



Dept of Water, Land & Biodiversity
Conservation

**Didicoolum Drain/Marcollat
Watercourse**

Hydrogeological Assessment

Report

July 2004



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1. Introduction

GHD Pty Ltd (GHD) was engaged by the Department of Water, Land and Biodiversity Conservation (DWLBC) to conduct an assessment of hydrogeological conditions in the vicinity of the Marcollat Watercourse and Didicoolum Drain.

This commission resulted from discussions held with Mr Rob Kemp of DWLBC, in which it was stated that the proposed Didicoolum Drain will pass through properties of both low and high agricultural value, with the reasons for the variation in land capability being unknown. In a meeting held on 16 February 2004, it was stated that there was a need to consider the effects of installing the drain on groundwater, land, soils and the wetlands of the Marcollat Watercourse.

GHD was then invited by DWLBC to tender for the hydrogeological investigation in the Marcollat Watercourse and agricultural flat in the vicinity of the proposed Didicoolum drain. A proposal was submitted to DWLBC on 27 February 2004, and approval obtained on 19 March 2004 by the receipt of contract documentation.



2. Location and Physiography

The Didicoolum drain (as proposed) is to be located about 50km south of Keith, between Bordertown and Kingston S.E (Figure 1.) It is intended to pass through the J. Nitschke, A. McGregor, M. Verco, D. Prosser and T. Truscott properties and discharge into an existing drain on a property owned by B Brinkworth, extending for a distance of about 17km.

The Didicoolum drain alignment and the Marcollat Watercourse occur in an area of relatively flat land bounded to the east and west by low hills of sand; the Harper Range on the eastern side and the Woolumbool Range to the west. The Harper Range tapers out just to the north of the Kingston – Bordertown road. Land elevation ranges from about 25m in the flats to about 70m in parts of the Woolumbool Range.

The Marcollat Watercourse occurs on the western side of the flat and consists of a string of swamps and lagoons (wetlands) linked by naturally occurring and/or manmade channels. There are over 20 wetlands in the study area (Harper Range, Woolumbool Range, Brinkworth property boundaries at both north and south) including The Muddies, Little Sister, The Sisters, Lever Swamp, Bullocky Swamp, South Reedy, Little Reedy, Big Reedy, Reedy Swamp, North Swamp and Bimbimbi (Kyeema) Swamp.

The watercourse extends for approximately 30 km from the south-western edge of the inter-dunal flat between the Harper Range and Stewart Range, flowing north-westerly towards Jip Jip Conservation Park. The flow in the Marcollat Watercourse is controlled at this location by a weir, referred to as the Jip Jip weir. The Marcollat Watercourse is considered to be of significant conservation value due to its size and diversity of flora and fauna and because the water regimes and salinities of the wetlands vary, providing a system of diverse and complimentary habitats.

It is estimated that Morambro Creek contributes approximately 15-25% of the total flow within the Marcollat Watercourse on a catchment area basis (REM 2003). The flows from Morambro Creek are supplemented by flows from the Naracoorte Creek. Together the flows are important in maintaining the high flow bands and removing salt from the wetland system.

Water also enters the Marcollat watercourse by surface flow across the flats to the east (some of which is collected by shallow drains), and probably by groundwater recharge from the Woolumbool Range to the west.

The Marcollat Watercourse has been modified considerably since settlement through the drainage of the area. In particular, flow from the south has declined and become more episodic due to the diversion of flow from the Mosquito Creek catchment to Drain M and the channelling of the remaining flow via Drain E. However, additional flow has been introduced from the east via the Nyroca Channel. The Marcollat Watercourse has also been altered within the study area by the construction of shallow drains on the gently sloping ground to the east of the watercourse and between a number of wetland lagoons. These drains have been installed to more rapidly move water from the flats



toward watercourse (reducing the period of land inundation) and also to speed up the movement of water along the watercourse. Some of the drains constructed between lagoons have been done so with channel base below the base of the lagoons.



3. Background

Much of the native vegetation throughout Australia has been cleared for agriculture. This includes large tracts of land in the upper south east of South Australia. Significant results of land clearance have included successful agricultural (farming) enterprises followed in many areas by salinisation, land degradation and then a loss of productivity. This is mainly due to land clearance leading to increased infiltration recharge of rainfall, rising groundwater levels, the mobilisation of salts in the soil profile, waterlogging, inundation and the concentrating of salt at, or near, the land surface through evaporation. This has also led to an increase in discharge of saline ground water as base flow to streams, resulting in additional biodiversity loss.

In the upper south east of South Australia, there is a perception that both salinisation and flooding of what was once useable land has occurred, and that drains are required to restore the functionality of the land.

The Upper South East Combined Councils Salinity Committee was formed, and investigations carried out in 1990 and 1991. In 1993, an Environmental Impact Statement titled "Upper South East Dryland Salinity and Flood Management Plan" was released, and a \$36 million (1993) drainage scheme proposed. The scheme included:-

- The excavation of 270km of drains
- The directing of surface water to downstream wetlands
- The protection of low lying land from salinisation
- The protection of native vegetation

- The disposal of drainage water (groundwater) to the ocean
- Limited discharge of saline surface and groundwater to the Coorong.

Since that time, information has continued to be gathered, including the publishing of a supplement to the EIS (1994), a review of the EIS on behalf of the Nature Conservation Agency, and a number of reports and papers from within government agencies relating to flow levels, pondage levels, agriculture and vegetation.

With respect to the Didicoolum drain, opinions of personnel both within the government agencies and on the land are divided, with the premise that the installation of the drain would provide the desired benefit being challenged. In particular, it has been stated that the land to the south of the Kingston – Bordertown road is salinised and of low productivity, whereas the land to the north of the road is of low salinity and is highly productive. A major concern (as stated) is that the drain will result in a loss of productivity of the land to the north of the road, and may not provide a significant benefit to the land south of the road.

This commission is intended to provide an overview of the likely outcomes of installing the Didicoolum Drain.



4. Scope of Work

The request for proposal sent by Michael Leak (DWLBC) on 16 February 2004 included a request to achieve the following objectives:-

- To understand site specific conditions and trends in the aquifer
- To draw conclusions on the effect of groundwater on wetlands and woodlands of the Marcollat Watercourse
- To draw conclusions on how groundwater impacts agricultural production in the Marcollat Flat
- To predict the effects of the drain on the aquifer, agronomy, and the environment
- To provide possible engineering solutions to mitigate potential impacts of the drain on groundwater, agronomy and the environment

It was also agreed that GHD would:-

- Assess the differences between the northern (fresh) and southern (saline) areas
- Provide comments on the effects on the watercourse and wetlands of constructing the drain
- Comment on the relative positioning of the drain in the flat
- Comment on shallow versus deep drains and the potential impact on the wetlands and watercourse

To meet these objectives, we visited the site, discussed issues with DWLBC personnel and landholders, and reviewed geological, hydrogeological, agricultural, and environmental information.

Activities including the site visit and the data review are described below, and a series of discussion sections are also presented, followed by a response to each stated objective.



5. Site Visit

The Marcollat Watercourse and portion of the proposed Didicoolum drain within the subject area were inspected on 22 and 23 March 2004.

This included travel along the Harper Range, including the inspection of a road cutting (to examine the soil profile), and traversing the flat plain from east to west, noting the presence of subdued calcareous outcrops, variations in pasture, the presence of shallow drains and old watercourse meanders and lunettes. Lagoons were also briefly inspected and the presence of reeds on the western margin of some lagoons noted (indicating possible groundwater discharge from the Woolumbool Range), along with the loss of understorey vegetation, the presence of old natural flow channels and the excavation of connecting and diversion channels. These channels have been constructed between wetland lagoons along the Marcollat watercourse and also to the east on "Willalooka". These channels have been installed to drain the land to the east of the watercourse on a local scale and those along the watercourse would have probably been installed to speed up the flow of water through the study area.

Also noted in the area to the south of the Kingston –Bordertown road was the presence of salt tolerant grasses (puccinellia and tall wheat grass) nearer the watercourse with clovers and other grasses more abundant to the east.

Discussions were also held with Dean and Sue Prosser and Tim Truscott, landholders to the north of the Kingston-Bordertown road. The abundance of limestone at or near the land surface on the Prosser property was noted, as was the presence of abundant clover, and a pump equipped water supply well was also started to demonstrate the high yield obtainable from the shallow unconfined aquifer.

The floodplain of the Marcollat watercourse was inspected on the Truscott property, the most northerly in the study area, and the impact on land of the impoundment of water at the Jip Jip weir discussed. The drain on the Brinkworth property immediately to the north of the study areas was also visited, as it is intended that the Didicoolum drain discharge to this structure.

Photographs taken during the site visit are presented in Appendix A.



6. Data Review

Information from a number of sources were obtained and reviewed. These included:-

- Soil borehole logs and salinity data from Michael Durkay(student)
- "Upper South East Dryland Salinity and Flood Management Plan" EIS and Supplement
- A Critical Review of the EIS "Upper South East Salinity and Flood Management Plan" and its Implication for Nature Conservation in the Coorong, prepared by V & C Semeniuk Research Group for the Nature Conservation Agency, Canberra 1993
- "The Geology of the South East" 1:500000 geological map sheet
- The "Naracoorte" 1:250 000 geological map sheet
- The Geology of South Australia, Vol 2, The Phanerozoic, Geological Survey Bulletin 54.
- M. Girado (2002) "Notes on the Hydrology of the Marcollat Watercourse". Prepared for the Morambro Creek Water Allocation Planning Committee.
- M. Girado (2001) "Recommendation to Alter the Cease to Flow Level of Jip Jip Wetland Complex (2001), by M. Girado (DWLBC)
- M. Girado (2000) "Topographical Survey and Assessment of Hydrologic Options for the Willalooka Wetland Complex" (2000) by M. Girado (DWLBC)
- M. Girado (1999) " Scoping Study – Determining Pondage Levels on the Marcollat Watercourse" (DWLBC)
- M. Girado (2000) "Discussion Paper – Implementation Group, Topographical Survey of Jip Jip", (DWLBC)
- Landholder meeting minutes, 1999, prepared by SKM
- The paper titled " Report on the likely impact of Drainage on Soils, Agronomy and Carrying Capacity on 'Kyeema'" by Tracey Strugnell, Catchment Agronomist, Combined South East Soil Conservation Board, (Undated)
- Site Preparation Report covering Vegetation Issues on "Kyeema" by Ainsley Forrest, Revegetation Consultant, Rural Solutions, SA.
- The paper titled "Whole Rock Amino Stratigraphy of the Coorong Coastal Plain, South Australia: Towards a 1 million year record of sea-level high stands" by Murray-Wallace et al in the Journal of the Geological Society, London, Vol 158
- Excursion notes titled "The Coorong" by Vic Gostin for the GSA excursion, February 1985
- PIRSA drillhole database data
- DWLBC "OBSEWELL" database data
- Kinhill Environmental Services (1998). Review of the Marcollat Watercourse Management Plan – Stage 1. Kinhill Engineers Pty Ltd. Prepared for the Department of Environment, Heritage and Aboriginal Affairs.



- REM (2003) Morambro Creek Water Resource and Ecological Assessment: Stage 2 Report. Report to the South East Catchment Water Management Board
- SEWCDB (1997). Farm Wetland Management in the Upper South East. Marcollat Watercourse Management Plan Stage 1.
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- Dowling, M. (1997) 'Farm Wetland Management in the Upper South East, Marcollat Watercourse Management Plan Stage 1'. SEWCDB, PIRSA, Millicent SA.
- Fordham (1998) Ecological study of wetlands in the Marcollat watercourse. Thesis for the degree of master of ecology and management.
- Hart, B.T., Bailey, P., Edwards, R., Hurtle, K., James, K., McMahon, A., Meredith, C, and Swaddling, K. (1991) 'A Review of the Salt Sensitivity of the Australian Freshwater Biota'. Hydrobiologia 210: 105-144.
- McGibbon (1994) The Willalooka wetlands: Baseline investigations into the Environmental impacts of land and water management. Prepared for the Department of Primary Industries and the Department of Heritage and Natural resources.
- South East Catchment Water Management Board (2004) Draft Water Allocation Plan for the Morambro Creel Prescribed Water Resources.
- Williams, W.D. (1986) 'Conductivity and Salinity of Australian Salt Lakes'. Aust. J. Mar. Freshw. Res. 37:177-182.
- White, J.M. (1999) 'Seasonal Variation in Salinity in the Watervalley Wetlands in the South East of South Australia'. Trans. Royal Soc. SA. 123(2), 77-80.

Information from these sources have been used to gain an understanding of agricultural, water and environmental aspects of the drainage program and forms the basis for the text that follows.



7. Discussion

7.1 Geology and Hydrogeology

The Naracoorte 1:250000 geological map sheet and the “Geology of the South East” 1:500000 geological map were examined along with the documents cited above to gain an appreciation of the geological framework underpinning the site.

These maps and references indicate that the site consists of stranded beach ridges (the Harper and Wollumbool Ranges), separated by interdunal flats. The beach ridges consist of medium to coarse grained calcarenites (calcareous sands) and were deposited when the ocean shoreline was present at these locations, with each ridge corresponding to a sea level high stand at times between ice ages (interglacial periods.) This means that at one time the sea was at Naracoorte and Padthaway, and has retreated over time to its present position, leaving a series of beach ridges and interdunal corridors behind. The interdunal corridors consist of lacustrine and lagoonal dolomites, limestone, clay and sand of the Padthaway Formation, and lagoonal sediments and shell beds of the Glanville Formation underlain by shoreline (beach) sands of the Bridgewater Formation. The lagoonal sediments were deposited in ancient equivalents of the present day Coorong, with sedimentation still occurring in these corridors through the deposition of material from sheet flow and also flow through watercourses.

This shallow sedimentary profile is underlain by marine limestone of the Coomandook Formation and then older units of the Murray Basin.

In general terms, the calcarenites of the Bridgewater Formation are likely to be of relatively high permeability and transmissivity, depending on cementation, dissolution, and fracturing, whereas the interdune corridor (Coorong type) sediments should be fine grained and hence of low primary permeability. However, limestones (with high primary porosity) are stated to be present in these corridor sediments and secondary porosity can be present in the form of fracturing and dissolution of the fine grained calcareous sediments.

This means that it is possible that the rock/sediment type within the interdune corridor could vary from clays and mudstones (low transmissivity) to limestones and fractured carbonate rocks (high transmissivity). Hence, the unconfined aquifer in the study area is likely to consist of Bridgewater Formation dune sands (Harper and Wollumbool Ranges) plus limestones dolomites and clays of the interdunal Padthaway Formation, and that due to the mix of different rock types and materials, the hydraulic properties of the aquifer could change markedly over short distances.

7.2 Depth to Water

DWLBC OBSWELL database data have been obtained for the study area and immediate surrounds. In addition, PIRSA drillhole database data have been obtained. This database presents summary drillhole information, including that for water wells. These data indicate that depth to water ranges from less than 0.5m near some lagoons



to between 1 and 2m on the flats, and greater than 5m near and in the Harper and Woolumbool Ranges, although it should be noted that the dates of record vary considerably.

The drilling logs provided by Michael Durkay (PhD student) also include measurements of depth of water intersection. These depths are from soil boreholes not completed as wells, and indicate that on the flats, water occurs at depths of between 0.75 and 4m below ground. These data were collected in February 2004.

PIRSA and DWLBC depth to water information is presented as Figure 2.

7.3 Groundwater Salinity

PIRSA drillhole database data includes salinity for many wells in and near the Marcollat Watercourse and Didicoolum drain alignment. These data indicate that salinity of groundwater varies from less than 2000mg/L at some locations in the Woolumbool Range to nearly 40000mg/L near Reedy Swamp. Recorded salinities in the vicinity of the line of lagoons south of the Kingston-Willalooka road are generally the highest of these reviewed (2645-39950mg/L), whereas recorded salinities from wells in the flats to the east are generally much lower (3885-10878mg/L), as are those from wells in the Woolumbool Range (1043-10565mg/L), and the flats to the north of the Kingston-Bordertown road (1570-5823mg/L).

Groundwater salinity data from Michael Durkay (PhD student) are only available for 3 wells, namely numbers 9, 10 and 11, located just north of the Kingston-Bordertown road. Salinities as recorded vary from 4.01 dS/m (4010EC) at Well 11, on 9 March 2004 to over 23dS/m (23000EC) at Well 10, on 6 May 2004. (i.e. 4000 μ S/cm to over 23000 μ S/cm).

The greatest (highest) salinities were recorded in wells 10 and 11. These wells have much more clay present in the soil profile than well 9, which has been logged as encountering mainly limestone.

Groundwater salinity data are presented pictorially in Figure 3. It should be noted that the salinity data constitute a composite set and are not date specific. These data may be of use in defining site characteristics in a general sense, but should not be used for detailed interpretation. One or more date specific datasets would be required for that purpose.

7.4 Soil Salinity and Lithology

Soil logs compiled by Michael Durkay (PhD student) have also been provided by DWLBC. These logs are for 33 boreholes drilled between the Harper and Woolumbool Ranges in 2004. Many of the boreholes were sited along the Marcollat Watercourse, whilst others were located to the east of the Didicoolum drain alignment and south of the Kingston-Bordertown road. Some were also drilled to form arrays across the interdune corridor. Depths of drilling ranged from 4 to 6m.

Sediments encountered in these boreholes include (as logged) loams and topsoils, calcrete, clay, clayey sand, sand, and limestone.



Generally, clayey sediments were encountered in boreholes located near the Marcollat Watercourse whilst limestone was logged as occurring further to the east. To the south of the Kingston-Bordertown road, the Didicoolum drain alignment as proposed is located in areas in which clays were encountered, the exception being borehole 39, one of the most southerly drilled by Michael Durkay. To the north of the Kingston-Bordertown road, holes drilled in the area to the east of the Marcollat Watercourse, encountered mainly limestone (as logged) although clays (instead of limestone) were intersected in holes drilled on "Minnamurra", at the northern end of the study area. Very little of the subsurface profile was logged as sand, which is in keeping with the low energy depositional environment of the Coorong and equivalents.

PIRSA drillhole records also indicate the presence of considerable thickness of clay in the subsurface profile, particularly south of the Kingston-Bordertown road near the Marcollat Watercourse. Further east, wells are recorded as intersecting limestone. The inferred extent of clayey sediments associated with the Marcollat Watercourse is presented as Figure 4.

North of the Kingston-Bordertown road, PIRSA records indicate that limestone occurs in the vicinity of the Marcollat Watercourse. Sand and sandstone (presumably Bridgewater Formation) also occurs at depths in a number of these wells.

7.5 Land Use

We understand that the land within the subject area is used predominantly for grazing. Stocking rates are reported to vary considerably, with the most productive land stated to be on the Prosser and Johnston properties, and located to the east of the Marcollat Watercourse immediately to the north of the Kingston-Bordertown road and to the east of where the Harper Range peters out. This land is currently sown to clover and other grasses. Some pastures are also irrigated by groundwater sourced from the shallow aquifer, with well yields of about 100L/s having been stated (Dean Prosser, pers comm).

In contrast, the land to the south of that road and east of the watercourse is reported to be of lower carrying capacity, and supports only salt tolerant grasses (e.g. puccinellia) near the watercourse but further east the land supports clovers, annual and perennial pasture (with higher stocking rates recorded). We also understand that the higher land (Woolumbool and Harper Ranges) support grazing at stocking rates lower than the Prosser and Johnston flats, but higher than the McGreggor land on the flat to the south of the Kingston-Bordertown road.

7.6 Ecosystems in the Marcollat Watercourse.

The needs of ecosystems depend on both the local influence of water in the watercourse and the surface water area. Each ecosystem can be described in terms of its vegetation, fauna and physical process components, and the flow requirements for each of those components. There are no strict boundaries between the ecosystems in this regard: fauna will occur in various systems, depending on the flow situation and



processes often link one system with another. Even vegetation types are not always strictly limited to a particular system

A history of clearance and grazing in the Marcollat watercourse has affected the quality and quantity of ecosystems and in general ecosystems are poorly conserved. However historical information and remnant vegetation suggests a number of ecosystems including:

- **Open Water** (*Phytoplankton*) - Provides hunting habitat for piscivorous birds and hunting habitat for insectivorous birds and bats.
- **Aquatic Macrophytes/ Herbland** In the Marcollat, the most common aquatic plants are *Vallisneria reniformis*, *Potamogeton spp*, *Triglochin procerum* and *Myriophyllum spp*. The main herbland plants are *Mimulus repens*, *Atriplex spp* and *Suaeda spp*. This ecosystem provides habitat for macro-invertebrate production, grazing and hunting water birds and bats, drought refuge for fish and a water source for terrestrial vertebrates. It is also a critical habitat to fish, frogs and macroinvertebrates for shelter, feeding and breeding.
- **Sedgeland with red gum** (*Eucalyptus camealdulensis*) **overstory** (*Gahnia filum*, *G. filium*, *Muehlenbeckia adpressa*, *Juncus spp isolepis*, *Machaerina articulata* *Poa caespitose* and other native grasses) – It provides a hunting habitat and nesting material for grebes and terns and a feeding and breeding and egg laying habitat for many birds (ibis, ducks etc).
- **Stream Bed (existing drain)** (*Eleocharis acuta*, *Distichili distichophylla* and pasture grasses) – This area is important for the transfer of fish, invertebrates, plant propagates between wetlands, and provides a grazing habitat for waterfowl. It also provides for the recharge of soil moisture for red gum.
- **Flood Dependent Riparian Zone** (*Poa labillardieri* and *Juncus ingens*) – Overhanging growth to shade and shelter fish.
- **Drought Tolerant Riparian Zone** (*Juncus australis* and *J. subsecundus*) – Provide habitat for frogs and snakes.
- **Red gum Riparian Zone** (*E. camealdulensis* over *Juncus spp.*, *Cyperus gymnocaulos*, *Machaerina articulata* and *Isolepis nodosa*) – This zone is a habitat for frogs, snakes and small mammals. Red gum roots provide habitat for cryptic fauna including fish, yabbies and substrate for grazing macro-invertebrates.
- **Red gum Floodplain** (*E. camealdulensis* over *Juncus*, *Juncus subsecundus*, *Carex inversa* and *Cyperus gymnocaulos*) - red gums provide nesting habitat for cockatoos, ducks and other birds, and a roosting habitat for birds and hunting habitat for insectivorous bats and birds.

(Note information sourced from McGibbon 1994, Fordham 1998, REM 2003)

7.7 Water Needs of identified Ecosystems

Water requirements specify the water availability and quality on which ecosystems depend, and must account for the variability inherent in that dependence. The



definition of water requirements is complex because the availability and quality of water in the Marcollat Watercourse and surface water area varies spatially and temporally. The volume and timing of flow fluctuates seasonally and according to long-term climatic trends. Four flow bands can be identified to describe the environmental requirements that support the diverging ecosystems, and the processes that occur in each band are summarised in Table 1. The flow bands are then described in relation to the Marcollat Watercourse in Table 2.

Table 1 Ecological Processes Associated with Flows

Flow Type	Ecological Processes	Flow Regime
No flow/ cease to flow	No flow in the streambed. Recovery and regeneration of grasses, sedges and red gums, and growth and regeneration of stream bed vegetation. Sediment drying and nutrient processing. Population control of pests.	Base Flow (B1)
Intermittent pulses	Short duration flow events that fill deep pools in the streambed and fill depressions in the catchment area. This provides aquatic habitat through summer and low flow periods for yabbies, fish, frogs and waterfowl and sustains grasses, sedges and red gums. Freshens water quality in pools.	
Sustained low flows	Water covers the streambed for a reasonable duration of time and creates connection between pools causing fauna exchange and colonisation between deep roots. Facilitates the recruitment of fish and invertebrates following trigger flows (high or moderate levels).	
Moderate flows	Flow sufficient to provide flora and fauna exchange between wetlands and watering of the riparian root zone.	Moderate Flow (B2)
High flows	Floods stimulates red gums and woodlands, promotes red gum recruitment and transfer of aquatic biota between wetlands. Provides low salinity flooding. Provides a trigger flow for aquatic fauna breeding.	High Flow (B3)
Very High flows	Very high flows create wetland habitats, sustain floodplain red gums, promote red gum recruitment, flora and fauna exchange between wetlands and recharge groundwater dependent ecosystems.	Very High Flows (B4)

Table 2 Environmental Water requirements of the Marcollat Watercourse

Flow Band	Flow Band Description	Key Functions of Flow Bands
B1	Dry to very low water level	<ul style="list-style-type: none"> No discharge from Jip Jip Recovery of vegetation intolerant of prolonged flooding (eg red gum) Regeneration of grasses and sedges Growth of herbland and halophyte vegetation Wading bird habitat Groundwater discharge* Some salinisation of wetland beds*



B2	Partial inundation	No discharge from Jip Jip Initiation of aquatic plant growth, macroinvertebrate production Provision of some waterbird habitat Wetland water predominantly generated from local runoff Salt load increases Minor groundwater recharge and potential contribution to groundwater mounding. *
B3	Major inundation	Some discharge from Jip Jip Removal of some salt from system Wetting of fringing vegetation Flows links wetlands, providing dispersal and recolonisation opportunities for aquatic fauna Some freshening of groundwater beneath wetlands*
B4	Continuous inundation between wetlands	Major discharge from Jip Jip Flow links wetlands, providing dispersal and recolonisation opportunities for aquatic fauna Extensive aquatic habitat and high temporary aquatic fauna carrying capacity Removal of salt from system

*Where conditions and soils types are favourable

7.8 Current Impacts on Ecosystems and Agricultural Land

7.8.1 Alteration to Natural Sill Levels on Willalooka Property

Drainage works on the Willalooka property have significantly reduced the full supply levels (FSL) of the wetlands with all wetlands now significantly below their natural FSL, and some holding only a fraction of their former volumes (M. Giraud, 2001). This will have the effect of speeding up the flows through the watercourse and reducing the lateral connectivity of wetland habitat (i.e. wetland extent.) The current FSL of the Willalooka wetlands range from approximately 0.5 to 0.1 metre lower than the natural FSL. The impact of these drainage works on flows associated with flow bands B3 and B4 from Morambro Creek and Naracoorte Creek would be to potentially confine these flows to the drain that links the wetlands therefore reducing the lateral area of flooding that would have been seen historically on the associated red gum riparian and floodplain zones.

Considerable interest and study has been shown on the red gums located on the Willalooka property in regard to the apparent decline in health of these trees. Reasons provided for the decline include grazing pressure (Fordham 1998) (Kinhill 1998) and salinity (Fordham 1998, Kinhill 1998, KBR 2000). Whilst both reasons are applicable it must be noted that the altered flow through the Willalooka wetland due to the reduction in FSL may have exacerbated the salinity problem. The reduction in FSL and the reduction in lateral flows would reduce the flushing effect from larger flows on accumulated salts in these areas. Red gums have a requirement for fresh water.



Williams (1986) and Hart *et al* (1991) suggest an accepted upper limit of less than 3000mg/l, hence the need for B3 and B4 flows to remove accumulated salts from the system and provide fresh water relief to the trees. Red gum decline may continue to occur under the current regime until major flow events (B4) provide the lateral extent of flooding required.

Additionally this flushing effect would have extended onto what is now agricultural land, particularly the small lunettes which once were part of the watercourse, flushing the salts accumulated by the evapo-concentration of trapped water. Under the current regime the accumulation of salts from evapo-concentration in these areas may also exacerbate the increased salinity of the wetlands from salts mobilised by across-flat flows (B2). The across-flat flows are essential for maintaining ecosystem balance in the more permanent wetlands on Willalooka.

Kinhill (1998) states *“it would appear that to ‘maintain a flow management system which does not impede the movement of water during high flows whilst also encouraging water movement more towards its natural pattern, i.e. more slowly over a wider area’ is a key concept that requires application if there is to be a realisation of both agricultural and biological aims”*.

It is unclear whether the installation of the Didicoolum Drain would be consistent with this statement, as it is assumed that the drain is to remove water and result in a relatively small inundation footprint.

7.8.2 Grazing

Clearing in the Marcollat Watercourse plus a long history of grazing by domestic stock has led to ecosystem decline and has prevented the redevelopment of habitat complexity. In periods of low flow, the establishment of vegetation is limited by grazing, compromising the growth of halophytes and herbland vegetation. Grazing in periods of high flows, in habitats dependant on water (particularly the riparian zone and floodplain,) has caused degradation by increasing water turbidity and pugging, resulting in the destruction of new/ regenerated growth of plants. This has led to a reduced habitat due to flora decline followed by fauna decline and hence ecosystem decline. The impact of grazing pressure on large stands of red gums on Willalooka is likely to result in little or no replacement of trees through self seeding, which would have significant consequences on fauna habitat. If wetlands are to be enhanced then protection from grazing will be required to enable depleted or disturbed habitats to be recolonised by plant and animal propagules.

It is therefore concluded that a major threat to the biological value of the Willalooka Wetlands is from grazing and the inability of riparian vegetation to re establish and that the fencing and revegetation of these wetlands would provide a vital habitat corridor in the Marcollat catchment. This point is supported by all management plans for the Marcollat Watercourse.

The Kinhill Review (1998) indicates that the vegetation surrounding the Kyeema Wetland has increased over recent years, probably in response to a light-grazing



regime in the riparian zone surrounding this wetland. This wetland would also benefit from the further reduction in grazing pressure.

7.8.3 Current Drain

The current drain has spoil banks well above the natural surface of the flats, which while broken in a number of places to allow water to enter off the flats, may be artificially holding water for longer periods than would naturally occur. This may cause waterlogging, particularly in the areas which were once wetlands, exacerbating pasture decline, thus leading to a decline in production. These areas include the mid to northern areas of Willalooka, the southern sections of Kyeema and the northern sections of Minimurra, and tend to be low lying and have clayey soils. Consideration should be given to creating more breaks in the spoil, thereby reducing the time water is held on the flat. This has particular importance during summer if considerable rains occur, where surface water can evapo-concentrate and leave salt on the land surface. Such a process would also require that the Jip Jip weir be lowered.

7.8.4 Jip Jip Weir

Prior to the construction of the weir immediately upstream of the Jip Jip water hole in 1984, the Jip Jip wetland complex was dominated by *M. halmat.*, *M. brevifolia* & red gum communities interspersed with a series of shallow (< 300 mm deep) depressions. At this time the Jip Jip complex retained no significant water, other than in these shallow depressions (Giraudo 2002).

The construction of the weir at Jip Jip has resulted in the death of red gums and *M. brevifolia* due to extended periods of inundation of the root zone and/or salinity effects (Kinhill 1998). Only the very largest red gums (base diameter of >1.5m) survived the hydrologic regime imposed on the wetland complex between 1984 and 1999 (Giraudo 2002, Kinhill 1998). In recent years, regeneration, particularly of red gums has occurred, and a recent reduction in the FSL of the wetland should allow these juvenile gums to reach maturity. The wetland is an important habitat and is surrounded by a large complex of native vegetation, and provides an important water bird habitat in the Upper South East.

Dowling (1997) suggests a return to more natural hydrologic regimes, viz "maintain a flow management system which does not impede the movement of water during high flows." The Kinhill Review highlights this as a key concept in the management of the watercourse. The review also demonstrates that..."To achieve this will require removal of existing barriers to water flow at Jaffray and Jip Jip" and called for the removal of the impedance to flow at this point in the watercourse, because of the severity of the impact on adjacent land.

7.9 Potential Impacts on Ecosystems and Agricultural Land due to the Didicoolum Drain Extension

The proposed alignment of the extension of the Didicoolum Drain runs parallel to the Marcollat Watercourse. Nominal depth of the Didicoolum Drain is likely to be 1.5 - 2.0



m. The drain will affect both the surface water and ground water conditions of the area, which could impact upon the ecology of the wetland.

The construction of the Didicoolum Drain is likely to decrease surface water flows (Flow Band B2) to the Marcollat Watercourse. The main factors contributing to these decreased flows are the estimated 10% reduction of the total wetland catchment area (MCDWAP 2004), and a reduction in surface run-off by the increased sub-surface storage capacity allowing more rainfall to infiltrate in the subsoil before run-off occurs. Contributions to the decrease in catchment may in fact be greater than anticipated by the MCWAP and additional information, and/or modelling, should be obtained to provide a more realistic figure.

This decrease in surface water may cause the more permanent wetlands to become semi permanent and hence reduce aquatic fauna habitat during drier years. An impact on the dispersal and recolonisation opportunities for aquatic fauna further downstream of the Marcollat watercourse would then occur. REM (2003) produced a hydrologic/hydraulic model of the Marcollat watercourse, which shows the importance of across flat flows to the more permanent wetlands. The model shows the reliance of the Kyeema wetland on across flat flows as apposed to flows from Morambro creek while little Reedy and Bullocky have a greater reliance on the Morambro creek flows.

The potential reduction in across flat flows would effect the permanency of the Kyeema wetland in particular, as this is more than twice the area and has four times the holding capacity of the other more permanent wetlands. This wetland is maintained by fresh surface water flows across the flat in drier years (B2 flows). This flat extends further to the east as the Harper Range peters out just north of the Kingston - Bordertown road. The cross flat flows are more significant in this area than further south, as the land over which the water flows is generally less saline than the land to the south near the watercourse (leading to fresher flows) and the flows from the Naracoorte and Morambro Creeks do not always reach this far north. The Kyeema wetland therefore should be a good location for larval survival, enhanced ability to set seed, survival of juvenile faunal species and maintaining fauna survival until large flow events (B3 and B4) provide dispersal opportunities. This wetland has only completely dried up once in the thirty years the current owners have owned the property (D Prosser, pers comm).

Borehole information supplied by Michael Durkay (PhD student) indicates that soils in the vicinity of the Marcollat watercourse and wetland lagoons are generally clayey and hence of low permeability, whereas those further east are more limestone rich and are of higher permeability. If the drain is installed below the water table in the limestones, then it is possible that significant areas of high agricultural productivity will be affected, as the extent of dewatering is higher in high permeability sediments than in tighter (low permeability) materials. This could include a reduction in carrying capacity due to the loss of water from within or below the root zone of summer pasture.

Conversely, if the drain is installed in the lower permeability clayey sediments nearer the Marcollat watercourse, the dewatering effect on surrounding land would be lessened. However, such an alignment would most likely preclude the flow of surface water to the watercourse and wetland lagoons, which would have a significant and



negative effect on wetland health, particularly on Kyeema, as there would be greater reliance on flows from Morambro Creek and Naracoorte Creek.

It should also be noted that the installation of a drain in low permeability (clayey) soils on 'Willalooka' and elsewhere would be unlikely to remove significant volumes of water and tonnages of salt from the soil profile because the dewatering effect in tight (low permeability) materials is much less than in higher permeability materials. Therefore, the drain at these locations is unlikely to lead to improvements in agricultural productivity.

In addition, if the drain is installed above the water table, then it is possible that water flowing in the drain from the south could leak to the aquifer in the highly productive 'limestone' area. This could lead to the salinisation of the aquifer if the water in the drain is saline.

7.10 Threats to Water Requirements

7.10.1 Morambro and Naracoorte Creeks.

Flow Band B3 and B4 are dependant on receiving water from Morambro Creek and/or Naracoorte Creek.

Flows from Morambro Creek to the Marcollat Watercourse are important both in terms of volume contribution and in providing fresh water to an otherwise predominantly brackish system. Moderate flows from Morambro Creek result in the displacement of more salt sensitive organisms to regenerate the wetlands. High Band Flows are likely to be important in providing surface water flows to the adjacent red gum woodlands, whilst lower Band Flows act to dilute the more saline runoff from the local catchment and salts accumulated by evapo-transpiration of water.

Morambro Creek flows are important in that they provide flows earlier in the season and more frequently than does the Naracoorte Creek (via Drain E) because of the large storage volume between Naracoorte and the intersection of the Marcollat Watercourse with the Nyroca Channel.

A draft Water Allocation Plan for Morambro Creek (MCWAP 2004), recognises the importance of fresh water outflows with salt concentrations 50 to 200mg/L from Morambro Creek into the Marcollat watercourse. The removal of Morambro Creek flows from the Marcollat Watercourse may result in an increased occurrence (days per year) that wetlands spend in Flow Band B1 and a reduced occurrence (days per year) that wetlands spend in Flow Band B4. The removal of accumulated salt from the Marcollat watercourse, resulting from insitu evapo-concentration during average rainfall years, only occurs under Flow Band B4, which implies combined flows from Morambro and Naracoorte creeks are important for the salt balance of the Marcollat watercourse. If these flushing events were not to occur, it can be expected that there would be an inter-annual upward trend in salinity.

The removal of Morambro Creek flows is likely to lead to a reduction in the size of the wetland lagoons and exacerbate existing salinity trends in the ecosystems of the



Marcollat Watercourse. An effect of an increase in salinity is a reduction in the diversity of aquatic and riparian species. This is likely to result in a reduction in habitat complexity and reduced abundance of flora and fauna, which may lead to dominance by one or two tolerant species in each group. In addition, the reproductive success of aquatic biota is impaired at high salinities ($\sim >4000\text{mg/L}$). At this level there is greater potential for poor larval survival, failure to set seed, failure to thrive and even death of juvenile faunal species. Furthermore, a potential reduction in large flows would reduce dispersal and migratory opportunities for aquatic fauna such as fish.

7.10.2 Local Surface Water Flows

Flow Band B2 is particularly important in the drier years when flows from Morambro Creek and Naracoorte Creek are insignificant in drier years. The wetlands that are generally permanent (eg Little Reedy, Bullocky and Kyeema), rely on local surface flows and recharge from surrounding hills to the west of the watercourse. The permanency of these wetlands is important in that they provide extensive aquatic habitat and high temporary aquatic fauna carrying capacity until flows in Flow Bands B3 and B4 provide dispersal and recolonisation opportunities.



8. Conclusions from Data Review

The information reviewed and details described above have led to the following conclusions:-

- ~ The interdune flats between the Harper and Woolumbool Ranges consist of clayey soils near the western margin and more limestone rich sediments further east
- ~ To the north of the Kingston – Bordertown road, the Harper Range tapers out, resulting in the presence of a large flat area consisting of limestone soils
 - ~ The limestone soils are of higher permeability and lower salinity than the clay soils further south near the watercourse. These soils are likely to significantly dewater if a drain is cut into them significantly below the water table, which could lead to a loss of production on the Truscott, Prosser, Johnston, Verco and parts of McGregor properties. This effect could also occur on other properties containing limestone soils cut by the drain and intercepting groundwater
 - ~ In general, the clayey soils are of low permeability and high salinity. In this type of soil, the dewatering effect of the drain is unlikely to extend far from the drain. Hence, the salt trapped in these soils may not be removed by drainage, and hence agricultural production is unlikely to significantly increase as a result of the installation of the drain.
 - ~ The Marcollat Watercourse wetlands are sustained by water from the Woolumbool Range, by flows from the south and by sheet flow from the east. Wetlands in the south are more often fed by flow from the south, whereas the wetlands such as Kyeema rely to a large extent on flows from the east.
 - ~ The installation of a drain will reduce flows from the east reaching the wetlands and could have a detrimental impact on ecology.



9. Responses to Scope Elements in Brief and GHD Proposal

9.1 Site Specific Conditions and Trends in the Aquifer

As stated above, the study area consists of dunes of the Woolumbool and Harpers Ranges (consisting of Bridgewater Formation) separated by a relatively flat area of Coorong style sediments consisting of clay, sand and limestone. Beneath these Coorong sediments are sands also of the Bridgewater Formation.

The shallow sediments have formed an unconfined aquifer, the properties of which depend upon sediment type and possible alterations due to diagenesis and weathering.

Depth to water in the interdune corridor is generally less than 2m below ground, as shown by Michael Durkay's drilling program and also in PIRSA drillhole database records.

Hydraulic conductivity values have not been obtained for this area, but on the basis of sediment type, could vary considerably, ranging from less than 10^{-3} m/d in clays to perhaps greater than 50m/d in limestones.

The direction of regional groundwater flow is shown in Figure 3.8 of the EIS as being approximately westerly, but in the study area could range from westerly, to northerly and also easterly, the latter being related to possible groundwater flow from the Woolumbool Range to the Marcollat Watercourse lagoons.

Figure 3.8 of the EIS indicates that the regional hydraulic gradient in the unconfined aquifer in the Marcollat area is about 5×10^{-4} , although this is likely to vary on a local scale.

The drilling records also indicate that limestone is generally closer to the land surface on the eastern side of the interdune corridor, and that clays overlie the limestone further west. The thickness of the overlying clay tends to increase to the west, reaching thicknesses of up to 6m in places. The limestone is logged to be present under the dune sands of the Woolumbool Range in places, which is concluded to indicate that the thickening of the overlying clays in the corridor is probably related to the formation of lakes (e.g. lagoons) and the deposition of fine grained sediment in these slightly lower lying areas.

9.2 How Groundwater Effects the Wetlands and Woodlands of the Marcollat Watercourse

The borehole logs provided by Michael Durkay and those available through PIRSA indicate that, in general, the Marcollat watercourse is underlain by several metres of clayey sediment. Such sediments are generally of low permeability and are considered to form aquitards or confining beds. As such they would restrict or preclude the infiltration of water from the watercourse and lagoons, and should also restrict the upward movement of groundwater from, for example, the underlying



limestones and the sandier Bridgewater Formation. It should also be noted that these sediments are saturated from near the land surface, with the water contained within being sourced from rainfall infiltration, stream and lagoon losses, and possibly from upward leakage. They will also contain high concentrations of salts because old Coorong sediments are likely to have been deposited in hypersaline environments (similar to the southern Coorong at present), by the transport of salt from deeper aquifers by upward leakage, and probably through the capillary rise of groundwater, losses to evaporation and the retention of salt.

In this context, salt will be lost from these sediments by flushing processes such as effects of rainfall infiltration, surface water infiltration and in some cases, losses to streams. However, due to the probable low permeability of the sediments, the rate of removal of salt is likely to be low, and may not match the rate of concentrating. This would lead to salinisation. Therefore, vegetation will only survive if its tolerance to salt is compatible with the salinity characteristics of its geographical location, this holds for both fresh and saline environments or there is sufficient flushing of salts to reduce salinity and facilitate growth for salt sensitive species. This can be by surface flow or by the movement of groundwater from, for example, the Woolumbool Range, as evidenced at some lagoons.

Changes in the groundwater regime have occurred through drought, land clearance, and by the installation of drainage schemes. Some vegetation benefits by such processes. For example, Teatree has invaded some lagoons elsewhere when the lagoons have dried out, red gums die when waterlogged for extended periods, and much vegetation dies when rising watertables bring salt to within the root zone.

Based on the assumption that the watercourse and lagoons are protected from the underlying aquifer by low permeability clays, and that recharge is by rainfall, surface flows, and groundwater flow from the Woolumbool Range, it could be reasonable to conclude that they will not be adversely affected by the installation of a drain. This is also based on the assumption that the low permeability of the clays will preclude the dewatering of the landscape in the vicinity of the lagoons. This conclusion also assumes that flows from the watercourse and lagoons will not be directed to the drain.

9.3 How Groundwater Effects Agricultural Production

In the study area, groundwater may significantly effect agricultural production, principally due to the proximity of groundwater to the land surface and the high salinities at some locations within the study area.

Depth to water throughout the flats in the study area is generally in the range 0.5-2.5m below ground level. It is possible that some deep rooted pasture species access groundwater in at least part of this depth range, and hence are sustained during periods of low rainfall. It is also possible that vegetation could be sustained by the capillary rise of groundwater, even if the water table lies below the root zone. Therefore, if deep drainage is installed, it could remove groundwater that sustains pasture growth.



However, also of significance is the salinity of groundwater. Salt tolerances of

pastures vary considerably, ranging from 4000-6000 EC for clovers and peas to 6000 – 12000 EC for fescue, rye grass and wheats, through to over 20000 EC for puccinellia and saltbush.

Hence it may not be possible to sustain growth of certain pastures within parts of the study area, which means that groundwater salinity may directly impact pasture selection and sustainability, (i.e. a landowner may not be able to plant a pasture of choice due to the presence of shallow saline groundwater). It is also possible that high stocking rates and pasture selection (e.g. clovers) on the Prosser and Johnston properties are due in part to the presence of shallow groundwater that is accessible by plants and sustains them in periods of low rainfall.

Soil salinity is also very important in this regard as the salt tolerances of vegetation relates also to soil salinity. Therefore, even if saline groundwater occurs at depth, the viability of pasture (and other vegetation) can be significantly effected by soil salinity. Evidence of this is shown on the Prosser, Johnston and Verco properties by the sustainable growth of a range of annual and perennial pastures, and conversely by the preponderance of puccinellia and tall wheat grass in the areas with clay rich soil profiles on the McGreggor property to the south of the Kingston-Bordertown road.

9.4 Effects of the Proposed Drain on the Aquifer, Agronomy and the Watercourse and Wetlands

The proposed alignment of the extension of the Didicoolum drain runs parallel to the Marcollat Watercourse. The nominal depth of the Didicoolum drain is likely to be 1.5 - 2.0 m. Based on the information reviewed and described above, the drain will affect both the surface water and ground water, and could also could impact the ecological values of the Marcollat wetland.

The construction of the Didicoolum Drain is likely to decrease surface water flows (Flow Band B2) to the Marcollat Watercourse, caused by two factors, namely a decrease of the total catchment area contributing to the wetlands of around 10% (MCDWAP 2004) and a reduction in surface run-off by increasing the sub-surface storage capacity allowing more rainfall to infiltrate in the subsoil before run-off occurs. Contributions to the decrease in catchment may in fact be greater than anticipated by the MCWAP and additional information, and/or modelling, should be obtained to provide a more realistic figure.

This decrease in surface water may cause the more permanent wetlands to become semi permanent and hence reduce aquatic fauna habitat during drier years. An impact on the dispersal and recolonisation opportunities for aquatic fauna further downstream of the Marcollat watercourse would then occur.

REM (2003) produced a hydrologic/hydraulic model of the Marcollat watercourse, which shows the importance of across flat flows to the more permanent wetlands. The model shows the reliance of the Kyeema wetland on across flat flows as apposed to flows from Morambro Creek while little Reedy and Bullocky have a greater reliance on the Morambro Creek flows.



The potential reduction in across flat flows would effect the permanency of the Kyeema wetland in particular as this is the more than twice the area and has four times the holding capacity of the other more permanent wetlands. This wetland is more significant as water is maintained by fresh surface water flows across the flat in drier years (B2 flows). This flat extends further to the east as the Harper Range discontinues near the Kingston - Bordertown road. The cross flat flows provide a significant volume of relatively freshwater which sustains faunal communities until large flow events (B3 and B4) provide dispersal opportunities.

Therefore, the Didicoolum drain extension in its current alignment will significantly reduce the volumes of water flowing to the wetlands from the east, and may also reduce agricultural productivity in the areas featuring limestone soils particularly in the area north of the Harper Range, whilst providing little salinity relief and hence little productivity increase in the saline clay soil areas to the south of the Kingston-Bordertown road. It will also preclude the flow of water into the wetlands via the Marcollat Watercourse.

With regard to the management of surface water flows along and in the vicinity of the Marcollat Watercourse, improvements could be made without the need for a new drain. These could include the reduction in the height of the Jip Jip weir plus or minus the reinstatement of lagoon banks and realignment or infilling of channels between wetland lagoons. These could lead to improvements in the movement of water through the wetland (to reduce the period of inundation of land adjacent the watercourse) whilst enabling sufficient flows to be retained in the wetland lagoons for ecosystem maintenance and enhancement.

9.5 Possible Engineering Solutions to Mitigate the Impact of the Drain

Factors that may influence the design and construction of proposed channels include the design flow rates required in the channels, the geotechnical properties of the ground in which the conduit is constructed, and the access of engineering plant and equipment to the location of the works. The consideration of these factors, both individually and in combination, in conjunction with the assessment of the overall objectives of the proposed channel, help to provide practical solutions to the problems and issues at a particular site or region.

It is understood that the main objectives of the Didicoolum Drain, if constructed, is to provide a number of functions, including:

- The transferring of water from south to north -
- The capturing of local groundwater, and

- To intercept surface flows of water in the region.

We understand that the Didicoolum Drain may function in each of these ways at various locations. Each of these is discussed below.



Transferring Water From South to North

One of the functions of the drain as proposed is to transfer water to an existing drain system to the north. A physical requirement for such a channel is that in some soil types (such as areas of limestone soils) it needs to be impermeable (i.e. it will need to not leak), as potentially saline drain waters could significantly effect local aquifers, and hence productivity. Therefore in areas of limestone or other high permeability soils, a liner may be required. Lining options include:

- Concrete Lining. This provides a conduit with a defined shape and very good hydraulic characteristics, and which is impermeable. This option will be greatly influenced by the availability of materials (eg transport costs to supply concrete and reinforcement), and access of plant and equipment. For a concrete lined channel, the cross-sectional shape can be determined to best suit the hydraulic properties of the flow requirements, since the effects of side slope stability and erosion are greatly reduced. This option has a very high capital cost but relatively lower maintenance and operating costs.
- Membrane Lining. This Option also provides a conduit that is impermeable, thus preventing water in the channel from affecting the surrounding groundwater. However, should the channel be constructed within the groundwater table of the surrounding landscape, there is the potential that the lining could be displaced by the pressure of the groundwater. Although this may not impair the function of the lining, it may cause maintenance problems. This option has high capital cost, but a relatively low maintenance and operating cost.
- Clay Lining. Clay is often used to line channels to provide a barrier preventing the channel flow from percolating into the groundwater. The construction is constrained by the availability of suitable clays, as well as the stability of the channel sides, and the propensity for erosion of the channel in varying flow conditions. As with the Membrane Lining Option, differential groundwater pressures can cause displacement of the lining. Also, the chemistry of local groundwaters could lead to dispersion if the clays are highly sodic. With clay lining, such displacement would compromise its integrity, thus allowing the transfer of water between the ground and the channel (or vice versa). Also, clay liners could be influenced by desiccation and cracking in periods of low or no flow, leading to unwanted water losses or ingress when flows increase. A clay lined channel has a lower capital cost compared to concrete and membrane lined channels, but relatively higher maintenance costs.
- Pipe. Another option for an impermeable conduit is to use a pipe. This option provides a conduit with very good hydraulic properties but is a high cost capital investment. Various materials could be used such as concrete, and high diversity polyurethane. Depending of the design flows required to be transferred, this option may prove suitable over critical sections, especially if base flows only are considered. For example, a pipe of the order of 900 to 1200 mm in diameter would have the capacity of transferring flows of the order of 50 to 85 ML per day.



Capturing Local Groundwater

Another purpose for the proposed drain is to provide a means for capturing lower quality groundwater, and to transfer it away from the region. In this case, the drain would need to be constructed with an invert that intercepts the local groundwater table, and be unlined, so as to allow the movement of groundwater into the drain. The ability for this option to meet the project objectives is greatly influenced by the local geotechnical properties. In areas where the soil properties exhibit higher permeability, the ground water is of relatively low salinity, and therefore does not need to be removed from the area. However, the areas where the ground water quality is poor, the soil permeability is also correspondingly low (i.e. clayey soils), and it should be noted that the drain would probably not collect significant volumes of drainage water.

Interception of Surface Flows

Also of note is the potential for the drain to intercept surface flows. Whilst this is an aim of the drainage scheme, some wetlands in the Marcollat system have been shown to depend on surface flows from the east. These flows will be removed by the drain unless they are allowed to pass over it by piping portions of the drain and reinstating the ground to its pre drain condition or vice versa. Given the relatively flat topography and hence the low overland flow rates, the length of drain required to be piped may be significant and hence very expensive. However, this may be a viable compromise option in areas north of the Kingston-Bordertown road, if only base flows are required to be transferred to the disposal system to the north.

The pumping of ponded surface water to the wetlands could also be considered but may be impractical due to the likely volumes required, operation and maintenance considerations, and the need for the process to continue into the future.

Alternative Route

Another option would be to reroute the drain to reduce, the effects on the wetlands, as much as practical, by providing a sufficiently large catchment area to generate the required surface flows. This could require a significant alteration to the alignment, with resultant cost impacts. It is also possible that in the Prosser and Johnston properties, the groundwater dewatering effects may rule out such an alignment revision, as it is thought that low permeability (clayey) soils occur only near the Marcollat Watercourse.



Appendix A
Site Photos



Photo 2 – Agricultural Landscape east of Reedy Swamp



Photo 3 – Existing Wetland Feature, Little Reedy Swamp

Photo 4 – Red gums and landholder installed drainage channel at North Swamp



Photo 6 – Vegetation and ephemeral wetland, Kyeema



Photo 7 – Southern End of T Brinkworth Drain

Photo 8 – Vegetation near main watercourse south of Kingston -
Bordertown road



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