
Threatened Vegetation										
MOU (Memorandum of Understanding)			No				Yes	Yes	Yes	Yes
NOI (Notice of Intent)	Yes	No	No	No	No	No	No	No	No	No
Agreeable to 100m Buffer										
Subsurface Attributes										
WATER										
pH	7.4	7.4	6.7	7.9		6.5	3.8	4.8	6.7	4.9
Inflow	Med-Fast	Med-Fast	Med-Fast	Slow-Mesd	Med	Slow	Fast	Slow-Med	Fast	Slow
Depth to Groundwater (m)	1.7	1.6	1.5	2.1	1.3	2.1	1.2	1.9	1.3	1.8
Salinity (mS/cm)									75	
SOIL										
Depth of Topsoil (cm)	85	116	72	125		115	81	54	72	37
Firmness	Med-Soft	Med	Soft	Med	Soft	Soft	Soft	Med-Hard	Med-Hard	Soft

3. Priority Number 1: Subcatchment MU55

3.1. Background

At the 'downstream' (eastern) end of the subcatchment, the watertable encountered in pits and bores was particularly shallow (0.5-1.0 m) and the rate of inflow into pits (a surrogate for drawdown in this study) was particularly high. Shallow watertables and saline groundwater are also causing tree deaths in upstream depressions, near the western end of the subcatchment. Since natural creeklines in the MU55 area are silted up and often fail to carry even surface water (let alone ponded groundwater) out of the catchment, these farmers have no way at present of draining their properties. There are immediate threats to private property (cropland/pasture, a farmhouse, several farm sheds, numerous fences), public infrastructure (six road crossings, of which two are already in dubious condition), and environmental assets (large patches of remnant woodland near the edge of Mongers Lake and in the Buntine East Water Reserve, numerous revegetation efforts).

There are five farming families in the subcatchment. All are enthusiastic about the drainage / revegetation project and have committed to put in several kilometres of spur drains at their own expense if we can provide the initial arterial drain, and deal with administrative and environmental requirements.

3.2. Proposed Works

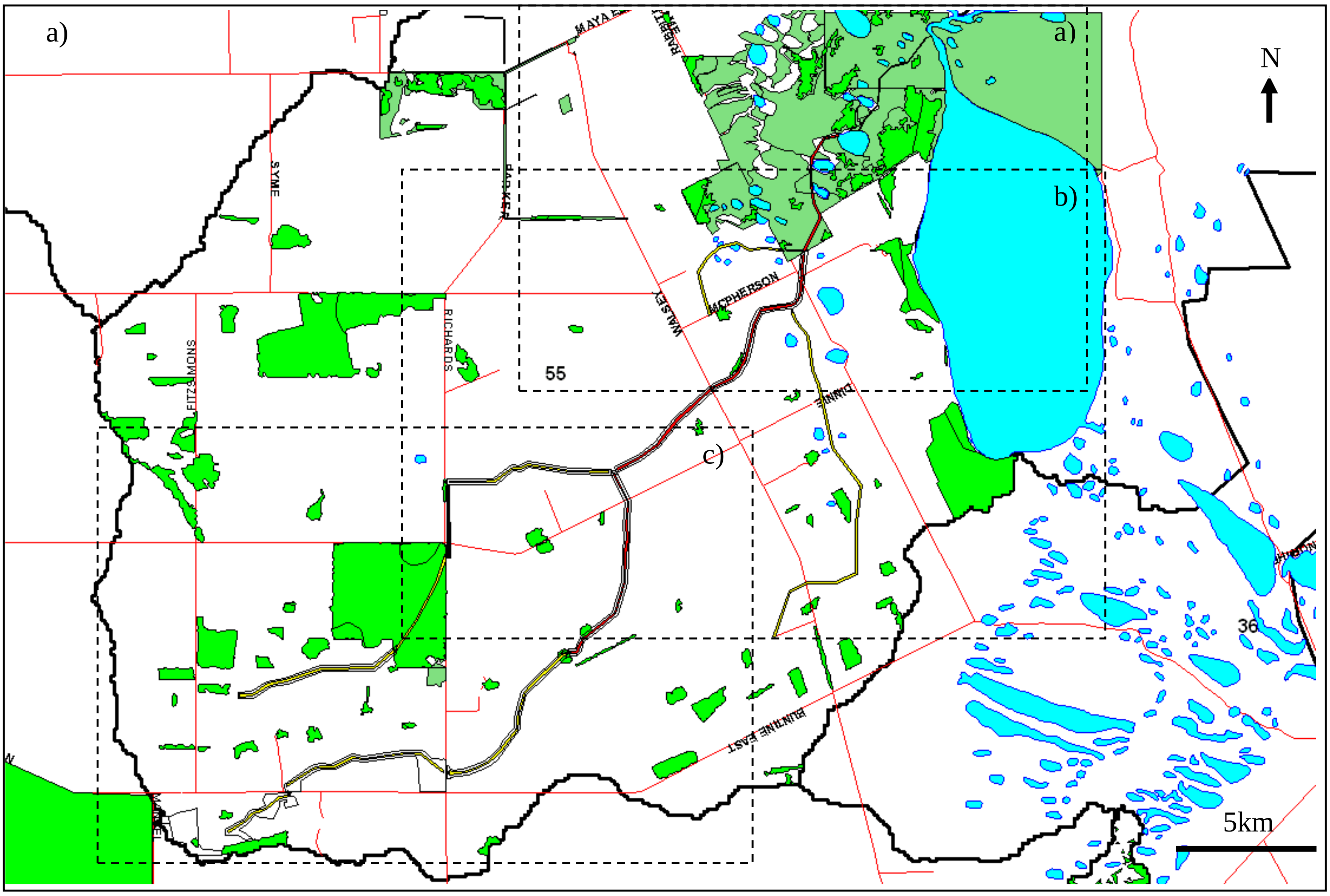
Drainage works planned for Subcatchment MU55 are summarised in Figs 16 a-d below. Notes included as text boxes with these maps also outline the proposed schedule. The plan, devised by local residents and YYCMG staff over numerous meetings, is as follows:

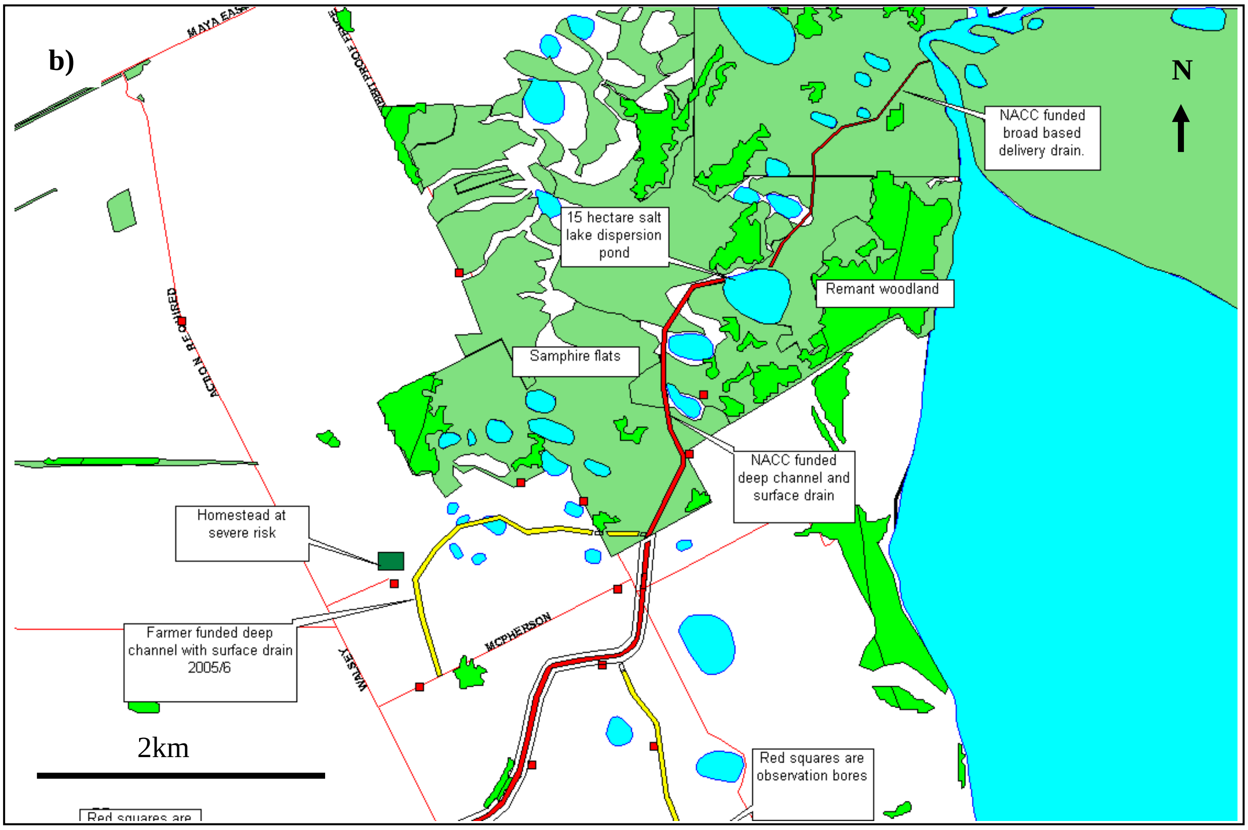
2005/6. The 10 km 'main drain' from the saltlake will be constructed with public funding. It will extend westwards from Lake Mongers, through degraded woodland, then through farmland to a point where the streams divide, north of Dinnie Rd. The easternmost 2 km section will be a delivery drain only, which will carry both surface water and groundwater. Elsewhere, the drain will separate the groundwater and surface flows, as described in Section 1.3 of this report. In addition, approximately 13 km of spur drains will be built (to YYCMG specifications) by resident farmers at their own expense. Future corridors will be marked out and prepared for revegetation; some will also be fenced during this period.

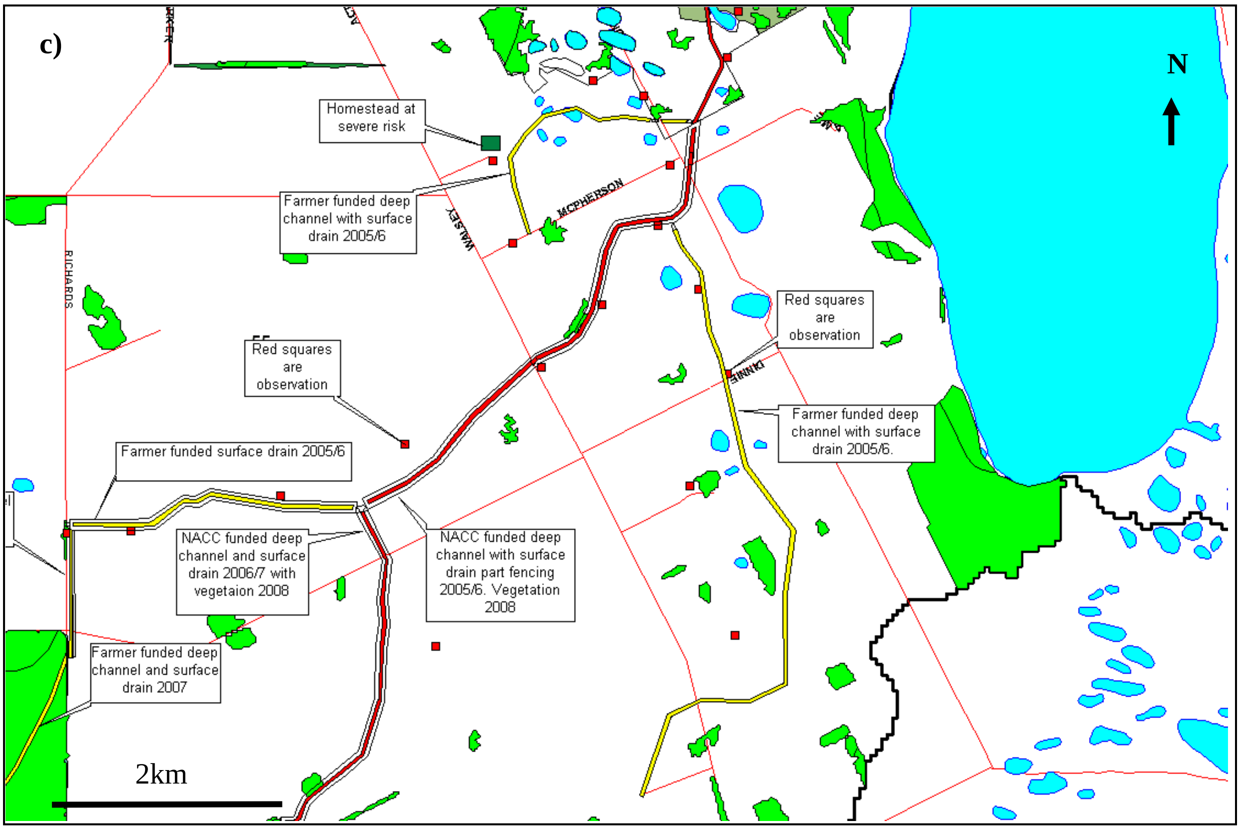
2006/7 Hopefully, a second round of public funds will be made available for an additional 3 km drain along the southern branch. This drain will be extended, using private monies, across Richards Rd to saline seeps near the top of the catchment. With support from the local farmer, we will then continue a fenced revegetation strip across the catchment divide to Buntine Reserve. A northern branch, also privately funded, will extend through the Buntine East water reserve, assuming appropriate permission can be negotiated with the Dalwallinu shire. Fencing, to exclude stock from the rehabilitation strip, will continue (planned fences, not built in the preceding year, will be erected now). We will also carry out limited reclamation work, such as deep-ripping (as detailed in Section 3.3 below).

2007/8 Depending on the progress of soil reclamation, we anticipate that ground will probably be suitable for planting to begin in 2007/8. A farmer-funded excavation will extend the northern branch from the Buntine East water reserve. Fencing and reclamation will continue.

>2008 Reclamation, revegetation and monitoring will continue as required.




b)
N
NACC funded broad based delivery drain.
15 hectare salt lake dispersion pond
Remant woodland
Samphire flats
NACC funded deep channel and surface drain
Homestead at severe risk
Farmer funded deep channel with surface drain 2005/6
MCPHERSON
WALSEY
2km
Red squares are observation bores
Red squares are


c)
N
Homestead at severe risk
Farmer funded deep channel with surface drain 2005/6
MCPHERSON
WALSEY
RICHARDS
Red squares are observation
Red squares are observation
Farmer funded surface drain 2005/6
NACC funded deep channel and surface drain 2006/7 with vegetaion 2008
NACC funded deep channel with surface drain part fencing 2005/6. Vegetation 2008
Farmer funded deep channel with surface drain 2005/6.
Farmer funded deep channel and surface drain 2007
2km

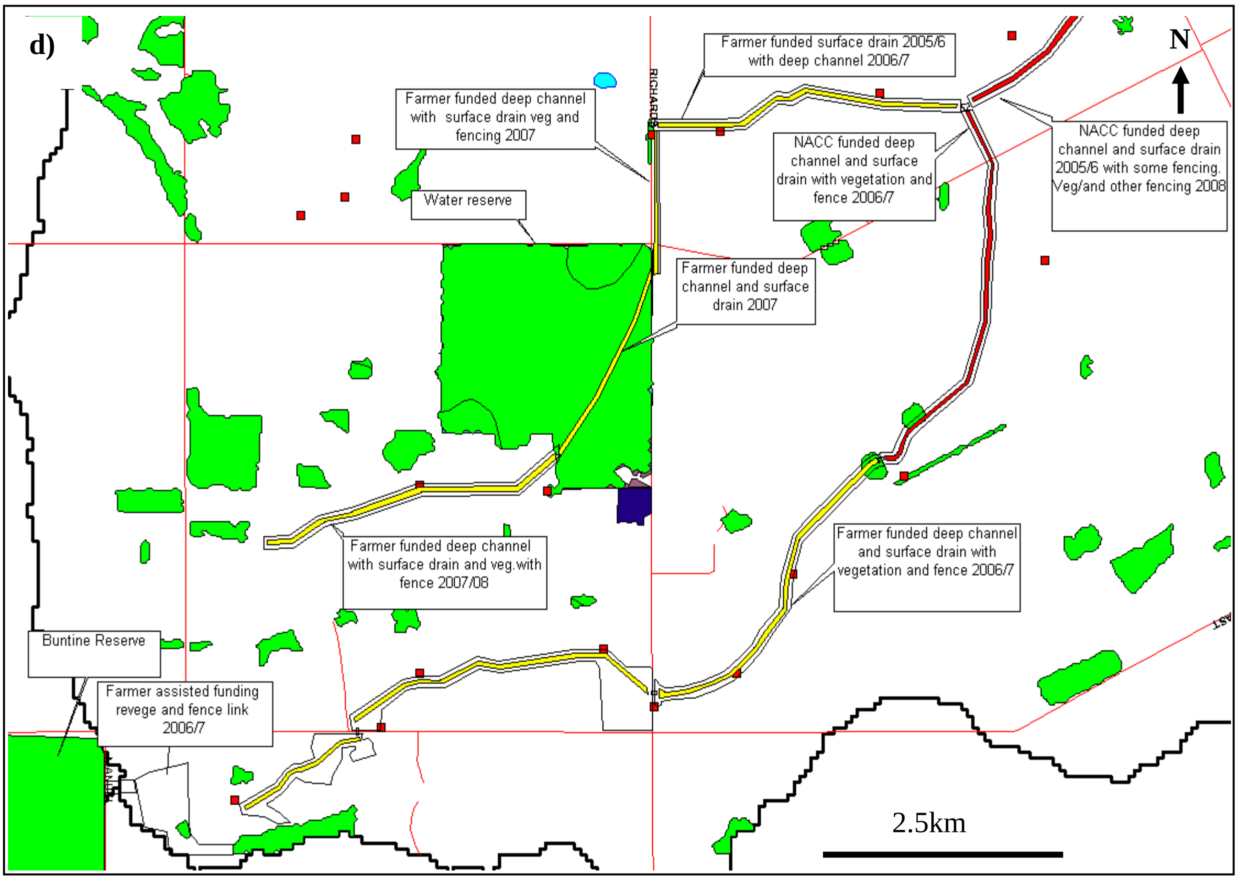


Fig 16. Proposed drainage plan for subcatchment MU55.

a) Overview; b) Northeast section; c) Central section; d) Southwest section. Publicly funded drains are shown in red. Privately funded drains are yellow. Drains bordered with a line on each side are fenced corridors.

3.3. Reclamation of Waterlogged and Saline Land

Drainage will certainly relieve waterlogging on valley floors. However, the soil will remain saline and, in some cases, also sodic. Soils, as long as they are no longer exposed to saline water, usually recover from salinity after several years of leaching. Sodic soils – those with a high proportion of sodium over magnesium and calcium ions on clay adsorption sites – are recognised by their elevated 'exchangeable sodium percentage' (ESP). With increasing sodium content, clays in the soil become unstable and are likely to become dispersive. The end result is that that soil structure breaks down in sodic soils. In dry conditions, the surface might be hardset or powdery, depending on local history. In wet conditions, dispersed clays gum up pores in the soil, which further reduces permeability and makes the land even more prone to waterlogging.

Fertility and workability might be gradually restored to sodic soils by natural processes over several decades (or even centuries). This lengthy process can be accelerated, however, by rapidly building up organic matter with an early salt-tolerant crop, such as tall wheat grass or pucinella, applying gypsum to resupply magnesium and calcium, and deep-ripping, both to work in the gypsum and organic matter, and also to open the soil profile to surface leaching. Reclamation practices are discussed in Moore (1998) and Barrett-Lennard (2003).

3.4. Revegetation

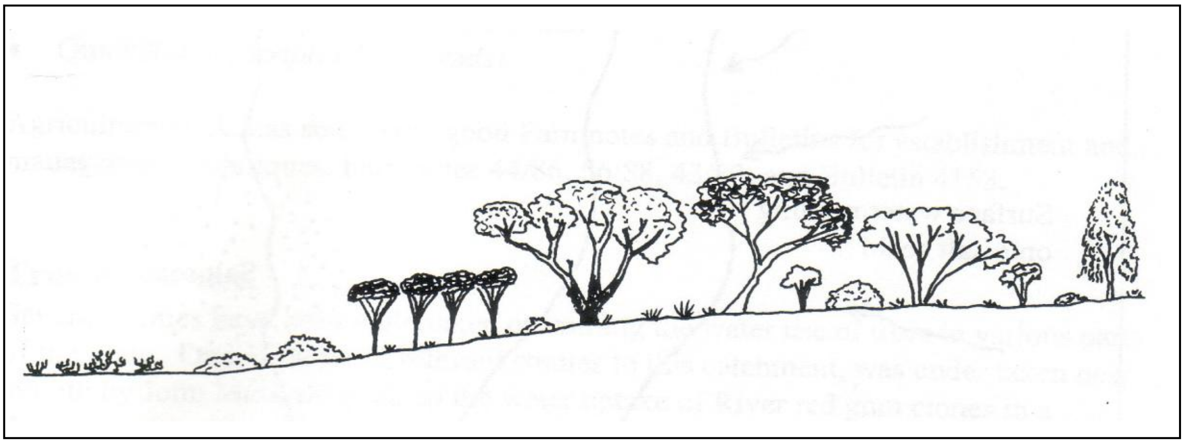
It probably needs to be emphasised that there is no prescriptive method that can (or should) be applied to drainage lines throughout the region – or even to all sections along a single drainage line. Instead, the methodology needs to be flexible, informed by regular monitoring and an understanding of the landscape. The species composition of seed-mix or tubestock (or some combination of the two, according to local needs) is discussed in Appendix IX. The following description of drainage lines in the southern part of the Yarra Yarra, as well as suggestions for their revegetation, has been taken from Clarke (undated). [Goodlands catchment revegetation report. Report prepared for the Goodlands Catchment Group, WA Department of Agriculture, Geraldton.]

"Drainage lines in the catchment are generally ill defined because of little vertical relief. The main drainage line in the western half of the catchment begins to be more defined as a series of interconnected salt lakes, beginning around Sawyers property. East this point the main drainage line is evident only from the distribution of red alluvial soils and the occasional small ephemeral pond.

"It is likely that prior to clearing, this drainage line would have only been a moisture gaining site with corresponding woodland vegetation system. Since clearing however, and the associated increase in water runoff, the drainage line can now conduct water slowly and ponding occurs where small depressions occur in paddocks. Areas bordering drainage line channels are moisture gaining sites and as such can make good sites for revegetation from not only a salinity point of view but also from a nature conservation and drainage line stability aspect.

"Drainage lines are important areas as they carry excess surface water from the catchments of neighbouring saltlakes. These areas are also at greatest risk from salinity. When revegetating areas flanking drainage lines we are trying to construct a similar community of plants that would have grown there originally or if conditions have deteriorated, try to construct the healthy saline plant communities that exists on naturally saline drainage lines.

“What follows is a typical cross section through a saline drainage line indicating appropriate species starting with the most salt tolerant closest to the drainage channel. A minimum vegetated width of 50 metres either side would be suitable.



samphire	Atriplex. Melaleuca uncinata	Eucalyptus loxophleba	E. salmonophloia
	bluebush spp. M adnata	E. salicola	Pittosporum phyllaraeoides
	M. eleuterostachya	E. brachycorys	Acacia eremaea
		Acacia acuminata	A. hemiteles ”

Fig. 17. **Typical cross section through a saline drainage line.**

“Much of the main drainage channel in the catchment has remnants of vegetation flanking its margins which if protected from grazing should regenerate in time. Generally natural regeneration events occur after episodic events such as flooding. An excellent example of this can be seen on Colin Bywaters property where after a heavy rainstorm floodwaters inundated vegetation along a fenceline. Several months later, around the high water mark of the flood, hundreds of *Melaleuca eleuterostachya*, *Melaleuca adnata*, York gums and mallee seedlings appeared. Colin then extended the boundary of the fence to exclude stock and now the five year old seedlings are 3 to 4 metres high.”

3.5. Monitoring

Table 3. Proposed monitoring schedule for Subcatchment MU55.

Attribute	Frequency
1. **Groundwater**	
pH and EC	monthly
filtered sample for analysis	quarterly
flow rate near discharge point	daily
flow rate in each spur	daily
rainfall & pan evaporation	daily
2. **Observation wells & piezometers (at least 3 transects)**	
depth to groundwater	weekly
pH and EC	monthly
3. **Sediment and debris**	
visual inspection	monthly
4. **Drain precipitates**	
visual inspection	monthly
specimens for identification	occasional
samples for analysis	quarterly
5. **Woodland near proposed delivery drain**	
photopoints	yearly
vegetation condition	yearly
fixed transects	
vegetation structure	
stem density	yearly
basal area	yearly
size-class distribution	yearly
canopy cover (or leaf area index)	yearly
floristics	
species composition (presence-absence, abundance)	yearly
diversity	yearly
rare flora	yearly
fauna	
indicator groups (eg birds, ants, trapdoor spiders)	yearly
6. **Lake edge shrubland near discharge** (mostly samphire & other chenopods)	
photopoints	yearly
fixed transects (as for woodland above)	yearly
7. **Drained soil**	
salinity	half-yearly
sodicity	half-yearly
water-holding capacity	half-yearly
plant colonisation	half-yearly
profile development	half-yearly
crust formation	half-yearly
8. **Cropland**	
plant colonisation	half-yearly
production	yearly
fertiliser rate	yearly

Revegetation along the drain corridor will begin once the valley-floor soil is capable of supporting non-saline vegetation. Additional surveys will be introduced at that time to monitor the success of plantings.

3.7. A Regional Corridor

By rehabilitating the drainage line in Subcatchment MU55 and extending the revegetated corridor westwards across the watershed, we would create an environmental link from the >3 000 ha Buntine Reserve in the Moore catchment basin to Mongers Lake in the Yarra Yarra. From the western shore at this part of the lake, there is a narrow promontory that almost closes the lake off, providing close access to the Yalgoo rangelands (Burbidge *et al.* 1989). To the south, there is continuous cover to the CALM reserve at Jibberding, and from there to Lake Goorly. Lake Goorly is connected to Lake Moore in the Ninghan catchment by the ‘Goodlands Environmental Link’, an initiative of the Goodlands Landcare Conservation District, which has been functioning as a wildlife corridor since 1997. The total distance along proposed and existing sections of the corridor is 120 km.

A spur from Lake Goorly links remnant vegetation in the Yarra Yarra with East Nugadong Reserve in the Avon catchment (see Kitchener *et al.* 1979 for a species list of the East Nugadong reserve). Features mentioned above are shown in Fig. 18.

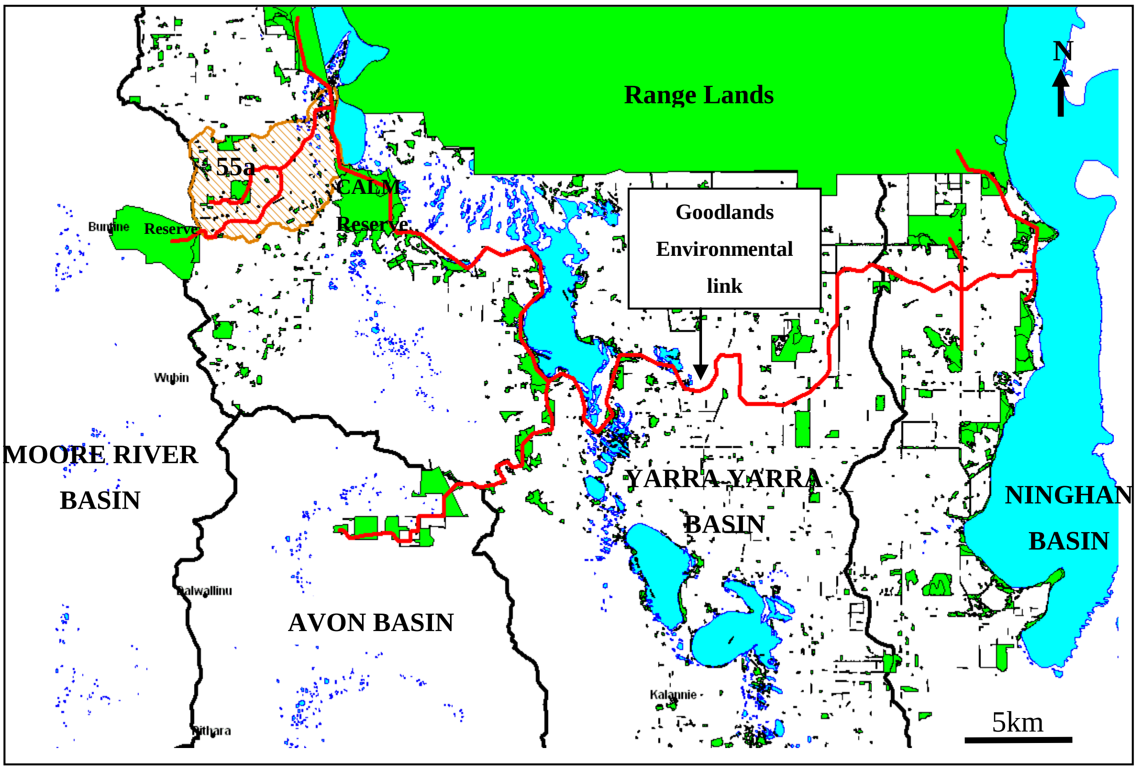


Fig. 18. Proposed and existing regional flora/fauna corridors.

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