Conceptual Model for Sale Common

Sale Common – Conceptual Model Information Summary Template

<table>
<tr><th>Ref.</th><th>Theme</th><th>Sub-Theme</th><th>Data Components, Information Sources</th><th>Description</th></tr>
<tr><td>1.1</td><td></td><td>Location, Name, Area</td><td>GIS</td><td>

*S*ale Common is located south of the township of Sale and is part of the Gippsland Wetlands system. The Thomson River and Flooding Creek are located to the west and north-west, and the La Trobe River is to the west. The confluence of the Thomson and Latrobe is occurs at the south-west corner of Sale Common. Heart Morass is located directly east of the wetland.

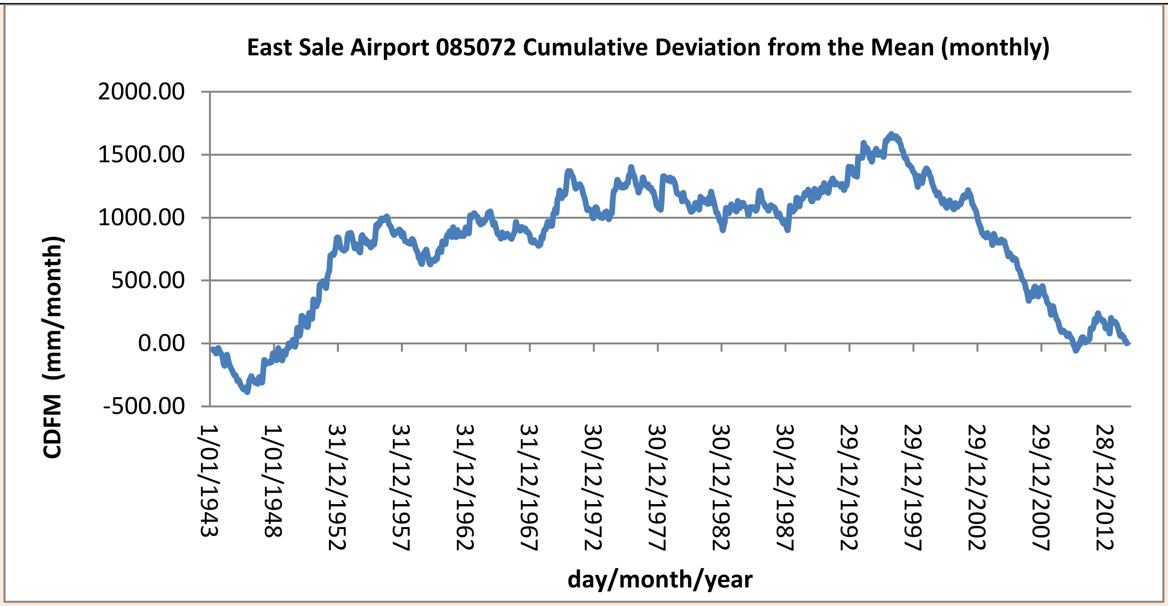
Sale Common is treated as one system in this study as there is no tidal influence to necessitate breaking the wetland into separate systems.

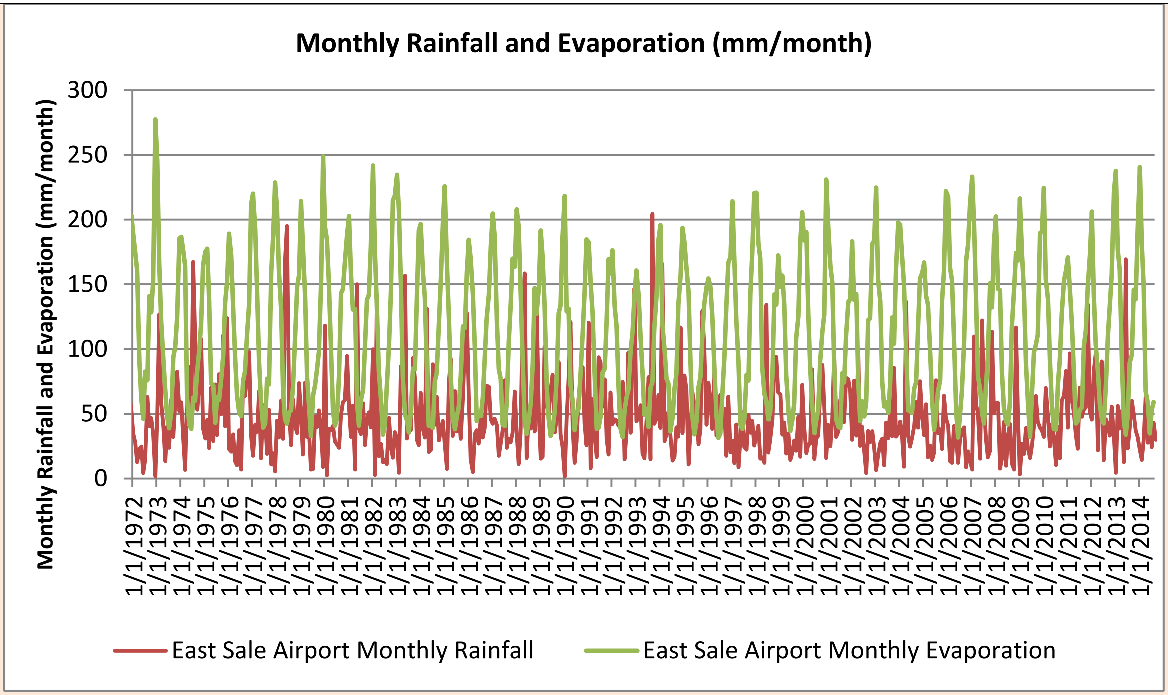
<table>
<tr><th></th><th>Central point (Z55)</th><th>Average length (km)</th><th>Average width (km)</th><th>Wetland area when full (km2)</th></tr>
<tr><td>Sale Common</td><td>E507301.9
N5779046.5</td><td>3.05</td><td>0.9</td><td>2.95 km2</td></tr>
</table>

Areas estimated by reading measurements off a map, therefore approximate only.

</td></tr>
</table>

1.2	Ecosystem Type	Type	GIS	Sale Common is generally described as a deep freshwater marsh (Water Technology, 2011). The GDE Atlas describes the wetland as a deep marsh, and classifies the wetland as an ecosystem reliant on the surface expression of groundwater with a high potential for groundwater interaction (Bureau of Meteorology, 2012).
1.3		Site history/ timeline	Site specific	Located to the south of Sale, the historical influences on the wetland are primarily driven by anthropogenic changes applied due to farming or water resource harvesting. Flows into the wetlands have been altered through several mechanisms; • Flow control structure located at McArdles gap and along the Latrobe River North bank; • Diversion of water resources upstream in the Thomson, Macalister and Latrobe Rivers, in particular the Thomson Dam; • The construction of the Sale Canal and Swing Bridge; • The introduction of agriculture including grazing and irrigation. Over the past decade there has been recognition of the reduced environmental health of the lower Latrobe wetlands. A proactive approach has been adopted to improve the conditions through various changes to the current water regime (refer to SMEC, 2012 and Water Technology, 2011).
1.4		Geomorphic description	Derived from state wide GMU mapping	The Victorian Geomorphology layer describes Sale Common as terraced plains with sands and gravels (Bureau of Meteorology, 2012). Digital Elevation Models of the wetland indicate it is low lying with regions of the wetland at elevations of -0.9 m AHD (depth of approximately 0.50 m is equivalent to approx.0.41m AHD) (Water Technology, 2011). The surrounding land is also flat.
1.5		Value	Listings on other databases (Ramsar, DIWA, Register of the National Estate, TLM icon sites)	Sale Common provides a rich environmental value for various flora and fauna species. It is recognised as the Sale Common Wildlife Reserve and is managed by Parks Victoria. Several species found within the wetland are listed within the Victorian Flora and Fauna Guarantee Act and the wetland is part of the Gippsland Lakes Ramsar site.
2.1	Climate	Rainfall	Bureau of Met and Jacobs Infilled data (N drive data)	There is one rain gauge within the vicinity of Sale Common at East Sale Airport. - Data period: 1943 - 2014 - Average annual rainfall: 599 mm/yr - Average monthly rainfall: 49.7 mm/yr The cumulative deviation from the mean plot indicates a long period of below average rainfall between 1998 and 2010. From 2010 to 2012 there was an increase towards the mean but there has been a decrease in since late 2012.

				
2.2		Evaporation	Bureau of Met and Jacobs Infilled (N drive data)	There is one evaporation gauge within the vicinity of Sale Common at East Sale Airport. Annual evaporation substantially exceeds rainfall at the East Sale Airport. East Sale Airport (Class A Pan Evaporation); - Data period: 1972 – 2014 - Average annual evaporation: 1,338 mm/yr - Average monthly evaporation: 112.6 mm/yr

Monthly Rainfall and Evaporation (mm/month)
Monthly Rainfall and Evaporation (mm/month)
300
250
200
150
100
50
0
1/1/1972
1/1/1973
1/1/1974
1/1/1975
1/1/1976
1/1/1977
1/1/1978
1/1/1979
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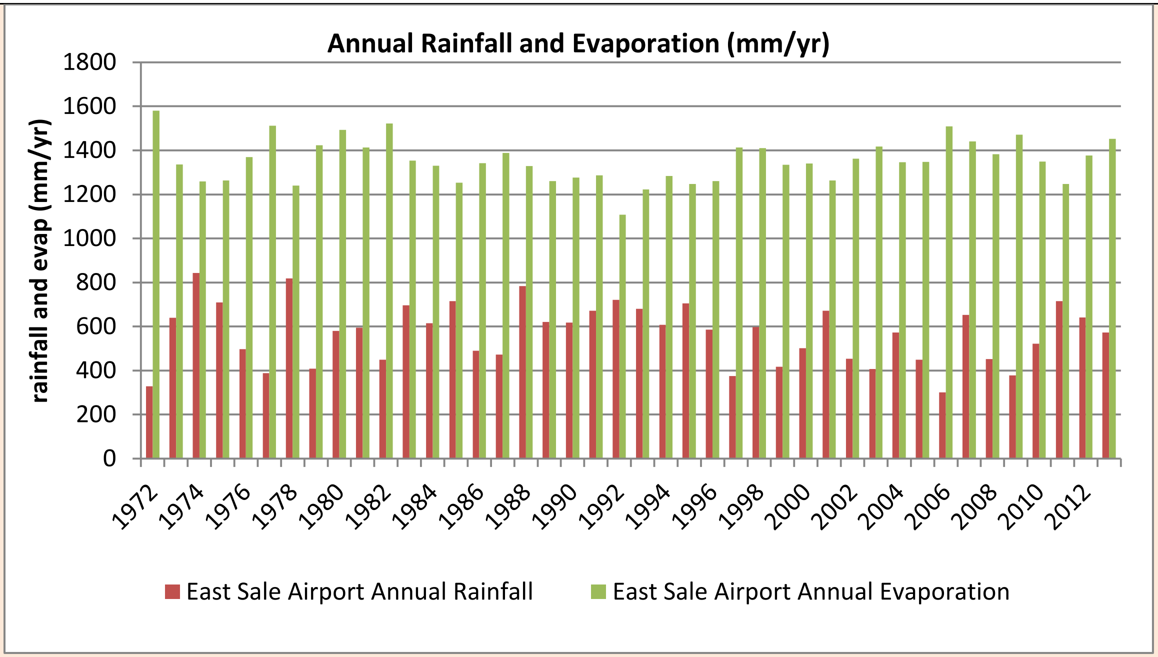
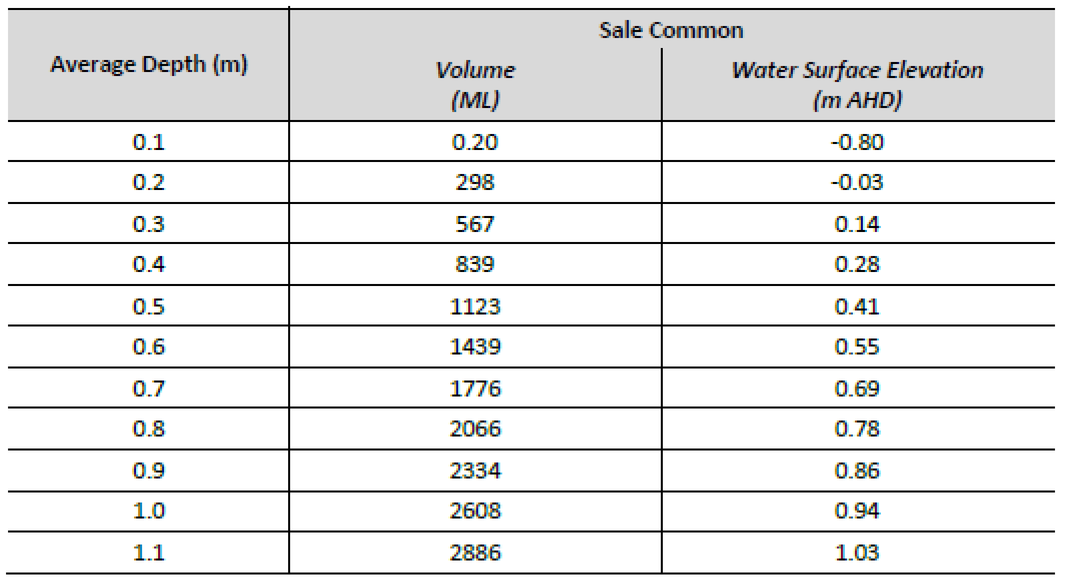
1/1/2010
1/1/2011
1/1/2012
1/1/2013
1/1/2014
East Sale Airport Monthly Rainfall
East Sale Airport Monthly Evaporation

				
3.1	Hydrology	Surface water regime, water levels, permanence, flow	Site specific	<u>Overview</u> Sale Common receives water from the Thomson and Latrobe Rivers via overtopping of banks during high rainfall and through an existing regulator at the north bank of the Latrobe River located between the Swing Bridge and Flooding Creek. The catchment of Flooding Creek includes storm water runoff from Sale. Tidal variations and backwater effects from Lake Wellington to the east also dictate fluxes into the wetland. Water level data (1990 – 1998) in Sale Common, presented in Parks Victoria (2008a), indicates a regime of flooding in late winter and early spring followed by drying over summer. No data is presented post 1998 to examine how the drought of the last 10 years has impacted upon this (water Technology, 2011). Overtopping of levee banks at McArdles Gap occurs at a water level in the adjacent Thomson River of around 0.42 m AHD. The wetland is at a similar level to the adjacent river, meaning that the maximum water level in the wetland is governed by the adjacent river level. Overtopping of levee banks along Flooding Creek occurs at a water level of around 0.49m AHD; however water levels in the wetland will continue to rise provided the inflow to Sale Common is greater than the overbank outflow to Flooding Creek.

Average depth-volume-water surface elevation relationships for Sale Common (Water Teechnology, 2011)



Average Depth (m)	Sale Common	
	Volume (ML)	*Water Surface Elevation (m AHD)*
0.1	0.20	-0.80
0.2	298	-0.03
0.3	567	0.14
0.4	839	0.28
0.5	1123	0.41
0.6	1439	0.55
0.7	1776	0.69
0.8	2066	0.78
0.9	2334	0.86
1.0	2608	0.94
1.1	2886	1.03

The flow volumes required to meet the wetland watering regime are:

- Wetting flow – 1123 ML (annual watering requirement)
- Flushing flows – 2246 to 3369 ML (2 -3 times the wetting volume)

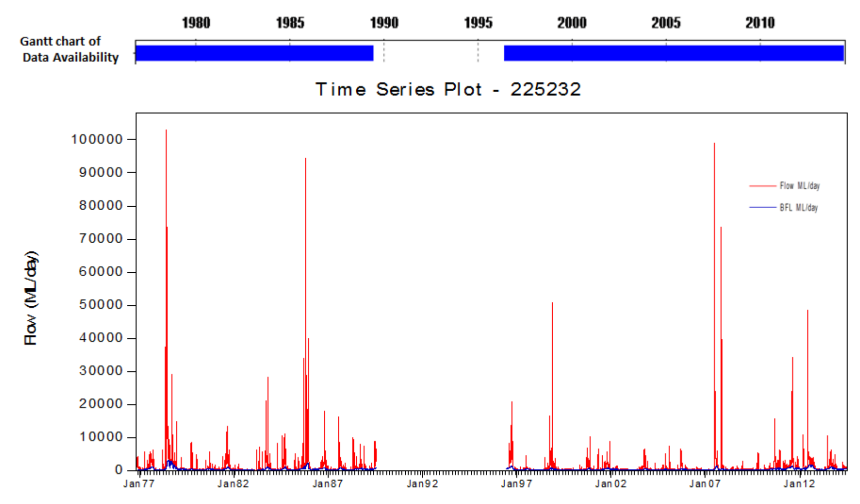
The volume required for flooding of the Floodplain Riparian Woodland every 5 years is in excess of 2886 ML Water Technology, 2011).

	Max when full	Average annual	Average seasonal
Wet surface area (m2)	2,950,000	2,227,000	Spring – unknown Summer – unknown Autumn – unknown Winter – unknown
Water level depth (m)	1	0.5	Unknown
Water level (mAHD)	0.94	0.41	Unknown

				Flow control Structures; Existing flow control structures in Sale Common include (Water Technology, 2011); Existing structures through Latrobe River North Banks • 1x 0.75 m diameter pipe (blocked) • Existing concrete structure with gates • 3 x 1.1 x 0.8 m road culverts • 1 x 0.75 m diameter pipe (Flooding Creek) (not used) Existing pipes connecting Sale Common and Flooding Creek (not used) • 2 x 0.60 m diameter pipe The Latrobe River Bank culvert inverts are at RL -0.6m AHD, and are at the lowest levels allowing flow into the wetland (SMEC,2012). A hydrological model of Sale Common was developed by Water Technology (2011) to investigate a series of infrastructure options aimed at restoring the environmental condition of the wetland.
3.2	Hydrology	Surface water inflows, outflows	In all cases available site specific information will override regional assessments	The flow into Sale Common occurs during flooding events of in the Thomson and the Latrobe when the rivers over top their banks. No rivers or creeks flow directly into Sale Common under non-flooding flow regimes. Stream gauges within the region which consists of stream flow data include gauges 226227(Latrobe) and 225232 (Thomson). Thomson River Flows from the Thomson River enter Sale Common during overtopping of the bank at McArdles gap. Overtopping occurs when water levels are around 0.42m AHD – 6,000 ML/day at McArdles Gap (Water Technology, 2011). For flows at McArdles Gap greater than 21,600 ML/day, the wetland will generally experience a longer duration of flooding (Water Technology, 2011). Latrobe Latrobe River flows enter Sale Common via overtopping along the river's north bank at various locations between Swing Bridge and existing water management structures (Water Technology, 2011). Flows generally around 15,000 ML/day measured in the Lower Latrobe River will cause overtopping of the northern bank into Sale Common (Water Technology, 2011). Flooding Creek Flooding Creek flows from the north of Sale Common and passes along the eastern fringe of the wetland.

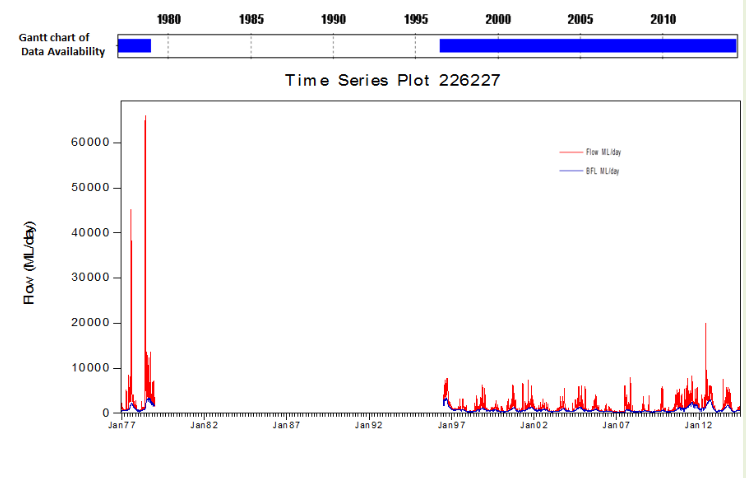
Floodwater from Flooding Creek (upstream of the Port of Sale) is now diverted into the Thomson River downstream of Sale, rather than through Sale Common. However, under certain existing conditions flows from Sale Common can spill into Flooding Creek at a number of low points along Flooding Creek (Water Technology, 2011). This water flows predominantly down Flooding Creek and back into the lower Latrobe River. Water Technology (2011) also reports the banks were most likely modified in the past to ensure flows would be from Sale Common into the Flooding Creek. It is possible that the banks of Flooding Creek could be lowered to allow flows from the Creek to enter Sale Common however discussion with Parks Victoria indicated that due to current concerns with water quality in Flooding Creek this is not considered a viable watering options. There is currently two existing culvert structures linking Sale Common with Flooding Creek which could allow the flow of water from one to the other. These are currently closed due to water quality concerns in Flooding Creek.

Flow at THOMSON RIVER @ BUNDALAGUAH (225232)



Statistics	Flow (ML/day)	BFL(ML/day)		Flow (ML/day)	BFL(ML/day)
Minimum	0	0	Average	1,085	366
Maximum	10,2902	3,096	Standard Deviation	3,285	339

LATROBE RIVER @ KILMANY SOUTH (226227)



Statistics	Flow (ML/day)	BFL(ML/day)		Flow (ML/day)	BFL(ML/day)
Minimum	202	202	Average	1,546	848
Maximum	65,899	3,373	Standard Deviation	2,177	597

	Average annual (m^3/d)	Average seasonal (m^3/d)
Thomson/ Latrobe Rivers	3,000	Spring – unknown Summer – 0 Autumn – 0 Winter – 3,000

Lake Wellington

The impacts of Lake Wellington water levels on Sale Common are associated with backwater, tidal and wind effects (Water Technology, 2012). Modelling by Water Technology (2012) indicated that under low river flow conditions an elevated level in Lake Wellington can affect water levels as far back as the Port of Sale. Depending on the operation of flow structures there is considered to be a potential for saline water to enter the wetland. Gauged water levels for Lake Wellington are available for the Bull Bay monitoring station which is approximately 15 km east of the mouth of the Latrobe River.

Evaporation and Evapotranspiration

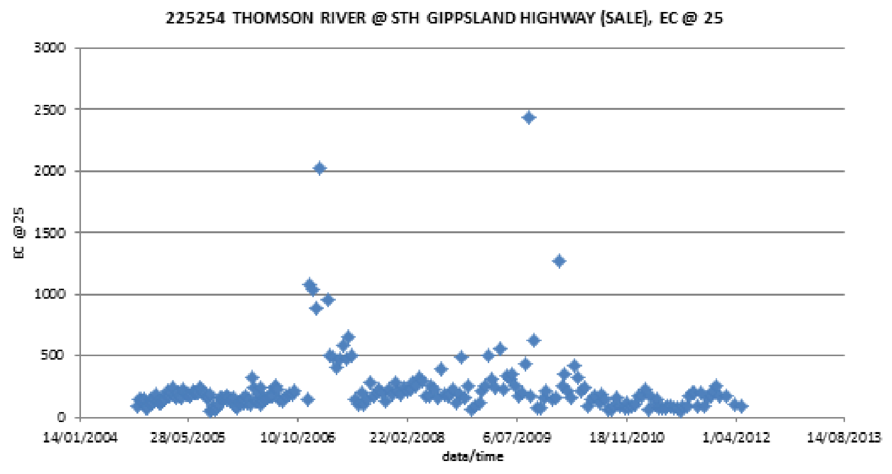
In addition to the available evaporation data from East Sale Airport, evaporation estimates based on work by SKM in 2009 have been utilised for previous hydrological models (Water Technology, 2011). Under various scenarios Water Technology noted; *"It was found that if Sale Common is filled in September, the wetland would be completely dry by March. If it was only half filled then it could be dry by January. This assumes no rainfall events occur while the Common is drying out."* Monthly evaporation estimates for Sale Common adopted by Water Technology (2011) include;

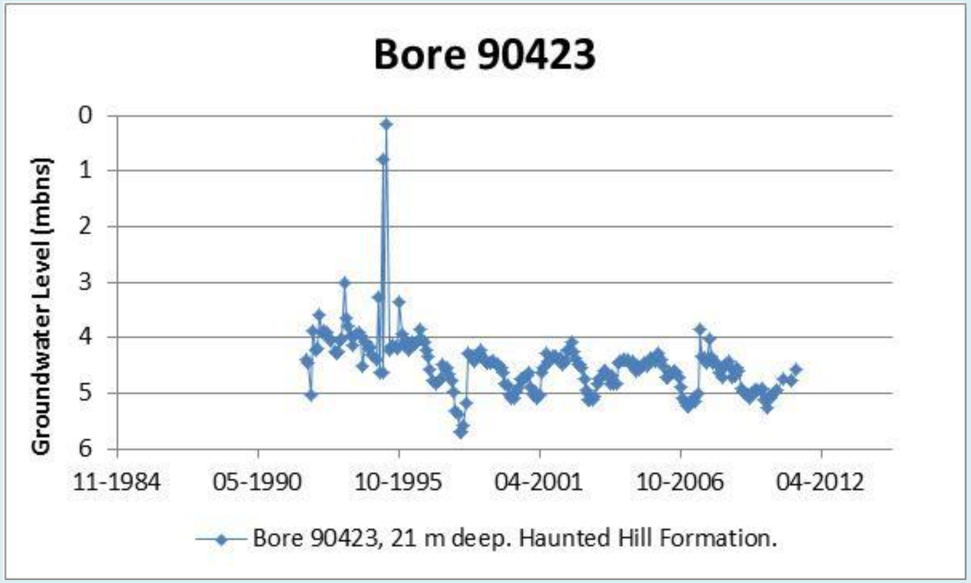
Month	Evaporation (mm)	Volume (ML)
January	103	272
February	80	211
March	75	198
April	50	132
May	28	74
June	12	32
July	31	82
August	54	142
September	78	206
October	112	295
November	104	274
December	125	330
January	103	272

<u>Groundwater</u>

Previous reports on groundwater discharge in the region (GHD, 2005) indicate there are discharge zones within nearby Heart Morass. GHD (2005) reports; *"Between Sale and Lake Wellington, shallow groundwater flow is generally southerly toward the Latrobe River and fringing wetlands and easterly toward Lake Wellington".* Resultantly there is likely to be groundwater discharge within Sale Common however there is limited information to quantify the volume.

3.3		Surface water quality,	Site specific	<u>Salinity</u>

		chemistry		Water quality associated with Sale Common is primarily related with salinity due to close proximity to Lake Wellington (which is saline) and the potential movement of salt wedges upstream in the lower Latrobe River and Thomson River during periods of low flow and high water levels in the lake. The mostly likely entrance of saline waters into Sale Common will be via water management structures. It is noted these risks have been reduced by positioning the invert of structures above likely levels of the salt wedge under most flow conditions (Water Technology, 2011). Measurements of EC at gauge 225254 -Thomson River at South Gippsland Highway (refer below), indicate the fluctuations of EC between late 2004 and early 2012 in the Thomson River. No water quality data was available for water held within the Sale Common to confirm this. Gauge 225254 (South of the wetland) 
4.1	Hydrogeology	Geology	GIS	The 1:250 000 surface geology map indicates the Sale Common is characterised by Quaternary swamp and lake deposits. Adjacent to the Sale Common are Quaternary alluvium deposits.
4.2		Aquifer(s)	GIS	The watertable aquifer comprises the floodplain alluvium and Haunted Hills Formation. The Haunted Hills Formation is characterised by a wide range in particle size, generally poor sorting, variable bedding, and widespread clay lensing with numerous erosional breaks. The formation extends as sheet deposits adjacent to the eastern and south Gippsland highlands and reaches a maximum thickness of almost 30m west of Bairnsdale, decreasing southwards to average 12 to 15m. Bore yields are mostly less than 5L/sec (Leonard, 2004, cited in SKM, 2006).

4.3		Soils	GIS	The Australian Soil Atlas indicates this area is dominated by hydrosol soil type. Hydrosols are soils that are seasonally or permanently saturated, for at least 2-3 months in most years. These soil types typically occur in swamps and low lying areas, including valley floors.
4.4		Groundwater movement and flow dynamics, groundwater levels, gradients, Recharge areas to discharge site, water levels	Describes the temporal nature of groundwater flow at the site, seasonality, depth to groundwater, long term trend of GW level. Describe the direction of groundwater movement from the recharge zone to the site.	The closest watertable observation bore to the Sale Common is SOB 90423, located 1,100 m from the wetland. Groundwater levels are relatively stable from 1990-2012, fluctuating between 4 m and 5 m below ground surface. The statewide depth to groundwater mapping indicates groundwater is within 5 m of the surface in the vicinity of Sale Common. In the area around bore 90423 the statewide mapping indicates increased depth to groundwater, ranging from 5-10 m below the surface.  Between Sale and Lake Wellington, shallow groundwater flow is generally southerly toward the Latrobe River and fringing wetlands and easterly toward Lake Wellington. Discharge zones occur at Heart Morass and Dowd Morass and therefore it is likely that they also occur in the Sale Common (GHD, 2005, cited in WaterTechnology, 2011). Estimates are: <table><tr><td></td><td>Upstream gradient</td><td>Downstream gradient</td></tr></table>

<table>
<tr><td></td><td></td><td></td><td></td><td><table><tr><td>Macleods Morass</td><td>0.8mAHD</td><td>0.8mAHD</td><td></td></tr></table></td></tr>
<tr><td>4.5</td><td></td><td>Groundwater quality, chemistry</td><td>Site specific</td><td>Statewide groundwater salinity mapping indicates groundwater is fresh in the immediate vicinity of the wetland (<500 mg/L TDS) and increases up to 1,000 mg/L TDS away from the wetland.</td></tr>
<tr><td>4.6</td><td></td><td>GW interaction with wetland

Volumes, Spatial variation temporal variation,</td><td></td><td>Water Technology (2011) developed a water balance model for the Sale Common. It was noted that the model did not include groundwater interaction. The reasoning for this was that GHD (2005) reported that between Sale and Lake Wellington, shallow groundwater flow is generally southerly toward the Latrobe River and fringing wetlands and easterly toward Lake Wellington. Discharge zones occur at Heart Morass and Dowd Morass and therefore conditions are likely to be similar for Sale Common (HydroTechnology, 1995). Therefore for the Water Technology (2011) study groundwater influences are assumed negligible.

There is nothing distinctive about topography, geology or hydrogeology that would prevent the southerly flow of groundwater from discharging to the Sale Common. However, since the topography is flat and the watertable gradient is also likely to be flat, the volume of flux between the watertable and Sale Common is expected to be small. The most likely process expected to be operating is a variably gaining/losing wetland, that contributes recharge to groundwater during flooding when the water levels in the Morass a higher than the elevation of groundwater, and groundwater discharges to the wetland during dry periods when the water level in the wetland is below the groundwater elevation. However based on topography, groundwater fluxes are likely to be small.</td></tr>
<tr><td>5.1</td><td>Ecology</td><td></td><td></td><td>The inclusion of Sale Common in the Gippsland Lakes Ramsar site signifies it ecological importance for a diverse range of flora and fauna species. It is recorded that Sale Common is generally filled from freshwater inflows from Latrobe River during October at which time bird abundance and diversity increased markedly (Australian Ecosystems,2010).

Within this broader region there are;
45 threatened fauna species;
185 bird species;
including 87 wader and waterbird species, 27 migratory species listed under the international Japan Australia Migratory Birds Agreement 1974 (JAMBA), China Australia Migratory Birds Agreement 1987 (CAMBA), and the Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention) (Parks Victoria, 1998)
Significant species recorded within or nearby Sale Common include (Water Technology, 2011 and Australian Ecosystems, 2010);
Dwarf Galaxias *Galaxiella pusilla* (found in Flooding Creek (Water Technology, 2011) – listed as vulnerable under the Environmental Protection and Biodiversity Conservation (EPBC) Act 1999 and</td></tr>
</table>

				protected under the Flora and Fauna Guarantee (FFG) Act, 1988; • Green and Golden Grass Frog – vulnerable under the EPBC Act; • Growling Grass Frog - vulnerable under the EPBC Act 1999 and protected under the FFG Act; • Southern Toadlet – vulnerable; • Four FFG Act 1988 listed bird species; ○ Eastern Great Egret *(Ardea modesta);* ○ White-bellied Sea-eagle *(Haliaeetus leucogaster);* ○ Australasian Bittern *(Botaurus poiciloptilus)* – vulnerable under the EPBC Act 1999; ○ Australian Painted Snipe *(Rostratula australis*) – vulnerable EPBC Act 1999 Flora There as six ecological vegetation classes which define Sale Common (Water Technology, 2011); • Aquatic Herbland • Tall Marsh Wetland • Floodplain Riparian Woodland • Aquatic Sedgeland • Open Water • Swamp Scrub
5.2	EWRs			The environmental water requirements of Sale Common have been thoroughly investigated by others (Water Technology, 2011) in an effort to restore ecological conditions of the wetland. This includes the design of water control structures by SMEC (2012) to restore the ecological health. Water regimes recommended by Water Technology (2011) include; • Wetting Flow: Annual fill to inundate the aquatic sedge land to a depth of approximately 0.50 m approx. RL 0.41m AHD target filling level) with a wetland volume of 1,123 ML; • Flushing Flow: A higher velocity inflow to push water into and out of the wetland and fill the wetland to surface water elevation of RL 0.5 m AHD, every 3-5 years; • Drying Frequency: Allow Sale Common to dry for a period 3 to 6 months, generally, from September to March, relying only on local inputs and rainfall. Complete drying of the bed of the wetland every 3-5 years for 3-6 months over summer/autumn; • Larger flood events every 5+ years to flood the Common to RL 1.10 m AHD (2,886 ML).
5.3		Critical GW service	Site specific	Given the minor contribution that groundwater is likely to make to the overall water balance, therefore its critical service to the wetland ecosystem has not been identified. Possible services provided by groundwater are (speculative): - Minor extension of saturation of the wetland during drier conditions.

				- Provision of fresher water to fringing wetland vegetation
6.1	Risk assessment	Key Threat Summary (link to pre, during & post development scenarios)	Site specific / GIS	Current and future potential activities and likely impacts on water regime in Sale Common include: - Intrusion of saline and river water - Stormwater discharge - Water quality risks from contaminated drainage from East Gippsland shire's landfill site at Bosworth Road - Toxic blue-green algal blooms have occurred as a result of degraded water quality during dry periods (Parks Victoria, 2005). - Saline intrusion under low flow conditions. - Climate Change; potential for more saline intrusion due to rising levels in Lake Wellington - Acid Sulphate Soils - Weeds ; Myriophyllum aquaticum). - European Carp (Water Technology, 2011)
6.2		Likelihood: susceptibility	Level of connectivity – are impacts likely to propagate to the GDE?	The connection between groundwater and the wetland is limited due to the low groundwater gradient. Reducing groundwater levels may increase the volume of surface water lost to the groundwater through increased duration of losing conditions, however it is unlikely that the volume will be significant enough to alter the water regime of the wetland. For the same reason, quality impacts of reduced groundwater discharge are expected to be minimal. In general, Sale Common is expected to have low to medium susceptibility to hazards associated with groundwater extraction.
6.3		Likelihood: management	What is the potential to address the threat to the significant site	There are few extraction bores in the vicinity (being mostly wildlife reserve), with the majority unmetered D&S. This means that it would be difficult to closely manage any significant extractions. Management of groundwater extraction associated with coal and CSG may be more feasible than managing stock and domestic extractions and therefore there may be more potential to address the potential threat associated groundwater extraction associated with coal and CSG extraction.
6.4		Consequence: sensitivity	Ecological response if	Wetland water regime is not sensitive to changes in groundwater flux (volume or quality), since there is little groundwater contribution to the wetland. Wetland ecology is assumed to be largely reliant on the wetting/drying

			GW flux was reduced	regime of surface inflows.
6.5		Consequence: value	Whether it is listed on DIWA, Ramsar, Register of the National Estate, TLM icon sites, etc. See 'value' section 1.5	Wetland is high value, especially as a site for supporting a number of significant species and it's listing under the Ramsar Convention. It should be considered high value.
7.1	Data Gaps	Key unknowns		Interaction between groundwater and the wetland. It is assumed to be small due to the flat groundwater gradient, but there is limited data to support this.
7.2		Recommendation of monitoring		Depth to watertable below the lake bed Seepage tests for lake bed sediments (K) Depth to watertable and gradients in surrounding catchment River and creek inflow volumes Wetland size, volume and variation over the year
8.1	References			Key info sources and links SMEC, 2012. Sale Common & Flooding Creek Wetland Watering Infrastructure. Design Report by SMEC for West Gippsland CMA Australian Ecosystems, 2010. Bird Surveys of Latrobe River Wetlands. Report prepared for: West Gippsland Catchment Management Authority Water Technology, 2011, Sale Common Hydrological Investigation. Report prepared for West Gippsland Catchment Management Authority. Parks Victoria (2008) Interim Water management Guidelines for Key Wetlands of the Gippsland Lakes RAMSAR Site. Report prepared for the Parks Victoria Wildlife Unlimited (2010) Surveys of Thomas and Latrobe Rivers Floodplain Project Sites. Report prepared by Wildlife Unlimited on behalf of West Gippsland Catchment Management Authority Bureau of Meteorology, 2012. *Groundwater Dependent Ecosystem-Atlas – various layers*, Australian

				Government. http://www.bom.gov.au/water/groundwater/gde/map.shtml SKM (2006) Sale WSPA Groundwater Resource Appraisal. Prepared for Southern Rural Water.

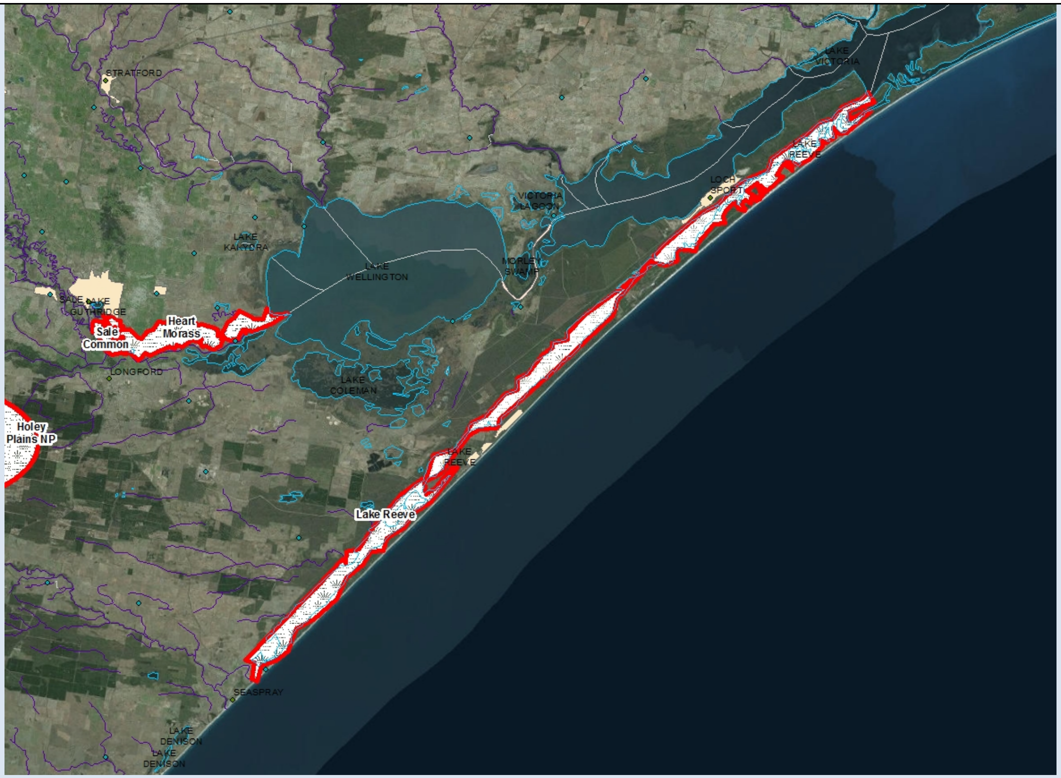
Conceptual Model for Lake Reeve

Lake Reeve – Conceptual Model

<table>
<tr><th>Ref.</th><th>Theme</th><th>Sub-Theme</th><th>Data, Information Sources</th><th>Description</th></tr>
<tr><td>1.1</td><td>General</td><td>Name, location, extents (length & width, area)</td><td>GIS</td><td>
<p>Lake Reeve is a long and narrow coastal wetland located parallel to Ninety Mile Beach in Gippsland. It is 60 km long and stretches between Seaspray in the south east to Rotamah Island (Lake Victoria) in the north west (SKM 2004).</p>
<p>Lake Reeve is considered as three separate systems for this study:</p>

The distal (western end) between Seaspray and Golden Beach causeway which is influenced by flows from Merriman Creek and Carr Creek.
The central section between Golden Beach causeway and Track Ten which is usually dry.
The proximal (eastern) section between Track Ten and the opening to Lake Victoria which is tidally influenced

<table>
<tr><th></th><th>Central point (Z55)</th><th>Average length (km)</th><th>Average width (km)</th><th>Wetland area when full (km2)</th></tr>
<tr><td>Western section</td><td>E526661.3
N5763876.5</td><td>22.36</td><td>0.73</td><td>16.3 km2</td></tr>
<tr><td>Central section</td><td>E540763.6
N5778196.1</td><td>18.6</td><td>0.66</td><td>12.28 km2</td></tr>
<tr><td>Eastern section</td><td>E555381.9
N5791028.4</td><td>21.2</td><td>0.74</td><td>15.69 km2</td></tr>
</table>
<p>Dimensions estimated by reading measurements off a map, therefore approximate only.</p>
</td></tr>
</table>

				
1.2		Ecosystem Type	GIS	Lake Reeve is variously described as a semi-saline to saline coastal wetland. Descriptions from existing sources include: - Coastal saltmarsh (Boon et al. 2014) - Semi-saline wetland (BOM 2012, GDE Atlas, Victorian 1994 wetlands layer (DELWP)) - An extensive intermittent saline wetland providing highly significant habitat for large numbers of migratory birds (Ramsar listing for Gippsland Lakes, in SKM 2004). - At its distal (western) end, Lake Reeve is an intermittently inundated mosaic of saltmarsh (mainly Wet Saltmarsh Herbland with some Coastal Tussock Saltmarsh), Seasonally Inundated Sub-saline Herbland, and unvegetated saline mud flats; at its proximal (eastern) end, it is permanent saline water fronting onto Lake Victoria and fringed by coastal saltmarsh and Swamp Scrub (paperbark) communities (Boon et al. 2011).
1.3		Site history/ timeline	Site specific	The variation of Lake Reeve from the pre European settlement environment can be attributed to several factors: - The establishment of a permanent ocean entrance to the Gippsland Lakes in 1889 at Lakes Entrance. This has resulted in an increase in salinity across the Gippsland Lakes, and lower and less variable Lake Reeve levels (Bird 1966; Harris et al 1998, in SKM, 2004; Boon et al. in press). - The construction of road infrastructure around and through Lake Reeve. This infrastructure has created

<table>
<tr><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td></td><td></td><td></td><td></td><td>hydraulic barriers which restrict the flow of water within the lake (SKM, 2004).
- The construction of the Lake Reeve Floodway in 1978 directly connecting Merriman Creek and Lake Reeve during significant flow events.
- The construction of dwellings around Lake Reeve including Loch Sport, Golden and Paradise Beach, the Honeysuckles and Seaspray. Leachate from septic tanks may have entered Lake Reeve from these dwellings; recreation vehicular access resulting in localised erosion may also have occurred.

Additionally there is anecdotal evidence to suggest prior to European Settlement; Merriman Creek to the west of Lake Reeve may have wandered across the lake into the sea east of the township of Seaspray (SKM, 2004).</td></tr>
<tr><td>1.4</td><td></td><td>Geomorphic description, wetland elevation, catchment geomorphology</td><td>Derived from state wide GMU mapping</td><td>The landscape is flat and low-lying, with elevation less than 10 mAHD in the immediate vicinity of Lake Reeve. Lake Reeve is separated from the ocean by a thin strip of land that is characterised by a series of up to 13 parallel sand dunes (Rosengren 1984, in SKM 2004). These sand dunes were created as sea levels stabilised about 6,000-10,000 years ago, and now constitute Ninety Mile Beach on their seaward side and the border of Lake Reeve on their landward side (Bird 1965, 1993).The Victorian Geomorphology mapping describes the area as having terraced plains with sands and gravels (BOM 2012).

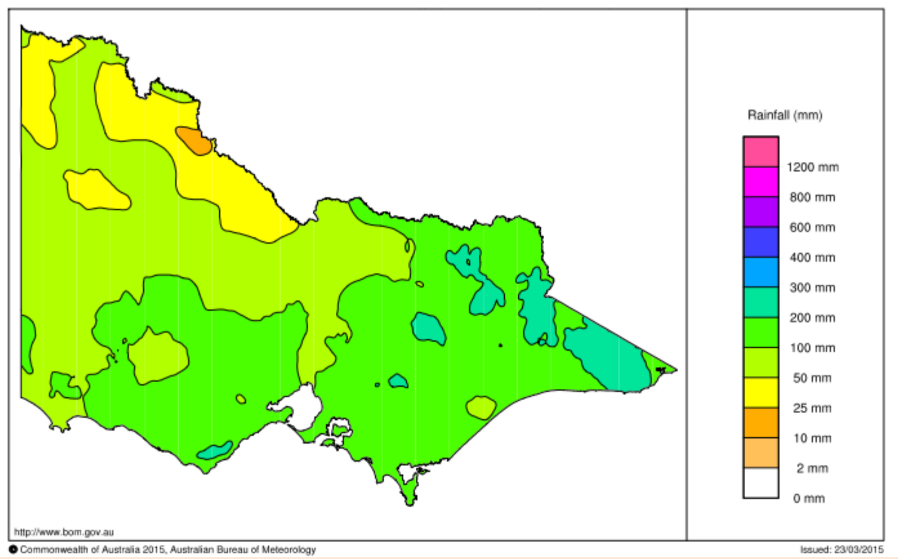
<table>
<tr><th></th><th>Elevation of wetland base (deepest point)</th></tr>
<tr><td>Western section</td><td>0.1 mAHD</td></tr>
<tr><td>Central section</td><td>0.1 mAHD</td></tr>
<tr><td>Eastern section</td><td>0.1 mAHD (DEM)</td></tr>
</table>
Elevations estimated from DEM, therefore approximate only.</td></tr>
<tr><td>1.5</td><td></td><td>Value</td><td>Listings on other databases (Ramsar, DIWA, Register of the National Estate, TLM icon sites)</td><td>Lake Reeve provides habitat for a number of vulnerable and threatened species and supports large populations of migratory wading birds.
Lake Reeve provides habitat for 26 species of waterbird birds protected under CAMBA (the China-Australia Migratory Birds Agreement), and 24 species protected under JAMBA (the Japan-Australia Migratory Birds Agreement): see DSE 2003 (cited in SKM 2004).
The Gippsland Lakes (which includes Lake Reeve) are listed on the:
- Register of National Estate
- Ramsar Convention

Lake Reeve is not listed in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia 2001) but other Gippsland Lakes (Victoria, Wellington, King) are included.</td></tr>
<tr><td>2.1</td><td>Climate</td><td>Rainfall</td><td>Bureau of Met – data on N drive</td><td>The Lake Reeve area is characterised as having low to moderate annual rainfall variability, meaning that rainfall is relatively consistent from year to year (BOM 2011). The area has a wet winter and low summer rainfall (BOM, in SKM</td></tr>
</table>

2012).

A rainfall gradient exists along the length of Lake Reeve, with higher rainfall at the eastern end (673mm/yr at Bairnsdale) and lower at the western end (590 mm/yr at Seaspray) which is in a rainshadow.

Rainfall isohyets for the year to date show the rainshadow area to the west of Lake Reeve in a map format instead (BOM 2015).



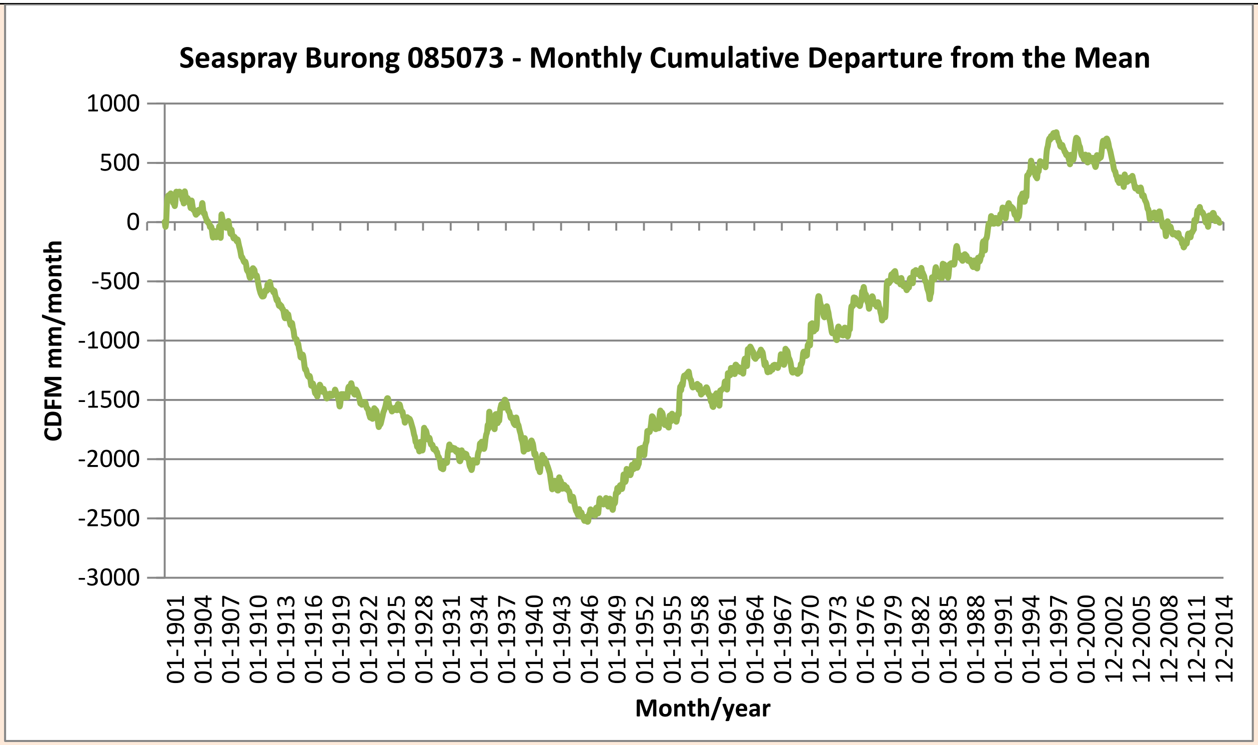
The two closest rain gauges are:

- Seaspray Burong 085073, 2.1 km west of Lake Reeve

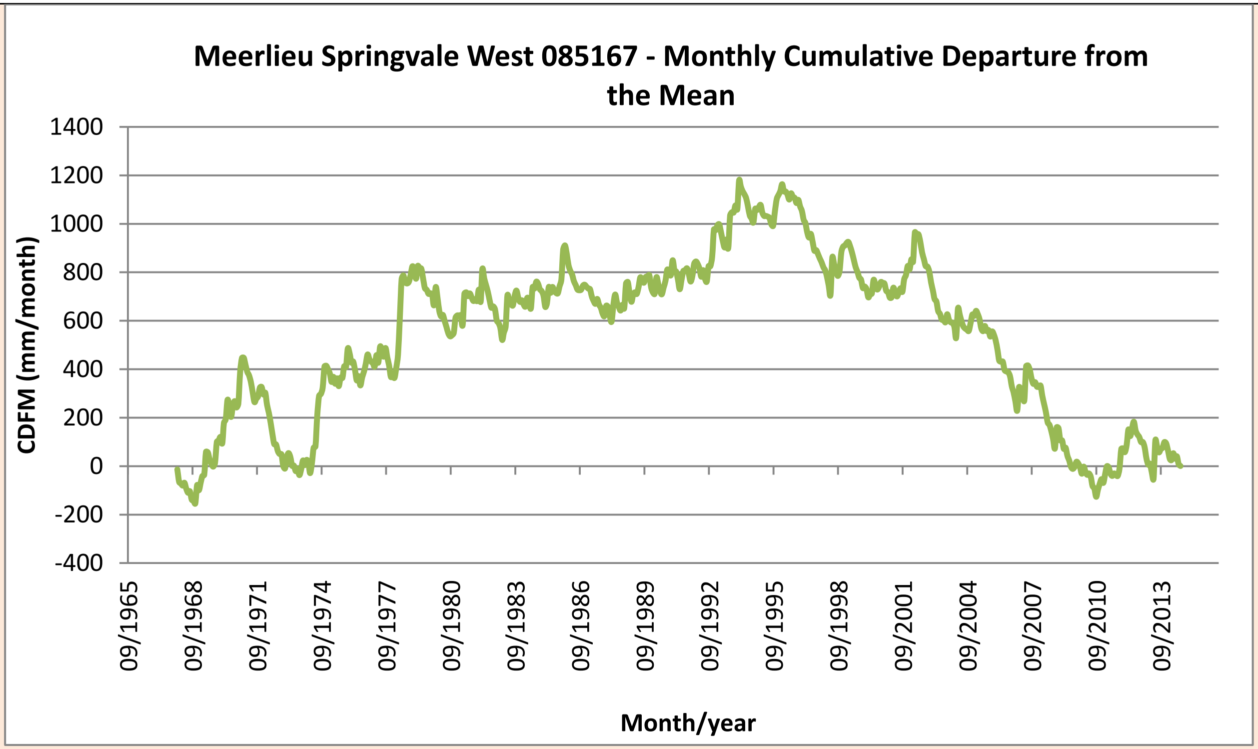
    - Data period: 1900 – 2014
    - Average annual rainfall: 595 mm/yr
    - Average monthly rainfall: 49.6 mm/yr

- Meerlieu Springvale West 085167, 15.3 km north of Lake Reeve
    - Data period: 1968 – 2014
    - Average annual rainfall: 625 mm/yr
    - Average monthly rainfall: 51.9 mm/yr

Graphs of the monthly cumulative departure from the mean (see below) show that rainfall was consistently below average between 2002 and 2010. It was slightly above average rainfall between 2011 and 2012, and since then has hovered around the long-term average value.

Seaspray Burong 085073 - Monthly Cumulative Departure from the Mean
CDFM mm/month
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
01-1901
01-1904
01-1907
01-1910
01-1913
01-1916
01-1919
01-1922
01-1925
01-1928
01-1931
01-1934
01-1937
01-1940
01-1943
01-1946
01-1949
01-1952
01-1955
01-1958
01-1961
01-1964
01-1967
01-1970
01-1973
01-1976
01-1979
01-1982
01-1985
01-1988
01-1991
01-1994
01-1997
01-2000
12-2002
12-2005
12-2008
12-2011
12-2014
Month/year

<table>
<tr><td></td><td></td><td></td><td></td><td>


</td></tr>
<tr><td>2.2</td><td></td><td>Evaporation</td><td>Bureau of Met – data on N drive</td><td>
Annual evaporation substantially exceeds rainfall at Lake Reeve.
The closest evaporation gauge is at East Sale Airport (85072), approximately 28 km north of Lake Reeve.
- Data period: 1972 – 2014
- Average annual evaporation: 1,338 mm/yr
- Average monthly evaporation: 112.6 mm/yr
The evaporation reported at East Sale Airport is a Class A Pan measurement. The evaporation from Lake Reeve, an open water body can be estimated by multiplying the East Sale Airport Class A Pan data by a factor of 0.8 (SKM, 2004). The factored annual evaporation estimates at Lake Reeve are provided below. Evaporation is generally at least double rainfall, and is therefore a significant influence on the water balance.
</td></tr>
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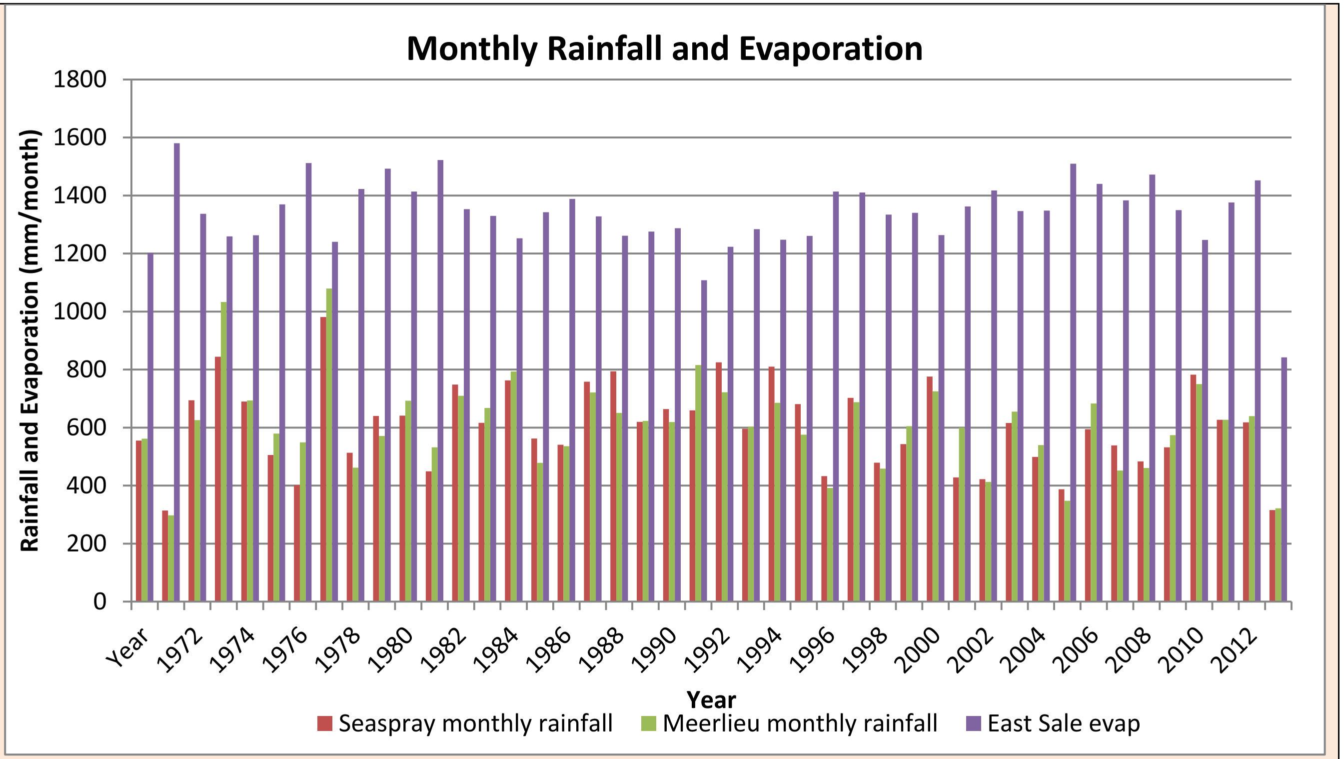
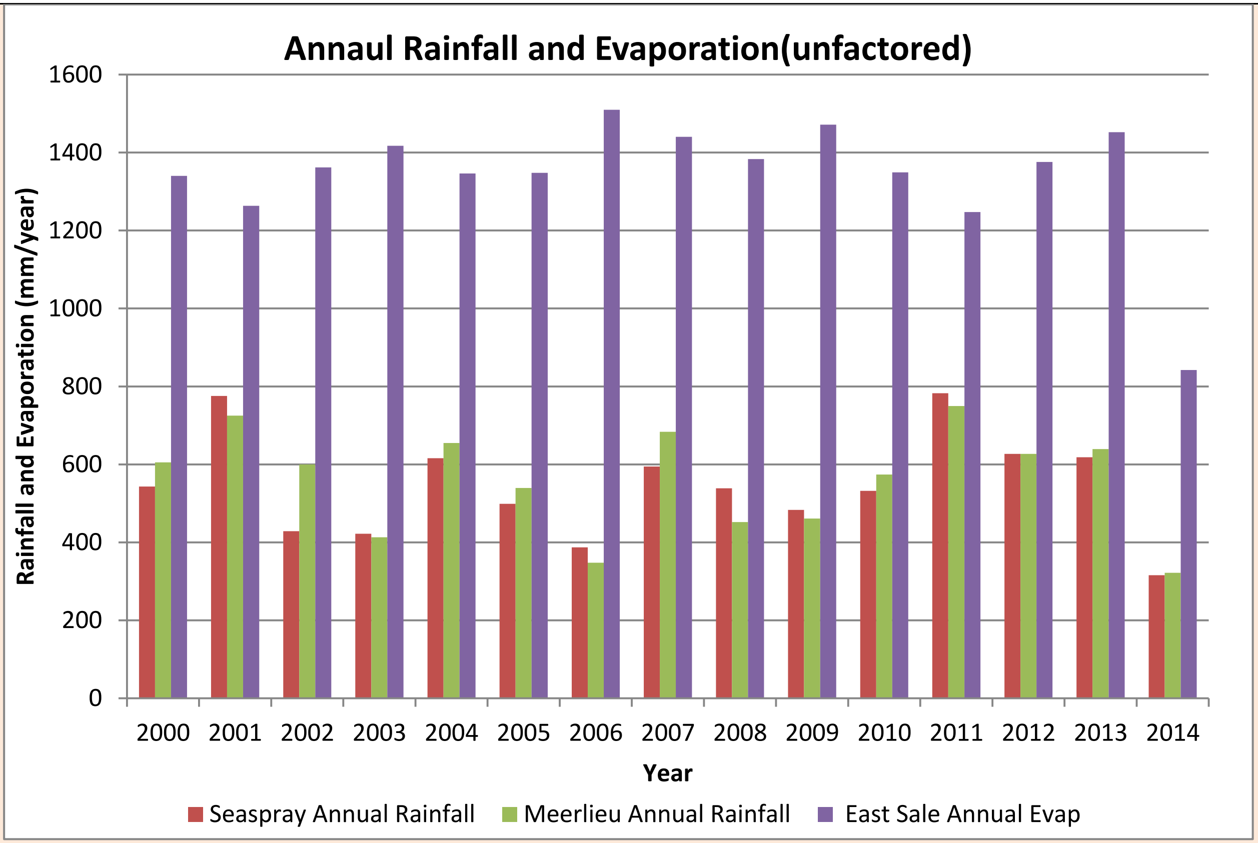
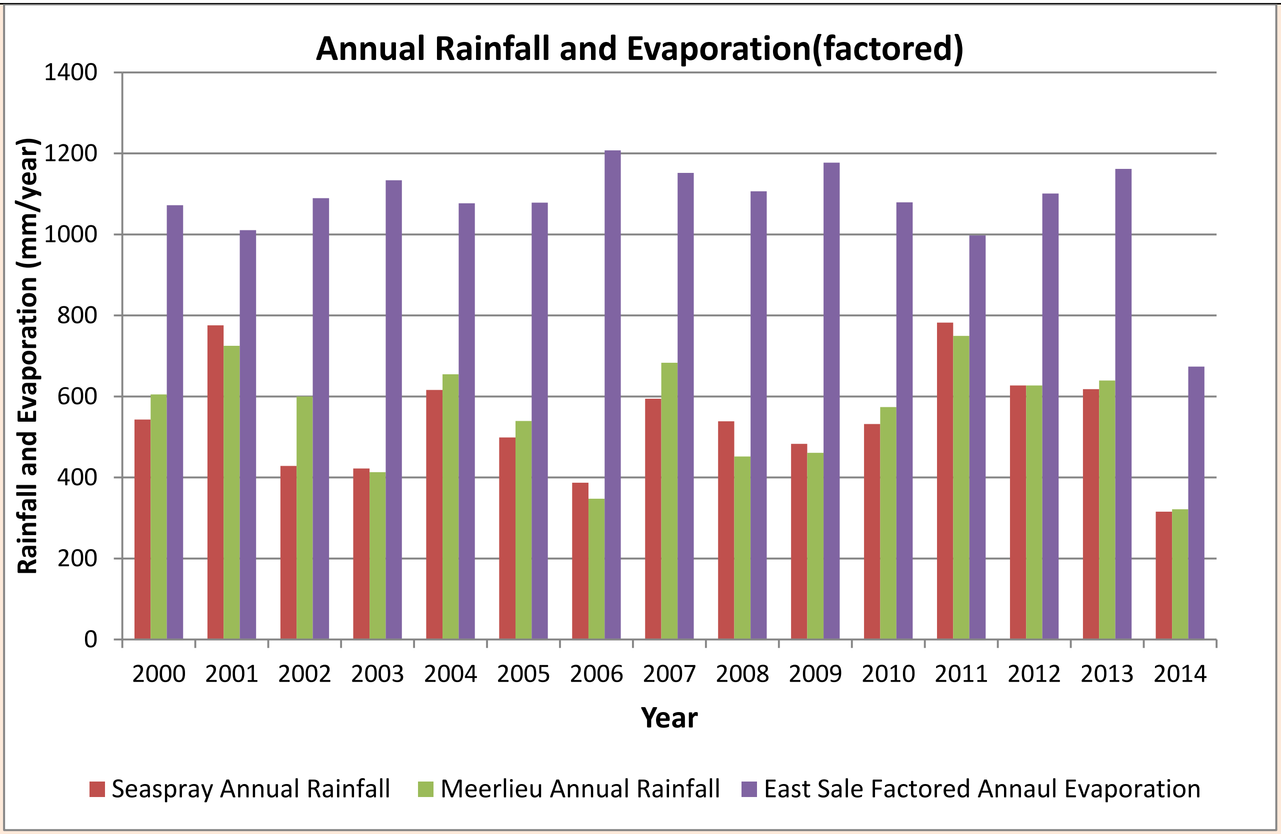
				Monthly Rainfall and Evaporation Rainfall and Evaporation (mm/month) 1800 1600 1400 1200 1000 800 600 400 200 0 Year 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 Year Seaspray monthly rainfall Meerlieu monthly rainfall East Sale evap

Annaul Rainfall and Evaporation(unfactored)
Rainfall and Evaporation (mm/year)
1600
1400
1200
1000
800
600
400
200
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year
Seaspray Annual Rainfall
Meerlieu Annual Rainfall
East Sale Annual Evap

				
3.1	Hydrology	Surface water regime, wet surface area, water levels, permanence, flow, changes in	Site specific	Overview Due to the large area Lake Reeve covers it is appropriate to review the hydrology of the site based on catchment regions. The proximal (eastern) end Lake Reeve is permanently inundated because of its permanent linkage with Lake Victoria. The distal (western) end lies in a rainshadow area and is often dry. This results in the development of large saline mud and sand flats (Rosengren 1984 in SKM 2004). No changes in storage have been identified, other than seasonal fluctuations. Eastern end Lake Reeve is connected to the ocean at its eastern end via Lake Victoria/Lakes Entrance inlet, which was excavated in 1889. Since then, this ocean connection has resulted in: - lower water levels in Lake Reeve (and the Gippsland Lakes more generally) and

storage

- less variability in lake water levels (Harris et al 1998, in SKM 2004)
- inflow of marine water to the Lakes system, causing increasing salinity through the entire Lakes complex.

Water flow and levels in the eastern part of Lake Reeve are now tidally influenced, whereas in pre-European times the Gippsland Lakes as a whole would have operated as an intermittently closed and open coastal lagoon, with prolonged fresh periods when the entrance to the ocean (near today's Lake Bunga) was closed. Saline conditions would have existed only after the entrance was temporarily opened by floods or storm surges. Water now flows towards the south west from the Lake Victoria inlet and water depth is a maximum depth of 1.8 m. Salinities at the mouth of Lake Reeve (between Sperm Whale head and Rotomah Island) are now often 20 g/L (seawater is 35 g/L). The extent of tidal influence reaches Track Ten (west of Loch Sport). Between Track Ten and the Golden Beach causeway there is some tidal influence as water is transmitted under Track Ten through pipes during large tidal events (SKM 2004).

Easterly winds cause seiching (waves) within the Gippsland Lakes and thus an increased inflow of saline water from Lake Victoria (SKM 2004).

The inflow of saline water from Lake Victoria maintains permanent inundation in the eastern part of Lake Reeve from the intersection with Lake Victoria to Loch Sport.

During wet years, flooding of the Gippsland Lakes occurs, and can result in lake water levels being several feet higher than sea level (SKM 2004). Floods are more common from the Lake Victoria entrance than the western end of the Lake, and anecdotally occur about twice every 15 years (SKM 2004).

	Max when full	Average annual	Average seasonal
Wet surface area (m2)	15,690,000	12,000,000	Spring – unknown Summer – unknown Autumn – unknown Winter – unknown
Water level depth (m)	1.8	1.4	Unknown
Water level (mAHD)	1.9	1.5	Unknown

All estimates based on anecdotal information – high uncertainty.

Western end

The western end of Lake Reeve is seasonally or intermittently inundated, and usually dries out by early summer. The reach between the Golden Beach causeway and Greables Island dries out first, followed by the western-most reach (Greables Island to Merriman Creek inlet). Flow of water is to the north east, away from the Merriman/Carr Creek inlets.

Water levels in the distal end of Lake Reeve are lowest in summer/autumn when inflows (from Merriman Creek and Carr Creek) are lowest and evaporative losses are greatest. Maximum water depth is about 1m at the Golden Beach causeway

<table>
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<p>(SKM 2004).</p>
<p>Floods are less common for the western end of Lake Reeve, anecdotally occurring once every 15 years (SKM 2004).</p>
<table>
<tr><th></th><th>Max when full</th><th>Average annual</th><th>Average seasonal</th></tr>
<tr><td>Wet surface area (m2)</td><td>16,322,800</td><td>6,000,000</td><td>Spring – 16,322,800
Summer - 0
Autumn - 0
Winter – 8,000,000</td></tr>
<tr><td>Water level depth (m)</td><td>1</td><td>0.35</td><td>Spring - 1
Summer - 0
Autumn - 0
Winter – 0.4</td></tr>
<tr><td>Water level (mAHD)</td><td>1.1</td><td>0.4</td><td>Spring – 1.1
Summer - 0
Autumn - 0
Winter – 0.5</td></tr>
</table>
<p>All estimates based on anecdotal information – high uncertainty.</p>
<p><u>Central Section</u></p>
<p>Between the inflows from the east and west the remainder of Lake Reeve is largely dry. Inflow contributions occur from direct catchment rainfall runoff and groundwater recharge, but the volumes are anticipated to be very small (SKM, 2004). The area north east of Golden Beach can be supplied from tidal water from Lake Victoria which is transmitted via pipes under Track Ten.</p>
<p><u>Barriers to flow</u></p>
<p>There are a number of hydraulic barriers across Lake Reeve that restrict the flow of water:</p>

A road barrier between The Honeysuckles and The Island (the Honeysuckles Causeway) in Lake Reeve
A topographic high between Greables Island and the western part of the lake
The three road causeways between Greables Island and both sides of the lake.
The Golden Beach Causeway (Longford-Letts Beach Road
A road barrier where Track Ten crosses the lake.
The Loch Sport Causeway connecting the town with the open beach

<p>Pipes under each of these barriers transmit some flow, and in high flows or floods water overtops these barriers.</p>
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<tr>
<td>3.2</td>
<td>Hydrology</td>
<td>Surface water</td>
<td>In all cases available site</td>
<td><u>River inflows</u></td>
</tr>
</table>

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<tr>
<td></td>
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<td>inflows, outflows</td>
<td>specific information will override regional assessments</td>
<td>Two creeks contribute flow to the western end of Lake Reeve on a seasonal or intermittent basis:
- Carr Creek is the largest stream draining into Lake Reeve. It has a catchment area of 250 km^2 and flows seasonally. The creek contributes very small seasonal flows except during a wet winter (Nicholson, 1972). When it does flow, the creek enters Lake Reeve from Pancake Flat, opposite Glomar Beach, about 9 km from the extreme western end of Lake Reeve at the Honeysuckles. The creek is not gauged and so average annual flows are not recorded in the Victorian Data Warehouse.
- Merriman Creek contributes flood flows every one or two years via a flood channel that runs through Seaspray (Wellington Shire, 1996). Average flows from Merriman Creek are ~88 ML/day, but these flow to the ocean via an intermittent opening at Seaspray and mostly do not reach Lake Reeve. During floods, a regulating structure directs flow to Lake Reeve at a maximum rate of 1,296 ML/day. On occasions, flood flows from Merriman Creek have reached as far east as Carr Creek or even the Golden Beach Causeway (Ron McGuiness, landowner, pers. comm., SKM 2004; Nicholson, 1972).
<table>
<tr><th></th><th>Average annual (ML/d)</th><th>Average seasonal (ML/d)</th></tr>
<tr><td>Carr Creek</td><td>15*</td><td>Spring – unknown
Summer – 0
Autumn – 0
Winter – 60 ML/d (5400ML)</td></tr>
<tr><td>Merriman Creek</td><td>5**</td><td>Spring – unknown
Summer – unknown
Autumn – unknown
Winter – unknown</td></tr>
</table>
* based on an assumed flow of 60ML/d in winter from Carr Creek, spread over the whole year = 15ML/d
** no data, but assumed to be significantly less than Carr Creek

<u>Lake inflows/tidal influence</u>

Lake inflows (from Lake Victoria) and tidal influences (from the Lakes Entrance Inlet via Lake Victoria) dominate the water balance at the eastern end of Lake Reeve.
When the Gippsland Lakes are in flood the eastern end of Lake Reeve is flushed with fresh water. This occurs about twice every 15 years, and can result in Lake levels several feet above sea level.
Permanent water is maintained in the eastern end of Lake Reeve by the tidal influence from the Lakes Entrance Inlet (via Lake Victoria). The ‘usual’ maximum water depth (assume this means seasonal) is about 1.8m in the eastern part of the Lake. The tidal influence maintains permanent water between the lake Victoria inlet and Loch Sport, but some tidal influence is observed down to the Golden beach causeway, as pipes under Track Ten transmit high tides further down the Lake.</td>
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</table>

Catchment runoff

The Lake Reeve catchment has an area of approximately 911 km2, of which the majority is made up by the Merriman Creek catchment (529 km2) and the Carr Creek catchment (250 km2).

	Whole lake	Western section	Central section	Eastern section
Whole catchment area	911,000,000	na	na	na
Wetland catchment area (excl. river catchments)	132,000,000	48,602,000*	36,615,000*	46,783,000*
Dry wetland catchment area (excl. max. wetland area)	87,730,000	32,302,000	24,335,000	31,093,000

* assumes catchment area is proportional to wetland area

Catchment runoff to Lake Reeve consists of runoff from rural and urban land uses, as well as from plantation forests and areas of native vegetation, including heathlands and low coastal scrub/woodlands.

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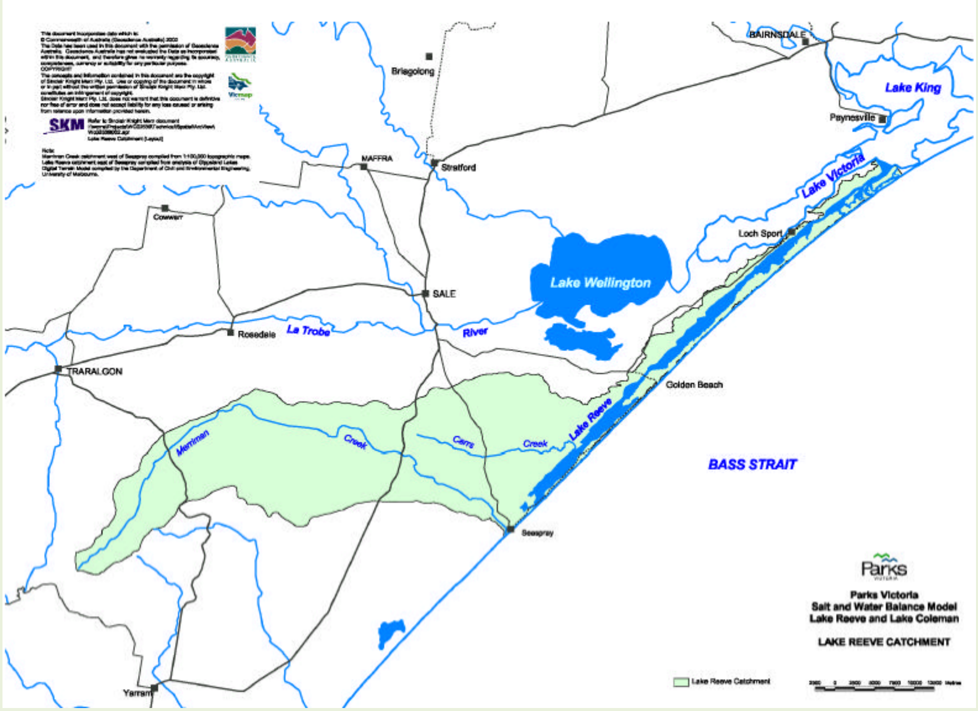

<u>Direct recharge</u>

The Lake bed is extensive (49 km2) and is directly recharged by rainfall (WBM Oceanics 2000, in SKM 2004). The percentage of infiltration vs runoff is not known.

<u>Evaporation</u>

Multiplying the recorded evaporation by a pan factor of 0.8 gives an estimated annual evaporation at Lake Reeve of 1,070 mm/yr (SKM 2004). This is well in excess of the annual rainfall.

Since Lake Reeve is long and shallow (i.e. large surface area to volume ratio), it heats quickly and is therefore more susceptible to evaporation than deeper lakes (SKM 2004).

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<tr>
<td>3.3</td>
<td></td>
<td>Surface water quality, chemistry</td>
<td>Site specific</td>
<td>

There is no water quality data available for Lake Reeve, although previous reports have tested the Lake and groundwater for parameters including EC and nutrients. The saline groundwater at Loch Sport is thought to be a result of seepage from the base of the Lake (Nicholson 1972 in SKM 2004), although the same report notes that there is saline sand and mud on the lake bed that limits seepage. Another report suggests groundwater discharges to the Lake at the same location (Hydrotechnology 1995). The conflicts indicate that the interaction between groundwater and the Lake is not understood.

Salinities in the eastern end of Lake Reeve are likely to be more constant (~ 20 g/L) because of the permanent connection

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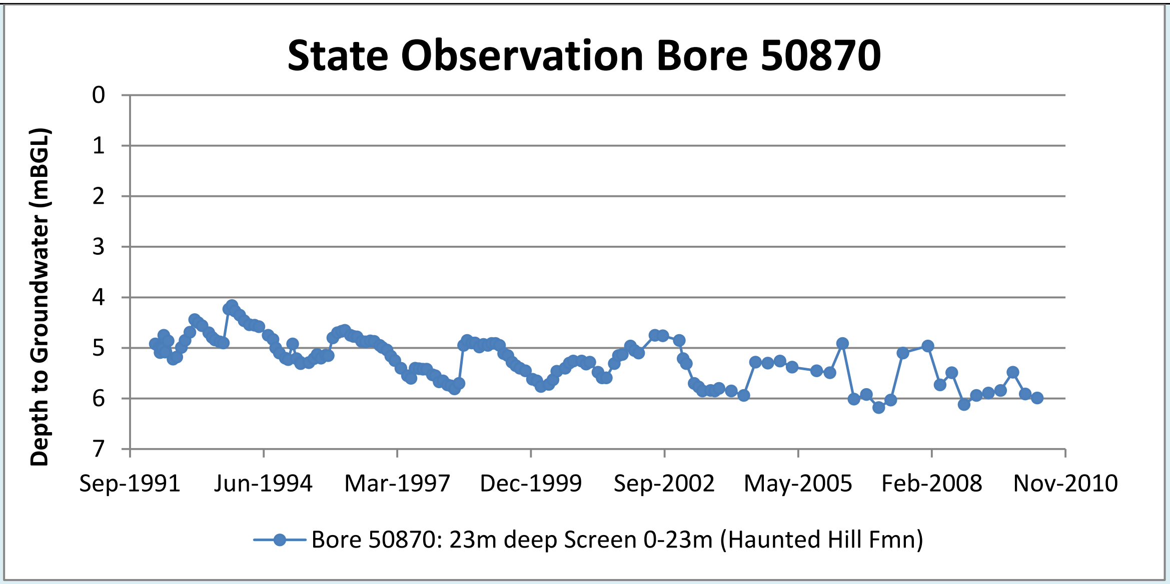
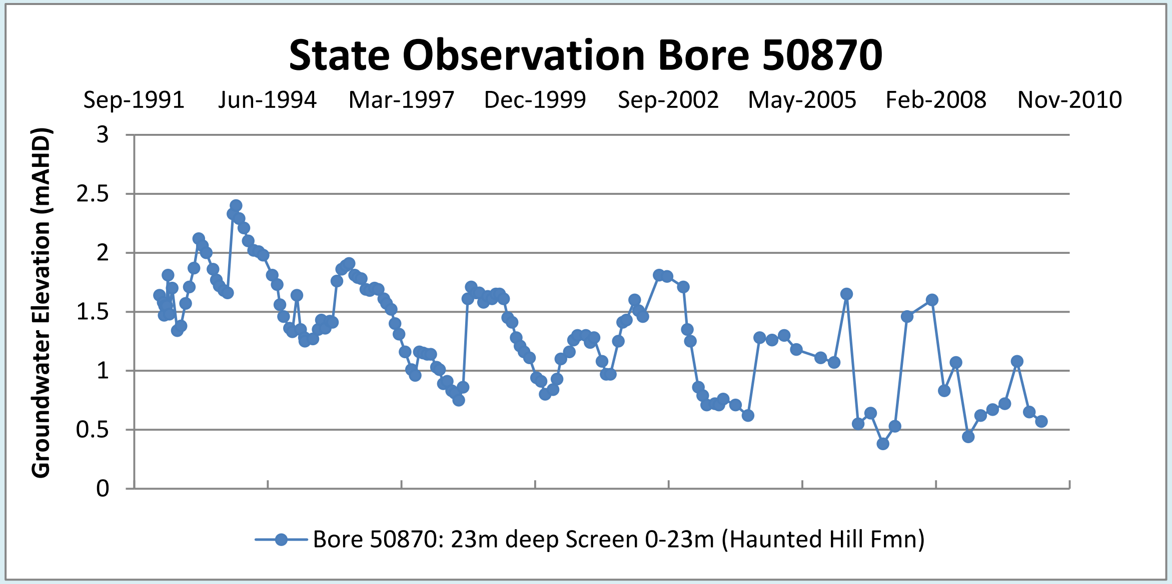
				to the ocean at Lakes Entrance via Lake Victoria. There is likely to be some variation however, with freshwater inflows down the main rivers that discharge into the Gippsland Lakes (e.g. Mitchell River) and with wind and storm surges that result in seiching of water within Lake Victoria. In contrast, salinities in the central portion and western end of Lake Reeve are likely to be highly variable, according to floods down Carr and Merriman Creeks, local catchment runoff, possible intrusions of saline groundwater, and evaporative losses. Note that sediment salinities might be considerably higher than surface water salinities, because of evaporative concentration of salts. Testing did not find evidence of contamination from septic tanks in Dutson Downs (Lee and Hayes 1993 in SKM 2004), but did find elevated abundances of E. coli, coliform bacteria and nitrate from septic tanks in Loch Sport (SKM 2003 in SKM 2004).
4.1	Hydrogeology	Geology	GIS	The Sale 1:250 000 geology map indicates the surface geology at Lake Reeve is Quaternary Aeolian dune deposits consisting of sand, clay and calcareous sand on its inland side, and Quaternary Aeolian coastal and inland dunes and swamp deposits on the coastal side. The lithology log for State Observation Bore 50870 (inland side of the Lake) indicates sand lithology to a depth of 19 m below surface.
4.2		Aquifer(s)	GIS	The watertable aquifer in this area is shallow and resides in the Quaternary sediments. This is the most likely source of interaction with Lake Reeve.
4.3		Soils, substrate	GIS	Lake Reeve is characterised by widespread carbonate mud accumulation throughout most of the lagoon, which is expected to be up to 30 cm thick in some parts of the lagoon. The carbonate mud is thought to have resulted from gradual deposition of the shells of marine and estuarine organisms such as crabs and molluscs.
4.4		Groundwater movement and flow dynamics, groundwater levels, gradients, Recharge areas to discharge site, water	Describes the temporal nature of groundwater flow at the site, seasonality, depth to groundwater, long term trend of GW level. Describe the direction of groundwater movement from the recharge zone to the site.	Information on groundwater levels is very limited in this area. The closest watertable monitoring bore to Lake Reeve is bore 50870, which is approximately 4 km north of the Lake. Nevertheless, the groundwater levels for this bore indicate a reasonably shallow watertable (around 5 m below surface) and seasonal fluctuations. In many areas the water table is within two metres of the surface, particularly around the lakebed (SKM 2004).

levels

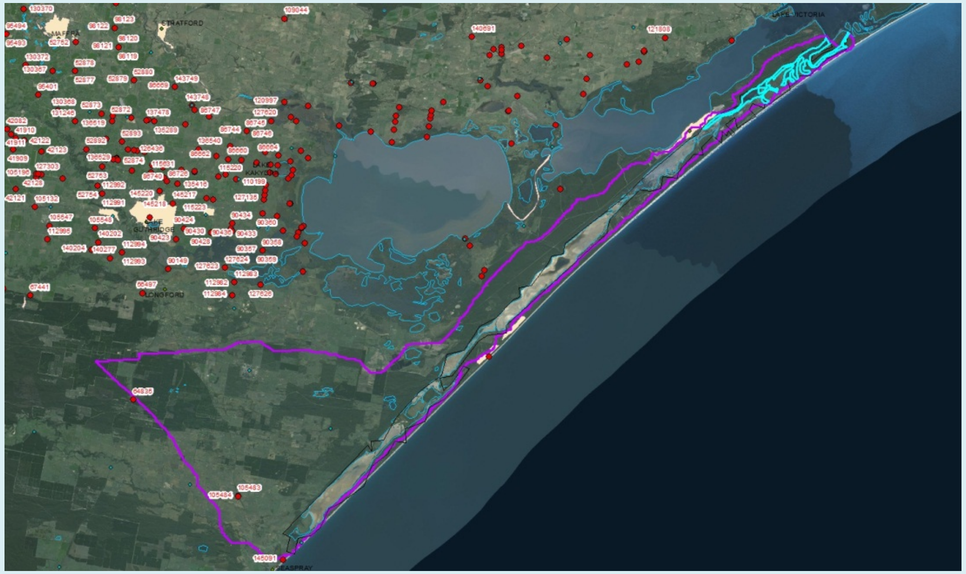


The groundwater elevation is generally less than 2m above sea level even 4km from the coast, indicating a low hydraulic gradient in the watertable aquifer.



Groundwater recharge to the watertable aquifer is primarily from the infiltration of rainfall, with seasonal fluctuations in response to seasonal rainfall.

Groundwater gradients are expected to be low due to the flat topography and high permeability of sediments surrounding the lake. A groundwater divide is mapped between Lake Reeve and Lake Wellington/Victoria to the north, indicating that direct rainfall recharge contributes flow to both the north and the south. Low gradients mean the rate of groundwater flow will be slow. A review of groundwater and lake levels supports the existence of this groundwater divide. Similarly, a groundwater divide exists in the dunes between Lake Reeve and the coast, indicating that direct recharge of rainfall in this area flows towards both the lake and the ocean. The groundwater catchment is small, which indicates that groundwater discharge to Lake Reeve is also likely to be minor.



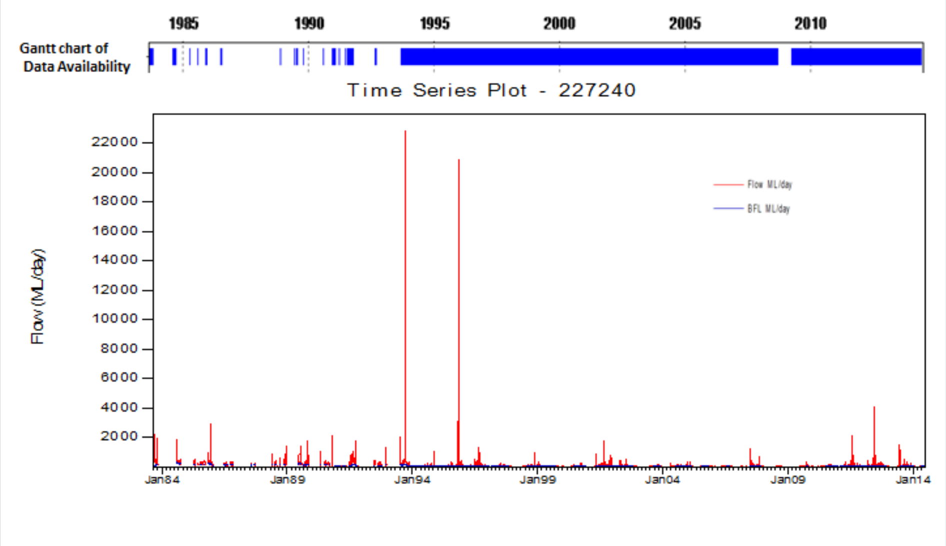
The gradients indicate that the wetland is gaining, although since gradients are low it is possible that the direction of flow between the lake and the watertable aquifer changes seasonally in response to changes in lake water levels. Since the wetland is conceptualised as predominantly gaining, groundwater levels must be higher than lake levels.

Estimates are:

	Upstream watertable head (mAHD)	Downstream watertable head (mAHD)
Western section	0.6	0.6

<table>
<tr><td></td><td></td><td></td><td></td><td><table><tr><td>central section</td><td>0.6</td><td>0.6</td></tr><tr><td>Eastern section</td><td>0.6</td><td>0.6</td></tr></table>
Groundwater discharge is expected to occur from the shallow alluvial aquifer into Lake Reeve. SKM (2004) conceptualise this to occur primarily from the southern edge of the lake, however discharge from the north is also expected to occur in some areas (Figure 1). SKM (2004) indicate that landowners believe groundwater is unlikely to be a major influence to the overall lake hydrology, although the greatest groundwater inflows are likely to occur from a northwest direction at the western end of the Lake.
Annual groundwater discharge into Lakes Reeve and Victoria from the shallow alluvial aquifer in the area of Loch Sport is estimated to be 40 to 160ML/year (HydroTechnology, 1995).
The information available on groundwater interaction with Lake Reeve is limited, and partly contradictory, but indicates that there is a high level of uncertainty regarding groundwater discharge to Lake Reeve.</td></tr>
<tr><td>4.5</td><td></td><td>Groundwater quality, chemistry</td><td>Site specific</td><td>There is very little data on groundwater quality in the vicinity of Lake Reeve. In dry periods, the groundwater level near the lake shore tends to drop to sea level and become saline. After rain the groundwater levels rise and becomes fresher (Nicholson, 1972).
A previous study was undertaken to investigate the impact of septic tank contamination from Loch Sport on Lake Reeve. The study found that many areas around the lake margins had elevated groundwater salinity, particularly near Loch Sport, which was interpreted as an indication of seepage of lake water to the watertable aquifer (SKM, 2004).
Elevated abundances the faecal bacterium E. coli, as well as coliform bacteria more generally and nitrate were found in groundwater at Loch Sport with the conclusion that septic tanks in the township of Loch Sport were leaking. The nitrogen load per unit catchment area contributed by groundwater discharging from Loch Sport to Lakes Reeve and Victoria was estimated to be between 2 and 20 times the average for the entire Gippsland Lakes catchment (SKM, 2004).
Rising salinity levels in Lake Reeve are thought to be generated by rising groundwater levels and consequent land salinity, and evaporation of water in the lake (SKM 2004).</td></tr>
<tr><td>4.6</td><td></td><td>GW interaction with wetland</td><td></td><td><u>Groundwater inflows/outflows</u>
There is little information on groundwater contributions to Lake Reeve, but the conceptual water balance suggests that groundwater is not a significant component of Lake inflows.</td></tr>
</table>

		Volumes, Spatial variation temporal variation,		Eastern end A small volume of groundwater discharge to the Lake has been assumed to occur from the shallow alluvial aquifer at Loch Sport (40-160 ML/year) (HydroTechnology 1995). However the low permeability substrate and the permanent inundation (mostly from tidal flows from Lake Victoria) make any significant groundwater contribution seem unlikely. Another study suggests that saline groundwater at Loch Sport is the result of seepage from Lake Reeve into the shallow aquifer (SKM 2003). These conflicts show that the direction of groundwater flux around Loch Sport is uncertain or variable, and at any rate, is limited due to low permeability saline sands and muds on the lake bed. Western end Groundwater interaction at the western end of the lake is also uncertain. The water regime is dominated by evaporative losses and, during inundation, by flood flows from Merrimans Creek and Carrs Creek, and very small seasonal flows from Carrs Creek (Nicholson 1972 in SKM 2004). Low permeability sands in the area from Seaspray to Golden beach prevent seepage from the lakebed into the groundwater (Nicholson 1972 in SKM 2004). They are expected also to prevent groundwater discharging to the lake when the watertable is higher, but thus assumption has yet to be tested. Since surface water flows dominate inflows to the western end of Lake Reeve, baseflow could be a significant contribution at certain times of year. However, inputs from Merrimans Creek are largely flood flows, and therefore have a limited baseflow component. Carrs Creek is seasonal and contributes very small flows to Lake Reeve except during floods. The baseflow component is therefore also likely to be insignificant. MERRIMAN CREEK @ PROSPECT ROAD SEASPRAY : (NOTE: LAKE REEVE INFLOW from Merriman creek IS VIA A FLOODWAY – therefore only peak flows reach Lake Reeve and baseflow is not a significant contribution)



Statistics	Flow (ML/day)	BFL(ML/day)		Flow (ML/day)	BFL(ML/day)
Minimum	0	0	Average	88	30
Maximum	22,802	346	Standard Deviation	413	40

Groundwater levels are likely to be controlled by direct infiltration of rainfall, so that levels are higher (and fresher) during periods of high rainfall, and lower (and more saline) during dry periods (Nicholson 1972, in SKM 2004). The groundwater catchment for Lake Reeve is very small and watertable gradients are very low. As such, any flow towards Lake Reeve is minimal.

<u>Central section</u>

Flows into the central section of Lake Reeve a considered to be dominated by the transfer of flow via pipes from the eastern and western ends of the Lake. Conceptually catchment runoff and groundwater are considered to be contributors however the quantities associated with these flows could be considered to be minimal.

The most likely conceptualisation of the Lake Reeve water balance is that a losing/gaining relationship may exist between the Lake and groundwater, although flux volumes would be very small. The Lake is likely to fill quickly either after rainfall (western and eastern end) or from tidal inflows (eastern end). The Lake may recharge groundwater when levels are higher than the watertable. As Lake levels drop primarily through evaporation, groundwater storage may contribute to the Lake. However, low permeability sands and muds at the base of the Lake are expected to prevent significant flux between the Lake and the groundwater (Nicholson 1972, in SKM 2004). In summary, it is likely that evaporative losses are the element forcing the water balance of the central part and distal end of Lake Reeve. This is consistent with the seasonal or intermittent inundation that occurs in these parts of the lake. By contrast, tidal- and wave-driven inundation with saline

				water from Lake Victoria drives the water balance of the proximal (eastern) end of the lake. Even with little flux between the groundwater and the lake, high watertables may be important for prolonging water levels in the lake, by preventing leakage of flood waters from the lake bed. This will only be significant if species rely on a certain length of inundation which is unlikely, given the intermittent nature of inundation from flooding.
5.1	Ecology			Lake Reeve provides habitat for a number of vulnerable and threatened species and is connected to the Ramsar listed Gippsland Lakes. The following outlines what is known of fauna and flora identified in Lake Reeve. Fauna Lake Reeve has high diversity of waterbirds, attracting 12,000 migratory waders each year. It is one of the five most important areas for waders in Victoria (Norris and Mansergh 1981, ANCA 1995, PV 1998), supporting large populations of Red Knot (Calidris canutus), Sharp-tailed sandpiper (Calidris acuminata), and Curlew sandpiper (Calidris ferruginea) (Ramsar Convention Bureau 1999). It provides habitat for 26 species of birds protected under the China-Australia Migratory Birds Agreement, and 24 species protected under the Japan-Australia Migratory Birds Agreement (DSE 2003, in SKM 2004). Habitat availability for significant fauna fluctuates due to changes in salinity, water depth, and probably human disturbance (Norris and Mandsergh 1981, in SKM 2004). Flora The most extensive vegetation type in and around Lake Reeve is Coastal Saltmarsh. A number of different saltmarsh types have been mapped in the lake, including Wet Saltmarsh Herbland with some Coastal Tussock Saltmarsh as well as the related Seasonally Inundated Sub-saline Herbland. Unvegetated saline mud flats are also common Boon et al. 2011, 2014). Vascular plant species recorded for these saltmarsh communities include: - *Sarcocornia quinqueflora* (Wet Saltmarsh Herbland) - *Gahnia filum* (Coastal Tussock Saltmarsh) - *Austrostipa stipoides* Coastal Tussock Saltmarsh) - *Tecticornia pergranulata*, (Coastal Hypersaline Saltmarsh) - *Tecticornia halocnemoides*, (Coastal Hypersaline Saltmarsh) The latter two species are indicative of hypersaline saltmarshes; the first species of saltmarshes of areas with more moderate salinity regimes. The *Gahnia* and *Austrostipa* communities are typical on slightly elevated land, where inundation is less common and salinities generally lower.

				Fringing the coastal saltmarsh are areas of Swamp Scrub, dominated by the Swamp Paperbark *Melalueca ericifolia* , which relies on a regime of regular wetting and drying to flush out saline water and create dry episodes for sexual recruitment (SKM 2004). Behind the Swamp Scrub communities are areas of coastal heathland and woodland, often dominated by *Banksia* spp. It is possible that these rely to some degree on localised areas of (fresh) groundwater for their water supply.
5.2		EWRs	Site specific	Possible environmental water requirements may include: - A certain duration of inundation each year or every two years to maintain a mosaic of different vegetation types along and across the lake bed - Flushing of the lake with fresher water to enable growth of native flora and fauna (SKM 2004) every year at the central portion and western end. Freshwater flushing is unlikely to occur often in the eastern end because of the permanent connection with Lake Victoria at Sperm Whale Head. Localised freshening, however, may be required for the recruitment of some plant taxa even in the proximal end of Lake Reeve, and this would probably be supplied by localised runoff. - Fluctuations in water levels and salinity required to maintain lake vegetation (Norris and Mansergh 1981, in SKM 2004). - Fluctuations in Lake water levels and salinity required to maintain the habitat for the food source of migratory birds (Norris and Mandsergh 1981, in SKM 2004).
5.3		Critical GW service	Site specific	Given the minor contribution that groundwater probably makes to the overall water balance, its critical service to the Lake ecosystem has not been identified. Possible services provided by groundwater are (speculative): - Minor extension of flooding duration, probably limited to the western end of the lake. - Provision of fresher water to the area around Loch Sport at low tides or following floods.
6.1	Risk assessment	Key hazards (link to pre, during & post development scenarios)	Site specific / GIS	Potential threats to the ecology of Lake Reeve (from SKM, 2004): - Sea-level rise (eustatic and storm-surge), resulting in altered hydrological and salinity regimes - Rising salinities in surface waters and surface sediments, caused by an elevated watertable and by the evaporation of saline water introduced after storm surges etc - Rising phosphorus and nitrogen concentrations in the lake resulting in algal blooms, from catchment runoff and septic tank leachate - Changes in flooding/drying regime - Potential damage to vegetation from vehicle access and stock grazing - Groundwater extraction within Lake Reeve catchment for D&S use (e.g domestic water supply in Loch Sport, which is high during summer holidays). - Groundwater extraction in coal mines - Groundwater extraction/aquifer depressurisation for gas extraction

				This risk assessment considers the hazards associated with licenced groundwater extraction only.
6.2		Likelihood: susceptiblity		The connection between groundwater and the wetland is very limited, so reducing groundwater levels will not significantly alter groundwater flux to/from the Lake. For the same reason, quality impacts of reduced groundwater discharge are expected to be minimal. In general, Lake Reeve is expected to have low susceptibility to hazards associated with groundwater extraction, since groundwater flux is already low.
6.3		Likelihood: management	Stresses on groundwater system	The groundwater catchment is small, so most groundwater extraction in the region occurs in other groundwater catchments. There are no bores that extract from the watertable aquifer within the Lake Reeve catchment (CHECK). Even if extraction was occurring in the watertable aquifer close to Lake Reeve, the reduction in watertable elevation would be minimal since the proximity to the ocean would maintain elevations at close to sea level. However if extraction did occur, there may be salinity impacts from sea water instruction into the aquifer. The potential to lower the watertable level is therefore low.
6.4		Consequence: sensitivity		Wetland water regime is not sensitive to changes in groundwater flux (volume or quality), since there is little groundwater contribution to the wetland. Wetland ecology is assumed to be largely reliant on the wetting/drying regime of surface inflows and is therefore not particularly dependent on groundwater. There is no obvious critical groundwater service that supports wetland ecology. Sensitivity to changes in groundwater contribution is therefore low.
6.5		Consequence: value		Wetland is high value, especially due to the abundance of waterbirds and it’s listing under the Ramsar Convention. It should be considered high value.
7.1	Data Gaps	Key unknowns		Interaction between groundwater and the Lake. It is assumed to be small due to low K lake bed and flat watertable gradient, but there is limited data to support this.
7.2		Recommendation of monitoring		Depth to watertable below the lake bed Seepage tests for lake bed sediments (K) Depth to watertable and gradients in surrounding catchment River inflow volumes Wetland size, volume and variation over the year

8.1	*References*			Key info sources and links: Bird ECF (1965). *A geomorphological study of the Gippsland Lakes*. Research School of Pacific Studies, Department of Geography Publication G/1. Australian National University, Canberra. Bird ECF (1966). The impact of man on the Gippsland Lakes, Australia. In *Geography as human ecology. Methodology by example.* Edited by Eyre SR & Jones GRJ. Pages 55-73. Edward Arnold, London. Bird ECF (1993). *The coast of Victoria*. Melbourne University Press, Carlton. Boon PI, Allen T, Brook J, Carr G, Frood D, Hoye J, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M & Yugovic J (2011). *Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management*. Report to DSE, Bendigo. Available on-line at http://www.vu.edu.au/institute-for-sustainability-and-innovation-isi/publications Boon PI, Carr G, Sinclair S, Frood D, Harty C & Yugovic J (2014). Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation. *Aquatic Conservation: Marine & Freshwater Ecosystems* DOI: 10.1002/aqc.2442 Boon P, Cook P & Woodland R (in press). The challenges posed by chronic environmental change in the Gippsland Lakes Ramsar site. *Marine and Freshwater Research* BOM 2011, Climate data online, accessed March 2015, http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall-variability/index.jsp BOM 2012, Atlas of groundwater dependent ecosystems, accessed March 2015, http://www.bom.gov.au/water/groundwater/gde/map.shtml BOM in SKM 2012, Atlas of groundwater dependent ecosystems (GDE Atlas), Phase 2, Task 5 report, Seasonal rainfall zones map. BOM 2015. Current year to date rainfall totals for Victoria, http://www.bom.gov.au/jsp/awap/rain/index.jsp?colour=colour&time=latest&step=0&map=totals&period=cyear&area=vc Davis R, Reas C and Robbins L (2006) Calcite mud in a Holocene back-barrier lagoon; Lake Reeve, Victoria, Australia. Journal of Sedimentary Research. Abstract only. Environment Australia 2001, A directory of important wetlands in Australia, Ed. 3, Environment Australia, Canberra SKM, 2004. Hydrology and Management of Lake Reeve. Report for Parks Victoria

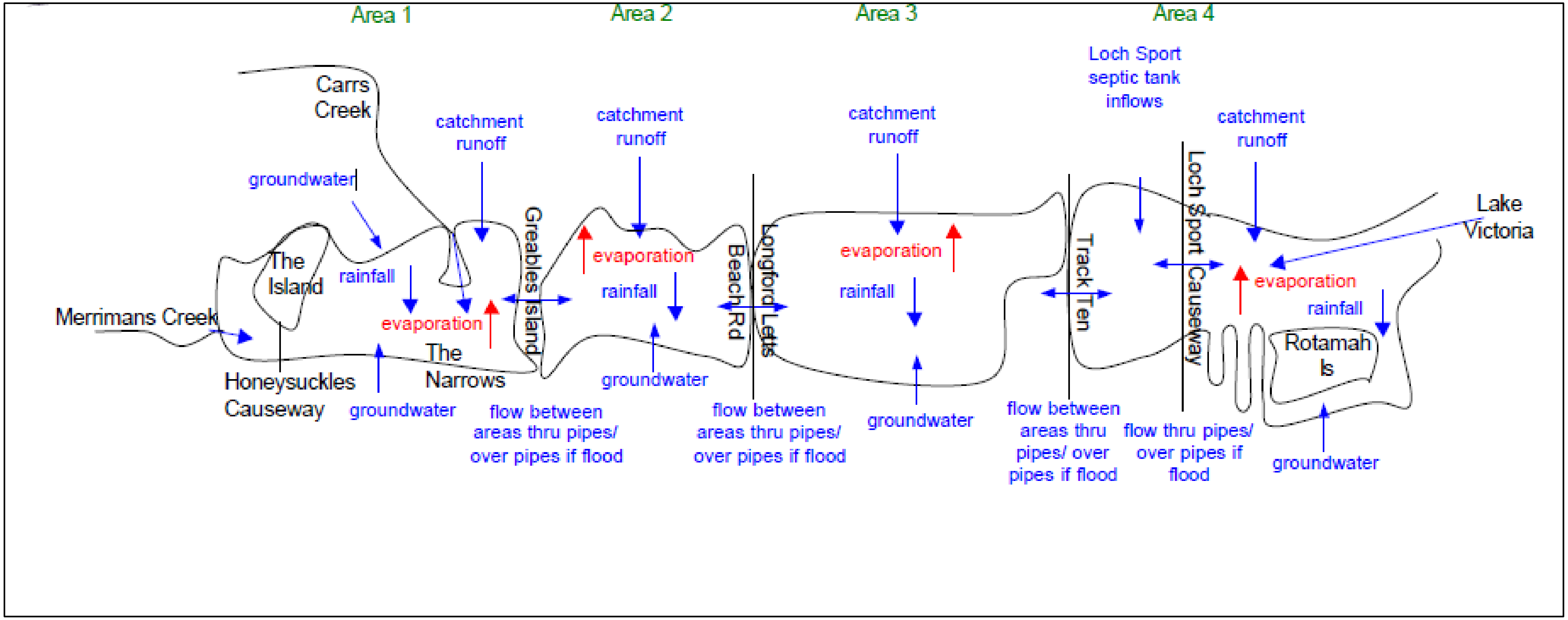


Figure 1 Hydrology, from SKM 2004

Conceptual Model for Giffard Plains

Giffard Plains/Holey Plains – Conceptual Model Information Summary

Ref.	Theme	Sub-Theme	Data, Information Sources	Description
1.1	General	Name, location, extents (length & width, area)	GIS	**Giffard Plains and Holey Plains** The study area is made up of the following wetland sites: ● Wetlands within Giffard Plains. Notable water bodies include the Long Swamp, Harrier Swamp, Clear Water Lake, Ben Winch Swamp, Bellbird Swamp and Craig Swamp (Parks Victoria, 1998 and National Water Commission, 2012). The Holey Plains State Park Management Plan (Parks Victoria, 1998) indicates "a total of 26 wetlands occur in swales between sand ridges where drainage is impeded". ● Wetlands within Holey Plains. There is limited information available, but the GDE Atlas spatial tool (National Water Commission, 2012) indicates approximately 16 deep and shallow marsh wetlands exist within the area. The Giffard /Holey Plains area is located approximately 20-40km south west of Sale within the West Gippsland CMA. Holey Plains is delineated as a 10 742ha State Park, whilst Giffard Plains is within the13,800ha Mullungdung State Park. The two areas are separated by Merrimans Creek.

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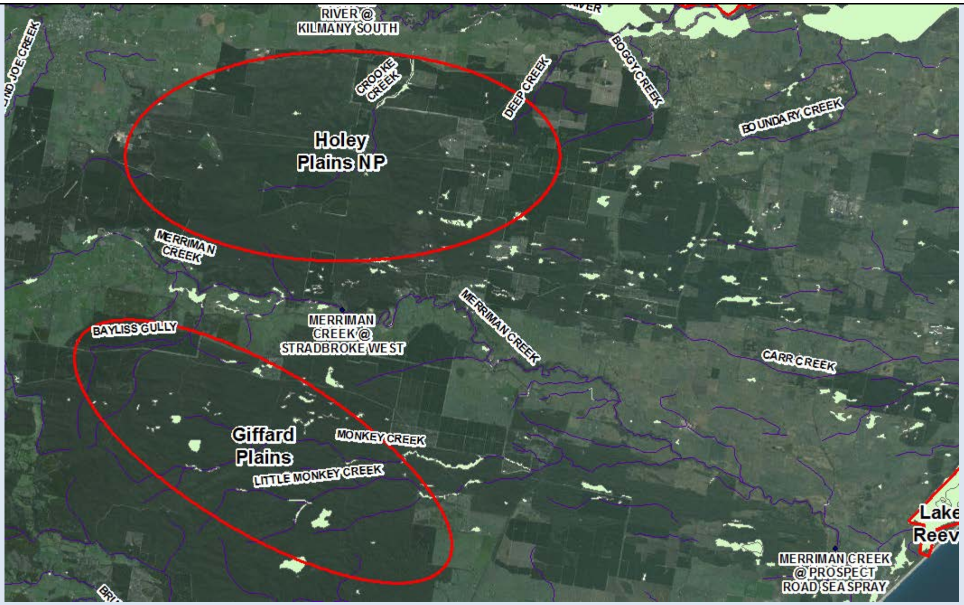
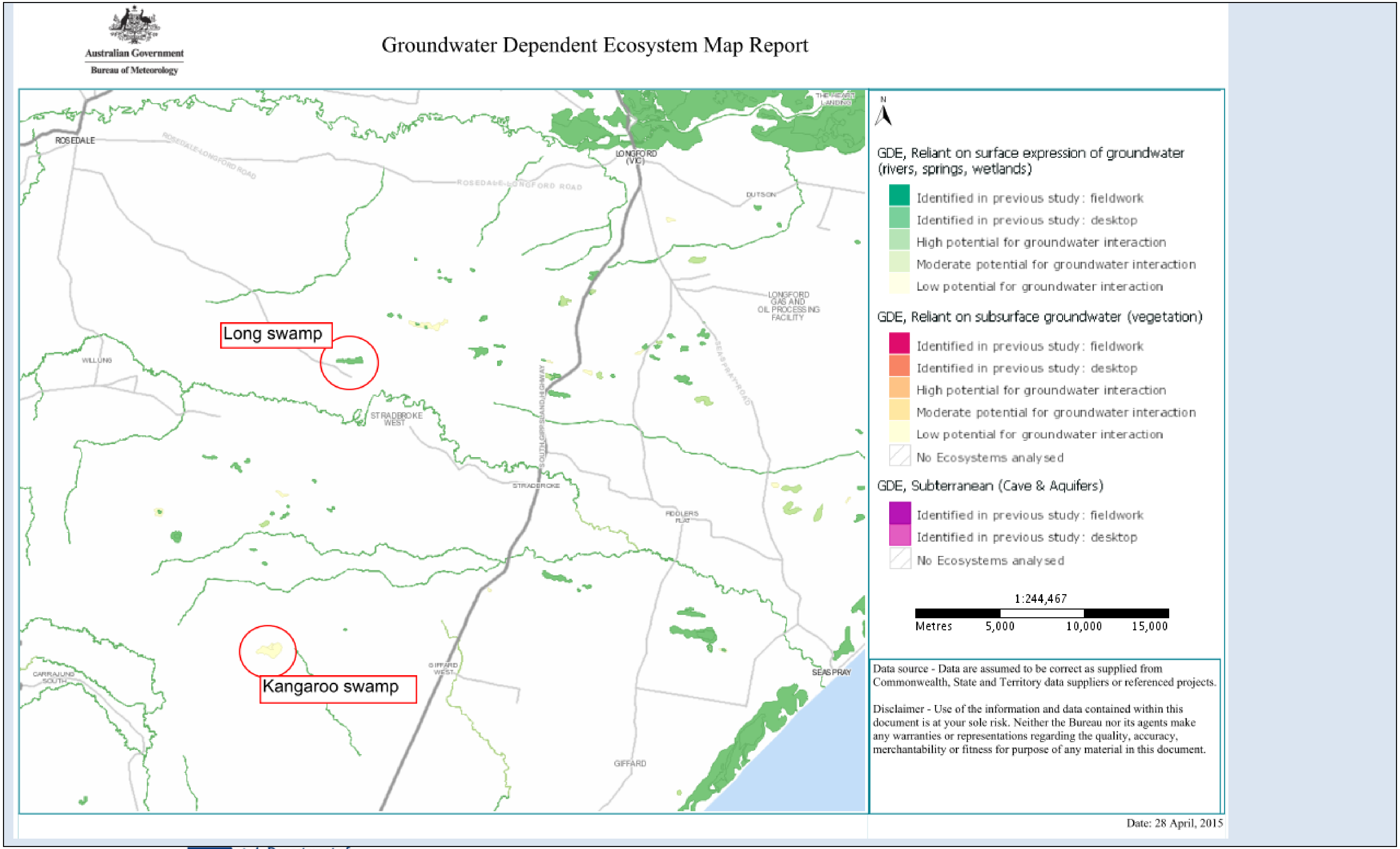


The location of the areas and a ‘typical’ swamp within each area is shown below:
<table>
<tr><td></td><td>Central point (Z55)</td><td>Average length (km)</td><td>Average width (km)</td><td>Wetland area when full (km2)</td></tr>
<tr><td>Holey Plains</td><td>E492577.3
N5771820.3</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>- Long Swamp</td><td>E494197.9
N5766892.5</td><td>1.2</td><td>0.145</td><td>0.174 km2</td></tr>
<tr><td>Giffard Plains</td><td>E489071.5
N5758921.9</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>- Kangaroo Swamp</td><td>E490659.1
N5753497.9</td><td>1.05</td><td>0.36</td><td>0.378 km2</td></tr>
</table>
</td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td>Ecosystem Type</td>
<td>GIS</td>
<td>The wetlands with the Giffard Plains and Holey Plains region are mapped regionally as deep marsh and shallow marsh wetlands (GDE Atlas – wetlands layer, Bureau of Meteorology, 2012).
The wetlands may also be classified as Seasonal Herbaceous Wetlands of the Temperate Lowland Plains (Threatened Species Scientific</td>
</tr>
</table>

				Committee, unknown date), Listed in March 2012 as critically endangered under the EPBC Act, see http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=97&status=Critically+Endangered) The wetlands are generally located in the swales between sand ridges (Parks Victoria, 1998). Wetlands within Holey Plains/Giffard Plains are classified as ecosystems that rely on the surface expression of groundwater, and are classified as having a high to low potential for groundwater interaction (refer to GDE map below) (GDE Atlas –Bureau of Meteorology, 2012).



Australian Government
Bureau of Meteorology

Groundwater Dependent Ecosystem Map Report

GDE, Reliant on surface expression of groundwater (rivers, springs, wetlands)

- 🟩 Identified in previous study: fieldwork
- 🟩 Identified in previous study: desktop
- 🟩 High potential for groundwater interaction
- 🟩 Moderate potential for groundwater interaction
- 🟨 Low potential for groundwater interaction

GDE, Reliant on subsurface groundwater (vegetation)

- 🟥 Identified in previous study: fieldwork
- 🟧 Identified in previous study: desktop
- 🟧 High potential for groundwater interaction
- 🟨 Moderate potential for groundwater interaction
- 🟨 Low potential for groundwater interaction
- ▨ No Ecosystems analysed

GDE, Subterranean (Cave & Aquifers)

- 🟪 Identified in previous study: fieldwork
- 🟪 Identified in previous study: desktop
- ▨ No Ecosystems analysed

1:244,467

Metres 5,000 10,000 15,000

Data source - Data are assumed to be correct as supplied from Commonwealth, State and Territory data suppliers or referenced projects.

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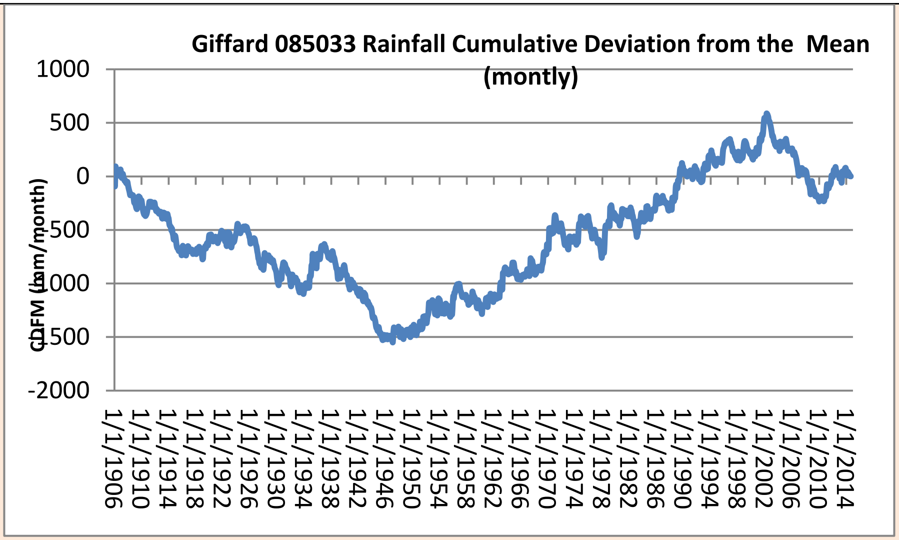
Date: 28 April, 2015

<table>
<tr>
<td>1.3</td>
<td></td>
<td>Site history/ timeline</td>
<td>Site specific</td>
<td>Post-European settlement, sections of the region have been developed for forestry and farming (livestock grazing and irrigation) purposes (GDE Atlas – Landuse layer, Bureau of Meteorology, 2012). There are also several Flora and Fauna reserves within the area including Giffard Flora Reserve, Mullungdung State Forest and Holey Plain State Park.
There are a number of limestone quarries located along Merriman Creek, providing major exposure of Gippsland Limestone.
There are large forestry plantations in the area of the headwaters (HVP plantations).
Irrigators extract from Merriman Creek around Gormandale.
Fires went through plantations in the area of the headwaters in 2009 which has impacted on the sediment load and water quality of Merriman Creek in recent years.</td>
</tr>
<tr>
<td>1.4</td>
<td></td>
<td>Geomorphic description, wetland elevation, catchment geomorphology</td>
<td>Derived from state wide GMU mapping</td>
<td>The Victorian Geomorphology layer describes the region as having terraced plains with sands and gravels (GDE Atlas – Victorian geomorphology layer – Bureau of Meteorology, 2012). The plains consist of a series of dunes orientated parallel with the coast. North of the Princess highway, the dunes have a higher clay content, whereas south of the highway in the Holey and Giffard Plains areas they are more permeable.
The wetlands are generally located in the swales between sand dunes (Parks Victoria 1998).
The Seasonal Herbaceous Wetland community occurs in the shallow depressions between dunes where a low permeability clay or organic matter holds water for 3 to 6 months (TSSC, undated).
<table>
<tr><td></td><td>Elevation of wetland base (deepest point)</td></tr>
<tr><td>Long Swamp (Holey Plains)</td><td>122.7 mAHD</td></tr>
<tr><td>Kangaroo Swamp (Giffard Plains)</td><td>163.7 mAHD</td></tr>
</table>
Elevations estimated from DEM, therefore approximate only.</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>Value</td>
<td>Listings on other databases (Ramsar, DIWA, Register of the National</td>
<td>The region provides habitat for a number of vulnerable and threatened species.
The following list includes sites within the region which are classified as Protected Areas under the *Environment Protection and Biodiversity Conservation Act 1999*;
- Holey Plains State Park(in addition to a listing on the Register of the National Estate)
- Stradbroke Flora and Fauna Reserve
- Kangaroo Swamp Nature Conservation Reserve
- Mullundung State Park (in addition to a listing on the Register of the National Estate)
The region does not list any wetlands in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia 2001) or under the Ramsar convention.</td>
</tr>
</table>

			Estate, TLM icon sites)	
2.1	Climate	Rainfall	Bureau of Met – data on N drive	The average rainfall across the region ranges between 550mm/yr and 600mm/yr indicating minimal change across the region. There are two rain gauges within the vicinity of the study area; - Giffard 085033, 10-25kms south east of the region. - Data period: 1906 - 2014 - Average annual rainfall: 564 mm/yr - Average monthly rainfall: 47 mm/yr - East Sale Airport, approx. 20-40 kms north east of the region. - Data period: 1943 - 2014 - Average annual rainfall: 599 mm/yr - Average monthly rainfall: 49.7 mm/yr The Giffard cumulative departure from the mean graph shows that rainfall was consistently below average between 2002 and 2010, with some above average rainfall between 2010 and 2012. Since then, rainfall has been approximately average at Giffard. The East Sale Airport Graph indicates decreasing below average rainfall between 1997 and 2010, with some above average rainfall between 2010 and 2012. Since then rainfall has been below average.


Giffard 085033 Rainfall Cumulative Deviation from the Mean (montly)
CDFM (mm/month)
1000
500
0
-500
-1000
-1500
-2000
1/1/1906
1/1/1910
1/1/1914
1/1/1918
1/1/1922
1/1/1926
1/1/1930
1/1/1934
1/1/1938
1/1/1942
1/1/1946
1/1/1950
1/1/1954
1/1/1958
1/1/1962
1/1/1966
1/1/1970
1/1/1974
1/1/1978
1/1/1982
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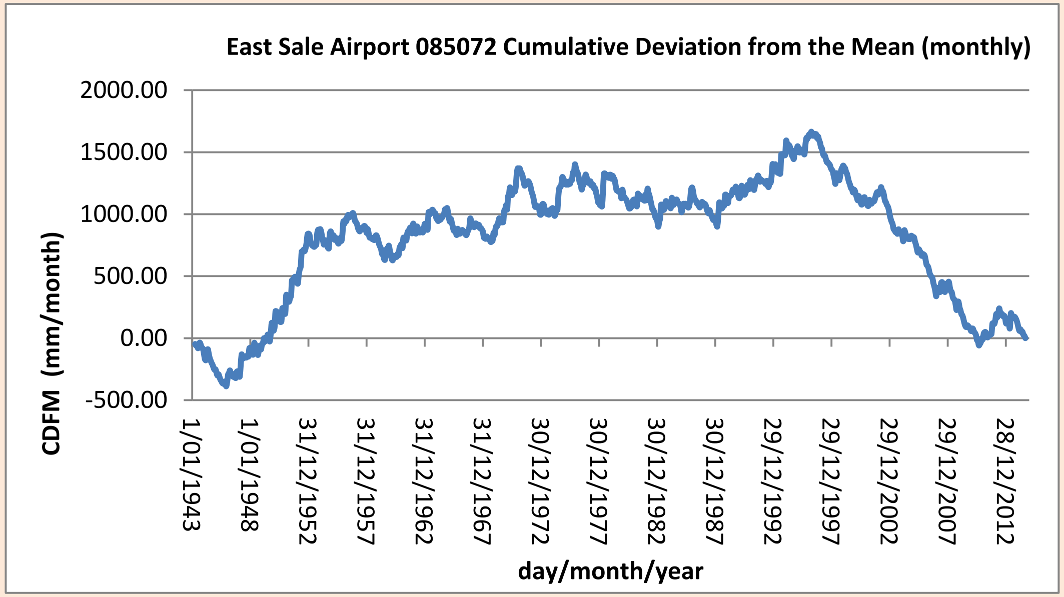
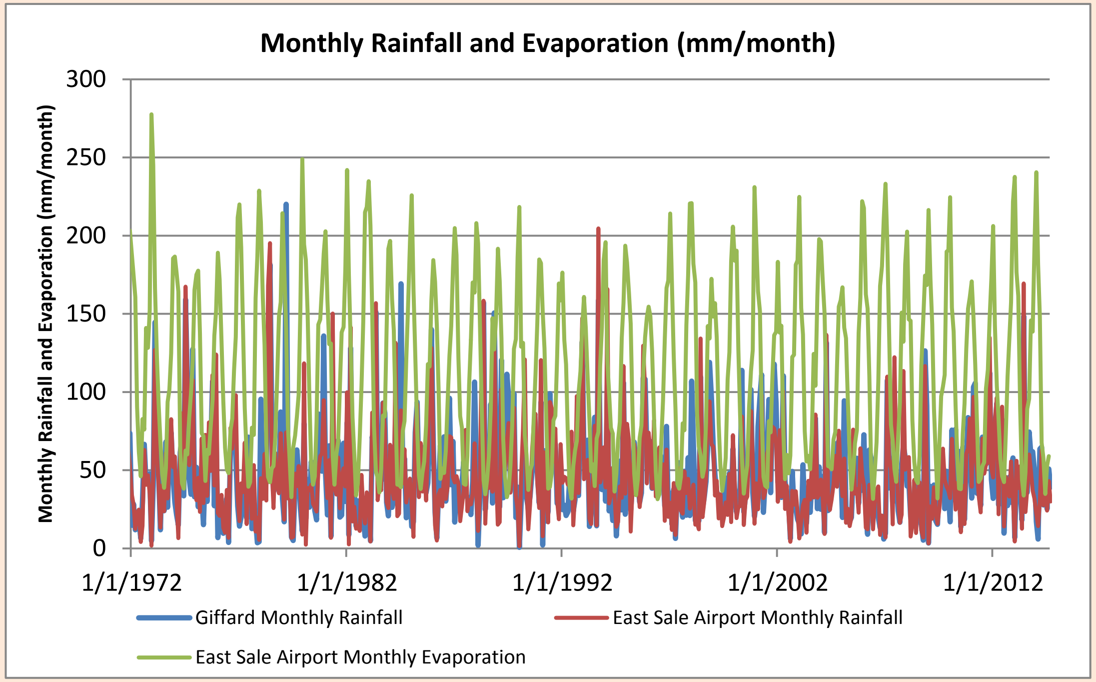
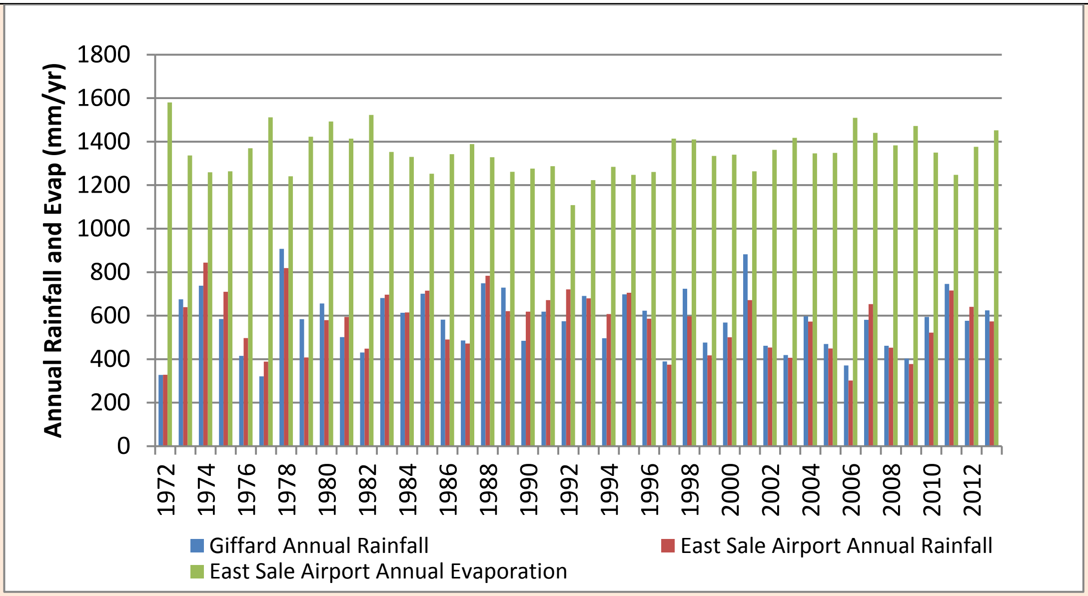
1/1/1998
1/1/2002
1/1/2006
1/1/2010
1/1/2014


East Sale Airport 085072 Cumulative Deviation from the Mean (monthly)
CDFM (mm/month)
2000.00
1500.00
1000.00
500.00
0.00
-500.00
1/01/1943
1/01/1948
31/12/1952
31/12/1957
31/12/1962
31/12/1967
30/12/1972
30/12/1977
30/12/1982
30/12/1987
29/12/1992
29/12/1997
29/12/2002
29/12/2007
28/12/2012
day/month/year

2.2		Evaporation	Bureau of Met – data on N drive	Annual evaporation substantially exceeds rainfall at within the region. The closest evaporation gauge is at East Sale Airport (85072), approximately 20-40kms north east of the region. - Data period: 1972 – 2014 - Average annual evaporation: 1,338 mm/yr - Average monthly evaporation: 112.6 mm/yr 

				
3.1	Hydrology	Surface water regime, wet surface area, water levels, permanence, flow, changes in storage	Site specific	There is minimal information available on the water regime in the area. <u>Giffard Plains and Holey Plains Wetlands</u> The wetlands within the Holey and Giffard plains generally display internal drainage systems on coarse sand and fine gravel; (Parks Victoria, 1998). Specific to the Seasonal Herbaceous Wetlands is the following water regime: ● Inundation is typically seasonal. The wetland is subject to predictable annual wet and dry periods, usually filling during the wet season (except during drought periods) and drying out in most years. The depth, duration and frequency of inundation of the ecological community are highly variable, reflecting the catchment, the physical properties of the site and the prevailing weather conditions. However, in 'typical' years (determined by long-term climatic trends) the wetlands are inundated for up to a few months and the depth of water is usually shallow (<1 metre). Occasionally there may be little to no inundation for one to several years, as was the case in the drought of the mid-2000s (TSSC, undated). The Victorian wetland dataset classifies both Long Swamp and Kangaroo Swamp as having a seasonal water regime. <u>Barriers to flow</u> The Main concerns related to barriers to flow is the construction of road infrastructure within the region. It is noted the South Gippsland

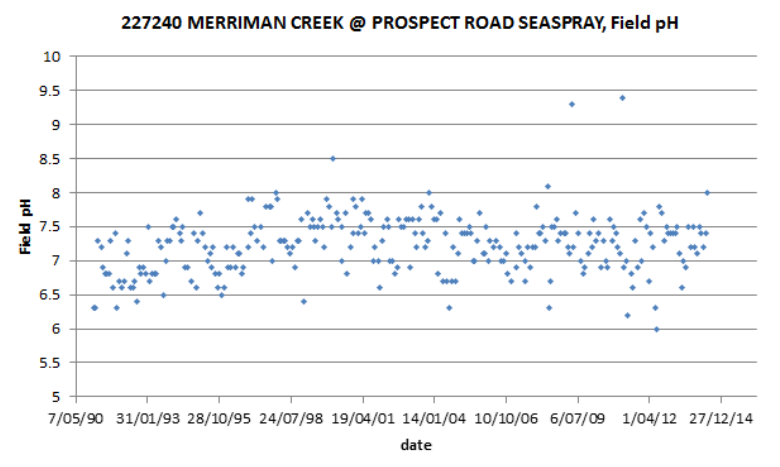
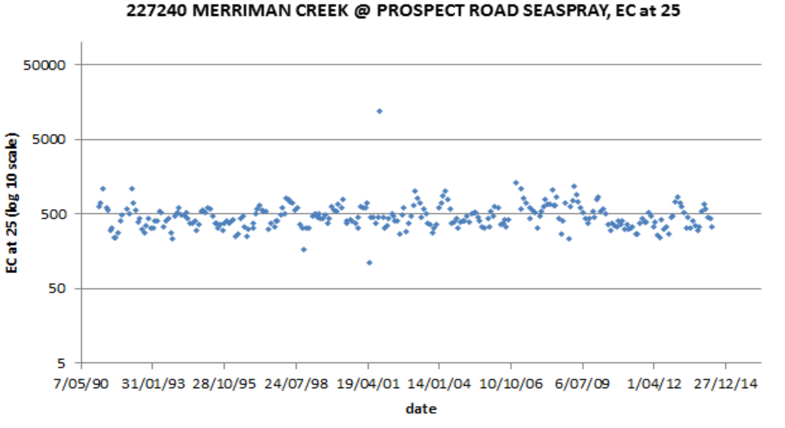
Highway has modified the drainage paths into sections of Holey Plains (Parks Victoria, 1998). Additionally the blockage of culverts (access roads) after heavy rains is anticipated to influence drainage paths (Parks Victoria, 1998).

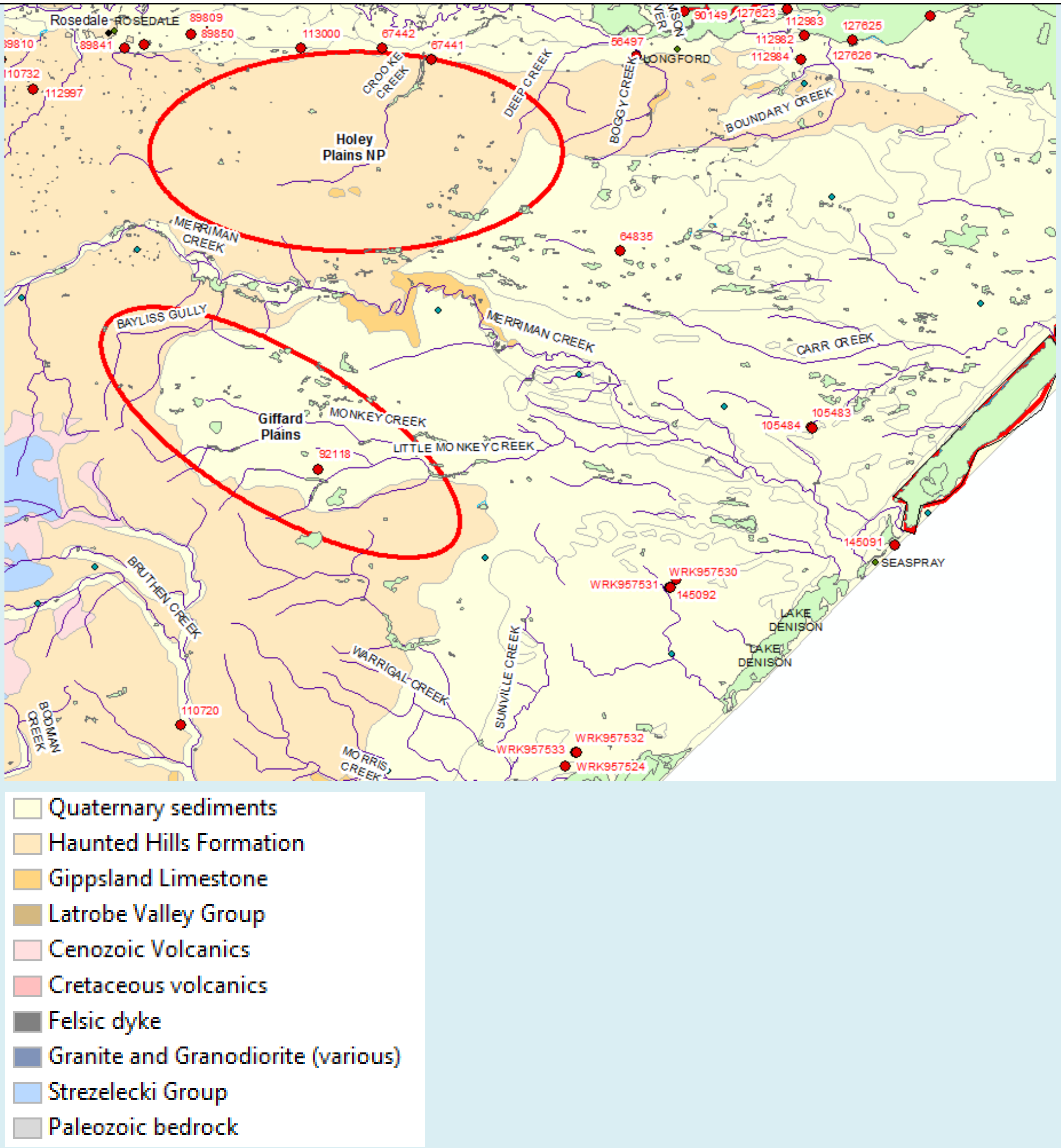
Based on the descriptions of water regime for a typical Seasonal Herbaceous Wetland, the wetland saturation details for wetlands on the Holey and Giffard Plains may be:

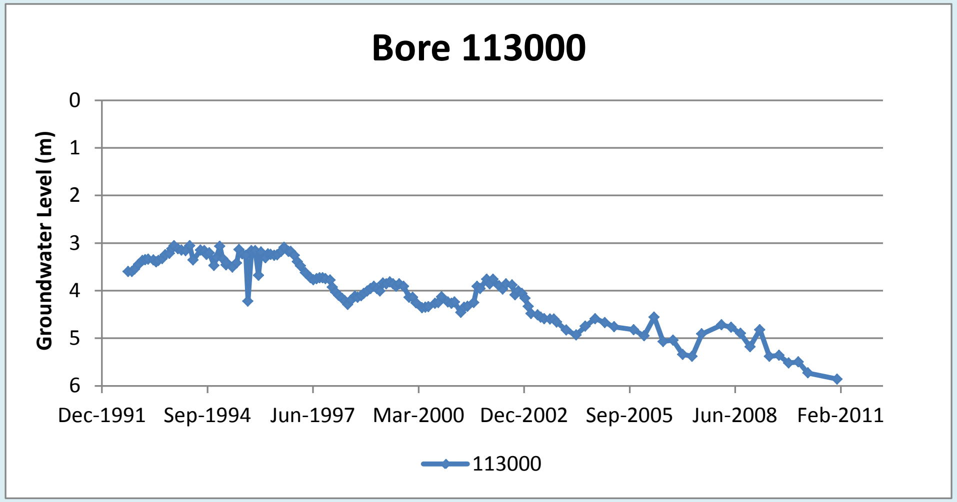
	Max when full	**Average annual**	**Average seasonal**
Long Swamp (Holey Plains)			
Wet surface area (m2)	174,000	43,500	Spring – 174,000 Summer - 0 Autumn - 0 Winter – ?
Water level depth (m)	1	0.25	Spring - 1 Summer - 0 Autumn - 0 Winter – ?
Water level (mAHD)	123.7	122.95	Spring – 123.7 Summer - 0 Autumn - 0 Winter – ?
Kangaroo Swamp (Giffard Plains)			
Wet surface area (m2)	378,000	94,500	Spring – 378,000 Summer - 0 Autumn - 0 Winter – ?
Water level depth (m)	1	0.25	Spring - 1 Summer - 0 Autumn - 0 Winter – ?
Water level (mAHD)	164.7	163.95	Spring – 164.7 Summer - 0 Autumn - 0 Winter – ?

Maximum areas estimated from GIS aerial Landsat imagery. It is assumed that this maximum extent persists for 3 months, therefore average annual wet area was assumed to be ¼ of the maximum area.

<table>
<tr><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>3.2</td><td>Hydrology</td><td>Surface water inflows, outflows</td><td>In all cases available site specific information will override regional assessments</td><td><u>River inflows</u>
There are no river inflows to these wetlands.
<u>Catchment runoff</u>
Seasonal wetlands in Holey Plains and Giffard Plains wetlands are fed from local rainfall in the catchment.
<table>
<tr><th></th><th>Long Swamp (Holey Plains)</th><th>Kangaroo Swamp (Giffard Plains)</th></tr>
<tr><td>Wetland catchment area (excl. river catchments)</td><td>No data – assumed to be 3 times wetland area – 522,000</td><td>No data – assumed to be 3 times wetland area – 1,134,000</td></tr>
<tr><td>Dry wetland catchment area (excl. max. wetland area)</td><td>No data – assumed to be 2 times wetland area – 348,000</td><td>No data – assumed to be 2 times wetland area – 756,000</td></tr>
</table>
<u>Evaporation</u>
An estimate of evaporation for the region is adopted from the East Sale Airport which is 1,338 mm/yr. Since the wetlands have a maximum of less than 1m of water in them, evaporation is expected to be the chief outflow.
<u>Groundwater inflows/outflows</u>
There is little information available on the groundwater influence within the region.
The seasonal wetlands are unlikely to be connected to regional groundwater as they are generally located higher in the landscape and are shallow depressions that are unlikely to intersect the regional watertable.
There may be contributions to the wetland water regime from recently infiltrated rainfall that travels along local flow paths either in the unsaturated zone or in a perched aquifer</td></tr>
<tr><td>3.3</td><td>Hydrology</td><td>Surface water quality, chemistry</td><td>Site specific</td><td>There is limited data available with respect to the water quality within the region. The only available data is Merriman Creek measurements of pH and EC data at Prospect Road (approximately 25kms south east of the region). The measurements are provided in the figures below and have been variable in measurement frequency since 1990. The influence of farming activity between Holey Plains/Giffard Plains and the measurement site should be considered when evaluation these measurements. Runoff from fields is expected to influence the pH and salinity levels, although these influences would not be pronounced for the wetlands, since they are up-gradient from most farming..</td></tr>
</table>

				 
4.1	Hydrogeology	Geology	GIS	The Warragul 250,000 geology map indicates that the surface geology within the Holey Plains National State Park is the Tertiary Haunted Hills Gravel deposits comprised of fluvial sand silt, gravel and ferruginous sand. The surface geology in the Giffard Plains is the Quaternary Aeolian dune deposits comprised of sand, clay and calcareous sand.

				
4.	Hydrogeol	Aquifer(s)	GIS	The watertable aquifer comprises both the Quaternary sediments and the Tertiary Haunted Hill Formation aquifers. These aquifers are the

2	ogy			most likely source of interaction, if any, with the wetlands of the Holey and Giffard Plains.
4.3	Hydrogeology	Soils, substrate	GIS	“The Holey Plains State Park is underlain by brown coal in the east and peats occur in some sections. The coal deposits have a high sulphur content. They are not suitable for use because of problems with air pollution control, and are unlikely to be developed. Soils are nutrient-poor sands or duplex soils with a sandy loam surface and a block structure B horizon. Some areas of limestone bedrock underlie a brown clay soil in parts”. (Parks Victoria, 1998) Seasonal Herbaceous Wetlands occur in depressions within dune systems, where low permeability clay and organic material hold water for 3 to 6 months.
4.4	Hydrogeology	Groundwater movement and flow dynamics, groundwater levels, gradients, Recharge areas to discharge site, water levels	Describes the temporal nature of groundwater flow at the site, seasonality, depth to groundwater, long term trend of GW level. Describe the direction of groundwater movement from the	There is limited groundwater information in the Holey Plains/ Giffard Plains area. Those bores located in close proximity to the study area are generally intersecting/ screened in the deeper regional aquifers and therefore do not provide a representation of the regional watertable aquifer. There is one bore located directly north of the Holey Plains State Park, Bore No. 113000, which is monitoring the shallow alluvial aquifer at the edge of the Latrobe River floodplain. Monitoring of this bore ceased in 2011, however up until this point monitoring indicates reasonably shallow watertables in the area (around 3m to 6m below surface). The data shows some seasonal fluctuations and illustrates a significant groundwater level decline of around 3 m since the 1990s. It is likely that the watertable is deeper in the Holey/Giffard Plains areas, as they are at a higher elevation.  The groundwater flow path of the watertable aquifer systems are likely to follow local topography, flowing from areas of higher elevation (e.g. dunes, Strzelecki Ranges) towards lower elevation areas such as drainage lines (e.g. Merriman Creek). In the deeper regional aquifers systems groundwater movement is generally from the Strzelecki Ranges to the Gippsland Lakes and/or the ocean. Groundwater recharge to the watertable aquifers is primarily from the infiltration of rainfall, with the seasonal fluctuation occurring as a

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>recharge zone to the site.</td>
<td>
<p>response to rainfall. Recharge of these aquifers may also occur from flood events although only over short durations.</p>
<p>Groundwater around the wetlands is the result of recently infiltrated rainfall and has short residence times in the dune system. It is thought to flow along local flow paths either in the unsaturated zone or within perched aquifers, and discharge in the dune swales.</p>
<p>There is no connection to the regional watertable for Kangaroo Swamp, as demonstrated by the estimate of watertable elevation below. However based on watertable elevation, Long Swamp may be connected to the watertable, which is at a depth of between 0 and 10m deep at the swamp.</p>
<table>
<tr><th></th><th>Upstream watertable head (mAHD)</th><th>Downstream watertable head (mAHD)</th></tr>
<tr><td>Long Swamp (elevation: 122.7 mAHD)</td><td>124.8</td><td>119.3</td></tr>
<tr><td>Kangaroo Swamp (elevation: 163.7 mAHD)</td><td>109.4</td><td>105.6</td></tr>
</table>
<p>Elevations based on DEM</p>
</td>
</tr>
<tr>
<td>4.5</td>
<td>Hydrogeology</td>
<td>Groundwater quality, chemistry</td>
<td>Site specific</td>
<td>Groundwater salinity for the watertable aquifers in this area is likely to be fresh. The median groundwater EC reading for bore 113000 was 574 uS/cm for EC measurements recorded between 1993 and 1999.</td>
</tr>
<tr>
<td>4.6</td>
<td>Hydrogeology</td>
<td>GW interaction with wetland
Volumes, spatial variation, temporal variation</td>
<td>Site specific</td>
<td>
<p><u>Groundwater inflows/ outflows</u></p>
<p>There is little information on groundwater contributions to the wetlands of the Holey and Giffard Plains, therefore the classification of groundwater connection at the site can only be hypothesised from the conceptual water balance and previous studies undertaken in similar hydrogeological settings.</p>
<p>The seasonal wetlands are unlikely to be connected to groundwater as they are generally located higher in the landscape and are shallow depressions that are unlikely to intersect the regional watertable, although there is a possibility that a relatively shallow watertable exists at Long Swamp. The most likely connection is that the wetlands lose water into the groundwater system, although a low permeability base prevents significant volumes of seepage and maintains water in the wetlands for up to 6 months.</p>
<p>The primary water source for these wetlands is thought to come from surface water runoff during local rainfall events. Seasonal rainfall over the winter and spring period likely sustains their water levels for a period of time but they dry out over summer and autumn.</p>
</td>
</tr>
</table>

5. 1	Ecology	Value		The damper-low lying areas consist of species such as Manna Gum, Grey Gum, Swamp Paperbark and a variety of sedges which are more adapted to the heavier, moister soils found here. The higher sandier areas consist of plants that have adapted to drier conditions such as Yellow Stringybark, Black She-Oak and Bracken Fern (Oliver, N., 2005). The range of ecosystem types provide extensive habitat to a number of flora and fauna species. . Below is a list of flora and fauna identified within Holey Plains. There is limited ecological information on Giffard Plains however due to the close proximity of the sites it is anticipated there will be an overlap of ecological activity. Significant flora and fauna in Holey Plains listed under the Flora and Fauna Guarantee Act (Parks Victoria, 1998) include; **Flora** Swamp Everlasting, *Bracteantha sp. aff. Subundulata* (vulnerable in VIC), Small Pepper-cress, *Lepidium hyssopifolium*, (endangered in VIC and Australia) Dwarf Kerrawang, *Rulingia prostrate*, (endangered in Australia, vulnerable in VIC) **Fauna** Powerful Owl, Ninox strenua, (endangered in VIC) White-bellied Sea-Eagle, Haliaeetus leucogaster, (endangered in VIC) In addition there is an extensive list of EPBC vulnerable species which are common to Seasonal Herbaceous Wetlands (Threatened Species Scientific Community, unknown date). Of notable inclusion are the Growling Grass Frog and the Dwarf Kerrawang. The Growling Grass Frog incurred a population crash in 1979 possibly due to water quality problems (Parks Victoria, 1998). The Dwarf Kerrawang is known to be associated with wetlands within the area (Parks Victoria, 1998). Additionally the Long Swamp in Holey Plains is identified as a site of Regional Zoological Significance (Mansergh & Norris 1982 in Parks Victoria, 1998).
5. 2	Ecology	EWRs.	site specific	Possible environmental water requirements may include: • The wetlands require predictable annual wet and dry periods, usually filling during the wet season and drying out in most years (except during drought periods)
5. 3	Ecology	Critical groundwater service	site specific	Groundwater is not anticipated to provide a critical service to ecology at Kangaroo Swamp. At Long Swamp the water regime is surface water dominated, however groundwater is shallow and therefore may be important for: • Prolonging the duration of inundation in the wetland • Providing moisture for the soil profile through capillary action, and for evapotranspiration by wetland flora
6. 1	Risk assessmen	Key hazards (link to pre, during &	Site specific /	Possible hazards to the Holey Plains and Giffard Plains include: • Drainage modification (e.g. construction of roads)

	t	post development scenarios)	GIS	● Groundwater extraction in the region may lower the watertable, impacting on the hydrological regime of any communities that are reliant on groundwater. The combination of changes in rainfall driven recharge (due to climate change) and extraction for offshore gas activities and irrigation are likely to represent the greatest threat to groundwater levels in this region. ● "Giffard Plain is in the centre of the Ignite Energy/ExxonMobil coal seam gas exploration tenement." (2013, http://webcache.googleusercontent.com/search?q=cache:1ixkZ92ydPkJ:www.scer.gov.au/files/2013/03/VictorianFarmersFederationStadbrokeBranch.doc+&cd=10&hl=en&ct=clnk&gl=au), which presents a threat from surface activities such as well fields, transport and co-produced water treatment and disposal, and also gas extraction that may lower watertable elevations. ● Climate change - wetlands dependant on rainfall may be strongly influenced by a continuing decline and a shift away from a regular pattern in rainfall and more frequent and severe droughts. This means that wetlands which are now seasonally inundated could shift to a more intermittent or unpredictable filling cycle.
6.2		Likelihood: susceptiblity		As there little flux is expected between the watertable aquifer and the wetlands on the Holey and Giffard Plains, susceptibility to any impacts from groundwater extraction will be low.
6.3		Likelihood: management	Stresses on groundwater system	There are no bores that extract from the watertable aquifer within the catchment of Long Swamp or Kangaroo Swamp. Extraction from deeper aquifers has the potential to impact the watertable in the area.
6.4		Consequence: sensitivity		Seasonal wetlands in the area are unlikely to rely on groundwater; changes in surface water runoff are likely to be the biggest risk to the hydrological regime of these wetlands. However, since the watertable may be relatively shallow at Long Swamp, there is the potential that wetland ecology is partially dependent on this as a component of the water balance.
6.5		Consequence: value	Site specific	The wetlands are high value, as it is within State Park and is recognised as providing habitat to several vulnerable and endangered species. They are not listed on the DIWA or Ramsar databases. The wetlands are considered as of moderate value.
7.1	Data Gaps	Key unknowns		Knowledge gaps exist around the nature of groundwater connection of the Holey Plains and Giffard Plains seasonal wetlands, particularly for Long Swamp. Additional groundwater data is also required to confirm the hypothesised water regime for the seasonal wetland communities, particular in relation to confirming or otherwise any groundwater connection.

				Significant uncertainties also exist for wetland volume, aerial extent and water levels.
7.2		Recommendation of monitoring		Depth to watertable Seepage tests for wetland bed sediments (K) Depth to watertable and gradients in surrounding catchment Wetland size, volume and variation over the year
8.1	References			Parks Victoria, 1998, Holey Plains State Park – Management Plan, Park Victoria Threatened Species Scientific Committee, unknown date, *Advice to the Minister for Sustainability, Environment, Water, Population and Communities from the Threatened Species Scientific Committee (the Committee) on an Amendment to the List of Threatened Ecological Communities under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* Bureau of Meteorology , 2012. Groundwater Dependent Ecosystem-Atlas – various layers, Australian Government. http://www.bom.gov.au/water/groundwater/gde/map.shtml Oliver, N. 2005. Won Wron and Mullungdung State Forests. Forest Notes. Department of Sustainability and Environment.

Conceptual Model for Macleods Morass

Macleods Morass– Conceptual Model Information Summary Template

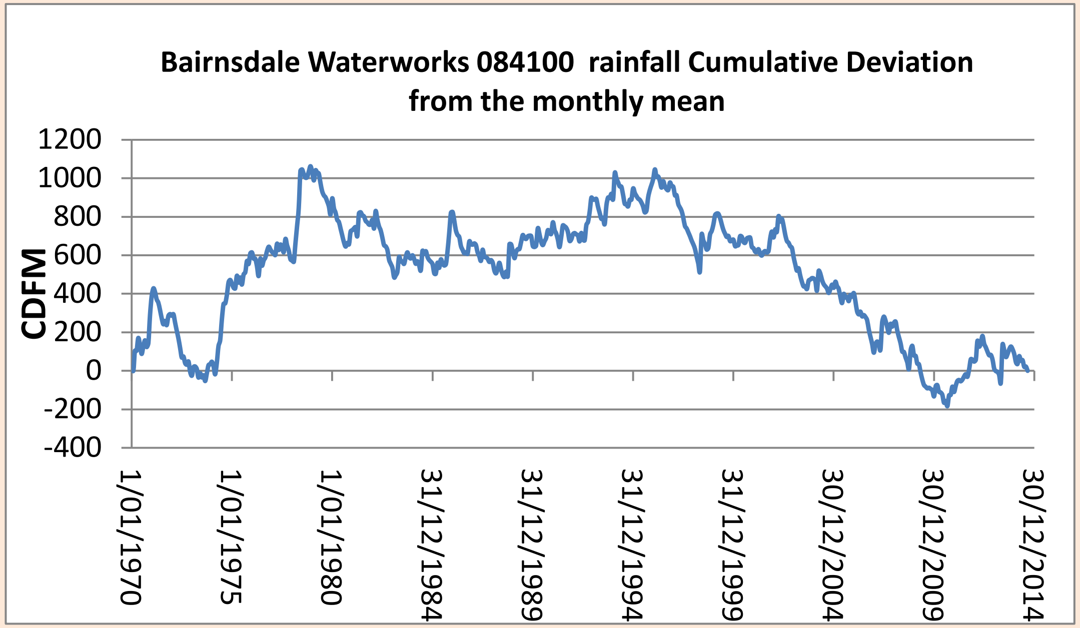
Ref.	Theme	Sub-Theme	Data Components, Information Sources	Description
1.1		Location, Name, Area	GIS	Macleods Morass is a low-lying deep freshwater marsh, forming an extensive wetland on the Mitchell River Floodplain directly south of the township of Bairnsdale in east Gippsland. It is bound by the Mitchell River to the east, the township of Eagle Point to the south, agricultural land to the south-west and west and Bairnsdale to the north. The morass is approximately 508 ha in size and is a Wildlife Reserve managed by Parks Victoria. Jones Bay is located to the east of the morass at the mouth of the Mitchell River. Macleods Morass is treated as one system in this study as there is no tidal influence to necessitate breaking the wetland into separate systems.

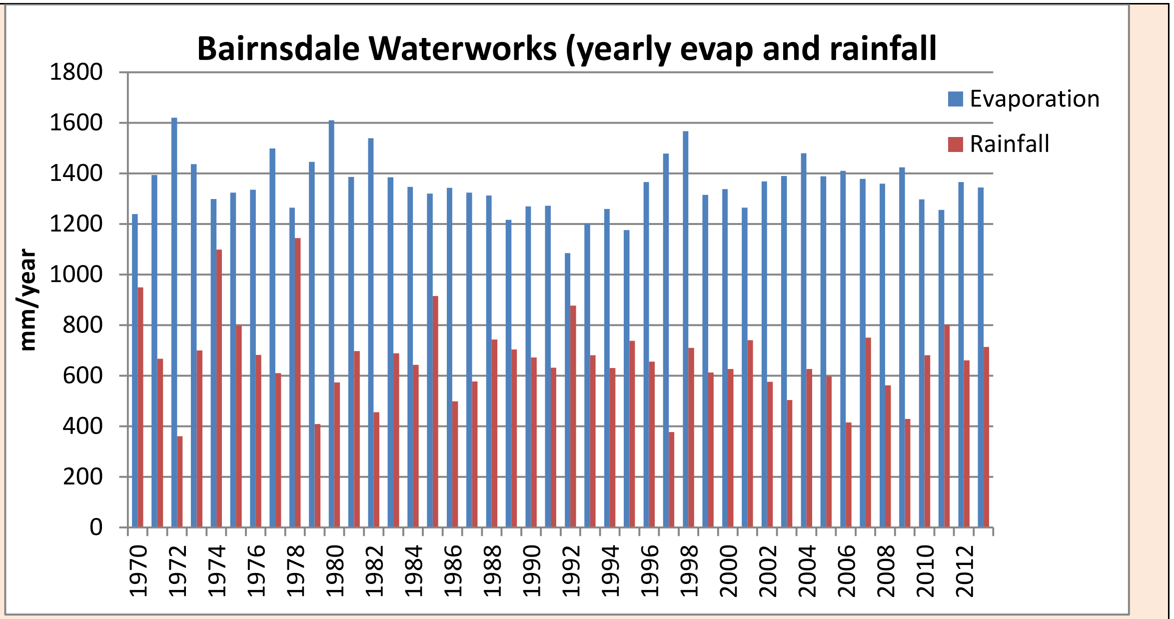
	Central point (Z55)	Average length (km)	Average width (km)	Wetland area when full (km2)
Macleods Morass	E555256.5 N5811493.1	6.8	1	2.1 km2

Areas estimated by reading measurements off a map, therefore approximate only.

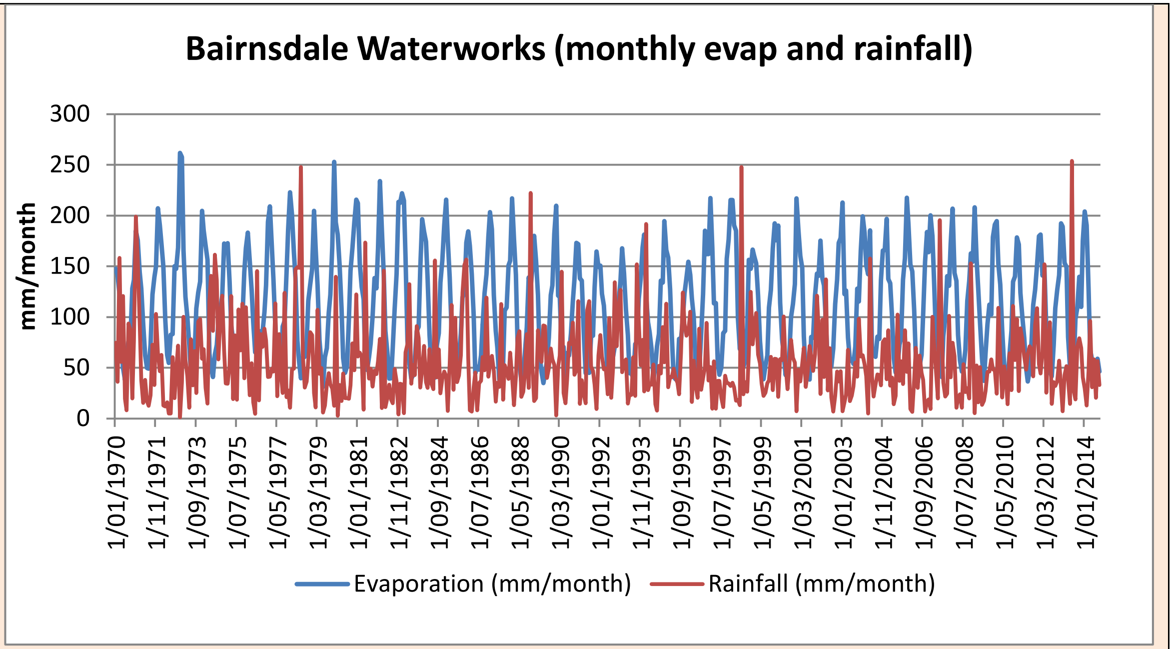
Ref.	Theme	Sub-Theme	Data Components, Information Sources	Description
1.2	Ecosystem Type	Type	GIS	Ecosystem descriptions for Macleods Morass include; - deep marsh (GDE Atlas Bureau of Meteorology, 2012) - freshwater marsh; the morass was originally classified as a 'deep freshwater marsh' but this has reduced due to European settlement (Parks Victoria, 2005). It is estimated 30% of the morass can still be classified under this description (Corrick and Norman, 1980) in Parks, Victoria, 2005). Macleods Morass is classified as an ecosystem which relies on the surface expression of groundwater. This is a high potential for groundwater interaction (Bureau of Meteorology, 2012).
1.3		Site history/ timeline	Site specific	Modifications to Macleods Morass due to the European settlement began in the early 1900s when extensive drainage works were completed (Parks Victoria, 2005). The establishment of a permanent entrance to the Gippsland Lakes in 1889 has also influenced the water regime of the region (Parks Victoria, 2005). Since 1939 wastewater from East Gippsland Water's Wastewater Treatment Plant has been discharged

				into the north of the Morass, this was initially untreated, however in 2001/02 East Gippsland Water completed a major construction project that invoice a network of three artificial wetlands to remove large amounts of nutrients in the wastewater and also the levee banks and structures to control water flows and levels through Macleods Morass. In 1961 under the Land Act 1958 (Vic) 422.8 ha of the morass became the Macleods Morass Wildlife Reserve (Parks Victoria, 2005). Over the years the area has increased to its current area through Government purchases.
1.4		Geomorphic description	Derived from state wide GMU mapping	Macleods Morass is described as 'terraced plains with sand and gravels' (Bureau of Meteorology, 2012). Foster, 2011 estimated that the average elevation of the wetland base was 0.5mAHD.
1.5		Value	Listings on other databases (Ramsar, DIWA, Register of the National Estate, TLM icon sites)	Macleods Morass provides habitat for a diverse array of wildlife and is an integral part of the Gippsland Lakes system. It is part the Gippsland Lakes Ramsar Site and is Listed in the Directory of Important Wetlands in Australia (Environment Australia 2001). It is classified as a Wildlife Reserve, with further classification as a State Game Reserve. Within the morass there are flora and fauna species which are threated in Victoria and listed under the Flora and Fauna Guarantee Act (FFG Act). The bird population consists of species listed under the Japan Australia Migratory Birds Agreement 1974 (JAMBA) and the China Australia Migratory Birds Agreement 1987(CAMBA). The Environment Protection and Biodiversity Conservation Act 1999, applies to the morass (Parks Victoria, 2005). Culturally there is significant importance to the Tatungoloong clan of the Gunai/Kurnai peoples. The morass includes significant cultural places and objects and is associated with folklore and customs (Parks Victoria, 2005).
2.1	Climate	Rainfall	Bureau of Met – data on N drive	The nearest rainfall gauge to Macleods Morass is the Bairnsdale Waterworks (Station 084100) located directly north of the morass. Bairnsdale Waterworks Daily Rainfall; - Data period: 1970 – 2014 - Average annual rainfall: 633.5 mm/year - Average monthly rainfall: 55 mm/month

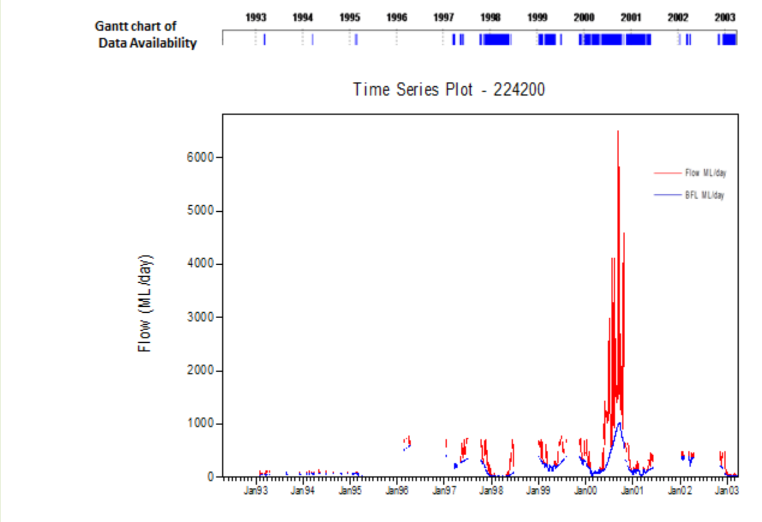
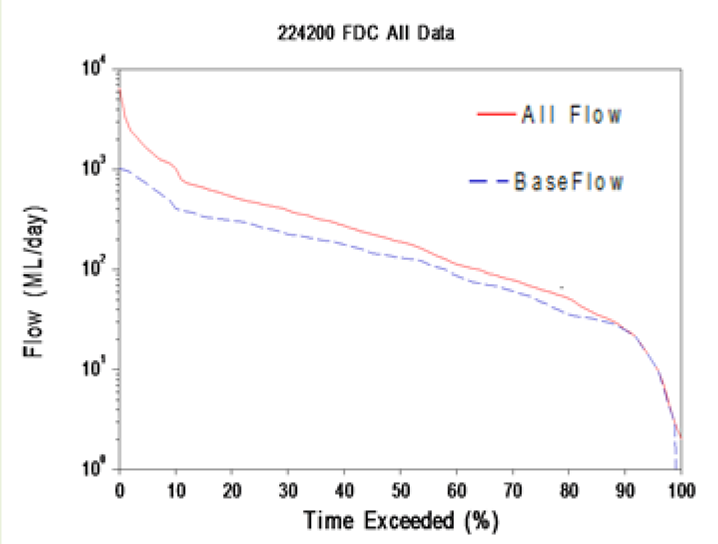
				The cumulative deviation from the monthly mean plot below indicates a below average rainfall from mid-1990 to 2010. Between 2010 and 2012 there was an increase in the trend. Recently it appears the rainfall is approaching the long term average. 
2.2		Evaporation	Bureau of Met – data on N drive	The nearest evaporation gauge to Macleods Morass is the Bairnsdale Waterworks (Station 084100). The station measures Class A Pan Evaporation. Annually the evaporation is greater than the rainfall. Bairnsdale Waterworks (Class A Pan Evaporation); - Data period: 1970 – 2014 - Average annual evaporation: 1356.8 mm/yr - Average monthly evaporation: 112.7 mm/month

Bairnsdale Waterworks (yearly evap and rainfall
mm/year
1800
1600
1400
1200
1000
800
600
400
200
0
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Evaporation
Rainfall

<table>
<tr><td></td><td></td><td></td><td></td><td>
</td></tr>
<tr><td>3.1</td><td>Hydrology</td><td>Surface water regime, water levels, permanence, flow</td><td>Site specific</td><td><u>Overview</u>
Due to the continuous inflow of treated wastewater from the East Gippsland Wastewater Treatment Plant and the presence of drainage channels and levee the morass is generally wetter for longer durations than under ‘natural’ conditions (Parks Victoria, 2005). This has altered the natural regime of wetting and drying typically experienced by wetlands within the area.
<table>
<tr><th></th><th>Max when full</th><th>Average annual</th><th>Average seasonal</th></tr>
<tr><td>Wet surface area (m2)</td><td>2,134,000</td><td>1,524,000</td><td>Spring – unknown
Summer – unknown
Autumn – unknown
Winter – unknown</td></tr>
<tr><td>Water level depth (m)</td><td>Unknown</td><td>Unknown</td><td>Unknown</td></tr>
<tr><td>Water level (mAHD)</td><td>Unknown</td><td>Unknown</td><td>Unknown</td></tr>
</table></td></tr>
</table>

				<u>Barriers to Flow;</u> Barriers to the natural water regime include (Parks Victoria, 2005); • The construction of drains, levees and floodgates to limit the inundation of the morass; • The establishment of upstream weirs and control structures on the Mitchell River reducing the minor flood events; • Removal of vegetation on nearby agricultural land.
3.2	Hydrology	Surface water inflows, outflows	In all cases available site specific information will override regional assessments	<u>Overview</u> Flows into the Morass are dominated by; • Catchment runoff from Cobbler Creek and other smaller intermittent streams. • Urban stormwater runoff from Bairnsdale occurs via McGees Gully • Major flooding in the Mitchell River, resulting in complete inundation of the morass. • Disposal of treated wastewater from East Gippsland Water's Bairnsdale Wastewater Treatment Plant. <u>Rivers</u> Mitchell River inflows are predominately regulated. A weir and a series of drop-boards on the main drain connect the lower part of the morass with the Mitchell River (adjacent to Paynesville Road) (Parks Victoria, 2005). These structures are managed by Parks Victoria to prevent inflow of highly saline river water into the morass (Parks Victoria, 2005). During periods of flood levels tend to extend beyond the morass into low lying agricultural land. This water is often pumped for irrigation purposes which can affect the flooding regime of low lying areas in the morass. A licence from Southern Rural Water (SRW) is required before an extraction of theses water can occur (Parks Victoria, 2005). MITCHELL RIVER @ BAIRNSDALE (224200)

Gantt chart of Data Availability
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Time Series Plot - 224200
Flow (ML/day)
6000
5000
4000
3000
2000
1000
0
Flow ML/day
BFL ML/day
Jan93
Jan94
Jan95
Jan96
Jan97
Jan98
Jan99
Jan00
Jan01
Jan02
Jan03

224200 FDC All Data
Flow (ML/day)
10^4
10^3
10^2
10^1
10^0
All Flow
BaseFlow
0
10
20
30
40
50
60
70
80
90
100
Time Exceeded (%)

	Average annual (ML/d)	Average seasonal (ML/d)
Carr Creek	15*	Spring – unknown Summer – 0 Autumn – 0 Winter – 60 ML/d (5400ML)
Merriman Creek	5**	Spring – unknown Summer – unknown Autumn – unknown Winter – unknown

East Gippsland Wastewater Treatment Plant

Some 95% of all the recycled water produced by Bairnsdale Wastewater Treatment Plant each year is used to help sustain the Macleods Morass. Outflows from treatment plant represent approximately 15% of freshwater input into the morass in an average year (Parks Victoria, 2005). The WWTP is connected to the morass via levees and water control structures and enters the morass via a constructed wetland. Additionally the structures direct stormwater from McGees Gully allowing for multiple discharge points across the northern section of the morass.

Lakes

Jones bay, a saline marsh is located to the east of the morass at the mouth of the Mitchell River. There is the potential for the intrusion of brackish water into the lower sections of the morass under tidal influences in Mitchell River (Parks Victoria, 2005).   The correct operation of water control structures to at Paynesville Road should prevent the intrusion of brackish water.

Evaporation

Evaporation at Macleods Morass can be represented by the Class A Pan Evaporation at the Bairnsdale Waterworks. The average annual evaporation is estimated as 1356.8 mm/yr.

Catchment Runoff

Flow from Cobbler Creek is dominated by agricultural runoff and is a potential source of elevated nutrient and sediment levels. Stormwater discharge from Bairnsdale enters the morass via MaGees Gully. The discharge passes through a gross pollutant trap however it is anticipated this discharge has elevated

<table>
<tr><td></td><td></td><td></td><td></td><td>levels of nutrients and sediments. Direct rainfall also contributes to inflows into the morass (Parks Victoria, 2005).
<table>
<tr><th></th><th>Macleodss Morass</th></tr>
<tr><td>Whole catchment area</td><td>5,160,821</td></tr>
<tr><td>Wetland catchment area (excl. river catchments)</td><td>5,080,000</td></tr>
</table>
* assumes catchment area is proportional to wetland area

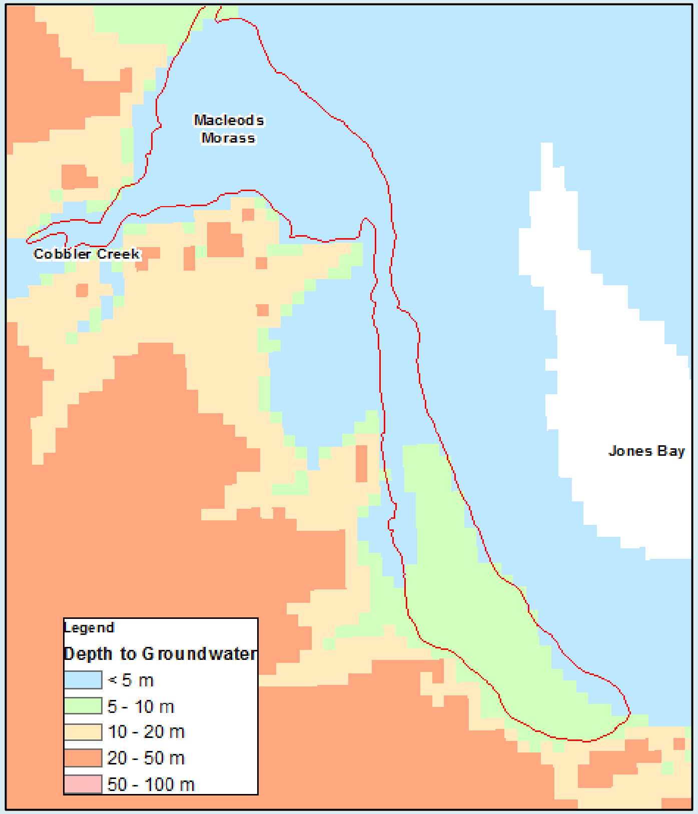
<u>Groundwater</u>

It is recognised groundwater discharge occurs near the northern boundary of the morass (Parks Victoria, 2005). Although the quantity is unknown the discharge is recognised in the surrounding plant species which are predominately more saline tolerant (Parks Victoria, 2005). It is likely that groundwater discharge would have a seasonal relationship, that is predominately occur during drier periods when the water level in the wetland was lower than the groundwater elevation.</td></tr>
<tr><td>3.3</td><td></td><td>Flow, quality, chemistry</td><td>Site specific</td><td>Water quality at the morass is primarily concerned with;

Saline inflows; primarily from the Mitchell River due to backwater effects (limited due to water control structures);
Nutrient inflows from the WWTP and runoff;
Sediment inflows from the WWTP and runoff.

Although there is currently no suitable public water quality data available for the morass it is recognised the morass experiences periods of sustained and elevated nutrient levels. The year round input from the East Bairnsdale wastewater treatment plant and direct catchment runoff from urban and agricultural sources impact on the water quality. The morass has also been susceptible to salt water intrusion since the Gippsland Lakes were opened in the 19th century.</td></tr>
<tr><td>4.1</td><td>Hydrogeology</td><td>Geology</td><td>GIS</td><td>According to the 1:250 000 scale surface geology mapping, the Macleods Morass resides upon Quaternary aged swamp and lake deposits, comprised of grey-black carbonaceous mud, silt and clay. The western boundary of the Morass is defined by an escarpment that represents former higher sea levels in Bass Strait (Parks Victoria, 2005). West of this boundary, the surface geology shifts from swamp deposits, to alluvial deposits and alluvial terrace deposits.</td></tr>
</table>

				Underlying the Quaternary alluvium, which is typically around 5 m thick in this area, are the sands, silt and gravels of the Haunted Hill Formation.
4.2		Aquifer(s)	GIS	The watertable aquifer in this area is comprised of Quaternary alluvium and Haunted Hill Formation sediments.
4.3		Soils	GIS	Soil samples taken as part of Foster (2011), found the that majority of soil samples taken were classes as silty clay loams, plus several silty clay, one sandy silt loam and a probable loamy peat. The study also found that Macleods Morass displays several potential acid sulphate soil sites with little actual acidity but sufficient reserves of reducible inorganic sulphur from pyrite to produce significant acid. In addition, the Morass also contains many sites of actual acid sulphate soils, however their impact on the environment varies – the region to the north with slight impact and the region to the south moderate impact (Foster, 2011).
4.4		Groundwater movement and flow dynamics Recharge areas to discharge site	Describes the temporal nature of groundwater flow at the site, seasonality, depth to groundwater, long term trend of GW level. Describe the direction of groundwater movement from the recharge zone to the site.	Groundwater level information is limited in the area around Macleods Morass. The closest watertable observation bore to the site is located approximately 3.5 km north-west of the morass, on the Lindenow Flats. State Observation Bore 140280 is 14 m deep and is likely to represent groundwater levels in the Haunted Hill Formation. The hydrograph provided in the figure below shows groundwater levels recorded at this site and indicates shallow groundwater levels, typically between 2-3 m below the surface.  Statewide depth to groundwater mapping indicates groundwater is within 5 m of the surface across most

				of the Morass and to the east of the Morass. To the south of the Morass however, groundwater depths are shown to be deeper (5-10 m below the surface) and to the west of the Morass the depths also appear deeper. Groundwater elevation mapping undertaken as part of the Secure Allocation, Future Entitlements (SAFE) project indicated that reduced water level (RWL) was approximately 0.8mAHD.  **Figure 2 – depth to groundwater from statewide dataset** The groundwater elevation (groundwater gradient) indicates that that some groundwater is likely to discharge to the wetland (i.e. the wetland is gaining) on the basis that groundwater elevations is higher than the wetland base 0.5mAHD, however since the groundwater gradient is low it is possible that the direction of flow between the wetland and the watertable aquifer changes seasonally in response to

<table>
<tr><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td></td><td></td><td></td><td></td><td>changes in wetland water levels (switches between gaining and losing). Since the wetland is assumed to be generally have water in it, it is likely that this will result in the groundwater elevation being lower than the wetland water level and therefore the morass can be conceptualised as generally predominantly losing wetland and during drier conditions when the water level drops below the RWL (approximately 0.8mAHD) is would be a gaining wetland.

Estimates are:
<table><tr><th></th><th>Upstream gradient</th><th>Downstream gradient</th></tr><tr><td>Macleods Morass</td><td>0.8mAHD</td><td>0.8mAHD</td></tr></table></td></tr>
<tr><td>4.5</td><td></td><td>Groundwater quality, chemistry</td><td>Site specific</td><td>There is no groundwater salinity information from bores in this area to indicate likely salinity concentration. The statewide groundwater salinity mapping indicates groundwater salinity ranges from 1,000 – 3,500 mg/L TDS.</td></tr>
<tr><td>4.6</td><td></td><td>GW interaction with wetland

Volumes, Spatial variation temporal variation,</td><td></td><td>The Beureau of Meteorology Groundwater Atlas indicates the Macleods Morass is a GDE reliant on the surface expression of groundwater (i.e. a wetland) with a high potential for groundwater interaction.
The role of groundwater interaction with the Morass is unknown and there is no published information available to inform its significance in terms of the hydraulic regime of the Morass. Parks Victoria (2005) identifies saline groundwater seeps at the escarpment near the northern boundary of the Morass which is evidenced by salt tolerant plant species in this area, however site specific groundwater data is not available to make any conclusions. Based on the discussion above, it is likely that groundwater only discharges to the wetland during drier periods when the wetland water levels is below the groundwater elevation, the remaining time the wetland would be losing water to the groundwater.</td></tr>
<tr><td>5.1</td><td>Ecology</td><td></td><td></td><td>Macleods Morass provides habitat for a number of vulnerable and threatened species and is connected to the Ramsar listed Gippsland Lakes. The following outlines key fauna and flora identified in Macleods Morass;

Fauna
There are 23 vulnerable fauna species found within Macleods Morass (Parks Victoria, 2005). There a 3 nationally vulnerable species (Environment Protection and Biodiversity Conservation Act) including;

• Green and Golden Bell Frog <i>(Litoria aurea);</i></td></tr>
</table>

				• Warty Bell Frog *(Litoria raniformis);* • Dwarf Galaxias (*Galaxias pusilla*). In addition the Shortfinned Eel *(Anguilla australis)* and Longfinned Eel *(Anguilla reinhardtii)* are found in Macleods Morass and are commercially harvested (Parks Victoria, 2005). 100 bird species, including 53 waterbird species have been identified in the morass. There are 7 migratory birds listed under both the Japan Australia Migratory Birds Agreement 1974 (JAMBA) and the China Australia Migratory Birds Agreement 1987 (CAMBA). 4 bird species are listed under the Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention)(Parks Victoria, 2005). Endangered species in Victoria, in addition to a listing under the FFG Act include; • Great Egret *(Egretta alba)* • Whitebellied Sea-eagle *(Haliaeetus leucogaster)* • Lewins Rail *(Rallus pectoralis)* • Freckled Duck (*Stictonetta naevosa*) The Intermediate Egret *(Ardea intermedia)* is identified as critically endangered in Victoria and is also listed in the FFG Act. The morass is also an Important breeding site for the White Ibis (Threskiornis molucca),Straw-necked Ibis (Threskiornis spinicollis) and the Black-winged Stilt (Himantopus himantopus). **Flora** Ecological vegetation classes identified in the morass include (Parks Victoria, 2005); • Deep Freshwater Marsh • Swamp Scrub • Estuarine Wetland • Floodplain Reed Bed • Coastal Salt Marsh • Damp Sands Herb-rich Woodland • Plains Grassy Woodland • Valley Grassy Forest/Swamp Scrub Mosaic • Dry Valley Forest/Swamp Scrub/Warm Temperate Rainforest Mosaic.

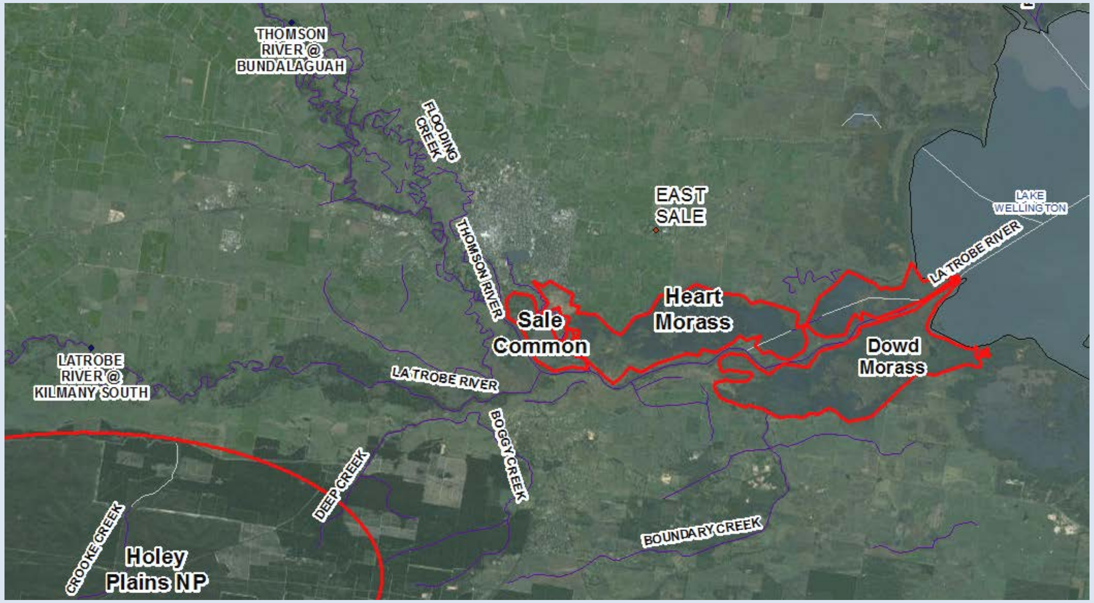
				The Plains Grassy Woodland EVC is recognised under the FFG Act. Swamp Scrub, Damp Sands Herb-rich Woodland and Dry Valley Forest/Swamp Scrub/Warm Temperate Rainforest Mosaic are endangered under the conservation status of the Gippsland Bioregion.
5.2	EWRs			Possible environmental water requirements may include: • Return of the wetting and drying water regime to improve the population of Giant Rush (Juncus ingens) and Dwarf Galaxias. • A return to aerobic conditions enabling for natural nutrient breakdown processes.
5.3		Critical GW service	Site specific	Given the minor contribution that groundwater is likely to make to the overall water balance, therefore its critical service to the wetland ecosystem has not been identified. Possible services provided by groundwater are (speculative): - Minor extension of saturation of the wetland during drier conditions. - Provision of fresher water to fringing wetland vegetation - Maintain saturation of potential acid sulphate soils and help to keep them relatively neutral/slightly alkaline.
6.1	Risk assessment	Key Threat Summary (link to pre, during & post development scenarios)	Site specific / GIS	Current and future potential activities and likely impacts on the water regime of Macleods Morass include: • Intrusion of saline river water • Stormwater discharge • Water quality risks from contaminated drainage from East Gippsland shire’s landfill site at Bosworth Road • Change in water regime as a result of discharge of treated wastewater and stormwater from Bairnsdale • Toxic blue-green algal blooms have occurred as a result of degraded water quality during dry periods • Water quality risks from agricultural runoff
6.2		Likelihood: susceptiblity	Level of connectivity – are impacts likely to propagate to the GDE?	The connection between groundwater and the wetland is limited due to the low groundwater gradient and the lower permeability clay base of the wetland. Reducing groundwater levels may increase the volume of surface water lost to the groundwater through increased duration of losing conditions, however it is unlikely that the volume will be significant enough to alter the water regime of the wetland.

				For the same reason, quality impacts of reduced groundwater discharge are expected to be minimal. In general, Macleods Morass is expected to have low to medium susceptibility to hazards associated with groundwater extraction.
6.3		Likelihood: management	What is the potential to address the threat to the significant site	There are few extraction bores in the vicinity (being mostly wildlife reserve), with the majority unmetered D&S. This means that it would be difficult to closely manage any significant extractions. The wetland is located in an unincorporated area which means it does not overly any WSPA. Management of groundwater extraction associated with coal and CSG may be more feasible than managing stock and domestic extractions and therefore there may be more potential to address the potential threat associated groundwater extraction associated with coal and CSG extraction.
6.4		Consequence: sensitivity	Ecological response if GW flux was reduced	Wetland water regime is not sensitive to changes in groundwater flux (volume or quality), since there is little groundwater contribution to the wetland. Wetland ecology is assumed to be largely reliant on the wetting/drying regime of surface inflows. The actual and potential ASS beneath Macleods Morass are likely to be sensitive to changes in groundwater flux as a reduction of groundwater may dry out the base of the wetland and expose the ASS and therefore would also be sensitive.
6.5		Consequence: value	Whether it is listed on DIWA, Ramsar, Register of the National Estate, TLM icon sites, etc. See 'value' section 1.5	Wetland is high value, especially as a site for supporting migratory birds and it's listing under the Ramsar Convention. It should be considered high value.
7.1	Data Gaps	Key unknowns		Interaction between groundwater and the wetland. It is assumed to be small due to low permeability of the clay layer beneath the wetland bed and the flat watertable gradient, but there is limited data to support this.
7.2		Recommendation of monitoring		Depth to watertable below the lake bed Seepage tests for lake bed sediments (K)

				Depth to watertable and gradients in surrounding catchment River and creek inflow volumes Wetland size, volume and variation over the year
8.1	References			Key info sources and links Bureau of Meteorology, 2012. *Groundwater Dependent Ecosystem-Atlas – various layers*, Australian Government. http://www.bom.gov.au/water/groundwater/gde/map.shtml Environment Australia, 2001, A Directory of Important Wetlands in Australia, Third Edition, Environment Australia, Canberra. Foster, R (2011). An investigation of acid sulphate soil in the Macleods Morass, East Gippsland, and their impact on aquatic primary productivity. Honours Thesis, School of Geosciences, Monash University Parks Victoria, 2005. Macleods Morass and Jones Bay Wildlife Reserves – Management Plan, Parks Victoria, Melbourne.

Conceptual Model for Heart Morass

Heart and Dowd Morass– Conceptual Model Information Summary Template

Ref.	Theme	Sub-Theme	Data Components, Information Sources	Description
1.1	General	Location, Name, Area	GIS	Heart Morass is located approximately 7 km south east of Sale. The 1800ha morass consists of a series of large, shallow connected basins. It is bound by a levee and the Latrobe River to the south, Flooding Creek and Sale Common to the west, Lake Wellington to the east and agricultural land to the north. The morass has combined land tenure between private and public stakeholders. Dowd Morass is located to the south of Heart Morass and is on the southern bank of the Latrobe River. The 1500 ha morass is bound by Lake Wellington to the east and agricultural land to the south and west.  Due to the availability of data and degree of tidal influences, Heart Morass was selected for modelling as part of this project. Heart Morass is considered as three separate systems for this study: • Western - Direct river inflows to West Heart Morass were through a single culvert structure

<table>
<tr><td></td><td></td><td></td><td></td><td>connected to the Latrobe River
• Central - substantial inflows to the Central Heart Morass occur through three structure connections with Latrobe River and flow through Boulton’s levee from West Heart Morass.
• Eastern - Three structures from Latrobe River provide flow into East Heart Morass. Direct inflows of water from Lake Wellington into the Eastern Heart Morass are possible through two mechanisms; Overtopping of morass at the Lake, or Overtopping of the bank of the lower Latrobe River at low points near the boat ramp at Allmans levee (Water Technology, 2014).
<table>
<tr><th></th><th>Central point (Z55)</th><th>Average length (km)</th><th>Average width (km)</th><th>Wetland area when full (km2)</th></tr>
<tr><td>Western section</td><td>E510856.8
N5779014.8</td><td>4.5</td><td>1.6</td><td>8.7 km2</td></tr>
<tr><td>Central section</td><td>E512418.7
N577912.3</td><td>3.1</td><td>1.5</td><td>4.7 km2</td></tr>
<tr><td>Eastern section</td><td>E517640.8
N5780242.4</td><td>5</td><td>1.1</td><td>5.07 km2</td></tr>
</table>
Areas estimated by reading measurements off a map, therefore approximate only.</td></tr>
<tr><td>1.2</td><td></td><td>Ecosystem Type</td><td>GIS</td><td>Ecosystem descriptions for Heart Morass based on existing resources include;
• Shallow marsh and deep marsh (GDE Atlas - Bureau of Meteorology, 2012)
• Deep freshwater marsh (Bowler and Debono 2012)
Dowd Morass is classified as;
• Deep marsh (GDE Atlas - Bureau of Meteorology, 2012)
• Brackish- water wetland (Boon et al , 2008).
Both study areas are classified as ecosystems which rely on the surface expression of groundwater and there is a high potential for groundwater interaction (Bureau of Meteorology, 2012).</td></tr>
<tr><td>1.3</td><td></td><td>Site history/ timeline</td><td>Site specific</td><td>European settlement has significantly influenced the environmental conditions of the region. Notable events include;
• 1841 – European settlement. Establishment of agricultural practices (grazing and irrigation</td></tr>
</table>

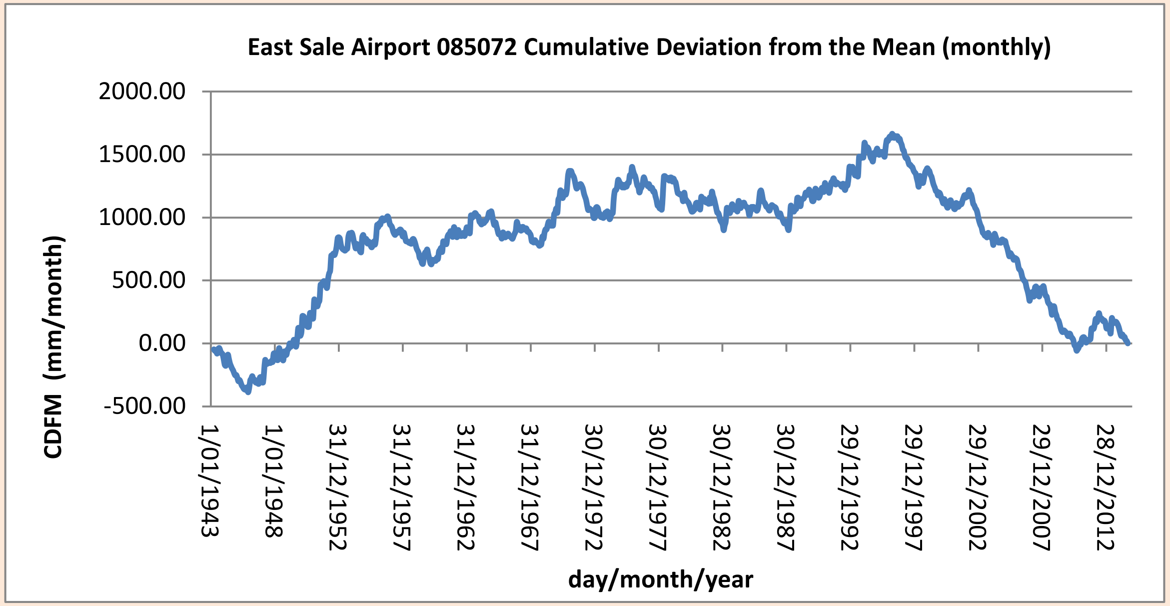
				extraction) (GHD, 2005). • 1973 - A series of levee banks, approximately 0.9 – 1.9 m AHD, were constructed within the morass in 1973 when it was in private ownership. (By comparison, the bank alongside the Latrobe River is about ~ 0.3 m AHD) These levees almost completely separated the wetland into a number of discrete sections. • Early 1970s - Two small channels were constructed to establish a hydraulic connection between Dowd Morass and the Latrobe River. • 1975 - State Government of Victoria purchased the Dowd Morass as a State Game Reserve and breaches were created in the internal levees to improve water circulation. • 1889 - The establishment of a permanent artificial entrance to the ocean at Lakes Entrance • 1900s o Construction of water infrastructure aimed at draining the morass. Infrastructure includes culverts, levees, drains and internal fences. Construction in Dowd Morass occurred in the 1970's when the morass was under private ownership; o The continuation of agricultural practices resulted in the removal of native vegetation increasing salinisation and acidification within the area; o Construction of water diversion schemes (dams) along the Latrobe, Thomson and Macalister Rivers; o Continuous inundation of Dowd Morass to prevent the intrusion of saline water from Lake Wellington. • Late 1990/2000s o Recognition of restoration requirements for the area, including vegetation and water regime restorations. The Heart Morass Restoration Project for the Western section of the morass is an example of a completed restoration project. o Dowd Morass completed dried out in during the 1997/1998 summer for a period of 3 months (SKM, 2003) • 2006 – Heart Morass was complete dry for the first time in living memory of local landholder (Bowler. M, Debono. K, 2012).
1.4		Geomorphic description	Derived from state wide GMU mapping	The landscape of Heart Morass and Dowd Morass is flat and low-lying. A Digital Elevation Model (DEM) of Heart Morass indicates must of the morass is below 0 m AHD with the lower reaches at -1.46 m AHD (Water Technology, 2009).

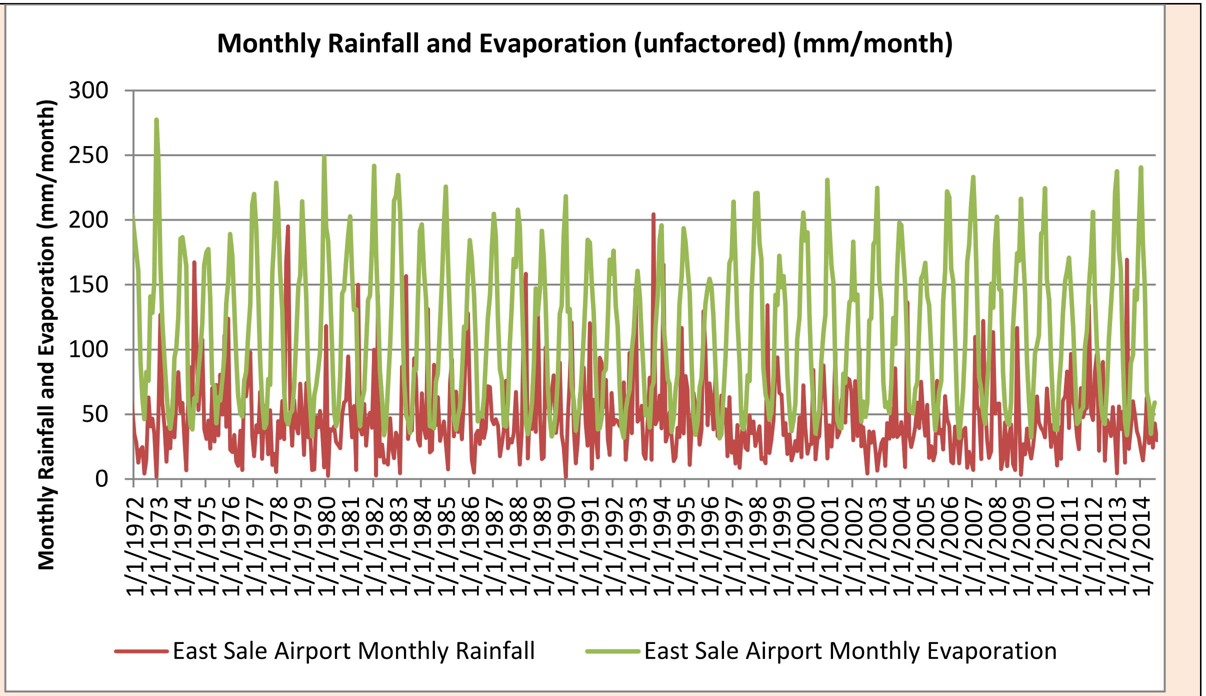
<table>
<tr><td></td><td></td><td></td><td></td><td>The Victorian Geomorphology layer describes both Heart Morass and Dowd Morass as terraced plains with sands and gravels (Bureau of Meteorology, 2012).
<table>
<tr><th></th><th>Elevation of wetland base (deepest point)</th></tr>
<tr><td>Western section</td><td>-0.5 mAHD</td></tr>
<tr><td>Central section</td><td>-0.5 mAHD</td></tr>
<tr><td>Eastern section</td><td>-0.5 mAHD (DEM)</td></tr>
</table>
Elevations estimated from DEM, therefore approximate only.</td></tr>
<tr><td>1.5</td><td></td><td>Value</td><td>Listings on other databases (Ramsar, DIWA, Register of the National Estate)</td><td>Heart Morass and Dowd Morass provide an important habitat for a number of vulnerable and threatened species and supports large populations of migratory wading birds. This is recognised via the Ramsar classification of Dowd Morass and the eastern sections of Heart Morass (part of the Ramsar Gippsland Lakes listing).

The tenure of Heart Morass varies between private and public stakeholders and is split between the eastern and western section of the morass. The eastern section of Heart Morass is a State Wildlife Reserve (State Game Reserve). The western section is private land, owned and managed by the WET Trust in conjunction with WGCMA (Water Technology, 2014). Dowd Morass is managed by Parks Victoria but was under private ownership in the 1970s. Currently the eastern section of Dowd Morass is a State Game Reserve. Both sites supports a number of species with high environmental value including numerous waterbird listed under the Japanese/Australian Migratory Bird Agreement (JAMBA) and the Chinese/Australian Migratory Bird Agreement (CAMBA).

The wetlands are listed as part of the Lake Wellington classification in the Directory of Important Wetlands in Australia (DIWA) (Environment Australia 2001) and are on the Register of National Estate. There is also historical value including;

- Site of an Aboriginal Massacre – unknown date (GHD, 2005).
- Rickety Bridge (Heart Morass)</td></tr>
<tr><td>2.1</td><td>Climate</td><td>Rainfall</td><td>Bureau of Met (N drive data)</td><td>There is one rain gauges within the vicinity of the Heart and Dowd Morass; East Sale Airport. The station is approx. 3.5 kms north of Heart Morass;
- Data period: 1943 - 2014
- Average annual rainfall: 599 mm/yr
- Average monthly rainfall: 49.7 mm/yr</td></tr>
</table>

				The cumulative deviation from the mean plot indicates decreasing rainfall from the mean between 1998 and 2010. From 2010 to 2012 there was an increase towards the mean but there has been a decrease in since late 2012. 
2.2		Evaporation	Bureau of Met (N drive data)	There is one evaporation gauge near the study areas – East Sale Airport. The measurements are of Class A Pan Evaporation, statistics for the site include; - Data period: 1972 – 2014 - Average annual evaporation: 1,338 mm/yr - Average monthly evaporation: 112.6 mm/yr Plots of the evaporation and rainfall are provided below. To account for the discrepancy between Class A Pan Evaporation measurements and the evaporation over a water body plots are also provided where a pan factor has been applied to the evaporation. The pan factor applied is 0.8 (SKM, 2003).

Monthly Rainfall and Evaporation (unfactored) (mm/month)
Monthly Rainfall and Evaporation (mm/month)
300
250
200
150
100
50
0
1/1/1972
1/1/1973
1/1/1974
1/1/1975
1/1/1976
1/1/1977
1/1/1978
1/1/1979
1/1/1980
1/1/1981
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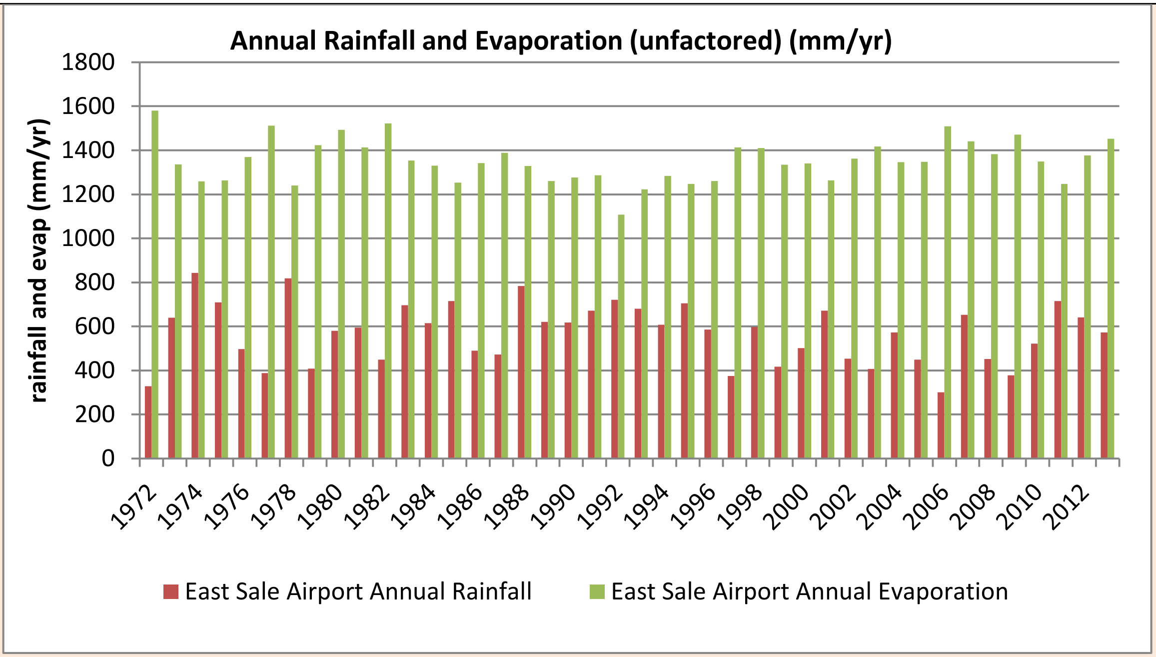
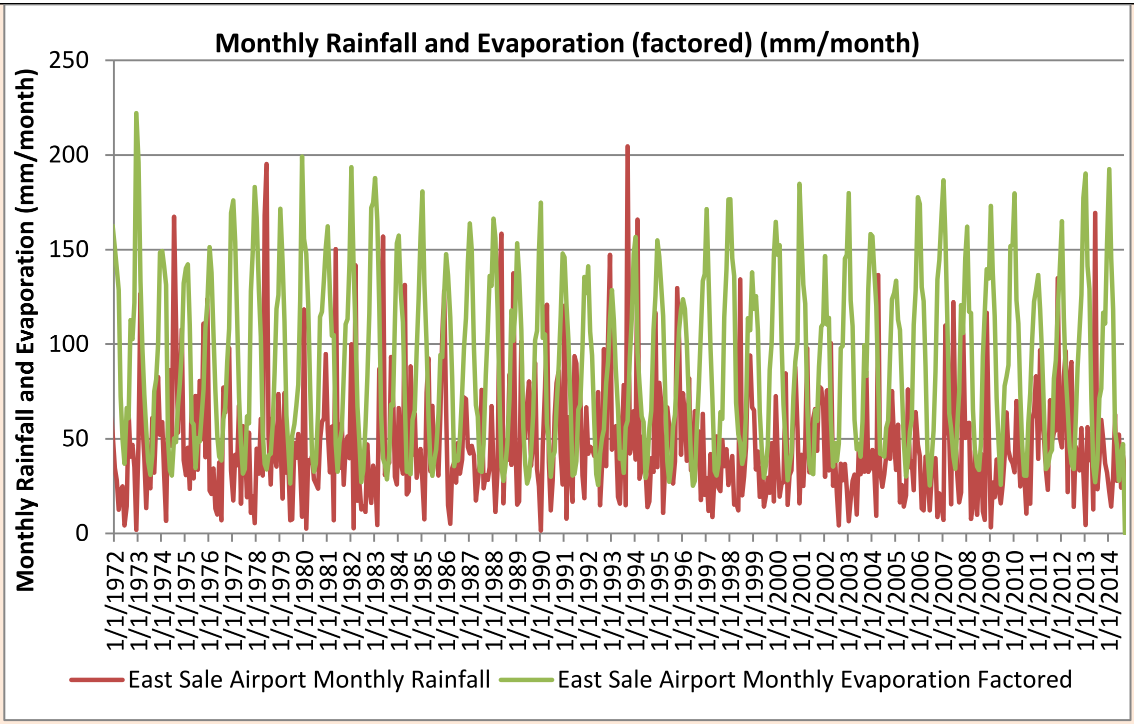
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013
1/1/2014
East Sale Airport Monthly Rainfall
East Sale Airport Monthly Evaporation

Annual Rainfall and Evaporation (unfactored) (mm/yr)
rainfall and evap (mm/yr)
1800
1600
1400
1200
1000
800
600
400
200
0
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
🟥 East Sale Airport Annual Rainfall
🟩 East Sale Airport Annual Evaporation

Monthly Rainfall and Evaporation (factored) (mm/month)
Monthly Rainfall and Evaporation (mm/month)
250
200
150
100
50
0
1/1/1972
1/1/1973
1/1/1974
1/1/1975
1/1/1976
1/1/1977
1/1/1978
1/1/1979
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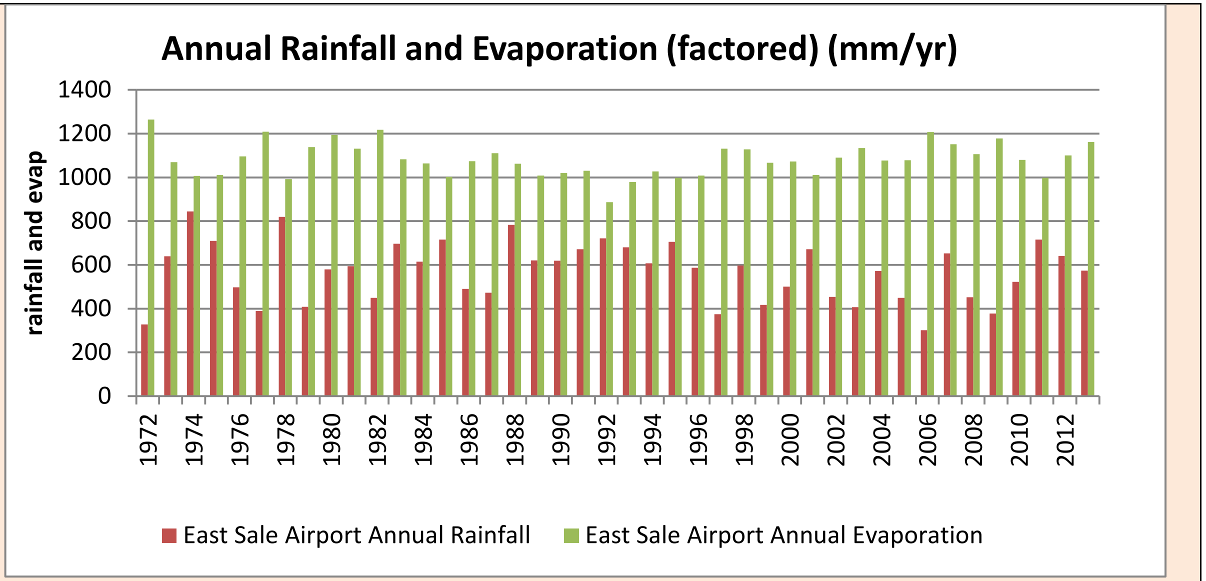
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013
1/1/2014
East Sale Airport Monthly Rainfall
East Sale Airport Monthly Evaporation Factored

				
3.1	Hydrology	Surface water regime, water levels, permanence, flow	Site specific	***<u>Heart Morass</u>*** <u>Modelling Overview</u> Two water balance models have previously been developed for Heart Morass; GHD (2005) and Water Technology (2009). GHD developed a REALM water balance model whilst Water Technology developed 1D and 2D MIKE models. The 1D "management model" by Water Technology was aimed at replacing the REALM model to obtain a greater understanding of the flooding/drying cycle of the morass. The 2D model was developed to complement the 1D model and provide a more detailed assessment of flooding patterns. <u>Water Regime Overview</u> Heart Morass experiences an ephemeral water regime that has a long history of modification due to anthrophonic influences. The morass receives water during relatively major flood events from the Latrobe River and from backwater effects and water level variations from Lake Wellington. Due the nature of the hydrology it is recognised the water regime of Heart Morass should be divided into three sections; Eastern Heart Morass,Central Heart Morass and Western Heart Morass (GHD ,2005 and Water Technology, 2009). <u>Western Heart Morass (Sale Common to Boulton's Levee)</u> Water received in the Western Heart Morass primarily occurs via overbank flows during flood conditions

from the Latrobe River and through structures along the northern bank of the Latrobe. The effect of water levels in Lake Wellington can also impact on the inflows (Water Technology, 2014).

Central Heart Morass (Boulton's levee to Freshwater Hole Road)

The inflows into Central Heart Morass are similar to Western Heart Morass.

	Max when full	Average annual	Average seasonal
Wet surface area (m2)	4,760,000	4,050,000	Spring – unknown Summer – unknown Autumn – unknown Winter – unknown
Water level depth (m)	1	0.7	Unknown
Water level (mAHD)	0.5	0.2	Unknown

Eastern Heart Morass (Freshwater Hole Road to Lake Wellington (Allamans levee))

As per the other sections of the morass flow is received via overbank flows from the Latrobe and through direct inflows flow from Lake Wellington, via Allmans levee (Water Technology, 2014).

Using information from various sources Young (2000) summarised the flood regime of Heart Morass. The summary indicates that at annual high water levels Latrobe River floodwaters will break out of the northern bank at low points along the eastern end of the morass. Flows then move westward towards the centre of the morass. With minimal increases in river water level a spill over the levee into the central and western sections typically occurs (from Young (2000) in Water Technology, 2009).

Water control Structures

There are a total of 11 locations within Hearts Morass with hydraulics structures (Water Technology, 2014). These locations include;

- 3 culverts through Allmans levee (connection to Lake Wellington)
- 8 culvert locations through the Latrobe River Northern levee
- 2 culverts along Boulton's Levee (central Heart Morass)

It is noted by Water Technology (2009) that many of the structures are in poor condition

				Dowd Morass *Modelling Overview* A salt and water balance (numerical model) of Dowd Morass was completed by SKM in 2003 as part of the implementation of the Lake Wellington Salinity Management Plan. It was recognised the model adequately simulates the behaviour of the system to quantify the relative contributions to the water level and salinity regime of Dowd Morass (SKM, 2003). Additionally a model based of the wetlands adjacent to the Latrobe River was completed by GHD in 1991. *Water Regime Overview* The water regime of Dowd Morass is described as ‘permanently flooded’ (Boon et al 2008). It receives approximately 66% of its water and 13% of incoming salt from the Latrobe River during overbank flows (SKM 2003). It also receives water and salt from backwater effects from Lake Wellington, direct rainfall, overland/interflow and via water control structures between the Latrobe River and the morass. In addition water and salt can be removed via these pathways. The figure below is an excerpt of inflows into the morass from the SKM (2003).

<table>
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<td></td>
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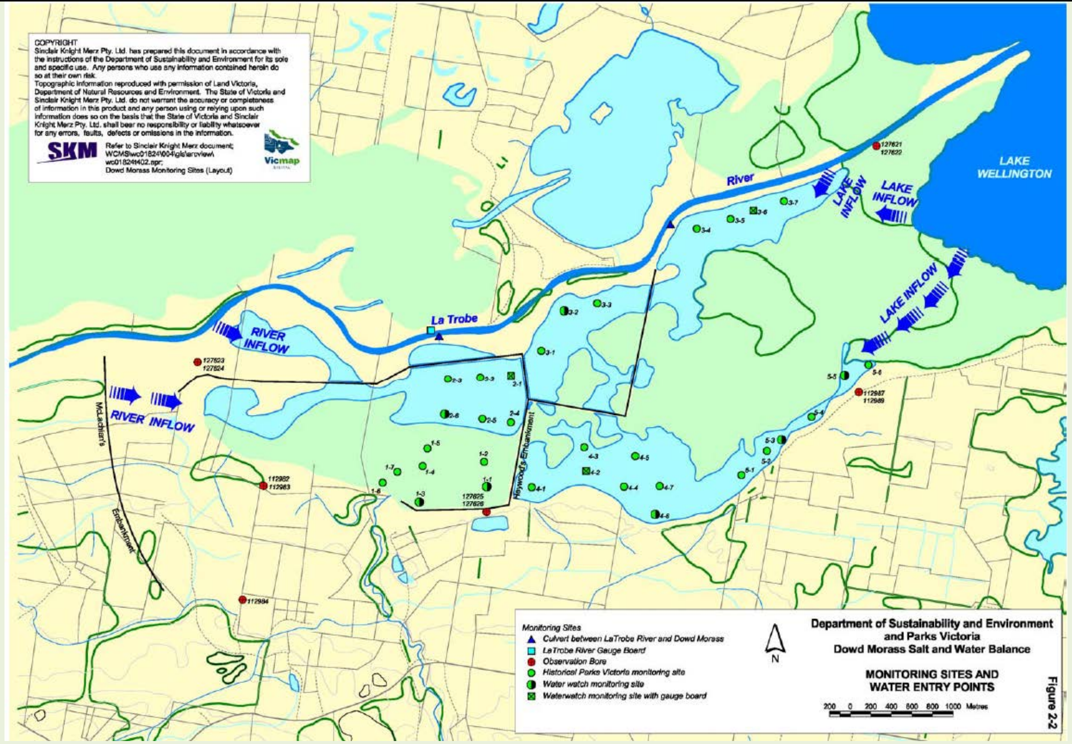
<td>


Water Control Structures

Levee banks across the morass are at approximately 0.9-1.9m AHD separating the morass into number of sections (Boon et al, 2008). Many of the levee banks constructed in the 1970s have now been breached (SKM, 2003). There are also a series of drains connecting the Latrobe River to the morass which operate via gravity flow. Gated culverts were installed on these drains post 1987 to control the inundation of the morass (SKM,2003).
</td>
</tr>
<tr>
<td>3.2</td>
<td>Hydrology</td>
<td>Surface water inflows, outflows</td>
<td>In all cases available site specific information will override</td>
<td>
<u>River inflows</u>

The confluence of the Latrobe and Thomson feed inflows into Heart Morass during high flow events. There is no available flow data downstream of the confluence (approximately Swing Bridge) and flows from the Latrobe and Thomson Rivers are to be combined to estimate total flows passing Heart morass to the south
</td>
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</table>

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<tr>
<td></td>
<td></td>
<td></td>
<td>regional assessments</td>
<td>
<p>and Dowd Morass to the north. It is recognised flood waters from the Latrobe and Thomson Rivers now occur less frequently with shallower inundations due to extractions from these rivers and the construction of ditches and drain within the morass (from Young, 2000 in Water Technology, 2014).</p>
<p>The REALM model developed by GHD (2005) indicated flow conditions at the time of the report would result in flooding of Heart Morass to a 0.1m average depth with a frequency of 1 month for every 5 years (GHD, 2005 from Water Technology, 2009).</p>
<p>The two overbank flow locations from the Latrobe River in which water and salt can be introduced into Dowd Morass include (SKM, 2003) ;</p>

Long water Hole, approximately 5km upstream of the morass;
A low point in the river bank adjacent to the western end of the morass, approximately 9km upstream of the confluence with Lake Wellington;
These levels are approximately at 0.35mAHD.

<p>If the Latrobe River levels are low and Lake Wellington levels are particularly high there is an overflow section at Dowd Morass approximately 2 kms upstream of the confluence (SKM, 2003). SKM (2003) reports this as approximately 2% of incoming water and 39% of incoming salt and is at an elevation of approximately 0.3 mAHD.</p>
<table>
<tr><th></th><th>Average annual (m^3/d)</th><th>Average seasonal (m^3/d)</th></tr>
<tr><td>Latrobe River and West Heard Morass contribution</td><td>6,150*</td><td>Spring – unknown
Summer – 0
Autumn – 0
Winter – 6150 m^3/d</td></tr>
</table>
<p>* based on the assumption that the majority of the volume of water within the wetland can be attributed to inflows from the Latrobe River, West Heart Morass or rainfall. Volumes from Water Technology 2014 were used to determine this volume.</p>
<p>Flow at THOMSON RIVER @ BUNDALAGUAH (225232):</p>
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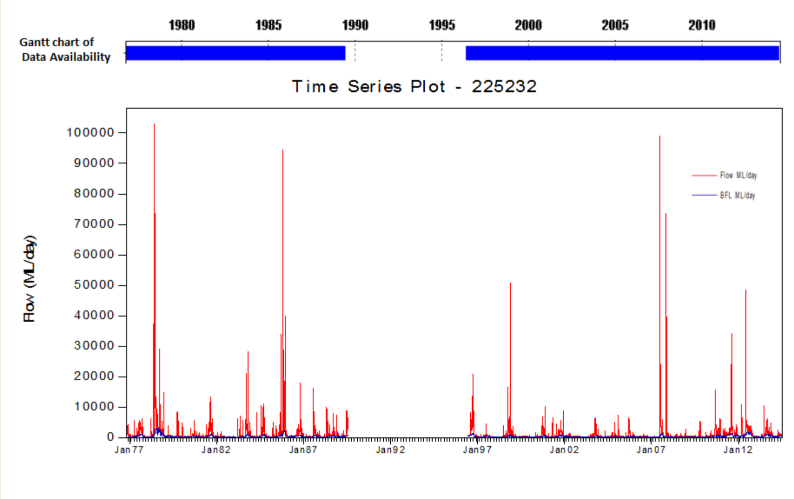
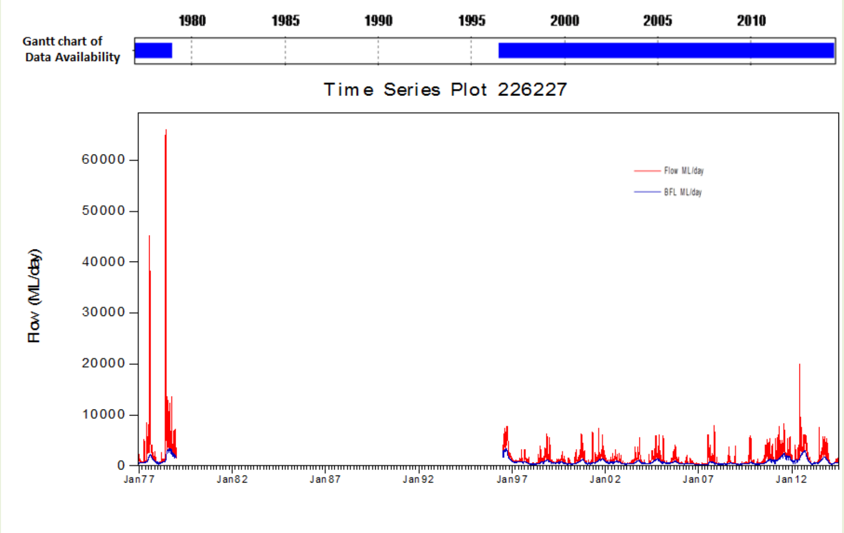


<table>
<tr><th>Statistics</th><th>Flow (ML/day)</th><th>BFL(ML/day)</th><th></th><th>Flow (ML/day)</th><th>BFL(ML/day)</th></tr>
<tr><td>Minimum</td><td>0</td><td>0</td><td>Average</td><td>1,085</td><td>366</td></tr>
<tr><td>Maximum</td><td>10,2902</td><td>3,096</td><td>Standard Deviation</td><td>3,285</td><td>339</td></tr>
</table>
LATROBE RIVER @ KILMANY SOUTH (226227):
</td>
</tr>
</table>



Statistics	Flow (ML/day)	BFL(ML/day)		Flow (ML/day)	BFL(ML/day)
Minimum	202	202	Average	1,546	848
Maximum	65,899	3,373	Standard Deviation	2,177	597

LATROBE RIVER @ KILMANY SOUTH (226227)

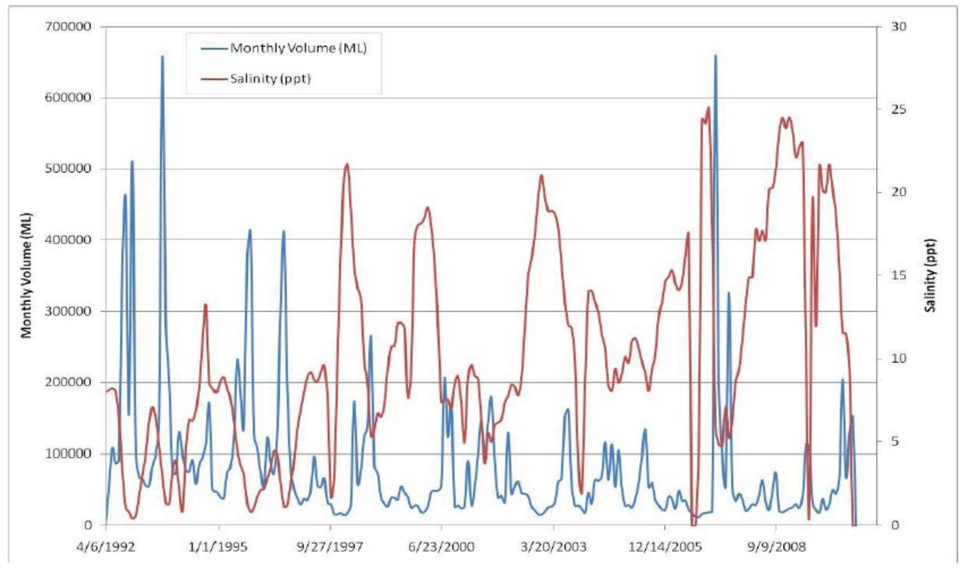
Lake inflows/tidal influence

Lake Wellington to the east of Heart Morass provides a tidal influence at the mouth of the Latrobe River, with high water levels influencing the overbank flows into Heart Morass and Dowd Morass. The lake is the most distant from the permanent ocean entrance. A frequency analysis of water levels between 1991 and 2009 at Bull point (eastern end of Lake Wellington) by Water Technology (2009) indicates the water level generally varies between 0.0 m AHD and 0.2 m AHD.

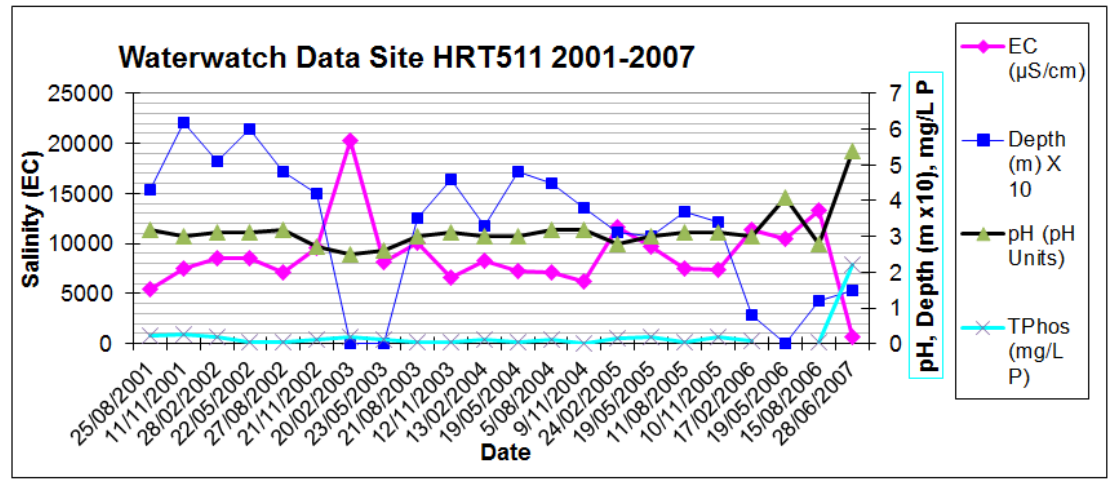
Inflows into Dowd Morass directly from Lake Wellington occur via the Dardenelles area which separates the morass and the lake (SKM, 2003). This accounts for approximately 3% of water and 42% of incoming salt (SKM, 2003). The level in the lake is required to be greater than 0.65 m AHD which is approximately the level of the Dardenelles area (SKM, 2003).

				Catchment runoff *Heart Morass* Catchment runoff would be dominated from surface runoff to the north of the morass and rainfall which falls within the morass. In GHD's water balance the catchment runoff area was considered to be 740ha which comprised the Sale RAFF base to the north. 640 ha this land was undeveloped pasture. An 8% runoff coefficient was estimated for the 740 ha catchment (GHD, 2005). *Dowd Morass* The water inflow contribution from direct rainfall and catchment runoff is estimated to be 16% and 11% respectively (SKM, 2003). Catchment runoff is estimated to contribute to 3% of incoming salt with the catchment area for Dowd Morass approximately 65km^2 (SKM, 2003). Irrigation Extraction; *Heart Morass* Irrigation extraction where historically reported within the morass however anecdotal evidence indicates these have reduced in recent times and did not occur within recent years of the 2005 GHD study. The irrigation component of the GHD REALM water balance was ignored (GHD, 2005). Evaporation The nearest climate station is the East Sale Airport (station 85072) where Class A Pan Evaporation measurements are recorded (refer to the climate data section). It is recognised there is a significant difference in heat storage, and hence the surface energy exchange, exists between the Class measurements and a large open water body. Generally lower evaporation will occur from a large water body. A method for accounting from this is to introduce a Class A Pan coefficient. Hoy (1997) derived such coefficients for a number of Australian lakes with estimates being in the range 0.66 to 0.92, with 0.8 often the adopted value (SKM, 2003) In the 1D model Water Technology (2009) reports using monthly Pan factors for each section of Heart Morass applied to the daily Class A Pan evaporation data from the East Sale Airport. However in the 2D model a uniform evaporation of 71mm/month across Heart Morass was applied. Pan factors implemented in the Heart Morass GHD REALM model include; Summer 0.94, Autumn 0.85,

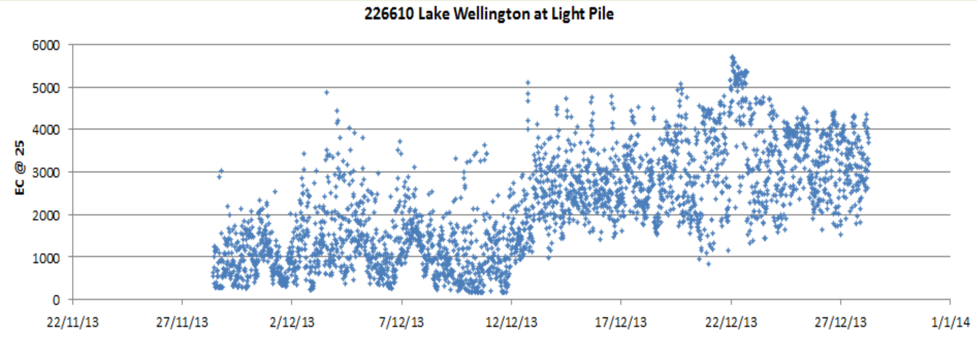
				Winter 0.53, Spring 1.00 (GHD, 2005) In the SKM model (2003) pan coefficients of 0.8 and 0.9 were trialled for Dowd Morass however a coefficient of 1 was determined to provide the model will appropriate calibration results (SKM, 2003). It was noted this value was not appropriate and there could be other factors causing a loss of water from the morass. Groundwater inflows/outflows • GHD (2005) reports Heart Morass is predominately a groundwater discharge zone with and average daily groundwater discharge of 0.5 ML/day. • SKM (2003) reports the groundwater discharge contribution to Dowd Morass is a negligible proportion of the water and salt inflow (<1%).
3.3	Hydrology	Flow, quality, chemistry	Site specific	Salinity There have been numerous extensive studies completed on salt loads and salinity levels within the area and the interactions between Lake Wellington and the Latrobe River (Water Technology 2014, Brizga et al 2011 and SKM 2003). Salinity is a key factor in the ecological condition of Heart Morass and Dowd Morass and forms a complex relationship due to altered flows from the Latrobe River and water influxes from Lake Wellington. The influence of groundwater discharge is variable, it is anticipated to contribute to the salinity levels within Heart Morass (GHD, 2005) but is a does not have a significant effect in Dowd Morass (SKM, 2003) SKM (2003) reports the main contributor to the salt load in Dowd Morass is Lake Wellington backing up the Latrobe River and spilling into the morass or overflow across the Dardenelles area. It is also noted a high water table is not likely to provide a significant contribution to the salinity of the morass (SKM, 2003). Salinilty levels are also noted to be higher in the southern section of the morass (SKM,2003). Lake Wellington – salt loads The salt balance of Lake Wellington is dependent on contributions from fresh water rivers, the evaporation cycle in the lake and the additional of saline water from Lake Victoria. Typical water-column salinities are

				between 0.5-10 g/L however these values will depend on the discharge from the Latrobe River and the intrusion from the eastern lakes (Raulings et al 2011). The figure excerpt from Water Technology's 2014 report on Lower Latrobe River Wetlands Infrastructure below Indicates the relationship between inflows and salinity levels in the lake. Prior to European settlement and the modification to the Gippsland Lakes entrance in 1889 it is consider the lake experience freshwater conditions (SKM 2010 in Water Technology, 2014). Information indicates for flows below the estimate mean daily flow a salt wedge will enter the Latrobe River from Lake Wellington, with flows above 200-300 GL/month required to flush all salt from the Latrobe (Water Technology ,2009).  *Total Monthly Inflow Volume and Salinity Record (at Bull Bay) for Lake Wellington (1992 to 2011) (Water Technology 2014)* *__Measurements__* Sporadic water quality measurements at the western part of the Heart Morass between 2001 and 2007

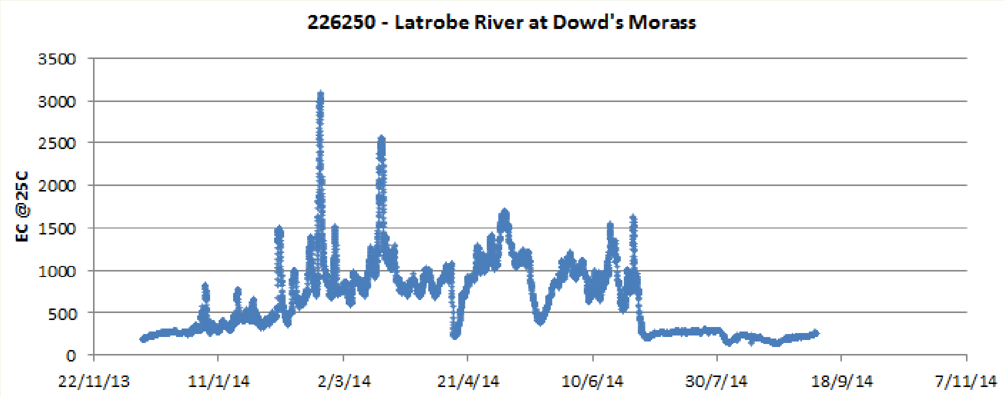
provide an indication of salinity and pH levels during a period when the morass was significant affect by drought (refer below). Measurements from 2013 and 2014 of EC are also publicly available for Lake Wellington (gauge 226610 and 226250) from the online Victorian water monitoring site (DEPI, 2014).



Water quality observations at a site in the western Heart Morass (Waterwatch 2001–07) (Bowler, M and Debono, K, 2012).



EC measurements at Lake Wellington gauge 226610

				 EC measurements at Dowd Morass, gauge 226250
4.1	Hydrogeology	Geology	GIS	The 1:250 000 geology map indicates the Heart and Down Morass reside upon Quaternary swamp and lake deposits. Lithology is characterised by carbonaceous mud, silt, clay and minor peat. The Heart Morass resides on the floodplain of the Latrobe and Thompson River. Morass sediments are typical of lagoonal and swamp areas and are predominately silt and clays. Sediment thickness may be 5 to 10 meters overlying sandier fluvial sediments. Some former river channels remain as billabongs within the swamp areas. To the north of the morass sandy fluvial sediments of the river terrace occur. The unconsolidated sediments may be in excess of 20 meters thick (GHD, 2005).
4.2	Hydrogeology	Aquifer(s)	GIS	Aquifers in the Heart/ Dowd Morass area: • Quaternary Aquifer (mainly river terrace fluvial sediments) o About 10 m thick o Form the primary watertable aquifer • Upper Tertiary/ Quaternary Aquifer (Haunted Hill Formation aquifer) o Approximately 40-50 m thick • Upper Tertiary/ Quaternary Aquitard (aquitard unit comprised of Nuntin Clay and Jemmys Point Formation etc) o Thin - absent south of the morass and thin (approx. 50 m thick) north of the Morass

				• Upper Tertiary Aquifer -Fluvial (Boisdale Formation aquifer) o Approximately 50 m thick • Upper Mid-Tertiary Aquitard (aquitard unit, comprised of Gippsland Limestone and other formations) o Nearly 600 m thick in this area • Lower Mid-Tertiary Aquifer (Latrobe Valley Group) o <100 m thick • Lower Tertiary Aquifer (Latrobe Group) o 250-350 m thick • Basement Aquifer (Palaeozoic bedrock) GHD (2005) modelled the watertable aquifer of the Heart Morass using a horizontal hydraulic conductivity value of 2 m/day.
4.3	Hydrogeology	Soils, substrate	GIS	**Heart and Dowd** • According to the Atlas of Australian Soils, the Heart and Dowd Morass reside on organosol soil type. Organosols are soils dominated by organic material • Uppermost soil horizons contain penetrating roots and decaying organic matter, producing a layer or organic matter. • Dominated by Holocene floodplain sediments that range from coarse sands to clays, with surface sediments dominated by fine sands and coarse silts. 28 sediment samples were analysed for grain size in the Heart and Dowd Morass floodplains and this indicated floodplain sediments of the Heart Morass average a grain size of 17um, indicating the prevalence of fine silts. • Surface sediments range from poorly to very poorly sorted and are generally coarser in the riparian woodland scrub than in the low-lying sedgeland. • Soils will be of variable permeability dependent on river influences include but will generally be of relatively low permeability • Low-lying sedgeland is most affected by acid sulphate soils (there is a gradual rise in surface soil pHF away from the central low-lying sedgeland towards the riparian woodland scrub and uplands) - soil horizons in these areas to about 50 cm depth had a median pHF of 2.95 at the surface and 3.80 below the surface. The uppermost soil horizon exhibited orange staining while lower horizons showed orange–red mottling that was more prevalent near deeper penetrating roots (Unland et al.

				2012). **Acid Sulfate Soils** ● Actual acid sulfate soils are present within the Heart and Dowd morass systems ● Potential acid sulfate soils are also present but do not make up a significant area of Heart, however field data suggests that the acid sulfate soils are mostly PASS. ● Metal toxicity is adversely affecting plant growth and establishment within the Heart Morass ● Dowd Morass has signs that remediation already exist (such as well established vegetation) which means it has moderate to neutral pH and lower concentrations of metals. However, if soils in the Dowd Morass were to degrade become exposed to oxic conditions, there is a potential for the acid sulfate soils to re-activate and cause environmental degradation (Taylor, 2011).
4.4	Hydrogeology	Groundwater movement and flow dynamics, groundwater levels, gradients, recharge areas to discharge site	Describes the temporal nature of groundwater flow at the site, seasonality, depth to groundwater, long term trend of GW level. Describe the direction of groundwater movement from the recharge zone to the site.	**General** Watertable aquifer – ● Recharge to the Quaternary aquifer occurs via rainfall and irrigation accessions. ● Groundwater flow is generally southerly to areas of lower topography and groundwater discharge occurs to lower lying landscape features such as Hearts and Dowd Morass and the Latrobe River or easterly towards Lake Wellington. ● Locally, groundwater flow may be modified by groundwater pumping and drainage (GHD, 2005). **Heart** ● Heart Morass is predominately a groundwater discharge zone (GHD, 2005). ● Small groundwater flow systems may also be present in areas of the morass dependent on local rainfall, flooding and discharge from outside of the Morass. ● Local groundwater flow within the morass would likely to be southerly to the Latrobe River and easterly towards Lake Wellington and other water bodies west of the lake ● Has shallow watertables (,2m), with watertable depth increasing with elevation to the north of the swamp (2-5m) ● All the morass area may seasonally suffer from shallow watertable via recharge where flooding and / or groundwater inflow (discharge) from other areas occurs (GHD, 2005). ● Figure 1 shows groundwater levels for three shallow bores that monitor groundwater levels for the watertable aquifer (all with drill depth less than 22m depth). The correlation with rainfall is not significant

although a general slight decline in watertable elevation from 1996 onwards correlates with the negative trend in the cumulative deviation from mean rainfall. The bores located further down the groundwater flow path (i.e. to the east) have a lower elevation (i.e. bores 90360 and 90357) relative to the bore located further upgradient (i.e. bore 90424). The bores located downgradient currently hover around 0 mAHD (i.e. sealevel) and hence interaction with sea water is possible.

- Figure 2 shows groundwater levels in meters below the top of the bore casing and indicates depths to groundwater of <2m for the bores located to the east of the morass and around 4 m for the bore located at the westerly end of the morass.
- Figure 3 shows groundwater levels for a shallow watertable aquifer bore (90434) and a deeper Boisdale Formation aquifer bore (90148). This figure indicates that in the past the vertical gradient was in an upward direction from the Boisdale Formation aquifer to the watertable aquifer. Throughout the period of low rainfall (1999 to 2010) when pressure on groundwater resources increased and rainfall recharge decreased, the gradient switched from upward to downward on a seasonal basis, driven by the drawdown impact of pumping from the Boisdale aquifer. From 2011 onwards however, higher rainfall conditions mean that the pressure on the groundwater resource is reduced and the gradient is once more consistently in an upward direction.

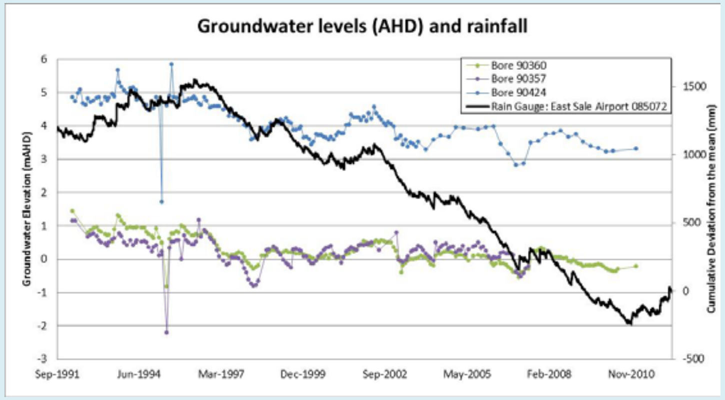
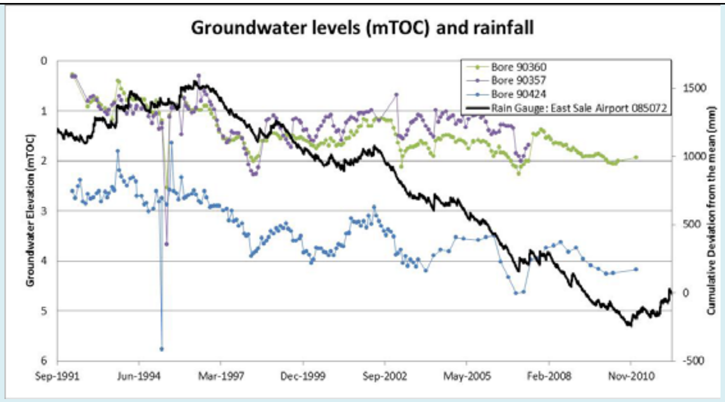
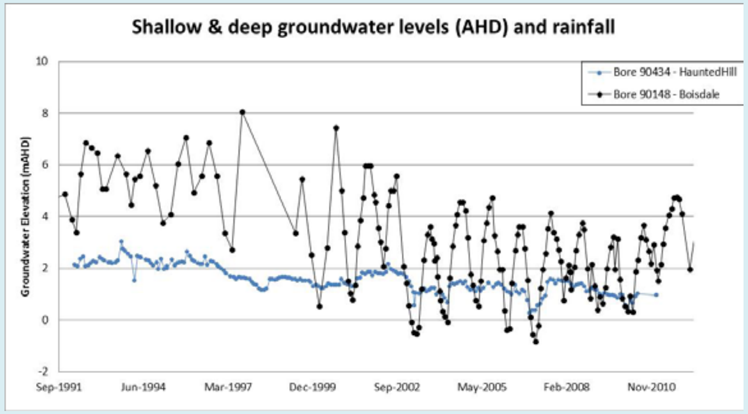


Figure 1 Groundwater levels (mAHD) for shallow watertable aquifer bores and cumulative deviation from mean rainfall data for the East Sale Airport rainfall gauge.

				 **Figure 2 Groundwater levels (mTOC –top of casing) for shallow watertable aquifer bores and cumulative deviation from mean rainfall data for the East Sale Airport rainfall gauge.**  Figure 3 Groundwater levels (mAHD) for a nested site of shallow watertable aquifer bore and Boisdale Formation aquifer bore. The gradients indicate that Heart Morass is gaining due to the groundwater levels being higher than the base elevation of average annual water level in the Morass (0.2mAHD), although since gradients are low it is possible that the direction of flow between the Morass and the watertable aquifer changes seasonally in response to changes in surface water levels in the Morass. Since the wetland is conceptualised as

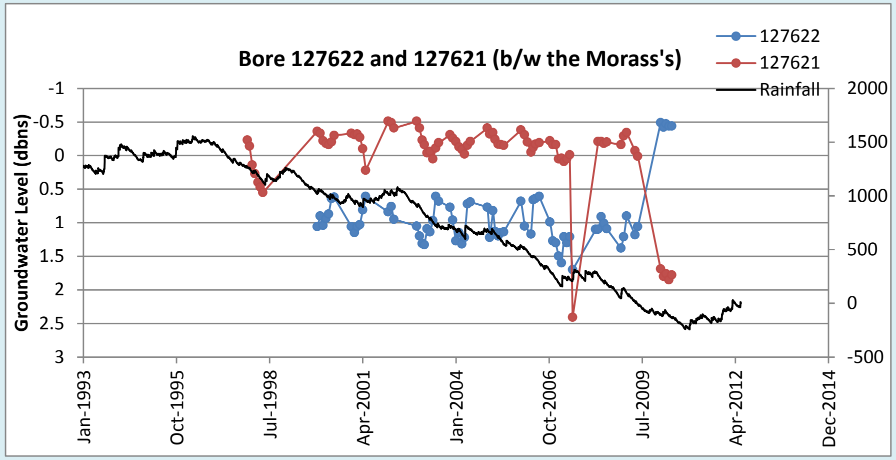
predominantly gaining, generally groundwater levels could be higher than morass water levels.

Estimates are:

	Upstream gradient	Downstream gradient
Western section	0.36mAHD	0.36mAHD
central section	0.35mAHD	0.35mAHD
Eastern section	0.35mAHD	0.35mAHD

Dowd

- Groundwater from the shallow quaternary aquifer is likely to move upwards to the water table which then discharges into the morass.
- Most of the groundwater to the morass is likely to be coming through the base of the morass rather than from the sides.
- Local groundwater flow within the morass would likely to be northerly from topographic highs around Dunston towards the Latrobe River and Dowds Morass.
- On a local scale, water levels in bores located within 150 metres of the edge of the morass are similar to morass water levels. This indicates that groundwater in the immediate zone around the morass is strongly influenced by morass water levels.
- Comparison of bores further away from the morass and water levels in the morass indicate that there is likely groundwater flow towards the morass.
- Groundwater hydrographs for nested bore sites around Dowd Morass show that the potentiometric surface from deeper bores is generally above the water level in the shallow bores. This suggests that there is also a potential for upward groundwater flow (SKM, 2003).
- Hydrographs for groundwater bores at three locations around the Morass have been produced. The bores are all located right on the boundary of the Morass and hence provide a good indication of groundwater conditions at the edge of the Morass. Figure 4 shows groundwater levels for the

				watertable aquifer in between the Heart and Dowd Morass. Groundwater is very shallow in this area and likely to be at essentially at the surface. Seasonal fluctuations of around 0.5 m are apparent. - Figure 5 shows groundwater levels on the south-west edge of the Dowd Morass. A distinct decline in groundwater elevation is noted in the hydrograph. The duration of the hydrograph is up to January 2011. It is likely that a recovery in groundwater levels from the millennium drought would be observed in these bores from 2011 to 2015. - Figure 6 shows groundwater levels on the south-east edge of Dowd Morass and shows stable groundwater elevations of around 1 m below the surface.  Figure 4 Shallow bore hydrographs - – Dowds Morass

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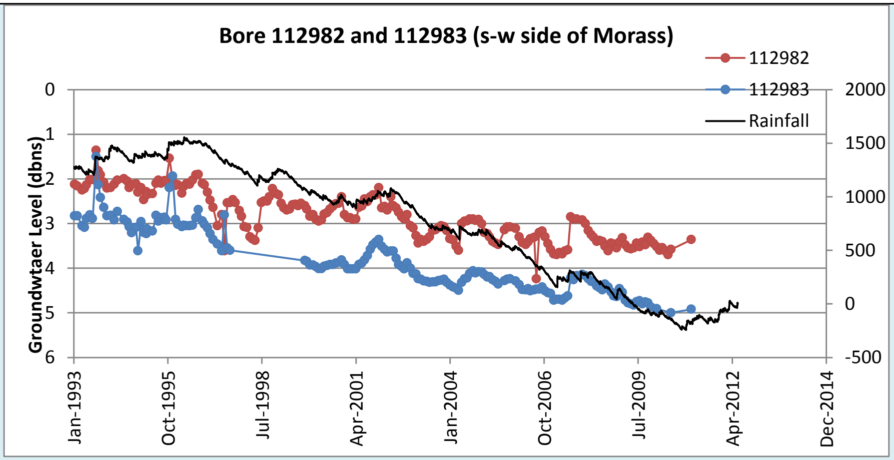

Figure 5 Shallow bore hydrographs – Dowds Morass south west side

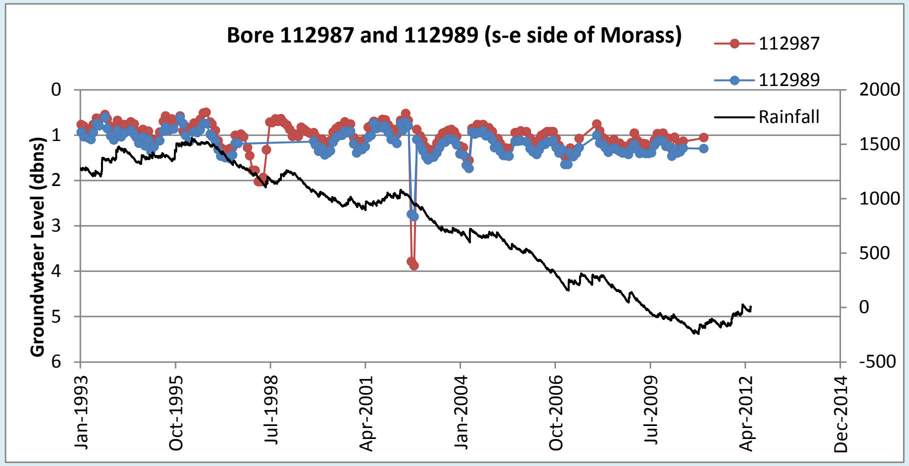

Figure 6 Shallow bore hydrographs – Dowds Morass south east side
</td></tr>
<tr><td>4.5</td><td>Hydrogeology</td><td>Groundwater quality, chemistry</td><td>Site specific</td><td>Groundwater salinity east of sale ranges from 1,000 to more than 7,000 mg/L TDS (i.e. 1 470 to 10 290 EC). Locally, around Heart Morass, groundwater salinity seems to be lower.</td></tr>
</table>

				Heart Morass • Groundwater salinities to the east of Sale varies from 1,000 mg/L to over 7,000 mg/L, however within Heart Morass data suggest lower salinity (between 1,000 and 3,000 mg/L) • Salinity trends are not known within the morass and would be affected by trends in discharging groundwater, quality of floodwaters and evaporitic processes over summer months (GHD, 2005). • GHD (2005) report that saline groundwater discharge presents an increasing threat to wetland biota. **Dowd Morass** • Average groundwater salinity of 4,500 μ S/cm (SKM, 2003)
4.6	Hydrogeology	GW interaction with wetland Volumes, spatial variation, temporal variation	Site specific	**Groundwater inflows/ outflows** Seasonally, local groundwater recharge or discharge within the morass may occur depending on surface water levels. The high groundwater inflows in 1998 correspond with a major flooding event in the region which provides evidence that suggests that seasonal fluctuations in river and morass water levels will impact on groundwater levels. Impacts from these processes will be limited to within the morass. It is therefore likely that groundwater will discharge to both Heart and Dowd Morass during drier periods or when the water level of the morass is below the groundwater level. However during periods of higher water levels, particularly during flood periods, the surface water will recharge the groundwater.
5.1	Ecology	Value		Heart Morass provide a suite of ecology conditions based around wetting and drying regimes resulting in a variety of environments suitable to a range of flora and fauna species. Although the wetting and drying regime of Dowd Morass is established due to anthropogenic influences it provides an important habitat for a number of endangered species. Heart Morass and assuming Dowd Morass given the close proximity provides a habitat for 23 birds identified under the Japanese/Australian Migratory Bird Agreement (JAMBA) and 23 birds identified (21 common with JAMBA) under the Chinese/Australian Migratory Bird Agreement (CAMBA). Notable bird species included in these agreements are; • Royal Spoonbill (*Platalea regia*) – identified as a breeding site of national significance (GHD,2005) • Great Egret (*Ardea alba*) – identified as a breeding site (noted as migratory under Environmental Protection and Biodiversity Conservation Act (EPBC Act) and the Flora and Fauna Guarantee Act (FFG Act)) (GHD,2005). • White-bellied Sea-Eagle (*Haliaeetus leucogaster*) - Marine and Migratory under the EPBC Act,

				listed under the FFG Act, vulnerable in Victoria Additional threatened and vulnerable species identified in Heart Morass include; (from Water Technology, 2014 and Ecology Australia, 2012); ● Intermediate Egret - critically endangered in Victoria and listed in the FFG Act ● Australasian Bittern -endangered in Victoria, listed in the FFG & EPBC Acts ● Royal Spoonbill - vulnerable in Victoria ● Dwarf Galaxias - vulnerable in Victoria, listed in the FFG Act and vulnerable under the EPBC Act ● Green and Golden Bell Frog (*Litoria aurea*) - vulnerable under the EPBC Act and vulnerable in Victoria ● Growling Grass Frog (*Litoria raniformis)* - endangered in Victoria, FFG Act and vulnerable under the EPBC Act. ● Azure Kingfisher (*Alcedo azurea*) - near threatened in Victoria ● Freckled Duck (*Stictonetta naevosa*) endangered in Vicotira and listed in the FFG Act (recorded in substantial numbers in January 2012) **Flora** Six broad vegetation types have been identified within the Heart Morass (with overlap in Dowd Morass) including (GHD, 2005); ● Reed Swamp (dominated by *Phragmites australis*) ● Aquatic Sedgeland (dominated by *Scoenoplectus tabernaemontani*) ● Swamp Scrub (dominated *Melaleuca ericifolia*) ● *Poa* Grasslands (dominated by Poa *spp.*) ● Coastal Salt Marsh (dominated by *Sarcorcornia quinqueflora* and other salt-tolerant species) ● Floodplain Riparian Woodland (dominated by *Eucalyptus tereticornis)* The threat to these vegetation types including Swamp Scrub (dominated *Melaleuca ericifolia*) is a critical factor as it provides the nesting and roosting sites for waterbird breeding which is critical for the Ramasr listing of the region (Raulings et al, 2011). Including the above vegetation types three vegetation types that are threatened in the Gippsland Plain Bioregion include (Water Technology, 2014); ● Swamp Scrub (endangered) ● Brackish Herbland (rare) ● Aquatic Herbland (rare)
1.16	GW service	Critical GW process	Site specific	Groundwater modelling (Water Technology, 2009) concluded that there is negligible difference in surface water levels due to the inclusion of groundwater inflows (Water Technology, 2009).

				Similarly to Heart Morass, groundwater modelling (SKM, 2003) reported that the groundwater discharge contribution to Dowd Morass is a negligible proportion of the water and salt inflow (<1%). Although the amount of groundwater discharge is likely to be small compared with river flows and the movement of seawater, fresh groundwater inflows may be important for supporting the ecology of the morass. Less salt tolerant plants could sustain repeated inundation by more salty water if their roots had permanent access to fresh water, such as a shallow groundwater lens (Boon, 2008). Groundwater may also maintain saturation of potential acid sulfate soils and help to keep them relatively neutral/slightly alkaline.
5.2	Ecology	EWRs.	site specific	Possible environmental flow requirements include; ● flushing of Heart Morass with fresh water; ● For vegetation flooding to an average depth of 0.1m to 0.5m for 1 month every 2 years and 2 months every 4 years (Water Technology, 2009); ● For birds (foraging and breeding) – flooding to an average depth of 1m for at least 4 months every 5 years (Water Technology, 2009); ● To “flush” out salt and reduce the salinity of the waters which are retained within Heart Morass; ● To enable ecological connection via periodic flooding.
5.3	Ecology	Critical groundwater service	site specific	Groundwater modelling (Water Technology, 2009) concluded that there is negligible difference in surface water levels due to the inclusion of groundwater inflows (Water Technology, 2009). Similarly to Heart Morass, groundwater modelling (SKM, 2003) reported that the groundwater discharge contribution to Dowd Morass is a negligible proportion of the water and salt inflow (<1%). Although the amount of groundwater discharge is likely to be small compared with river flows and the movement of seawater, fresh groundwater inflows may still provide the following environmental water requirements to both Dowd and Heart Morass to: ● Maintain saturation of potential acid sulfate soils beneath the Morass. If exposed, these PASS would cause environmental degradation of the sites and impact on the habitat for flora and fauna. ● Less salt tolerant plants could sustain repeated inundation by more salty water if their roots had permanent access to fresh water, such as a shallow groundwater lens (Boon, 2008).
6.1	Risk assessment	Key hazards (link to pre, during & post development scenarios)	Site specific / GIS	Potential threats to the ecology of Heart and Dowd Morass include: ● Continuous alteration to the flow regimes within the Latrobe, Thomson and Macalister catchments causing loss of wetland connectivity with the river, alteration to wetting and drying regime, loss of breeding cues and opportunities, saline in-flows from Lake Wellington and changes in water

				temperature resulting in reduction of breeding of fauna. ● Climate change – rising sea levels in Lake Wellington – resulting in increased inflows into the morass unless infrastructure controls are adapted causing increased salinity levels within the Morasses increasing and loss of connectivity with the natural lake system through potential levee construction. ● Climate change – drier climates resulting in increased salinity levels (higher evaporation). ● Incompatible Land Management – resulting in increased input of contaminants (sediment, nutrients and salt), loss of wetland habitat, change vegetation structure and species composition, reduced regeneration of indigenous plays and catchment salinity impacts.
6.2		Likelihood: susceptibility		The groundwater catchment is small, so most groundwater extraction in the region occurs in other groundwater catchments. The connection between groundwater and Heart Morass is likely to be limited by the lower permeability of the clay sediments underlying the Morass, therefore reducing groundwater levels will not significantly alter the water regime of the Morass. For the same reason, quality impacts of reduced groundwater discharge are expected to be minimal. In general, Heart Morass is expected to have low – medium susceptibility to hazards associated with groundwater extraction. It is assumed that in the absence of a risk assessment, Dowd Morass would have similar susceptibility.
6.3		Likelihood: management	What is the potential to address the threat to the significant site	Management of groundwater extraction is currently not preventative, since most extraction within the catchment is unmetered (D&S). If this was seen as a significant threat, there would not be the ability to more closely management it. Management of groundwater extraction associated with coal and CSG may be more feasible than managing stock and domestic extractions and therefore there may be more potential to address the potential threat associated groundwater extraction associated with coal and CSG extraction.
6.4		Consequence: sensitivity		Wetland water regime is not sensitive to changes in groundwater flux (volume or quality), since there is little groundwater contribution to the wetland. Wetland ecology is assumed to be largely reliant on the

				wetting/drying regime of surface inflows. Groundwater may support less salt tolerant plant species fringing the Morass and therefore due groundwater being a potential source of freshwater for these species, they would be more sensitive to any changes in groundwater flux. The PASS beneath the Morass are also likely to be sensitive to changes in groundwater flux as a reduction of groundwater may dry out the base of the wetland and expose the PASS and therefore would also be sensitive.
6.5		Consequence: value		Wetland is high value, especially as it provides an important habitat for a number of endangered species and is listed under the Ramsar Convention (Gippsland Lakes). It should be considered high value.
7.1	Data Gaps	Key unknowns		Seasonal variation of interaction between groundwater and both Heart and Dowd Morass. It is assumed to be predominantly gaining throughout the year, but there is limited data to support this.
7.2		Recommendation of monitoring		Depth to watertable below the lake bed of Central Heart Morass Seepage tests for lake bed sediments (K) River inflow volumes Wetland size, volume and variation over the year
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