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Waterway Management Consultants

LINCOLN HEATH ESTATE
POINT COOK ROAD, POINT COOK

SOUTHERN OUTFALL CATCHMENT

SURFACE WATER MANAGEMENT STRATEGY (UPDATE)

For: Australand P/L

24 September 2014

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1. INTRODUCTION

This report updates the surface water management strategy (SWMS) report dated 2 July 2012 for the southern outfall catchment in the Lincoln Heath Estate at Point Cook which is at 360-438 Point Cook Road.

The 2 July 2012 report itself followed on from and updated my original report "Lincoln Heath Estate Rural Lots SWMS, 10 March 2004". That report outlined the SWMS for the previous application for development of the land as a rural-residential estate. The new proposal is for conventional residential development following inclusion of the land within the urban growth zone under the Logical Inclusions process.

The Lincoln Heath South SWMS proposes full integration of the stormwater system in Lincoln Heath with that constructed in the abutting Alamanda Estate to the west. However it is possible for the strategy assets to be easily adjusted in future if urban development proceeds in the Point Cook South area. This update report therefore responds to issues relating to implications of the Lincoln Heath South SWMS in regard to future urban development proposals for the Point Cook South area, as discussed with Melbourne Water (MWC) and Metropolitan Planning Authority (MPA) officers at the meeting dated 8 July 2014.

2. EXISTING CONDITIONS

The gently undulating Lincoln Heath Estate is cleared agricultural land previously used for grazing and cropping. The topography of the southern portion of the site is dominated by a broad flat plain area at level of about 7.0 m AHD. On the southern boundary are the remnants of a shallow ephemeral meadow wetland that has been significantly altered by agricultural land use. The lower lying parts of this wetland show evidence of some salinisation. Otherwise there are no obvious waterways or water features anywhere within the development site.

Figure 1(a) is a nearmap.com extract showing the current site conditions and abutting development as in 2011. Figure 1(b) shows current conditions. Figure 2 is the site survey plan.

The land abuts the Alamanda Estate to the west and the existing Lincoln Heath Estate to the north. The southwest corner directly abuts the linked wetland system which drains all of the Alamanda Estate to the west.

Under existing conditions surface water can only escape southerly from the Lincoln Heath South site by broad shallow overflow from the ephemeral wetland when levels exceed 7.0 m

AHD. On this basis a nominal 100 year ARI flood level of 7.30 m AHD has been set for the site in its current condition.

3. PROPOSED DRAINAGE ARRANGEMENTS

3.1 Discussions with MWC

Discussions were held in 2012 with Melbourne Water Corporation (MWC) regarding the site constraints and drainage options.

As was the case for the Alamanda Estate it was acknowledged that the only feasible outfall drainage connection available to Lincoln Heath at that time was to the west via the linked wetland system in the Alamanda Estate, as an extension to MWC's Point Cook Drainage Scheme.

Although proposals have been advanced for provision of an alternative deeper outfall to the south as part of a possible future development of the Point Cook South area (and this proposition was supported by MWC in submissions to the Logical Inclusions process), such outfall facilities are unlikely to eventuate in a timescale suited to development of Lincoln Heath. Hence it was confirmed that:

- the Lincoln Heath South drainage design should be based on connection of low flow drainage at least to the Alamanda system;

- the design should provide for extension of the linked wetland concept within Lincoln Heath to best minimise fill depth requirements, address EVC requirements, provide best practice water quality management, and provide sufficient flood storage capacity to ensure maintenance of existing peak flow regimes discharged to the south;

- the distance between wetland segments and design of interconnecting pipelines should conform with accepted design as negotiated previously in the Alamanda Estate.

At a recent meeting with MWC and MPA officers on 8 July 2014, the same conclusions were reached. While the Point Cook South area is now within the Urban Growth Area, the MPA officers advised that preparation of a PSP for the area is not currently scheduled for several years, whereas the PSP for Lincoln Heath South is currently in preparation.

A consensus view from this meeting was however that the Lincoln Heath South SWMS should be shown to be compatible with possible future drainage strategies for Point Cook South.

Figure 1(a) Nearmap.com extract showing site conditions in 2011.

Figure 2(b) Nearmap.com extract showing existing site conditions in May 2014.

Figure 2 Site Survey 360-438 Point Cook Road

3.2 The Proposed Drainage Layout and Subcatchments

Figure 3 shows the proposed development layout, main EVC areas, and the linked wetland/retarding basins (WLRB's) that have been adopted after trial and error design to optimize fill requirements across Lincoln Heath South, whilst complying with other constraints. The existing linear wetland abutting in Alamanda estate is also shown.

Figure 3 Preliminary road network and main drainage layout.

The interconnecting pipeline between the two wetland segments west of the north-south collector road cannot be avoided due to minimal space between the identified EVC boundaries and the southern title boundary. The pipe size has been set at 1200 mm diameter which is larger than the 900 mm diameter pipes used in Alamanda. The length of 80 m is well short of the maximum of 220 m used previously in Alamanda.

The development drainage systems and overland flowpaths (OLF) will be laid out generally as shown on Figure 4. Pipe drainage from approximately 10 ha of the northern area will be directed into the existing Alamanda sediment basin south of Fongeo Drive.

The balance of the pipe drainage systems in Lincoln Heath will all be directed south to the main sediment basin. While 5 year ARI capacity pipes remain the standard throughout the estate, the opportunity exists for pipe sizes to be reduced in some places near the wetlands by providing surcharge pits with 1 year ARI capacity outfalls continuing on to the sediment basin, as indicated on Figure 4.

Detail design will confirm all pipe sizes and alignments and road lowpoints for OLF outlets.

Figure 4 **Proposed pipe drainage and overland flow (OLF) alignments**

3.3 Sediment basin and wetland concept details

The conceptual details for the various waterbodies in Lincoln Heath South are shown on Figures 5 and 6. Bathymetric details are shown as well but may be subject to variation as part of future detail design submissions.

The layout uses the same Normal Top water Level (NTWL) as has now been fixed in the Alamanda Estate wetlands. Although the original design level for those was 6.70 m, practical issues of construction within the margins of the receiving ephemeral wetland system forced a rise in NTWL. For future design purposes a NTWL of 6.90 m AHD has been adopted throughout the existing and proposed extended wetland system. System surcharges will occur as shallow broad overflows of confining berms to the south as is the case in Alamanda Estate.

Batter slopes, water surface setbacks and sediment drying zones have all been set to accord with current advice from MWC and Wyndham City Council (WCC).

In regard to the 1200 mm diameter link pipeline, inverts at the wetland inlets/outlets are set 0.8 m below NTWL at 6.10 m. The intermediate invert at the midpoint is set at 6.40 m to maximize physical grade on the pipes and minimize depth of ponding within the pipes. Cover restrictions in the available space prevent the pipe being raised to match the intermediate invert to NTWL as was the case in Alamanda. However this is not viewed as being counter-productive-the added depth allows the entire wetland system to be drained down in one operation if desired. As was the case in Alamanda Estate, no connections of subdivisional drainage are to be made to this link pipe.

The layouts provide for:

- transitioning of the wetlands to match in with existing construction in the Alamanda estate;
- minimum 6:1 batter slopes;
- standard safe subsurface edge slopes to all waterbodies (see Figure 9 for standard detail);
- minimum 10:1 hardstand access ramps;
- minimum 4 m path width access for full perimeter, external to road reserves for pedestrian and maintenance access;
- sediment basin sizings to achieve not less than 60% TSS removal;
- sediment drying areas sufficient to provide for handling of 50% basin capacity at 0.5 m drying depth;
- shallow, deep and submerged marsh areas, and open water zones complying with MWC Wetland Design Guidelines.

The confining southern embankment for the Lincoln Heath wetlands (western segments) is set at 7.70 m to match existing wetland construction along the south verge of Alamanda Estate.

The embankment for the eastern segment is set 300 mm higher at 8.0 m, to prevent any overflow southwards. The twin 1500 mm diameter pipe crossing of the north-south collector road will pass all inflows through to the west segment without creating head losses greater than 200 mm.

Another confining embankment is shown around the north edge of the western wetland segments at 7.50 m. This bank is intended to limit of frequency of inflows to the EVC areas. Those areas are dependent on seasonal inundation but exposure to unlimited stormwater drainage from the wetlands would damage the values. The crest level of 7.50 m is the current best estimate based on RORB modelling (Section 4) but may be subject to change depending on ecological advice.

When overflows do occur from the wetlands into the EVC area, the embankment will then trap and confine those waters. For this reason it is necessary to provide a means of draining down that inundation and a 300 mm valve with floodgate or automatically operated valve is therefore proposed to connect to the intermediate pit on the 1200 mm pipe.

A variety of wetland edge treatments could be used around the wetlands as part of detail landscape design. Appendix B shows an alternative stepped rock/planted edge detail that can be used to integrate trail/maintenance access close to the waters' edge and avoid mowing needs.

Hardwalling inserts, jetties and boardwalks can all be integrated with the design to suit landscape design needs. Hardwalling and boardwalks are not MWC capital or maintenance responsibilities and must be approved and maintained by Council.

The Urban Wetland recently built at Caroline Springs with extensive hardwalling provides another concept opportunity to be explored as part of ultimate landscape design.

3.4 Compatibility with future Point Cook South Drainage Systems

Neil M Craigie P/L prepared a report dated 3 July 2011 outlining a possible future SWMS for the Point Cook South area as part of the Logical Inclusions process. That report showed that drainage from Lincoln Heath South could be directed southwards into the Point Cook South system, rather than west through Alamanda Estate as is currently proposed.

Figure 7 is an extract from that report showing the conceptual SWMS layout in Point Cook South and the potential linkage to Lincoln Heath South.

The current proposal to drain Lincoln Heath South westwards via the Alamanda Estate linked wetland system does not in any way preclude a future redirection to the south as indicated on Figure 7. The linked wetland system in Lincoln Heath South and indeed the whole of the southeast wetland segment in Alamanda Estate can be so directed if that is deemed desirable in the future.

It should be noted that, as was the case in Alamanda Estate, minimum fill levels in Lincoln Heath South are driven by cover to inlet drainage pipes to the wetlands and not by the wetlands NTWL and calculated 100 year ARI flood levels. There is therefore no significant fill penalty for draining westwards compared to southwards.

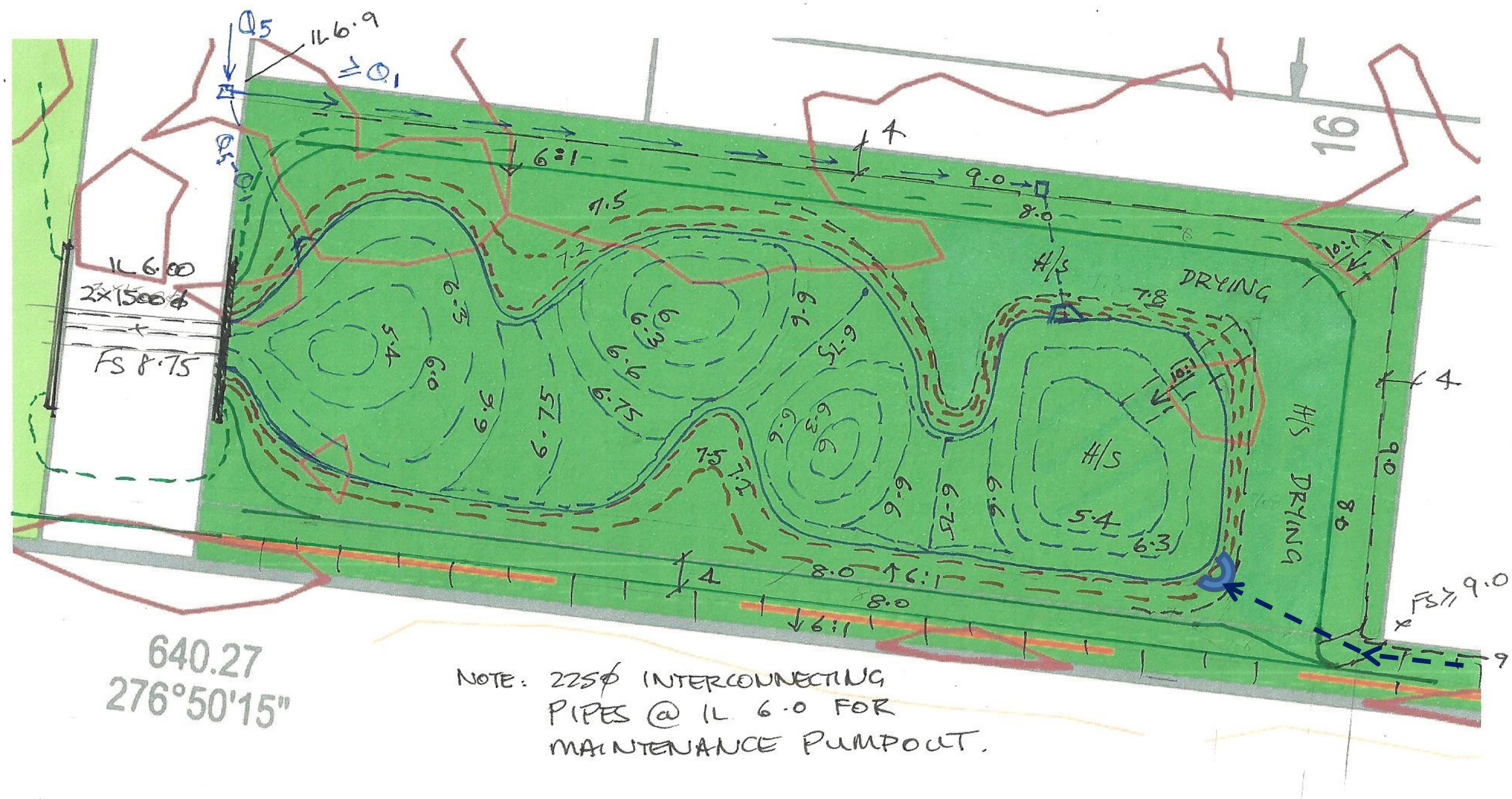


Figure 5 **Concept design detail for proposed new sediment basin and wetland, east of north-south connector road**

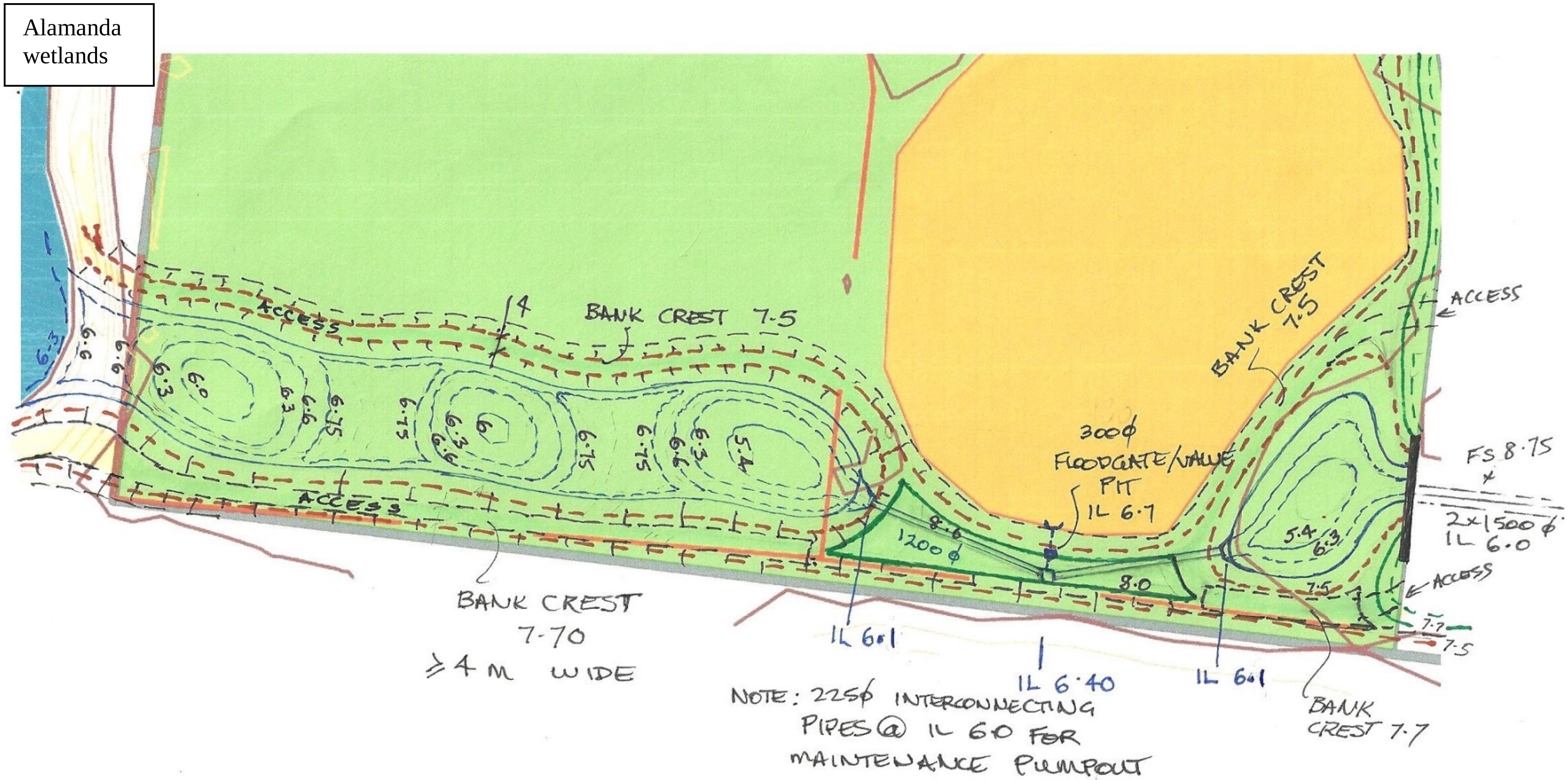
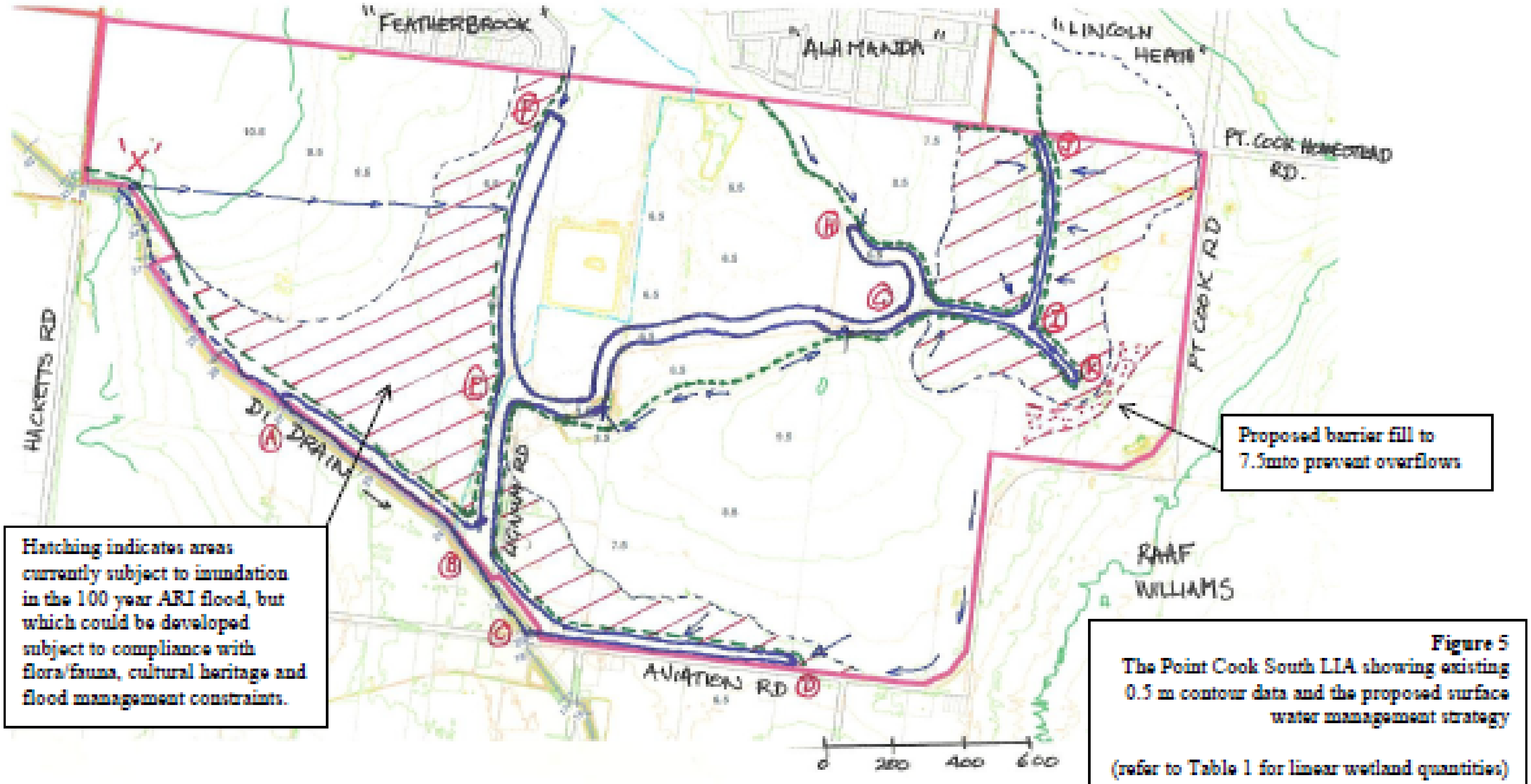


Figure 6 **Concept design detail for proposed new linear wetlands and link pipe, west of north-south connector road to Alamanda wetlands**



"X"-Proposed First Flush Flow Split in D1 Drain

Figure 7 Figure 7 Proposed SWMS for the Point Cook South area prepared as part of the Logical Inclusions Process in July 2011. Note the linkage shown to Lincoln Heath South as J to I

3.5 Stage-Area-Storage Relations

The storage volume provided in Lincoln Heath is significantly greater than was proposed for previous development plan iterations, because of the retention of the large reserve covering the EVC areas. When water levels exceed 7.50 m in the wetlands inflows to the EVC reserve commence and continue until that area is filled and becomes part of the total flood pondage. The extra flood storage created at 7.50 m is 30 ML.

TABLE 1 Stage-Area-storage relation – Lincoln Heath South System (including all sediment ponds)

Segment	Stage (m)	Total Area (m2)	Ponded Volume below NTWL (m3)	Active Storage above NTWL(m3)	Comments
East Segment (SB) and wetland)	6.90	1,700 SB 3,990 WL	~1,200 SB ~2,000 WL	-	NTWL
	7.20	6,140		1,775	TEDD
	7.50	7,325		3,795	
	7.70	7,600		5,285	
	7.80	8,000		6,065	
	8.00	10,670		8,025	South Embankment crest
West Segment (Road culvert pool and wetland)	6.90	1,000 Pool 4,445 WL	~700 Pool ~2,250 WL	-	NTWL
	7.20	5,800		1,690	TEDD
	7.50	7,380		3,665	North embankment crest
	7.70	65,000		49,165	South Embankment crest
	7.80	66,000		55,765	
Total Lincoln Heath South Retarding Storage	6.90	11,135	~6,150	-	NTWL
	7.20	11,940		3,465	TEDD
	7.50	14,705		7,460	
	7.70	72,600		54,450	
	7.80	74,000		61,830	

TEDD-Top of Extended Detention Depth

The corresponding figures for the Alamanda Estate system were taken from the 2008 report, adjusted to suit the raised NTWL, and are listed in Table 2 below.

TABLE 2 Stage-Area-storage relation – Alamanda Wetlands (including all sediment ponds)					
Segment	**Stage (m)**	**Total Area (m2)**	**Ponded Volume below NTWL (m3)**	**Active Storage above NTWL(m3)**	**Comments**
Total Southeast	6.90	7,500	6,190	-	NTWL of wetlands
	7.00	7,889		770	
	7.20	9,270		2,485	Top of extended detention depth (TED)
	7.50	11,400		5,585	
	7.70	13,859		8,110	Top of southeast segment ring bank
Total Southwest	6.90	9,900	8,400	-	NTWL of wetlands
	7.00	10,304		1,010	
	7.20	12,000		3,240	TED
	7.50	14,359		7,194	Top of southwest segment ring bank
	7.60	15,000		8,665	

4. FLOOD MODELLING

4.1 Developed Conditions

4.1.1 RORB Model Setup

A simple RORB hydrologic model was set up for the proposed total storage system in Alamanda Estate and Lincoln Heath South Estate.

Due to its fixed stage-discharge relation options, the RORB model is unable to fully simulate the time dependent unsteady interaction between differential water levels across the link pipes. A model such as Mike 11 could be used to achieve a more robust calculation but given the fail-safe nature of the surcharge overflow spillways for this system the extra detail is not considered to be warranted.

The existing outlet controls in the southwest corner of Alamanda Estate remain unchanged other than for adjustments to reflect the higher NTWL of 6.90 m throughout.

Hydraulic computations show that at level of 7.50 m AHD in the Alamanda southwest segment the peak flow able to pass from the southeast segment to the southwest segment via the 900 mm diameter link pipe is 0.43 m^3/s with headwater level of 7.70 m.

It follows therefore that with the northern bank in Lincoln Heath set 200 mm lower at 7.50 m, the flow through the link pipe will not be able to reach the theoretical peak of 0.43 m^3/s. In fact flows will reduce towards zero in the link pipe as water overflows the 7.50 m banks at either end of the system. When the extra 30 ML of storage is consumed in the EVC reserve water levels can rise again and the link pipe flows may increase again.

Various trial setups were run in the RORB model to assess the best approximation to the link pipe flow with the Lincoln Heath wetlands connected. It was found that modelling the Southwest Alamanda wetlands and its local catchment as a separate system was appropriate. The integrated southeast system (Alamanda and Lincoln Heath) was modelled as a separate storage with a diversion flow limited to 200 l/s being transferred across via the link pipe. Discharge capacity was allowed to rise from zero at 6.90 m to 0.2 m^3/s at 7.50 m then allowed to rise to 0.4 m^3/s at 7.70 m, above which weir flow over the south embankments becomes dominant.

The overall stage-storage-discharge relations for the total system are summarized in Table 3.

TABLE 3 Adopted Stage-storage-discharge relation-Alamanda Southwest (including all sediment ponds)

Wetlands	Stage (m)	Active Storage above NTWL(m^3)	Discharge (m^3/s)	Comments
Alamanda SW	6.90	0	0	NTWL of wetlands
	7.00	1,010	0.01	
	7.20	3,240	0.23	TEDD
	7.50	7,194	0.42	SW Embankment in Alamanda Estate Crest of EVC bank in Lincoln Heath South
	7.525	7,555	1.50	
	7.55	7,920	3.70	
	7.60	8,665	10.40	
Alamanda SE and Lincoln Heath	6.90	0	0	
	7.00	1,891	0.05	
	7.20	5,931	0.1	
	7.50	13,028	0.2	Crest of northern EVC bank in Lincoln Heath (240 m)
	7.51	46,890	0.21	
	7.70	60,511	0.4	Crest of south embankments (300 m)
	7.75	64,900	6.0	
	7.80	69,411	16.0	

4.1.2 Model Results

The RORB model results from Table 4 show that:

- All events up to the 2 year ARI storm are fully contained within the bunded storage system and thus the EVC areas in Lincoln Heath are effectively shielded from elevated peak flows, litter and scums carried by urban stormwater runoff.
- The 2 year ARI event just overtops the north bank in Lincoln Heath.
- The 5 year ARI event just overtops the southwest bank in Alamanda.
- Little change to flood level in the Alamanda SE/Lincoln Heath wetlands occurs whilst the EVC reserve storage is filling so that flood levels tend to equalize through the entire linked wetland system for 20 years ARI and more.
- The 50 year ARI event will completely fill the EVC storage and cause flood levels to rise again in the southeast segments.
- Even in the 100 year ARI event the storage available is sufficient, in theory, to prevent overtopping of the long southern embankment in the southeast segment. However in the event of a follow-up storm occurring (or an over-design event) the reserve storage would be full and hence flood levels could rise and overtop the southern embankments at some stage.

TABLE 4 RORB model results for Combined Alamanda South and Lincoln Heath South Linked Wetland Retarding Storage System

Wetlands	ARI	Peak Level (m)	Duration	Peak Outflow (m3/s)	Peak Storage (m^3)
Alamanda SW	1	7.30	36	0.29	4,540
	2	7.38	12	0.34	5,560
	5	7.50	12	0.63	7,260
	10	7.51	9	1.04	7,400
	20	7.53	9	1.89	7,620
	50	7.53	9	2.20	7,670
	100	7.54	2	2.80	7,770
Alamanda SE and Lincoln Heath	1	7.40	30	0.17	10,700
	2	7.50	30	0.20	13,100
	5	7.50	48	0.20	19,700
	10	7.50	36	0.20	26,100
	20	7.51	36	0.21	35,700
	50	7.53	36	0.26	48,000
	100	7.66	72	0.36	57,700

4.2 Comparison with Rural Conditions

Prior to development of Alamanda Estate the natural catchment draining to the depression that lies partly within Lincoln Heath and extends well into Point Cook South (the eastern depression on Figure 8 below), was some 74.5 ha measured at the Lincoln Heath boundary.

Figure 8 Major drainage despressions in Point Cook South

Recent research on the estimation of peak flood flows for rural catchments for Engineers Australia has been published in Australian Rainfall and Runoff (ARR) Project 5, Stage 2 Report, dated June 2012. This report recommends that ARR move to a regional regression analysis approach for calculating pre-development peak flood flows. The regional regression analysis approach is being developed by the Bureau of Meteorology, but has not yet been released for use by the industry. The report also considered the accuracy of the current ARR method (the Adams Rural Rational Method) and found that this method was appropriate, but suggested adjustment of the results for very small catchments as per the relation shown on Figure 5.3.6 of the ARR 2012 report (see below).

Peak flows for existing rural conditions are therefore to be derived using the current ARR Method with Adams equation for estimation of time of concentration with matched runoff coefficients, all in accord with the recommendations set out in Australian Rainfall and Runoff (ARR). The 10 year ARI runoff coefficients provided in Volume 2 of ARR are to be used and not those listed in other references such as VicRoads Design Manuals. The Figure 5.3.6 correction factors are then to be applied to calculated discharges.

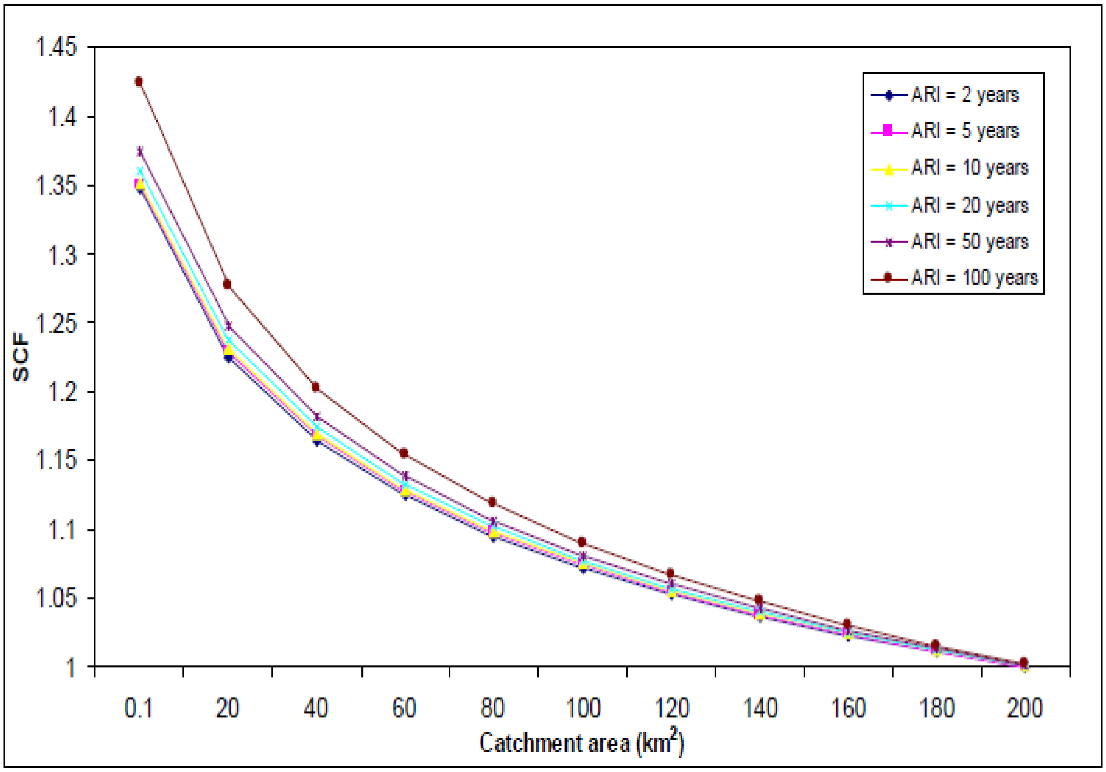


Figure 5.3.6 Relationship between scale correction factor (SCF) and catchment area

Table 5 provides rural catchment discharge estimates.

TABLE 5 Rural discharges from Alamanda and Lincoln Heath to Point Cook South	
ARI (years)	**Pre-development peak flow (m3/s)**
1	0.49
2	0.66
5	1.10
10	1.44
20	1.91
50	2.62
100	3.42

4.3 Discussion

With the long southern embankments in Alamanda and Lincoln Heath providing high capacity discharge at low flow/unit width values, the proposed linked wetlands design is effectively fail-safe. There is no possibility of significant scour problems occurring under flooding conditions.

From these results using this simplified RORB modelling approach the 100 year ARI flood levels in the southeast segments should be nominated as 7.70 m across Lincoln Heath.

Minimum floor levels of 8.30 m would then apply (600 mm freeboard).

However it should be noted that, as was the case in Alamanda Estate, minimum fill levels in Lincoln Heath South are higher than 8.30 m because they are driven by required cover to pipe drainage systems which have to free drain to the wetlands NTWL.

Table 4 indicates that the integrated wetlands system will prevent any discharge from these urban areas going south, even in the 100 year ARI event. This is the outcome that arises as a consequence of retaining the large EVC reserve area in Lincoln Heath with the proposed control embankment levels.

If there are concerns raised over loss of drainage flows going south, it would be possible to lower the Lincoln Heath embankment crest levels to say 7.40 m (north) and 7.55 m (south), to gain a distribution of flows that more closely mimics existing conditions. However, this may not be the preferred approach for development of the Point Cook South area.

It may be preferable in the short term to add an additional outlet for the EVC reserve storage zone in the form of a 300 mm nominal diameter pipe subway underpass of the 1200 mm diameter link pipe to the existing minor drainage line in the property to the south. Setting a shielded offtake for this pipe at say 7.10 m would allow seasonal filling and retention of water across the EVC areas but more rapidly drain the storage down after filling.

Optimisation of embankment levels along the Lincoln Heath/Alamanda wetlands frontage and the option of adding the pipe subway underpass are matters that should be considered further as part of future detail design.

It should also be kept in mind that adjustments to embankment levels and drainage outfalls can easily be completed at minimal cost as part of the Point South area development in future.

5. WATER QUALITY MODELLING

The MUSIC model Version 3 has been used to simulate the performance of wetland treatment system already constructed in Alamanda Estate (South), and that of the combined system incorporating the wetlands proposed in Lincoln Heath South. The 6 minute data sequence for Melbourne Airport 1996 was used as required by MWC. The results listed in Tables 6 and 7 show that:

- the combined Alamanda and Lincoln Heath wetlands system offers virtually identical pollutant removal performance to the existing Alamanda wetlands;
- performance comfortably exceeds best practice water quality treatment standards.

TABLE 6 WQ treatment performance – Alamanda South Wetlands System (Melb Airport 1996 6 minute rainfall)

Parameter	Total Source Loads	Discharge Loads	Treatment Effectiveness
Flow (ML)	199	180	10
Suspended Solids (kg/yr)	37,600	4,810	87
Total Phosphorus (kg/yr)	79	21	74
Total Nitrogen (kg/yr)	571	286	50
Gross Pollutants (kg/yr)	7,890	0	100

TABLE 7 WQ treatment performance – Combined Alamanda South/Lincoln Heath Estate Wetlands System (Melb Airport 1996 6 minute rainfall)

Parameter	Total Source Loads	Discharge Loads	Treatment Effectiveness
Flow (ML)	319	289	9
Suspended Solids (kg/yr)	62,300	7,850	87
Total Phosphorus (kg/yr)	128	34	73
Total Nitrogen (kg/yr)	912	470	48
Gross Pollutants (kg/yr)	12,500	0	100

Table 8 shows the results for the Lincoln Heath wetlands alone. Total urban catchment area is 25.8 ha with 10.5 ha directed into the Alamanda wetlands at Fongeo Drive.

TABLE 8 WQ treatment performance – Lincoln Heath South Wetlands System (Melb Airport 1996 6 minute rainfall)

Parameter	Total Source Loads	Discharge Loads	Treatment Effectiveness
Flow (ML)	88	77	12
Suspended Solids (kg/yr)	18,300	1,720	91
Total Phosphorus (kg/yr)	36	7	80
Total Nitrogen (kg/yr)	250	100	60
Gross Pollutants (kg/yr)	3,320	0	100

Although the MUSIC results provide surety in regard to catchment runoff quality protection for the receiving ephemeral wetland in the southwest corner of Alamanda, they also show that the volume of treated water discharged to that outfall will rise significantly when the Lincoln Heath wetlands are attached.

If this should be of concern then the option still remains to redirect water from the Alamanda (southeast) and Lincoln Heath wetlands southwards as part of the future Point Cook South development. Expert ecological advice should be sought as part of the Point Cook South PSP process to determine final design of drainage outfalls.

In the short term it may be preferable to add an additional outlet for the EVC reserve storage zone in the form of a 300 mm nominal diameter pipe subway underpass of the 1200 mm diameter link pipe to the existing minor drainage line in the property to the south. Setting a shielded offtake for this pipe at say 7.10 m would allow seasonal filling and retention of water across the EVC areas but more rapidly drain the storage down after filling. Water levels above 7.10 m in the EVC storage can be expected to occur for events greater than 2 years ARI.

6. DESIGN AND MANAGEMENT OF WETLANDS AND PONDS

The water quality within the wetlands and ponds will to a large extent reflect the quality of their water sources. The water quality regime and their stormwater treatment capacity will however depend on other factors as well including:

- wetland and open water design - including depth, area and length of shoreline,
- wetland and open water processes including wind and flow induced mixing, precipitation and flocculation mechanisms, and sediment-water column interactions,
- inputs of local groundwater,
- the chemical nature of the local soils,
- water residence times,
- physico-chemical and biological processes within the water bodies,
- degree of use by birdlife,
- degree of colonisation by water plants.

Detention of stormwater in any wetland or pondage for extended periods could lead to the following important water quality responses:

- Increases in algal and plant growth,
- Decrease or increase in turbidity and suspended solids,
- Increase in daytime oxygen levels and night time depletion,
- Decrease or increases in levels of phosphorus and nitrogen in the water column.

Whether water quality is actually improved or not will depend on the nature of physical, chemical and biological processes occurring within the wetlands and ponds.

During most periods the wetland or pondage system will tend to improve input water quality due to the biological and physical processes within it.

A critical issue to the site is the availability of sufficient water through summer and autumn to ensure adequate turnover of the water bodies (from 20 to 30 days preferably), particularly through drier years.

For the existing Alamanda wetlands alone the mean annual outflow is 180 ML/year and impounded volume is 14.6 ML (after raising of the NTWL from 6.7 to 6.9 m), so mean detention time is 30 days.

With mean annual outflow of 289 ML/year and impounded volume of 20.7 ML in the combined Alamanda and Lincoln Heath wetlands, the mean detention time reduces to 25 days.

After raising of the NTWL in the Alamanda wetlands the impounded storage volume was increased by 3.5 ML. This volume will eventually be reclaimed through sedimentation processes so the longer term impounded volumes will reduce with consequent further lowering of mean detention times.

For the Lincoln Heath wetlands alone the mean annual outflow is 77 ML/year and impounded volume is 6.2 ML so mean detention time is 29 days.

The species and numbers of organisms that can live in any aquatic system is dependent on many factors including flow regimes, water quality, food supply, riparian zone inputs, shading, competition and habitat. Habitat and habitat diversity will strongly determine the species and numbers of organisms found. In the absence of suitable habitat very few species will be found even in water bodies with excellent water quality (e.g. as in a local water supply storage reservoir). Generally the greater the habitat diversity in a water body the higher the number of species found.

Aquatic plants can provide food and shelter to invertebrates and fish. A range of aquatic plant species could naturally colonise any water body once it is filled, however it would be preferable to accelerate this process (and ensure desirable species) by extensive plantings of aquatic plants known to be indigenous to this area.

Healthy populations of water plants should be encouraged to develop in and around the wetlands and ponds as quite apart from their habitat value they:

- Take up nutrients that would otherwise be available for algal productivity,

- Can be a visually attractive and interesting part of the aquatic system,
- Give the system a more natural, less artificial appearance,
- Protect the edges from erosion, and make water level fluctuations less obvious.

Of course there is always the possibility that one or more species could grow in nuisance proportions (especially Typha species) but attention to monitoring and maintenance, and early control will prevent such conditions from arising. Depending on the rates of growth of aquatic species some harvesting may be required in future.

Wetland plantings should be selected primarily for water treatment purposes, but other species should also be included for the purpose of increasing ecosystem diversity and landscape interest.

Peak flood flow velocities of 0.5 m/s or less will not present any safety threat to users of the reserve nor to the wetlands or flora/fauna communities that will be established. Detail design must incorporate a number of best practice features as summarised in Table 9. The functional design shown on Figures 5 and 6 complies with all of these recommendations.

A suggested planting schedule of native submerged and emergent aquatic plants to be established at an early stage is shown in Appendix A. The design provides adequate open water to enhance landscape amenity, address vital hydraulic protection constraints, add to water treatment capability (eg., E.coli) and provide fish habitat (cover, diversity and shade).

A maintenance and monitoring strategy is important. Monitoring or inspection can be carried out as part of overall system maintenance. Minimal chemical and biological monitoring will be required to assess the systems performance and its satisfaction of objectives for improved water quality and environmental values.

A monitoring program will also be required to track water quality and wetland performance particularly for suspended solids and nutrient concentrations. Biological monitoring of algal, plant, invertebrate, fish and amphibian populations is also recommended.

The monitoring program will need to specifically target conditions within and around the sediment trap basins on pipe inlets.

TABLE 9 Optimisation of wetland and pondage performance	
Objective	**Means of Achievement**
1. That wetland or pondage conditions are consistent with desired beneficial uses.	• Periodic monitoring of water quality. • Layout design (size, shape, depth, plantings etc.) to maximise uses and habitat diversity. • Landscaping and native riparian plantings to create a natural vista. • Edge design for safety.
2. That the flora and fauna values of the wetland or pondage system are maximised.	• Maximisation of physical habitat diversity through variation in shape, depth, substrate and aquatic plants.
3. That the wetland or pondage does not adversely impact on the enjoyment, safety or amenity of users.	• Avoidance of high edge slopes and grading of side slopes (at least 1V:8H for 2.5 metres from edge grading to maximum of 1V:3H). • Avoidance of localised depressions in which mosquitoes could breed. • Minimisation of sediment inputs especially during the site redevelopment period. • Formulation of on-going maintenance and monitoring program.
4. That intractable water quality problems do not result within the wetlands or pondages.	• Restrict maximum depths to about 2.5 metres at most so stratification and low dissolved oxygen conditions are unlikely to occur. Greater depths could require artificial recirculation assistance (eg., air bubblers). • Minimise impact of spills from upstream areas (including excess runoff of Class A reuse water) by confining these to inlet sediment traps. • Avoid use of fertiliser or Class A reuse irrigation in adjacent landscaped areas as these can be significant sources of nutrients and promote algal blooms. Local bioretention swales will need to be incorporated around wetland edges if Class A reuse water is to be used for irrigation in the wetland and pondage verges. Alternatively, the water contained within the wetlands and pondages may be used for irrigation of abutting reserves. • <u>Full topsoiling of all underwater surfaces</u> may be required to suppress soil dispersivity concerns (geotechnical advice needed)
5. That the wetland or pondage does not create any adverse downstream impact.	• None anticipated. The wetland system will in fact provide significant treatment for site and catchment runoff. • Implement Site Best Management Practices during construction, especially to minimise generation of sediment in the construction phase and to collect sediment in the sediment traps. • <u>Full topsoiling of all underwater surfaces</u> may be required to suppress soil dispersivity concerns (geotechnical advice needed)
6. That the wetland or pondage does not require an unreasonable degree of maintenance input.	• Good wetland and sediment trap design. • Diverse wetland plantings to avoid one species taking over. • Minimisation of constructed assets and simplified operation of hydraulic controls. • Provision of adequate depth in shallow bench zones and throughout wetlands to allow for inevitable extra sediment generation input in early times and for longer term organic deposition. • Provision of sediment traps to confine the bulk of deposition and minimise disruption and cost of cleanouts. Sediment trap areas may need desilting anywhere from 2 to 5 years after reset on completion of all development.

TABLE 9 Optimisation of wetland and pondage performance	
Objective	**Means of Achievement**
7. That the wetlands or pondages are effective in removing pollutants from stormwater runoff.	• Achievement of stormwater residence times of days rather than hours. • Passage of urban runoff through a number of discrete cells rather than one large waterbody of uniform depth. • Provision and maintenance of sediment traps. • Design for development as modified natural ecosystems where biological processes can also operate to treat urban runoff. • Optimisation and protection of aquatic plant growth.

7. POTENTIAL WATER QUALITY PROBLEMS AND ISSUES

Detention of stormwater and groundwater in the wetland and pondage system for extended periods with little inflow could lead to some potential problems. These are considered in Table 10. While there is a moderate- low possibility of problem occurrence for the system if it is established as recommended, the table serves as a useful compilation of the water quality risks that must be addressed through appropriate design, maintenance and monitoring.

TABLE 10 POTENTIAL WETLAND WATER QUALITY PROBLEMS	
Problem	**Discussion**
Oxygen depletion	Oxygen depletion is unlikely to occur in the wetland system unless stratification develops. The sedimentation of organic materials leads to growth of benthic microbes that feed on this organic material. Such growth depletes oxygen from both the sediments in the benthic layer and the overlying water column. This can create anaerobic conditions and release other pollutants trapped in the sediments. This is unlikely to occur in the wetland system proposed due to the online nature of the system, and the maximum depth of 2 m which prevents stratification and promotes mixing over the full water column. Furthermore the aquatic plants will unsure that oxygen depletion is unlikely.
Microbiological contamination	Runoff typically contains high levels of micro-organisms sourced from animal droppings, illegal connections to stormwater, and sewer leaks or overflows. E.coli levels can increase in storm events. Roof runoff could have high levels depending on bird populations. Class A reuse water will not cause any concern regarding microbiological contamination. In any case bacterial die-off processes in the wetland would ensure that microbiological objectives are achieved at all times excepting following a high runoff event.
Algal Growth	Algal occurrence and growth is influenced by a number of factors as already discussed. The primary factors affecting algal productivity are total phosphorus and total nitrogen concentrations. As is the case for most waterbodies, the levels of these nutrients in the wetland will be in the range where mild blooms could potentially occur. With the use of Class A reuse water within the subdivisions and possibly for irrigation of lands within the waterway reserves, the potential for higher levels of nutrient inflow needs to be recognized. Irrigation of abutting reserve surfaces using the wetland water in lieu of the Class A supply would be preferred. However Class A water could be used if properly managed (drip irrigation only) and/or bioretention swales are provided between the irrigation areas and the waters edge. It is anticipated that some green algae will grow, especially as growths attached to aquatic plant stems. The occurrence of limited growths of filamentous algae and unicellular green

TABLE 10 POTENTIAL WETLAND WATER QUALITY PROBLEMS

Problem	Discussion
	algae is natural and should not be of concern. Strong growths may also occur in warm dry periods. It is probable that some attached algal species will also grow on plant surfaces. Again the frequency and severity of such growth will be related to the factors outlined above. Experience with many other wetlands throughout Melbourne indicates that the frequency of blue green algal blooms is low. Optimum growth conditions for blue green algae occur when, apart from abundant nutrients, there are long periods of sunlight and relatively calm and still conditions. The presence of low numbers of blue green algae in a waterbody is quite normal; it is bloom conditions that are of concern because of the aesthetic deterioration and the ability of some species to produce toxins. The most powerful control mechanisms for algae are biological controls rather than structural responses. It is therefore important that the wetland develops as a viable aquatic ecosystem, which supports macrophytes, invertebrates, amphibians and fish.
Mosquito Nuisance	The potential for mosquito hazards can be minimised through adoption of appropriate design and the establishment of a robust ecosystem. Design measures for minimising the possibility of mosquito nuisance include: • grading banks to ensure free shedding of water following draw down of floodwaters; • adoption of an edge grading of slope 1 in 8 with an edge lip of at least 200 mm and a minimum depth of 300 mm; • shaping to provide efficient circulation of flow; • Selection of aquatic plants which do not have broad leaves above the surface to minimise substrate for mosquito breeding. Floating vegetation should be discouraged as it may support a diverse mosquito fauna. All of these measures have been incorporated into the wetland design. Mosquito problems have rarely been observed in any wetland where the above precautions have been taken.

8. WETLAND MAINTENANCE AND MONITORING

Good wetland design is only part of the total requirement. Without adequate operation and maintenance procedures the wetland will reach a stage where it can no longer effectively carry out its design function.

A maintenance and monitoring strategy will need to be developed and implemented. Monitoring or inspection can be carried out as part of overall system maintenance. Minimal chemical and biological monitoring should be carried out to assess the systems performance and its satisfaction of objectives for improved water quality and environmental values.

Maintenance and monitoring programs can be expected to annually cost some 3% of the initial capital costs over the first few years but for a well designed system can reduce to below 1% in later years.

Operation and maintenance requirements of the wetland can be considered under general maintenance, special maintenance, and monitoring (Table 11).

TABLE 11 General Maintenance and Monitoring Requirements for Wetlands

General maintenance	Special maintenance	Monitoring
• Clearing inlet zone of litter • Maintenance of, grates and outlet structures • Control and management of weed growth along wetland margins • Maintenance and reinstatement of edge erosion following large flows • Desilting of sediment traps • Collection of litter on margins • Planting and vegetation management • Fish stocking	• Removal of polluting materials from system following a local pollution spill • Replacement of aquatic plants	• Routine water quality monitoring according to a set program especially for nutrient levels and presence of blue green algal cells • Monitoring of sediment accumulation rates in sediment traps • Weed and aquatic plant monitoring • Monitoring of other uses and activities including water bird numbers and user activities

9. CONSTRUCTION STAGE MANAGEMENT

The construction phases of the wetland and pondage system development and subsequent building works must also be properly managed to ensure environmental values are protected along the way. To do this, Site Environmental Management Plans (EMP's) will need to be prepared to address construction-related impacts. These plans would be submitted for approval prior to commencement of works on each stage or group of stages as the case may be.

Key items to be factored into the EMP's are as follows:

- All site works are to be carried out in accord with contemporary best site management practice.

- Implement erosion prevention and control measures generally in accordance with the provision of "Construction Techniques for Sediment Pollution Control" (EPA Publication No. 275, 1991), with "Environmental Guidelines for Major Construction Sites" (EPA Publication No. 480, December 1995), and with "Doing it right on subdivisions. Temporary environmental protection measures for subdivision construction sites" (EPA Publication No. 960).

- Areas of disturbance should be kept to a minimum on each stage and stage works areas clearly fenced to prevent machine access or materials storage elsewhere.

- Construct and establish wetland excavations to act as sedimentation pondages (in segments as appropriate to scale of stage development), as part of initial construction. Establishment of appropriate aquatic vegetation communities can follow in the subsequent season.

- Divert runoff from undisturbed areas away from active works areas.

- Divert runoff from disturbed areas around and away from the EVC areas.

- Locate soil stockpiles at least 20 metres from any drainage line or pit.

- Remove soil and clay from tyres before trucks leave site.

- Remove foreign soil and plant matter from trucks before entering site.

- All significant vegetation to be retained should be fenced out prior to commencement of any site works within appropriate setbacks.

- Timing and frequency of maintenance activities including removal of sediment from sediment ponds and swales should be clearly designated.

10. SUMMARY AND CONCLUSIONS

This report updates the previous issue dated 2 July 2012. It outlines the functional design for the surface water management assets comprising the southern wetlands in the Lincoln Heath Estate at Point Cook. The wetlands are to discharge to (and be fully integrated with) the existing wetland system in the abutting Alamanda Estate and thence to an existing ephemeral depression in the southwest corner of Alamanda Estate.

The report follows on from, and is wholly in accord with the report:"Alamanda Estate (South), Point Cook, Victoria, Functional Design Report For Wetland/Retarding Storage System, (6 July 2008).

The functional design for the extension of the linked wetland system through Lincoln Heath provides for a common NTWL to be provided through both estates at 6.90 m AHD.

It should be noted that the concept design could be very easily modified in the future to direct all drainage from Lincoln Heath South and the southeast segment of Alamanda Estate southwards, to connect into a possible future Point Cook South PSP drainage system.

As was the case for Alamanda Estate, fill levels in Lincoln Heath South are driven mostly by cover and grading requirements for inlet pipelines and not wetland NTWL's or 100 year ARI flood levels. Hence, there would be no significant penalty for Lincoln Heath South due to the decision to drain westwards via the Alamanda Estate.

Section 3 describes the proposed functional design with detail sketches provided in Figures 5 and 6. Section 4 presents RORB flood modeling results. Section 5 presents final MUSIC modeling for water quality treatment outcomes.

The RORB hydrologic modeling results in Table 4 show that with the functional design in place, peak outflow limits and flood level targets are effectively achieved, with full development of all upstream lands. In particular:

- All events up to the 2 year ARI storm are fully contained within the bunded storage system and thus the EVC areas in Lincoln Heath are effectively shielded from elevated peak flows, litter and scums carried by urban stormwater runoff.
- The 2 year ARI event just overtops the north bank in Lincoln Heath.
- The 5 year ARI event just overtops the southwest bank in Alamanda.
- Little change to flood level in the Alamanda SE/Lincoln Heath wetlands occurs whilst the EVC reserve storage is filling so that flood levels tend to equalize through the entire linked wetland system for events up to 20 years ARI and more.

- The 50 year ARI event will completely fill the EVC storage and cause flood levels to rise again in the southeast segments.

- Even in the 100 year ARI event the storage available is sufficient, in theory, to prevent overtopping of the long southern embankment in the southeast segment. However in the event of a follow-up storm occurring (or an over-design event) the reserve storage would be full and hence flood levels could rise and overtop the southern embankments at some stage.

The RORB modelling shows that post-development peak flows discharged southwards are zero for all events up to and including 100 years ARI. Although the MUSIC results provide surety in regard to catchment runoff quality protection for the receiving ephemeral wetland in the southwest corner of Alamanda, they also show that the volume of treated water discharged to that outfall will rise significantly when the Lincoln Heath wetlands are attached.

If there are concerns raised over loss of drainage flows going south and/or excess volumes being diverted west into the ephemeral wetland in the southwest corner of Alamanda, there are two simple options that could be considered as part of detail design:

- it would be possible to lower the Lincoln Heath embankment crest levels to say 7.40 m (north) and 7.55 m (south), to gain a distribution of flows that more closely mimics existing conditions. However, this may not be the preferred approach for development of the Point Cook South area.

- in the short term an additional outlet for the EVC reserve storage zone could be added in the form of a 300 mm nominal diameter pipe subway underpass of the 1200 mm diameter link pipe to the existing minor drainage line in the property to the south. Setting a shielded offtake for this pipe at say 7.10 m would allow seasonal filling and retention of water across the EVC areas but more rapidly drain the storage down after filling. Water levels above 7.10 m in the EVC storage can be expected to occur for events greater than 2 years ARI.

Optimisation of embankment levels along the Lincoln Heath/Alamanda wetlands frontage and the option of adding the pipe subway underpass are matters that should be considered further as part of future detail design.

It should be noted that the option still remains to redirect water from the Alamanda (southeast) and Lincoln Heath wetlands southwards as part of the future Point Cook South development. Expert ecological advice should be sought as part of the Point Cook South PSP process to determine final design of drainage outfalls.

With the long southern embankments in Alamanda and Lincoln Heath providing high capacity discharge at low flow/unit width values, the proposed linked wetlands design is effectively fail-safe. There is no possibility of significant scour problems occurring under flooding conditions.

From these results using this simplified RORB modelling approach the 100 year ARI flood levels in the southeast segments should be nominated as 7.70 m across Lincoln Heath.

Minimum floor levels of 8.30 m would then apply (600 mm freeboard).

However it should be noted that, as was the case in Alamanda Estate, minimum fill levels in Lincoln Heath South are higher than 8.30 m because they are driven by required cover to pipe drainage systems which have to free drain to the wetlands NTWL.

Geotechnical investigations will be required during detail design to confirm lining requirements for the wetlands.

It will be important to ensure the wetland base is as watertight as possible to mitigate seepage losses.

It will also be essential for any dispersive subsoils to be fully covered with topsoil or otherwise treated to mitigate ongoing high turbidity problems. Such soils can normally be retained in base area of the pondages, subject to at least 200 mm of suitable non-dispersive topsoil being spread over the entire area below NTWL.

Neil M Craigie

11. ABBREVIATIONS AND DEFINITIONS

AHD	Australian Height Datum. Common base for all survey levels in Australia. Refers to height in metres above mean sea level.
ARI	Average Recurrence Interval. The average length of time in years between two floods of a given size or larger
Ephemeral	Waterways which flow for only short periods of time after significant rainfall events. Also refers to wetlands which are either rarely inundated or only inundated for a very short period of time.
Evapotranspiration	The loss of water to the atmosphere by means of evaporation from free water surfaces (eg. dams or lakes or wetlands) or by transpiration by plants
Groundwater	All water stored or flowing below the ground surface level
Ha	Hectare (10,000 square metres)
Km	Kilometre (1000 metres)
M^3/s	Unit of discharge = cubic metre/second
ML	Megalitre (1000 cubic metres)
NTWL	The Normal Top Water Level (m AHD) or water surface level of a waterbody when just full to low flow overflow level.
Pond	A small artificial body of open water (eg. dam or small lake)
Retarding basin	A flood storage dam which is normally empty. May contain a lake or wetland in its base
Sedimentation basin (sediment pond)	A pond that is used to remove sediments from inflowing water mainly by settlement processes. Edge zones may have similar appearance to wetland margins.
Surface water	All water stored or flowing above the ground surface level
Swale	A drainage line with essentially trapezoidal cross-sectional form. Can have rocky or soil bed form, be fully vegetated with indigenous species, or grassed. The base can be fitted with a filter zone to further assist in pollutant removal (termed a bio-retention swale). Foundations can be ripped to encourage seepage losses in suitable soils.
Waterlogging	Term used to describe saturated surface soil conditions where some free surface water may also be present
Wetland	A transitional area between land and water systems which is either permanently or periodically inundated with shallow water and either permanently or periodically supports the growth of aquatic macrophytes (eg. swamp, marsh, fen, bog)

12. REFERENCES

Institution of Engineers, Australia (1987), *Australian Rainfall and Runoff, A Guide to Flood Estimation*
Stormwater Committee, Victoria (1999), *Urban Stormwater Best Practice Environmental Management Guidelines*. Pub. CSIRO
Engineers Australia, (2006), *Australian Runoff Quality. A Guide to Water Sensitive Urban Design*
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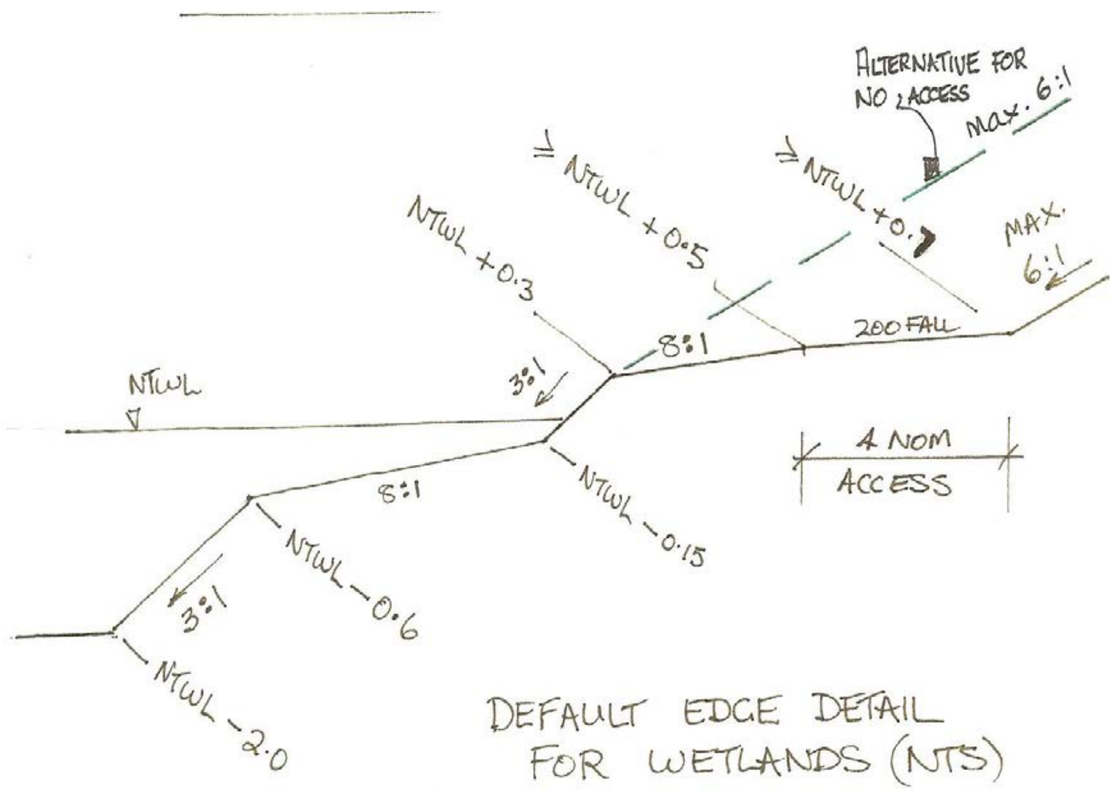


Figure 9

Standard Concept Drawing

DEFAULT EDGE DETAIL FOR WETLANDS
(Vegetation treatment only for upper slopes)

APPENDIX A SUGGESTED PLANTINGS LIST

A range of aquatic plant species could naturally colonise the wetlands once they are filled, however it is essential to accelerate this process (and ensure colonisation by desirable species) by extensive plantings of aquatic plants known to be indigenous to this area.
Healthy populations of water plants are essential for effective stormwater treatment. They:

- Take up nutrients from stormwater that would otherwise be available for algal productivity;
- Can be a visually attractive and interesting part of the aquatic system;
- Give the system a more natural, less artificial appearance;
- Protect the edges from erosion, and make level fluctuations less obvious;
- Provide food, shade and shelter to invertebrates and fish.

There is always the possibility that one or more species could grow in nuisance proportions (in particular some species of Typha, Cyperus and Paspalum) but attention to monitoring and maintenance, and early control will prevent such conditions from arising. Depending on the rates of growth of aquatic species some harvesting may be required in future.

Table A.1 shows the preferred depth zones of a range of water plants and gives an indication of planting density. In preparing the list reference has been made to Melbourne Water's Guidelines for Constructed Wetland Systems (2003). The main purpose of the plants is their ability to provide treatment to incoming stormwater; therefore perhaps 4 - 6 structural species are planted in large numbers while a further 10 or so species are planted to increase species, habitat and visual diversity. The densities suggested form an initial minimum. It is expected that over the first two years, there will be natural spread to achieve an optimum density. Some further in-fill planting may then be required. The establishment of submerged marsh may require several introductions of plant parts of Chara, Nitella and Potamogeton species.

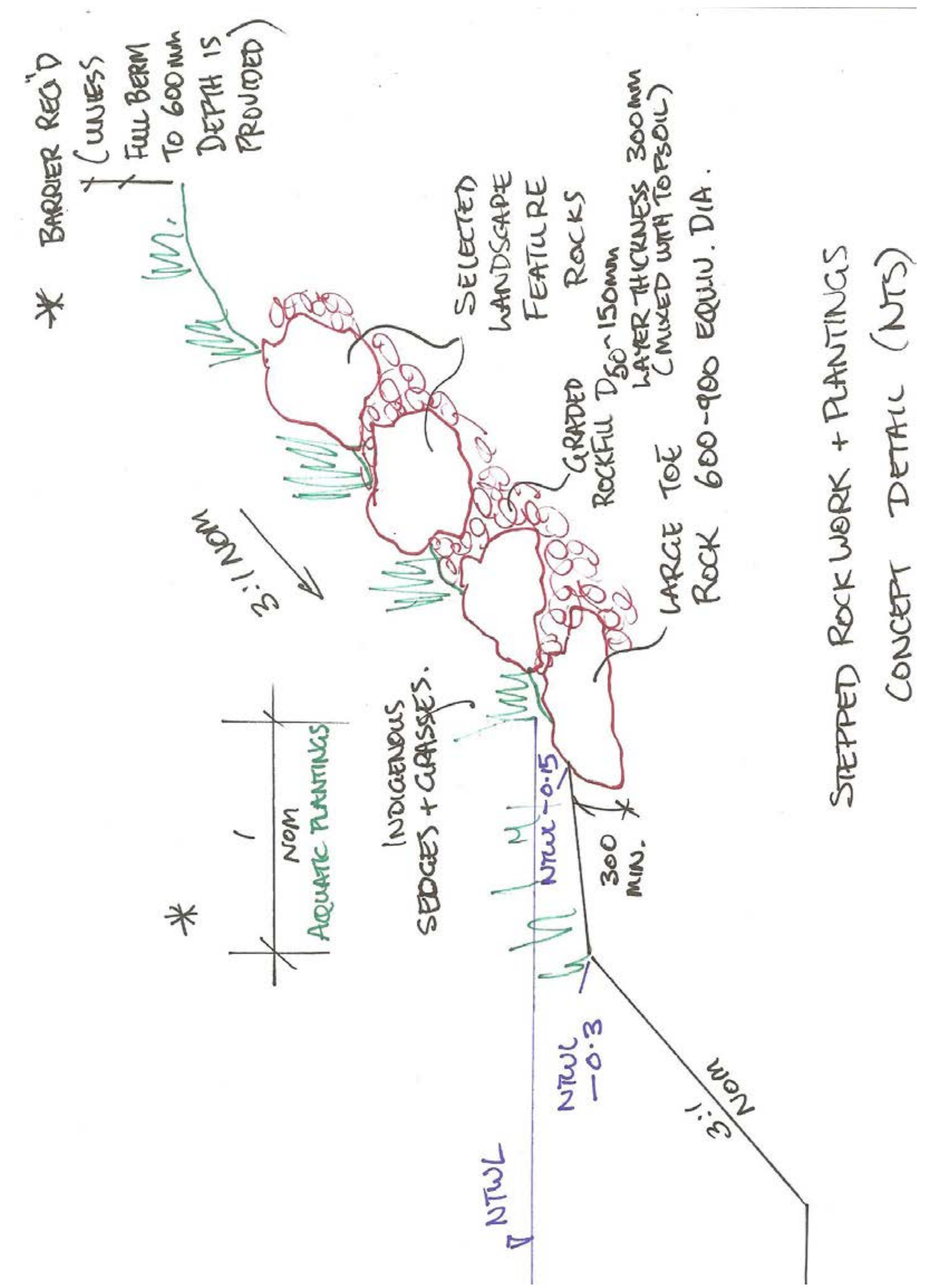
The plant list presented is extensive, and selection will be subject to availability and other local considerations. At a minimum some five species should be selected within each depth zone with perhaps two or three species comprising 80% of the plantings in each zone, and subject to availability, with further species included to provide for species diversity, ecological habitat and landscape enhancement. Species considered essential to wetland treatment performance are marked in bold and should be included if available from suppliers. An experienced aquatic plant contractor will mix the overall plants in each zone to obtain a pleasing landscape effect and furthermore will, even within a zone, be aware of plant depth preference and plant accordingly.

TABLE A.1 Plantings suitable for constructed wetlands in Western Region of Melbourne

Zone Code	Zone Description	Recommended Plants	Plants/ m2
Dryland	Dry land above 1 in 1 year level. Include these plants in landscape pallet. **SHADE ESTABLISHMENT IS A CRITICAL CONSIDERATION FOR SELECTION AND DENSITY OF PLANTINGS ESPECIALLY AROUND WATER EDGES.**	Acacia melanoxylon Eucalyptus camaldulensis Eucalyptus melliodora Eucalyptus obliqua Leptospermum myrsinoides Goodenia ovata Lomandra longifolia Lomandra filformis Microlaena stipoides Poa labillardieri Themeda australis	As per landscape design
1	+0.3m to 1 in 1 year level. Riparian zone native vegetation subject to infrequent ephemeral inundation. **SHADE ESTABLISHMENT IS A CRITICAL CONSIDERATION FOR SELECTION AND DENSITY OF PLANTINGS ESPECIALLY AROUND WATER EDGES.**	Eucalyptus camaldulensis Amphibromus nervosus Leptospermum lanigerum Leptospermum juniperinum Lepisdosperma laterale Carex appressa	As per landscape design
2	NTWL to +0.3m above NTWL Grasses and semi-aquatic native vegetation subject to frequent ephemeral inundation. **SHADE ESTABLISHMENT IS A CRITICAL CONSIDERATION FOR SELECTION AND DENSITY OF PLANTINGS ESPECIALLY AROUND WATER EDGES.**	**Carex appressa** **Eleocharis acuta** Carex gaudichaudiana **Crassula helmsii** Juncus pallidus Juncus sarophorus **Juncus australis** Isolepsis innundata Marsilea drummondii Schoenus apogon	4
3	Depth from 0 to -0.25m. Littoral Zone /Shallow Marsh. Experiences frequent drying	**Bulboschoenus caldwellii** **Bulboschoenus medianus** **Baumea acuta** **Baumea articulata** **Carex tereticaulis** **Crassula helmsii** **Eleocharis acuta** Isolepsis innundata Juncus holoschoenus Myriophyllum propinquim Triglochin striata	6
4	Depth from -0.25 to -0.5m Marsh/Deep Marsh. Dries up in extended drought period	**Eleocharis sphacelata** **Schoenoplectus tabernaemontani** Schoenoplectus pungens **Triglochin procerum**	4
5	>0.5 m Permanent Open Water Zone	**Potamogeton ochreatus** **Chara sp** **Nitella sp**	1 (rely on natural spread)

APPENDIX B STEPPED AND PLANTED ROCK EDGE TO WETLANDS

Examples of constructed wetland edges at 3:1 average slope to flanking pedestrian/bike trail (Delfin Lend Lease at Malcolm Creek, Craigieburn)


* BARRIER REQ'D (UNLESS FULL BERM TO 600MM DEPTH IS PROVIDED)
SELECTED LANDSCAPE FEATURE ROCKS
GRADED ROCKFILL D50~150MM LAYER THICKNESS 300MM (MIXED WITH TOPSOIL)
LARGE ROCK TOE 600-900 EQUIV. DIA.
3:1 NOM
INDIGENOUS SEDGES + GRASSES.
NOM AQUATIC PLANTINGS
NTWL -0.15
300 MIN.
NTWL -0.3
3:1 NOM
NTWL
STEPPED ROCK WORK + PLANTINGS
CONCEPT DETAIL (NTS)