KALKALLO BASIN

Concept Design Analysis

2.0

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Melbourne Water



Kalkallo Retarding Basin - Design of Stormwater Assets in Dispersive Soils

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Document history and status

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Important note about your report

The purpose of this report, and the associated services performed by Jacobs, Spiire and South East Soil & Water (SESW), is to document the preferred concept design for the southern portion of the Kalkallo Basin Designs, as per Tasks 4-6 of *the Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils* project. The purpose of this report is to assess the preferred conceptual design option and demonstrate the preferred asset configuration within the Kalkallo Basin. All modelling (including MUSIC, RORB and TUFLOW) and design input parameters will be presented as part of this report. This follows on from the previous options analysis and considers the outcomes of the workshop undertaken with Melbourne Water on 29/03/2021.

In preparing this report, Jacobs, Spiire and SESW have relied upon, and presumed accurate information provided by Melbourne Water and/or other sources as referenced in the report. Except as otherwise stated in the report, Jacobs, Spiire and SESW have not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, the observations and conclusions in this report may change.

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1. Introduction

1.1 Background

This report documents the outcomes of a preferred Basin Design, covering Tasks 4-6 of *the Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils* project. The predominant purpose of this report is to outline and document the key functionality of the proposed assets within the Kalkallo drainage reserve area.

The Kalkallo site poses significant issues, as it is located within a region of Melbourne that has highly sodic and dispersive soils. This ultimately means that the site is prone to high levels of erosion if improperly disturbed. Additionally, due to the dispersive soils within the site, the incoming stormwater is expected to be highly turbid, which may pose problems for downstream water bodies.

The current concept design/strategy for the Kalkallo retarding basin per the current Development Services Scheme (DSS) (MW, 2017) proposes three large wetlands, a series of constructed waterways and an upgrade of the existing retarding basin functionality. While this project will provide a broad design overview of the larger Kalkallo basin, especially from a retardation and water conveyance perspective, the scope of the project is to provide a more detailed assessment of the southernmost wetland (WLKC2, per the DSS). As such, this project places particular emphasis on minimising disruption to the sodic soils that have been identified within the southern catchment areas feeding WLKC2.

The goal of this report is to assess the suitability of the current Melbourne Water drainage scheme, and to present a clear proposal and concept design for the Kalkallo site.

1.2 Previous Analysis

Previous analysis has been undertaken as part of the *Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils* project. Tasks 1-3 included: inception meeting with key stakeholders, undertaking a Sodic Soil review for the site, undertaking a workshop with Melbourne Water and undertaking an options analysis to ascertain the best means for undertaking works within the site in future.

As part of the overall options analysis, evaluation of each design element within the Kalkallo Basin has been undertaken. This analysis focussed on the following aspects of the Kalkallo basin design:

- Best Practice water quality treatment (particularly regarding WL2)
- Stormwater Conveyance
- Retardation

Numerous options for each of the above categories were assessed via use of a 'Matrix Analysis', and the effectiveness of each option were ranked according to several key categories, including:

A. Upfront costs
B. Maintenance difficulty/ongoing costs
C. Meeting construction objectives
D. Effectiveness of meeting MW objectives
E. Ability to reduce turbidity
F. Ability to function in turbid water
G. Risk of failure over time
H. Suitability for the large site (scale)

I. Environmental and community considerations

Each of these categories had weightings associated with them, and each design option was scored, in order to select the most suitable overall design solution for the Kalkallo basin site. Through this process, it was determined that the best approach to the design of stormwater assets in dispersive soils is as follows:

- **Best Practice water quality treatment:** Spilt each of the large wetlands into multiple cells
  - To reduce the risk associated with the project, split each of the large wetland cells (per the current DSS) into several smaller cells. This will allow surveillance of the initial wetland cells to inform future construction and design methodologies for the site; and if there is a failure, it occurs at a much smaller scale limiting risks associated with the large scale asset.
- **Stormwater Conveyance:** Provide earthen/densely planted waterways to convey stormwater, with cross sections that differ from standard MW practice
  - Wide, flat, and relatively shallow cross sections; no utilisation of low flow channels, to further avoid any additional shear.
  - Rapid planting, shrouding or other means of protecting the waterways following excavation/construction will be essential in minimising erosion within the site.
- **Retardation:** Utilise targeted excavation to allow sufficient flood storage
  - Areas of disturbance must be stabilised with planting, shrouding or amelioration to minimise risk of erosion (i.e. through surface water interacting with the sodic and dispersive soils) in the short term. Once planting is established the site should become more stable.
  - Will require a topsoil survey of the site, to determine the best locations for assets/excavation to occur.

The above findings were presented to Melbourne Water as part of the Options Analysis Workshop. The options analysis and matrix analysis have been provided in Appendix B, with a summary of the workshop outcomes provided below.

1.3 Melbourne Water Workshop Outcomes

The workshop (undertaken on the 29th of March 2021) provided the opportunity to discuss the options analysis, provide input to the matrix assessment, and allowed for any additional feedback to be provided. The options analysis and matrix analysis is presented in Appendix B.

As an outcome of the Workshop, Melbourne Water generally accepted the outcomes from the options analysis and matrix assessment. A key outcome from the workshop was the need to assess the viability of a 'do nothing', or 'light touch' approach for the Kalkallo Basin site.

Investigations into the 'do nothing' option have considered the following:

- By not providing water quality infrastructure (i.e. wetlands), it is presumed that there will be a greatly reduced ability to treat total nitrogen and phosphorous entering the downstream creeks.
- By not providing water quality assets for the catchment, a precedent may be set for other DSSs within Melbourne.
- By not undertaking excavation associated with constructing the water quality assets, there won't be sufficient flood storage within the basin to accommodate a fully developed catchment. This will result in increased flood levels and reduced freeboards to properties adjacent to the Kalkallo basin.
- It is expected that the predominant source of turbid water will be from upstream construction sites, and not from the Kalkallo basin site itself. Leaving the site untouched may not inherently provide the best means of reducing turbidity of incoming stormwater.

- The main benefit of the 'do nothing' approach is that the site is likely to remain stable, providing that ground conditions are not disturbed and vegetation cover is not degraded. However, through proper design and construction methodologies, it is possible to construct water quality assets in dispersive soils.

Following the completion of the workshop with Melbourne Water, the options analysis and associated ranking matrix was adjusted to incorporate Melbourne Water's feedback. In adjusting the assessment matrix, it has been found that the preferred options are largely consistent with the findings in the draft Options Analysis Report, albeit with the inclusion of the 'do nothing' approach within the top 4 rankings for each outcome. While the 'do nothing' approach ranks higher, it still does not outrank the other proposed options.

2. Preferred Option - Design Analysis

Following the options analysis, and in agreeance with Melbourne Water a conceptual design has been developed to incorporate the following:

- Splitting each of the large wetlands within the DSS (MW, 2017) into multiple cells
- Providing densely planted waterways to bypass stormwater
- Employing targeted excavation to provide retardation storage
- Utilisation of currently proposed retarding basin outlet infrastructure (Engeny, 2017)

Each of the major elements of the conceptual design are summarised as follows.

2.1 Water Quality Design Analysis

The current DSS (MW, 2017) for the Kalkallo Basin site shows the implementation of three large wetlands located throughout the site, denoted as WLKC1 (Blue), WLKC2 (Orange) and WLKC3 (Green), as shown on Figure 1.



Figure 1: Water quality layout – as per current Melbourne Water DSS, (MW, 2017)

These three large wetlands are split into several smaller cells. All wetlands are expected to have an extended detention depth of 350mm, with a 3-day residence time. Stormwater entering the Kalkallo Basin will be diverted into large sediment basins, via weir or diversion pipe/infrastructure. These structures will divert the 1EY[1] flows into each sediment basin, while the 4EY flows will subsequently be directed towards the wetland cells. The diversion structures will be located at approximately J1, J2 and J3 per the current DSS (Figure 1). Each individual cell within each of the three wetland system will ultimately be connected via balance pipes/culverts between cells, which should be designed to allow maintenance of each cell individually. The

[1] EY – Average number of exceedances per year

current design proposal would see a single outlet control structure for each of the three wetland cells to ensure a 3-day residence time. Figure 2, below, shows a general layout for the water quality assets located within the site.

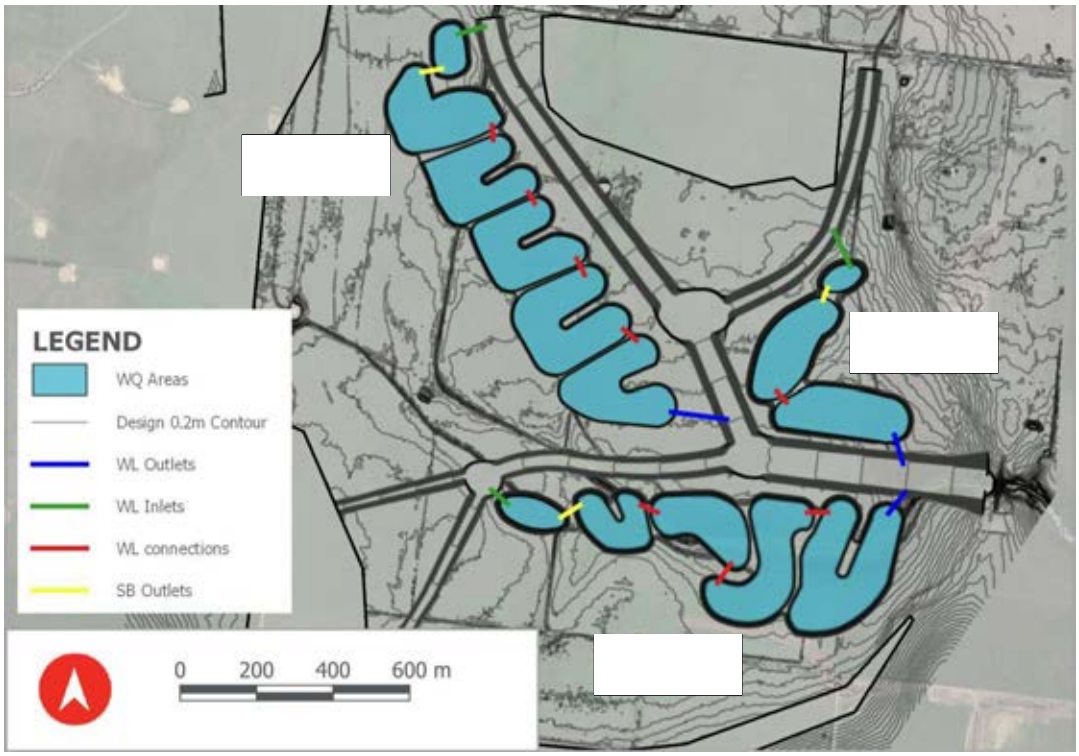


Figure 2: Kalkallo basin – proposed concept layout [Reference – WL: Wetland; WQ: Water Quality; SB: Sediment Basin]

It is important to note that while there will be sediment basins and wetlands located with the Kalkallo basin, it is acknowledged that they will likely have a reduced efficiency in treating the incoming turbid water, specific to the Kalkallo site. The incoming stormwater is expected to be turbid with fine sediments in suspension due to the highly dispersive soils in the catchment. This will especially be true whilst the catchment is developing. The nature of the suspended sediment load within the stormwater will likely mean that settlement of suspended solids will prove difficult. However, although the sediment basins will likely struggle to treat the fine sediments, they will still be effective in capturing the coarser materials within the incoming runoff. Furthermore, the sediment basins will play an integral role following the stabilisation/full urbanisation of the upstream catchments.

Keeping this in mind, it is deemed important that:

- The existing turbidity readings (NTU) for current/existing conditions is determined for the site. This will determine a baseline of acceptable NTU readings that should be discharged from the site both during, and post-construction (i.e. this process will be important in determining a baseline turbidity reading corresponding with pre-construction conditions).
    - Turbidity monitoring can be undertaken periodically, using a turbidity meter.
- Flocculation could occur for stormwater that exceeds the baseline NTU readings for the site. Some flocculation treatment could occur within the sediment basins throughout the Kalkallo basin.
    - If flocculation becomes the predominant means of removing fine clays and managing the water throughout the site, a larger water body will likely be required. This may be achieved through constructing larger sediment basins or locating a larger retention pool(s) near the outlet of the

Kalkallo basin. This would ideally allow greater volumes of water to be treated before discharging from the site. Such opportunities should be explored during future design phases.

Ultimately, it is expected that water moving through the water quality assets will be turbid as the upstream catchment develops. Future investigation and careful ecological assessment will be required during the planting phase of the project. However, during the initial review of this project, it is believed that the incoming turbidity should not have a significant impact on plant establishment within the wetland cells. It is expected that sufficient light penetration will be achievable, with light being able to extend at least a metre below Normal Water Level (NWL). As a point of reference, planting within Melbourne Water standard wetlands only extends to 700mm below NWL, with 80% of the vegetation between 100-350mm.

Although the wetland systems are expected to work in the turbid environment, it is suggested that testing is undertaken at a small scale, before construction of all major assets within the site. Therefore, splitting the wetland into several smaller cells would be beneficial in this instance, as the initial cells could be used for testing purposes. This testing and analysis of a small-scale system will help to de-risk the project moving into the future (e.g. if it is found that the wetland systems are found to not be suitable), and reassessment of options and/or a bolstering of design can occur.

2.1.1 MUSIC modelling

MUSIC modelling has previously been undertaken by Stormy Water Solution (SWS, 2014). This previous report assessed each of the three wetlands situated within the Kalkallo drainage reserve.

As noted previously, the water quality focus of this report is specific to WLKC2. As such, the previous modelling (SWS, 2014) has focussed on assessing the MUSIC modelling associated with the proposed concept. The previous MUSIC modelling has been reviewed, and the source and treatment nodes associated with WLKC2 (per Figure 3 below) have been updated.

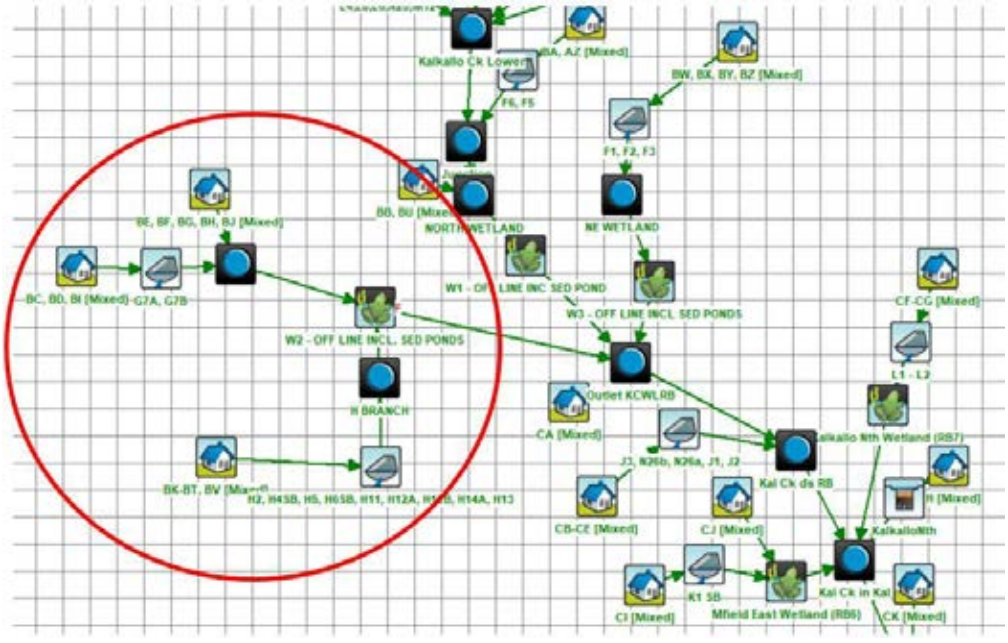


Figure 3: MUSIC modelling layout (associated WLKC2 nodes circle in red – denoted as W2)

As part of the MUSIC model review, several key parameters were updated, pertaining to the source nodes, and WLKC2 wetland node. There have been no proposed changes to the catchment areas or the fraction impervious values within each of the source nodes. Changes to MUSIC input parameters are outlined in Table 1.

Table 1: MUSIC input parameters and comparison to previous modelling (SWS, 2014)

Music Input	Previous Value	Updated Value	Comments
Source nodes [Mixed] Soil Storage Capacity (mm)	30	120	*Change based on Melbourne Water Music Guidelines (MW, 2018)*
Source nodes [Mixed] Inlet storage (% of Cap)	30	25	*Changed to default value*
Source nodes [Mixed] Field Capacity (mm)	20	50	*Change based on Melbourne Water Music Guidelines (MW, 2018)*
WLKC2 Inlet High Flow By-pass (m^3/s)	4.8	6.5	*Change based on updated RORB modelling outputs*
WLKC2 Inlet Inlet Pond Volume (m^3)	5500	5500	*No Change*
WLKC2 Storage Surface Area (m^2)	170,000	140,000	*Based on updates to source nodes and updated bypass information*
WLKC2 Storage Permanent Pool (m^3)	50,000	56,000	*Based on update to wetland surface area (0.4 x surface area)*
WLKC2 Storage Initial Volume (m^3)	50,000	56,000	*As above*
WLKC2 Outlet Equivalent Pipe Dia. (mm)	410	370	*Updated to produce appropriate notional detention time*
WLKC2 Outlet Notional Detention Time (hrs)	71.3	72.1	*Targeting 72 hour notional detention time*

Based on these changes to MUSIC input parameters, the treatment train results achieved are summarised in Table 2. Overall, the changes made to the modelling demonstrate that best practice targets for pollutant reductions are met (i.e. at least 45% reduction of nitrogen/phosphorus and 80% reduction of suspended solids).

Table 2: MUSIC results (note: values in brackets relate to previous modelling value (SWS, 2014))

	Sources	Residual Load	% Reduction
Flow (ML/yr)	3280 *(3670)*	3110 *(3470)*	5.2 *(5.6)*
Total Suspended Solids (kg/yr)	645000 *(699000)*	123000 *(171000)*	*80.8 (75.5)*
Total Phosphorus (kg/yr)	1330 *(1500)*	409 *(528)*	69.2 *(64.7)*
Total Nitrogen (kg/yr)	9220 *(10400)*	5010 *(5790)*	45.7 *(44.4)*
Gross Pollutants	145000 *(145000)*	5680 *(7760)*	96.1 *(94.7)*

As a further assessment, the inundation frequency and residence time for the proposed wetland has been checked. This analysis has been undertaken based on the Melbourne Water Constructed Wetland Design Manual – Part D (MW, 2020) via online MUSIC auditor tool (as referenced within the manual). A plot of the inundation frequency for the wetland system is shown in Figure 4.

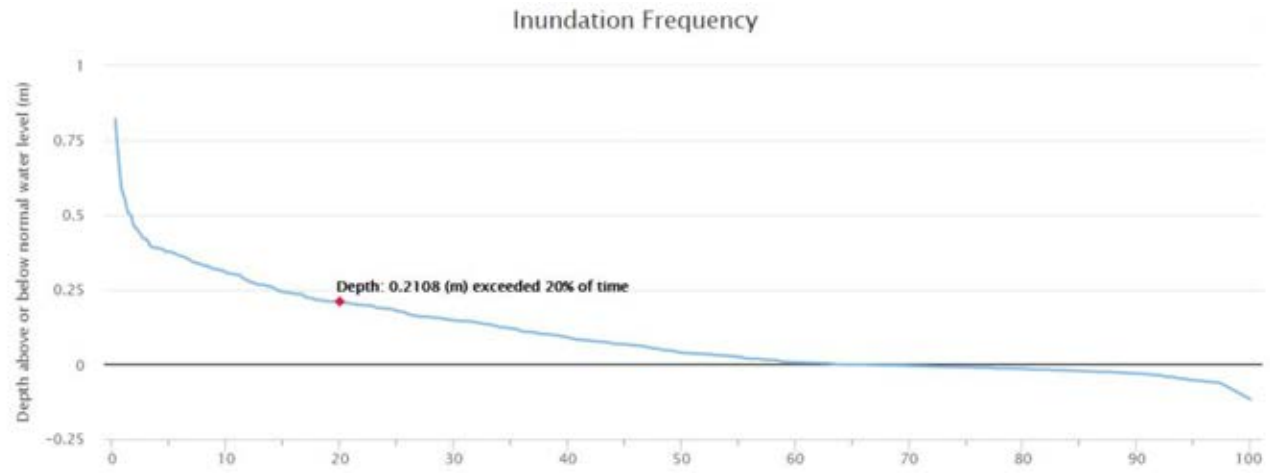


Figure 4: Inundation Frequency (via online MUSIC auditor tool)

Overall, the results from the online MUISC auditor tool are as follows:

- Shallow marsh and deep marsh zones meet deemed to comply criteria
- Water Level of 0.2108m exceeded for 20% of the time
- Water Level of 0.04m exceeded for 50% of the time
  - Noting that the effective water level is within 50mm of normal water level and is therefore acceptable
- A 90th percentile residence time of 3 days

Each of these results meet the key requirements relating to Melbourne Water's deemed to comply criteria (MW, 2020) relating to inundation frequency and residence time, which state that:

- The effective water depth (permanent pool depth plus extended detention depth) should not exceed half the average plant height for more than 20% of the time
- The macrophyte zone must provide a 90th percentile residence time of 72 hours (i.e. 3 days)

2.2 Water Conveyance Analysis

As shown in the Kalkallo Creek DSS (MW, 2017), the site will have an extensive series of waterways situated throughout the drainage reserve. Overall, the waterways will be designed such that the following key elements are met:

- Waterways will have a capacity to convey the 20% AEP flows (where greater rainfall events will engage the retarding basin, discussed in more detail in the next section).
- The waterways will grade and tie into key invert levels at the inflow locations within the basin.
- Junctions/open water areas have been provided at the confluence of each individual waterway reach.
- Shear stresses are to be significantly reduced where possible (targeting a maximum of 45 N/m^2, inclusive of 1.45x scale factor, which will account for bed/bank shear stresses in accordance with Melbourne Water's Constructed Waterway Design Manual (MW, 2019)).
  - Per Appendix B of Jacob's Sodic Soils Catchment and Site Review for the Kalkallo Retarding Basin (2021), it is noted that the minimum shear stress to impact the least hard of grasses (i.e. poorly established bunch grass) is 80N/m^2. It is also noted that the critical shear stresses, which will remove most in-channel vegetation, is in the range of 100-200N/m^2. The 45N/m^2 target, along

with the 1.45x scale factor is therefore largely appropriate, if not somewhat conservative, which will likely be best for the site.

- Important to note that the 45 N/m^2 would only be suitable for a surface that is established. Bypass infrastructure will likely be required (e.g. HDPE lined temporary channels), to ensure the ultimate waterways are established before receiving flows.

- In areas where shear forces are higher, rock beaching or other forms or protection will be used to further limit erosivity.
- Limit the use of, or carefully consider the design of low flow channels, as such channels can be a source of high shear stresses.

A summary of each of the individual stretches of waterway has been presented in Table 3, and the location of each waterway reach is shown in Figure 5.

Table 3: Key waterway design parameters (shear stress value in brackets represents the 1.45x scaled figure).

Waterway ID per DSS (Refer Figure 5)	***Length (m)***	***20% AEP Flow Rate (m^3/s)***	**Base width (m)**	**Flow Depth (m)**	**Channel Grade 1inX (m)**	**Channel Capacity (m^3/s)**	**Shear Stress (N/m^2) [w/ 1.45 scale factor]**
H14 – J1 (A)	680	26.1	18	1.2	1 in 600	26.5	14.0 [20.3]
G7 – J1 (B)	450	10.7	10	0.9	1 in 500	11.0	11.9 [17.3]
J1 – J6 (C)	720	31.2	28	1.1	1 in 600	31.6	14.0 [20.3]
F9 – J4 (D)	1000	42.4	35	1.0	1 in 300	45.4	26.7 [38.7]
F4 – J4 (E)	900	18.0	20	0.8	1 in 300	18.8	20.3 [29.4]
J4 – J6 (F)	400	57.8	46	1.0	1 in 300	57.9	27.7 [40.2]
J6 – J7 (G)	675	88.7	75	1.15	1 in 500	89.7	19.9 [28.8]

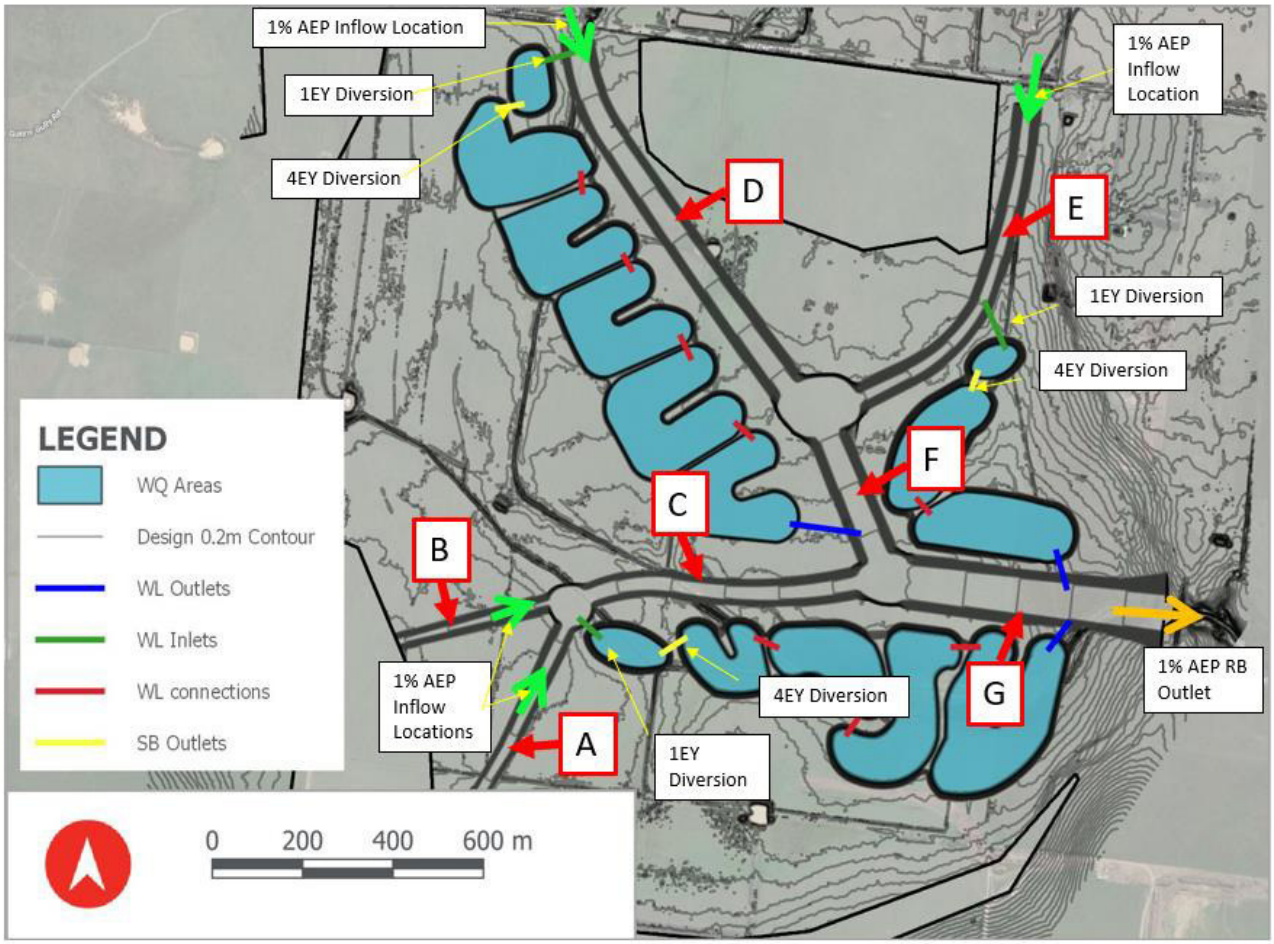


Figure 5: Waterway reference/location layout [Per legend – WL: Wetland; WQ: Water Quality; SB: Sed. Basin]

2.3 Retardation/Storage Analysis

The Kalkallo basin site will be utilised for retardation and provide significant water storage for future urban developments within the catchment. The footprint for the retarding basin is expected to be extensive and is roughly represented in Figure 6 (orange hatched area).



Figure 6: Retarding basin general extents

The retarding basin within the Kalkallo reserve will start to be engaged in storm events above the 20% Annual Exceedance Probability (AEP). Low flow events, including the 1EY and 4EY events, will be conveyed through the water quality assets, and flows up to the 20% AEP will be bypassed via the waterway channels (i.e. in order to provide protection to the wetland cells), and will provide sufficient storage for events up to the 1% AEP. It is expected that the existing/current outfall arrangement (located at towards the south of the site) at location J7 is retained and utilised for the ultimate retarding basin design (refer section 3.1.1 for outlet details).

It is important that the previous design 1% AEP flood level of 231.4 m AHD is not exceeded, as developments adjacent to the Kalkallo reserve have already been designed/constructed and appropriate freeboard levels to these properties need to be maintained.

The required basin storage will be achieved via the excavation of the wetland cells and waterway corridors. Due to the nature of the site, excavation will be challenging, with the exposure of highly sodic and dispersive soils. An investigation of the Kalkallo site has been undertaken which highlights important treatment measures and practices that will be required during the construction of the basin. Refer to section 5.3 of this report, and Appendix A for more detailed guidance based on a review of the sodic soils in the Kalkallo Basin site.

3. Hydrological Analysis

RORB analysis has been undertaken to determine the critical durations and temporal patterns associated with the 1% AEP peak inflows and the resulting peak flood level within the retarding basin. The overall RORB model has been adapted from previous modelling undertaken by Engeny (2017).

3.1 Key input parameters

The previous RORB modelling by Engeny (2017) has been updated to the Australian Rainfall and Runoff (2019) standard (Ball, et. al, 2019). As part of this process, key data has been derived from the ARR Data Hub, including:

- Intensity Frequency Durations (IFD)
- Aerial Reduction Factors
- Storm Losses
- Temporal Patterns
- Pre-burst depths

The RORB loss model parameter configuration has also remained consistent at this stage (i.e. remaining with the runoff coefficients in the existing model). The initial loss has been brought into line with the ARR data hub value, and has been taken as 16mm, while the Runoff Coefficient (RoC) values for each AEP event are as presented in Table 4.

Table 4: Runoff Coefficient Summary

Annual Exceedance Probability (AEP)	*Runoff Coefficient (RoC)*
1% AEP	0.60
2 % AEP	0.55
5 % AEP	0.50
10 % AEP	0.40
20 % AEP	0.30
50 % AEP	0.25
63.2 % AEP	0.20

Some sensitivity analysis was undertaken using an Initial Loss/Continuing Loss (IL/CL) model – however, it was found that the peak inflows were significantly different from those presented in the previous modelling undertaken by Engeny (2017). By instead utilising an Initial Loss/ Runoff Coefficient (IL/RoC) model, the peak flow rates were within the bounds of the previous modelling. A comparison between the results of these different modelling types has been provided in section 3.2.2 of this report.

As a check on the basin volumes, the peak flood elevations and storage requirements from both loss model schematisations were compared and it was found that the IL/RoC loss model gave a marginally higher peak flood level in the basin, and it was therefore selected in the concept design modelling.

It should be noted that the empirical modelling coefficient 'Kc' , has remained consistent with the previous modelling (Engeny, 2017), as reach lengths/types and sub-catchments have ultimately remained the same.

3.1.1 Retarding basin and outlet parameters

The Kalkallo retarding basin has been modelled in RORB using a storage node. The parameters within this node have remained consistent with previous Engeny modelling (Engeny, 2017), with the exception of an updated stage storage relationship (i.e. based on the updated concept design and associated terrain modelling). Some key parameters for the retarding basin are summarised below:

- Discharge Relation: Weir and Pipe Formulas
- Spillway:
  - 2x spillways
  - Spillway 1: 230.85 m AHD crest elevation; 45 m effective length
  - Spillway 2: 231.40 m AHD crest elevation; 155 m effective length
- Outlet pipe:
  - 1x outlet pipe
  - 1050 mm Pipe diameter
  - 40 m Length
  - 0.375% Slope
  - 226.65 m AHD entrance elevations

A comparison between the previous 'Engeny' modelling and the updated stage-storage relationship has been provided in Table 5.

Table 5: Stage Storage Comparison

Height/R.L. (m AHD)	*Engeny Storage (m^3)*	*Updated Storage (m^3)*
226.5	-	-
227	500	1,490
227.5	2,900	75,700
228	144,300	225,340
228.5	301,400	416,360
229	481,400	686,130
229.5	798,500	1,068,300
230	1,239,000	1,558,400
230.5	1,867,000	2,286,500
231	2,823,000	3,324,400
231.3	3,628,000	4,073,300
231.5	4,146,000	4,588,500
232	5,441,000	5,891,500

Height/R.L. (m AHD)	*Engeny Storage (m^3)*	*Updated Storage (m^3)*
232.5	6,736,000	7,204,700
233	8,031,000	8,519,900
233.5	-	9,835,300
234	-	11,151,000
234.5	-	12,466,000

3.2 Results

Through the RORB modelling:

- It was found that the critical duration corresponding to the critical peak 1% AEP flood elevation for the Kalkallo basin (i.e. peak outflow from the retarding basin) was 48-hour Duration (Dur), Temporal Pattern (TP) 25. This produced the following results:
  - The critical peak discharge rate from the retarding basin: 35.9 m^3/s
  - The required storage within the basin: 4,070,000 m^3
  - The expected peak 1% AEP flood elevation: 231.4 m AHD
- A full summary of peak inflows and outflows within the basin for a combination of storm events are provided in Table 6 (noting that peak inflows were used to determine key shear stress values within the basin).

Table 6: Summary of Peak flow, Storm Duration and Temporal pattern (for each AEP)

Inflow Location	*1% AEP*	*2% AEP*	*5% AEP*	*10% AEP*	*20% AEP*	*50% AEP*	*1EY*
Southern Inflow	50.7 m^3/s 1h TP26	40.7 m^3/s 1h TP23	33.7 m^3/s 1.5h TP14	24.3 m^3/s 1.5h TP14	15.0 m^3/s 1.5h TP4	8.6 m^3/s 30min TP7	7.0 m^3/s 30min TP7
Western Inflow	24.5 m^3/s 1.5h TP27	19.1 m^3/s 1.5h TP27	12.9 m^3/s 1.5h TP13	9.1 m^3/s 3h TP15	5.7 m^3/s 2h TP6	3.5 m^3/s 9h TP6	2.7 m^3/s 9h TP6
GunnsGully Rd Inflow	88.5 m^3/s 9h TP28	73.0 m^3/s 9h TP28	54.7 m^3/s 6h TP17	38.9 m^3/s 9h TP12	28.7 m^3/s 9h TP4	17.9 m^3/s 9h TP4	14.4 m^3/s 9h TP4
North-Eastern Inflow	37.3 m^3/s 1.5h TP28	30.7 m^3/s 1.5h TP28	23.0 m^3/s 2h TP15	17.0 m^3/s 2h TP14	11.7 m^3/s 1.5h TP6	7.1 m^3/s 1.5h TP6	6.0 m^3/s 1.5h TP6
Retarding Basin Outflow	35.9 m^3/s 48h TP25	23.9 m^3/s 96h TP25	10.4 m^3/s 96h TP19	4.7 m^3/s 72h TP20	4.4 m^3/s 96h TP8	3.6 m^3/s 48h TP8	3.3 m^3/s 48h TP8

The selection of the critical storm duration and temporal pattern was determined as follows:

- For each storm duration, the median flow rate was calculated by using the peak flow values for the associated 10 temporal patterns

- Noting that for ARR19 RORB modelling, there are 10 temporal patterns associated with each storm duration.

- The critical temporal pattern was determined by selecting the pattern which has a peak flow value nearest to but not exceeding the median flow value.
- The peak inflows are therefore the storm-duration and median temporal pattern combination that produces the highest flow rate.
- Similarly, the peak outflow from the basin is therefore based on the storm-duration and median temporal pattern combination that produces the highest discharge rate from the retarding basin.

3.2.1 Climate Change

There are two main likely impacts of climate change on flood hydrology – sea level rise and increased rainfall intensities. The area of interest is not subject to risk from sea level rise, and hence increased rainfall intensities were singled out to be assessed.

Current best practice for hydrological modelling of the increases in rainfall intensity suggest using a percentage increase in rainfall at the year 2100 for the Representative Concentration Pathway (RCP) of 8.5. The ARR data hub supply estimates up to the year 2090. A temperature increase of 3.48 °C has therefore been forecast from the available data for the year 2100. This has been calculated to translate to an 18.5% increase in rainfall intensity, based on the following formula:

- $P=100 \times (1.05^{\Delta T}3.48-1)\%$

An 18.5% increase in rainfall intensity has therefore been applied within the RORB model to simulate potential climate change conditions (noting that no other run parameters were varied). Table 7 shows the temperature increase forecasting completed by Spiire, while Table 8 below shows a comparison of the 1% AEP peak flows at key locations throughout the model between existing climate and 2100 climate conditions. The 18.5% increase in rainfall intensity has resulted in increases in flows of between 22-54%.

Table 7: Temperature Increase Forecast (RCP 8.5)

Year	***Temp increase - C***
2030	0.811
2040	1.084
2050	1.446
2060	1.862
2070	2.298
2080	2.719
2090	3.090
2100 (forecast)	3.480

Table 8: Climate change scenario flow rates

RORB Output Location	1% AEP RORB Output (m^3/s)	Climate Change RORB Output - 18.5% increase in rainfall intensity (m^3/s)	Climate Change - Critical Storm Duration and Temporal Pattern	Flow Increase %
Southern Inflow	50.7	61.9	1 hour; TP 22	22.1 %
Western Inflow	24.5	30.9	1.5 hour; TP 26	26.1 %
GunnsGully Rd Inflow	88.5	111	2hour; TP22	25.4 %
North-Eastern Inflow	37.3	46.1	1 hour; TP 27	23.6 %
RB Outflow	35.9	55.3	24 hour; TP 24	54 .0 %

The 1% AEP flood level in the basin increases from 231.4 to 231.5 m AHD under the Climate Change scenario, an increase of only 100 mm. This relatively minor increase in flood level is due to a combination of the large basin footprint and the large spillway width, which is allowing a significant outflow from the retarding basin to occur.

3.2.2 Comparison to previous modelling

As noted in section 3.1 – the predominant hydrological modelling utilised within this report has been adapted from a prior Engeny RORB model. The initial Engeny model utilised ARR87 modelling parameters, whereas the current modelling has been updated to utilised ARR19 methodologies. As noted previously, an Initial Loss (IL)/ Runoff coefficient (RoC) parameter configuration has been utilised as opposed to Initial Loss (IL)/ Continuing Loss (CL) parameters. However, the comparison of the peak flows generated from these various modelling configurations has been summarised in Table 9 below (noting that a continuing loss of 2.6mm/h was used):

Table 9: Peak Flow Rate comparisons between modelling configurations

Inflow Location	*Original Engeny Model (ARR87) – IL/RoC Peak Flow (m^3/s)*	*Spiire Updated Model (ARR19) - IL/RoC: Peak Flow (m^3/s)*	*Spiire Updated Model (ARR19) - IL/CL : Peak Flow (m^3/s)*
Southern Inflow	59.4 m^3/s (1.5h)	50.7 m^3/s (1h TP26)	69.3 m^3/s (1h TP26)
Western Inflow	22.5 m^3/s (9hr)	24.5 m^3/s (1.5h TP27)	35.2 m^3/s (1.5h TP26)
GunnsGully Rd Inflow	97.4 m^3/s (9h)	88.5 m^3/s (9h TP28)	121.3 m^3/s (2h TP22)
North-Eastern Inflow	38.8 m^3/s (2h)	37.3 m^3/s (1.5h TP28)	49.29 m^3/s (1h TP27)
Retarding Basin Inflow	170.6 m^3/s (9h)	184.0 m^3/s (2h TP25)	251.6 (2h TP 25)

4. Hydraulic Analysis

Following the hydrological analysis, a TUFLOW model has been developed, to more accurately model flood depths and shear stresses within the basin. The modelling will ultimately determine whether or not the conceptual design is viable or whether it will be subject to extensive erosion or flooding. As part of this report, the 1% AEP events have been assessed, with mapping of other AEP events provided in Appendix E. Full modelling and results will be provided separately (i.e. packaged alongside this report).

4.1 Inflow locations

The inflows within the TUFLOW model were applied via 2D_SA inflow polygons ('2D_sa' refers to a source-area boundary – these boundaries apply flow directly onto the cells located within the polygon area, with flows distributed onto lowest cells first). The inflow locations are as shown in Figure 7, and a summary of the inflows at each of these locations is summarised in Table 10 below.

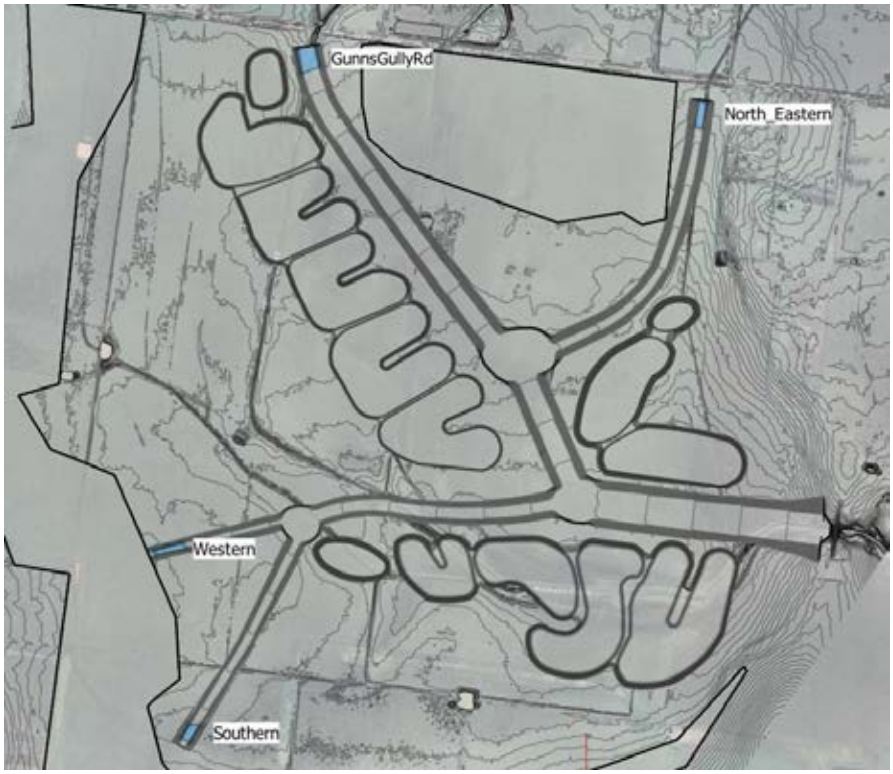


Figure 7: TUFLOW inflow location layout

Table 10: Key 1% AEP peak inflow information

Inflow Location	*Peak Flow Rate (m^3/s)*	*Annual Exceedance Probability*	*Critical Duration/Temporal Pattern*
Southern Inflow	50.7	1% AEP	1-hour Duration; TP_26
Western Inflow	24.5	1% AEP	1.5-hour Duration; TP_27
Gunns Gully Rd Inflow	88.5	1% AEP	9-hour Duration; TP_28
North-Eastern Inflow	37.3	1% AEP	1.5-hour Duration; TP_28

4.2 Key Tuflow Input Parameters

A summary of the key TUFLOW input parameters are summarised – this is inclusive of all assumptions made regarding geometry, boundary conditions and other miscellaneous inputs, as follows:

- **Modelling Type:** HPC GPU
- **Cell Size:** 2 metres
- **2D Timestep:** 1 second
- **1D Timestep:** 0.5 second
- **Material Type**: a default material utilising a manning's n value of 0.04 has been utilised; while a value of 0.06 has been adopted for the waterway corridors. A manning's n value represents the roughness/friction applied to water flowing over the surface – with higher values representing rougher surfaces consistent with Melbourne Water's Constructed Waterway Design Manual (MW, 2019).
- **Geometry:** Proposed concept surface was developed using 12D software; existing surface derived via LiDAR data.
- **Geometry Modifications**: Several z_shp files have been applied within the basin area, to modify the terrain (refer Figure 8).
    - The purple areas to the north and west have been raised, to account for potential areas of urban development. This is consistent with previous reporting, undertaken by Stormy Water Solutions (SWS, 2014).
    - Some geometry modifications have been applied to the outlet area, as LIDAR data did not sufficiently pick up the invert of the outlet channel. As such, the outlet area downstream of the basin has been lowered, to be in accordance with the culvert invert levels included within the RORB model Kalkallo basin storage node.
    - Incorporating the updated spillway in the 2D domain



Figure 8: Zshp modification areas (purple)

- **Initial Water Level:** An initial water level was set at TEDD (Top of Extended Detention Depth), within the wetland cells and sediment basin, illustrated within Figure 9.



Figure 9: TUFLOW initial water level layout

- The IWLs are summarised as follows:
  - WLKC1 IWL: 229.35 mAHD
  - WLKC2 IWL: 222.75 mAHD
  - WLKC 3 IWL: 222.85 mAHD

4.3 Modelling Checks

The overall condition of the modelling has been checked, to ensure that no major errors are present. As part of this process the following was checked:

- Minimum timestep should be approximately 1/10 of a normal Classic timestep (per TUFLOW wiki)
  - The HPC adjusted timestep for the Kalkallo TUFLOW model is 0.241s (noting that a classic timestep would be 1s, for the 2m grid; therefore, the HPC timestep is within acceptable bounds).

- Regarding TUFLOW outputs, it is noted that: maxNd should be <0.3 (otherwise may indicate poor boundary setup), the maxNc should be <1.0 (otherwise may indicate erroneously low cell elevation), and maxNu should be <1.0 (otherwise may indicate unusually high velocity) – these criteria are in line with figures outlined with the TUFLOW wiki and documentation. Results have been summarised in Table 11, demonstrating that they are within acceptable bounds.

Table 11: HPC output summary

Tuflow HPC Output	***Target Value***	***Recorded Value***
maxNd	< 0.3	0.12

Tuflow HPC Output	*Target Value*	*Recorded Value*
maxNc	< 1.0	1.0
maxNu	< 1.0	0.44

As an additional check, the TUFLOW modelling has been checked using CPU/classic solvers (as opposed to the HPC modelling). It's key to note that the peak cumulative mass error within this model was -0.17%, which is well within the acceptable bounds of ±1%.

It is also noted that there was effectively no difference in results between the HPC and classic TUFLOW modelling, with an approximate difference of ± 0.0001m difference between peak flood elevation results. Ultimately, these checks confirm that the TULOW model is stable, and that the preliminary results are reasonable.

4.4 Modelling results

Both flood depth and shear force results have been produced for the Kalkallo site, to ensure that both the flood levels within the retarding basin, and the shear forces throughout the basin are within acceptable bounds. As part of Section 4 of this report, 1% AEP results have been presented. Full mapping layouts for both the 1% and 10% AEP have been provided as part of Appendix E (with the remaining results associated with other AEPs to be provided separately, if necessary).

4.4.1 Flood depth results

The critical flood depths are associated with the 1% AEP 48hr duration, Temporal Pattern 25 (which pertains to the critical discharge from the retarding basin). Refer to Figure 10 for a map of the 1% AEP flood depth results. Overall, the modelling has shown that the flood elevation within the basin during the 1% AEP event, reaches 231.4 m AHD. This level is consistent with the RORB modelling, and the RL required to ensure freeboard levels to adjacent properties need to be maintained.

4.4.2 Shear Stress Results

The critical shear stresses are associated with the peak inflows into the drainage reserve area. The storm durations and temporal patterns associated with the peak inflows have been used to check the shear forces during the 1% AEP storm event (Refer Table 10, for a summary of key inflow values). For the shear mapping, the maximum shear results for each associated duration and temporal pattern have been combined to produce an ultimate maximum shear map. Figure 11 below shows the preliminary shear stress results associated with the 1% AEP event.

As can be seen in the shear mapping, the shear forces throughout the majority of the basin are very low. Though, there are some areas within the waterways that are showing shear stresses slightly higher than of 45 N/m^2. It is likely these areas of slightly higher shear correspond to more confined waterway widths, and breakout through the wetland cells. Though, drainage networks throughout the wetland cells have not been fully modelled, which could alleviate the shear impacts further.

Additionally, shear calculations undertaken as part of Section 2.2 of this report were associated with the 20% AEP event, and as such to accommodate the shear forces associated with the 1% AEP event, the waterway corridor widths could be adjusted slightly during the more detailed design phases to ensure these shear forces are reduced. However, if planting can be established within the waterway, the biomass should allow shear forces of up to $80N/m^2$ to be withstood. Though, within areas of high shear protective measures such as rock beaching or geofabric can be utilised as a more immediate alternative.

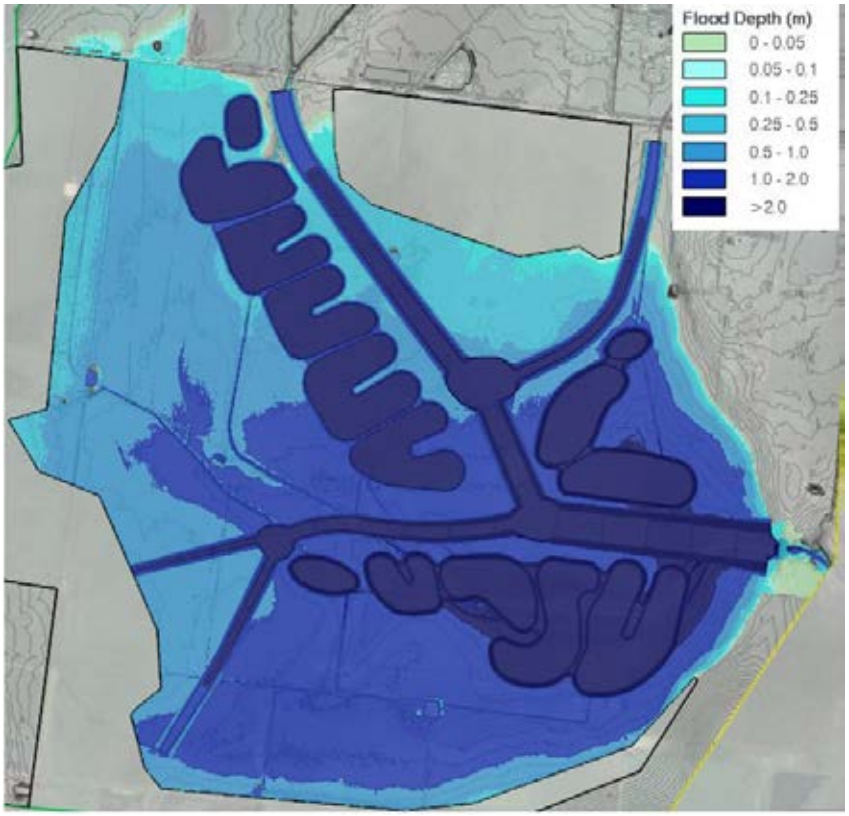


Figure 10: TUFLOW maximum flood depth mapping (1% AEP)



Figure 11: TUFLOW maximum bed shear stress mapping (1% AEP)

5. Further General Considerations

5.1 General Considerations

There are numerous ubiquitous considerations for designing and constructing within sodic areas. Some of these considerations have been summarised below and have been expanded upon within the review of sodic soils in the Kalkallo retarding basin, carried out by Jacobs and South East Soil and Water (SESW), 2021 (See Appendix A).

5.1.1 Design Considerations

There are numerous processes and criteria that can be utilised when designing assets within the Kalkallo basin (and in regions with sodic and dispersive soils in general). Below are examples of several key factors that will need to be considered during more detailed designs of the Kalkallo Basin. These considerations are, but not limited to the following:

- Design of test or "Pilot" assets. These test assets would be preliminarily assessed, to determine suitability of various design practices and stormwater assets. It is thought that these pilot assets could be monitored for research purposes, and regularly assessed by specialist consultants or academic organisations. It is expected that these test assets would help better inform the future strategies for the site.
- Design of infrastructure to consider scale of the asset, such that it can be constructed and established in a timely matter. With such a large scale, it could take longer to source and plant the basin in a timely manner; while extensive construction within the basin brings more risk of erosion, where larger sections of sodic and dispersive soils are exposed.
- Restrict development in steep areas (areas steeper than 1 in 6), or if not possible, providing appropriate scour protection (such as rock beaching) or through use of geofabrics or jute matting.
- Reduce all excavation depths where possible (where it has been found that greater depths will be subject to greater erosivity).
- Avoid removing trees or other organic coverage throughout the site.
- Utilisation of calcium-based ameliorants, to treat and stabilise sodic and dispersive soils where necessary

5.1.2 Construction Considerations

While the proper design of stormwater assets within the site is integral, it is equally important to ensure that appropriate construction techniques and methodologies are followed, to reduce the risk of erosion, both during and post construction. Some of the key recommended construction techniques are summarised (but not limited to) the following:

- All upstream drainage must be controlled and diverted around works sites as necessary;
- Reducing extents of machinery movement/ minimising extent of works;
- Reducing or eliminating freshwater contact with sodic and dispersive soils (including rainfall);
- For any structures required throughout the basin – assess and provide options that reduce disturbance and not disturbing any areas until necessary;
- Staging development of the basin, to reduce the amount of area disturbed at one time;
- Maintain/retain actively growing biomass where possible;
- Timely placement of organic matter/suitable topsoil, to assist in rapid propagation of grass seed;

- Ad hoc stabilisation of any dispersive soils and disturbed ground with ameliorants such as Gypsum or Lime; or with protection of soil with physical ameliorants or with organic material;
- Retention and reuse of all topsoil to cover exposed sodic soils;
- Shrouding / covering the surface with topsoil/mulch/straw etc. to stop the effect of rainfall impact on sodic and dispersive soils;
- Utilising geofabric barriers for soil protection;
- Regular (daily/weekly) assessment of site to identify bare areas;
- Ceasing major construction/excavation activities prior to rainfall event, where possible;
- Implementation of effective bypass systems during construction;
- Flocculation of stormwater throughout periods of construction (reducing turbidity to pre-determined value); and
- All drainage within work sites should be subject to collection and treatment, unless sodic and dispersive soils have been treated and runoff does not exceed turbidity targets.
- Any stockpiles to have a maximum height to with ratio of 2:1, with heights not exceeding 2m. The number of stockpiles should be kept to a minimum.
- Stockpiles must be covered immediately, and diversions should be in place to ensure runoff does not hit the stockpiled areas.
- Sediment control and retention measures/structures must be in place on the downslope from any stockpile.
- Any excess spoil should be removed from site as quickly as possible.

5.1.3 Ongoing Maintenance Considerations

It is expected that maintenance of the Kalkallo site will be imperative to its ongoing stability. Some key examples and ideas for ongoing maintenance techniques are as follows:

- Flocculation - ongoing treatment of any incoming turbid water as needed;
- Monitoring of the site and reapplication of topsoil/shroud material where necessary (i.e. where soil coverage is reduced);
- Enforcing management of construction sites (i.e., managing stormwater discharged from contributing catchments). This may include carefully staging construction to minimise exposed areas within the contributing catchments;
- Carry out slashing/mowing of groundcover where site remains vacant; and
- Investigate the irrigation of area using water with Gypsum/calcium additives within water, in order to further stabilise the soils.

5.1.4 Other Considerations

The general layout of the design has made allowance for filling around the edges of the basin area (per the previous DCE drawings). Based on the soil investigations previously carried out for the site, the soil profile seems to indicate that excavated material from within the site can be re-used as fill in these areas. However, this preliminary assessment would need to be subject to a more comprehensive geotechnical assessment during the design phases of the project.

Additionally, the salinity levels within the incoming flows may need consideration. Due to the extensive planting proposed throughout the site, especially within the wetland areas, there needs to be assurance that all planting will be suitable for the conditions within the basin. It is therefore recommended that a more

detailed ecological assessment is undertaken, when selecting plant species to be utilised within the site and bathymetry areas of the proposed wetlands.

5.2 Short Term Recommendations

Tools and procedures should be developed/employed by Melbourne Water, with the express goal of assisting or prompting designers to consider sodic and dispersive soils (i.e., prior to design). Erosion and failure of drainage scheme assets in sodic and dispersive soils can occur as a result of improper design that is not suited to the site conditions.

Internal awareness training within Melbourne Water, will likely play an important role in ensuring that key teams and personnel are familiar with sodic and dispersive issues and failure mechanisms. This will help when providing guidance to external stakeholders/developers and provide a mechanism to pre-emptively identify issues and manage these through the development of functional and detailed designs. Overall, it is likely that such procedures will be more suited for future sites within the catchment (or even other catchments).

Some other specific processes that are recommended in future, include:

- Mandate a soil test for every site in regions with sodic and dispersive soils, to determine the proportion of exchangeable sodium in soil in addition to standard physical dispersion tests;
- Providing pre-development advice which includes sodic and dispersive soil management requirements/considerations (within identified sodic regions);
- The requirement for the preparation of a Sodic and Dispersive Soil Management Plans to manage sodic and dispersive soils during earthworks;
- Testing of pre-existing turbidity of stormwater discharging into/out of the site (so as to guide benchmarks during construction);
- Preparing specialised standard drawings for waterways/wetlands in areas with sodic and dispersive soils (i.e. addendum to original design manuals). These would be utilised as a standardised means for undertaking design in areas with sodic and dispersive soils;
- Areas of topsoil to be mapped throughout the site, prior to design/construction. Retention and reuse of all topsoil containing organic matter, or importation of suitable/high quality topsoil where necessary; to ensure suitable organic material growth; and
- Test “Pilot” Construction (for research purposes).

6. Summary

The purpose of this report and the associated services performed by Jacobs, Spiire and South East Soil & Water (SESW) is to document the outcomes of the Basin Design – Options Analysis, Task 6 of *the Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils* project. This report follows on from the design options analysis and from the outcomes of the workshop undertaken with Melbourne Water, where a preferred concept design option for the site was determined. The focus of this report has been to produce a more detailed assessment of the selected preferred design option, while also providing key recommendations for construction and maintenance procedures.

Overall, the proposed design within the Kalkallo Basin has been categorised into three main fields: Water Quality, Water Conveyance and Retardation. The preferred design outcome for each category is a follows:

- **Water Quality Design Outcome**: Splitting the large wetlands (per the current DSS) into several smaller wetland cells.
- **Water Conveyance Outcome**: Utilising wide, flat (without the implementation of low flow channels) and densely vegetated waterways to convey flow and reduce risk of erosion.
- **Water Retardation Outcome**: Employing targeted excavation following topsoil mapping within the basin in order to determine the most appropriate location(s) to provide retardation storage.

Key hydrological and hydraulic modelling of the conceptual design has been undertaken for the entire basin, with more detailed conceptual design undertaken for water quality assets within the southern portion of the basin. Overall, the analysis and modelling as undertaken has demonstrated a suitable approach for the future development of the Kalkallo basin site.

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Appendix A. – Kalkallo Retarding Basin Sodic Soils Catchment and Site Review

Kalkallo retarding basin - design of stormwater assets in dispersive soils

Sodic Soils Catchment and Site Review

0003 | Draft

February 15, 2021

Melbourne Water



Kalkallo retarding basin - design of stormwater assets in dispersive soils

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Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
0001	04/02/21	Memorandum	C. Bannan			
0002	08/02/21	Draft Report	C. Bannan and P. Sandercock			
0003	15/02/21	Final Report	C. Bannan and P. Sandercock	P. Sandercock	P. Sandercock	P. Sandercock

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Appendix A. Literature review

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SESL Kalkallo Retarding Basin – Soil Science Investigation

Appendix B. Geomorphological flow criteria

Important note about your report

The purpose of this report and the associated services performed by Jacobs and South East Soil & Water (SESW) is to document the outcomes of a Sodic Soils Catchment and Site Review, Task 2 of ***the Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils*** project. The purpose of this task is to review the sodic soils in the Kalkallo retarding basin, develop general recommendations for the catchment and specific recommendations for the site to inform the design of stormwater assets. The work has been conducted in accordance with the scope of services set out in the contract between Jacobs (Australia) and Melbourne Water.

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1. Introduction

1.1 Background

This report documents the outcomes of a Sodic Soils Catchment and Site Review, Task 2 of the ***Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils*** project. The purpose of this task is to review the sodic soils in the Kalkallo retarding basin, develop general recommendations for the catchment and specific recommendations for the site to inform the design of stormwater assets.

1.2 Scope of review and inputs

This review considers previous soils studies completed in the Kalkallo Retarding Basin and its southern catchment, the sodic and dispersive properties of these soils and the implications of this on the design, construction and operation of stormwater assets. The review includes:

- A desktop review and description of the soils in the Kalkallo Retarding Basin and southern catchment area.
- Recommendation on what works are required in the southern catchment to minimise erosion of dispersive soils, treatment of soils during construction and options for stormwater quality treatment.
- Specific advice on how soils are to be treated within Kalkallo Retarding Basin to minimise clay dispersion during construction and operation of stormwater assets (i.e. physical and chemical treatment of soils, design of stable channel linings, depth and thicknesses of materials, ground covers).
- Specifications of surface treatments to inform design requirements for a range of stormwater assets (i.e. channels, sediment trap, sedimentation basins, wetlands) in dispersive soils.
- Advice on what further testing may be required to inform detailed design.

1.3 Report structure

The report has been structured as follows:

- Section 2 provides a review of sodic soils in the Kalkallo retarding basin.
- Section 3 documents general recommendations for the management of sodic and dispersive soils in the catchment.
- Section 4 provides specific recommendations for the site to inform the design of stormwater assets.
- Appendix A provides detailed notes and comments prepared when completing a review of available information supplied by Jacobs, Spiire and Melbourne Water.
- Appendix B specifies geomorphological flow criteria that may be used to assist in the design of surface treatments.

2. Review of sodic soils in the Kalkallo retarding basin

Five reports were reviewed in compiling this summary (Brizga and Seymour 2018, Van de Graaf 2018, GHD 2019, Jacobs 2019, SESL 2020), along with local soils and geology literature from the region and direct experience in new urban precinct growth areas draining into the Kalkallo retarding basin and surrounding areas (Jacobs 2020, Jacobs 2020).

Dispersive soils and their criteria for assessment were first researched by Emerson (1967) following the impact of dispersive soils on agriculture, irrigation farming and soil conservation throughout Australia in the early 1900's. Research on the relationship between Emerson Score and hydraulic conductivity carried out by Loveday and Pyle (1973), with additional publications and technical manuals produced throughout the 1970's-1990's by Northcote and Skene (1972) and field manuals by Charman and Murphy (1978, 1991, 2007). These provide detail on the identification and management of dispersive soils in Australia for agricultural, environmental and geotechnical uses.

Sodic soils in Australia are defined as those with an exchangeable sodium percentage (ESP) of 6% or greater. An ESP of 6% is considered to be the lower limit of sodium where a detrimental impact on plant growth is recorded. An ESP of 6% is also the threshold where exchangeable sodium in soil has an adverse impact on soil structure when in contact with fresh water, causing clay dispersion. Table 2.1 below is a useful guide to the interpretation of ESP values, sodicity and dispersion.

Table 2.1: Exchangeable sodium percentage (ESP) values, sodicity and dispersion.

ESP	Description
<5%	Non-sodic, soil is unlikely to reveal dispersion when in contact with fresh rainfall or runoff.
5 to <7%	Transition between non-sodic and sodic soil (sodic soil of 6%). Clay fraction within samples likely to reveal dispersion when in contact with fresh rainfall or runoff.
7 to <10%	Moderate to high sodicity. Dispersion likely to occur when soil is exposed to fresh rainfall or runoff.
10 to <15%	High to very high sodicity. Dispersion likely. Significant erosion risk when soil is exposed to fresh rainfall or runoff.
>15%	Very high to extreme sodicity. Significant erosion risk when soil is exposed to fresh rainfall or runoff.

The impact of sodic soil on runoff occurs when fresh water becomes in contact with an un-stabilised, commonly sodic, which disperses causing clay particles to suspend in solution and erode by mobilisation within surface runoff. This appears to be the primary impact of dispersive and sodic soil on waterways following construction in the Kalkallo region. This process impacts beneficial use criteria for water quality, specifically turbidity.

Impacts associated with wetting of sodic and dispersive soils potentially include soil structural decline, crusting, waterlogging, low rates of hydraulic conductivity, excessive runoff, erosion and poor agricultural performance. Types of erosion include sheet, rill, gully and tunnel erosion. These impacts are significant when sodic soils are disturbed or groundcover is removed or absent (Figure 2.1). Charman and Murphy (2007) provide further details of the impact of sodic and dispersive soils in an Australian context.



Figure 2.1: Example of erosion of sodic and dispersive soils which can result in elevated turbidity and sedimentation in waterways. Photos are from eroded areas in the upper catchment of Kalkallo Creek, located in the Beveridge North West Precinct Area.

Ford, Martin et al. (1993) records approximately 53% of Victoria's soils were sodic, with alkaline, sodic soils recorded throughout the Kalkallo area. Agriculture Victoria (2020) also provide mapping outlining the location of sodic conditions in the upper subsoil of Victorian soils, covering the Kalkallo area. These observations are confirmed from other work in the region by Jeffrey (1981), Jones, Boyle et al. (1996) and reports supplied and used in this review from Van de Graaf (2018), Jacobs (2020a) and Jacobs (2020b). Furthermore, these reports highlight that sodicity issues are moderate to severe within clay-dominant soils, particularly subsoils and increase in magnitude with depth above bedrock.

Previous consultant reports reviewed as part of this project include Van de Graaff (2018), Brizga and Seymour (2018), GHD (2019), Jacobs (2019) and SESL (2020). All provide general detail on the presence of dispersive or sodic soils in the area and ranges of methods for treatment. All reports note that the soils of the region are highly dispersive with photographic evidence of dispersive channel cuttings, turbid water and eroded channel batters made evident by Van de Graaff (2018). In most cases reports note that the use of gypsum is the primary ameliorant and option for rendering dispersive soils non-dispersive.

Dispersive and sodic soils occur in the area, with high likelihood that impacts will be observed with all forms of ground disturbance. Given the spontaneous dispersion of highly sodic clays in this region when exposed to rainfall, waterway impacts are likely to be severe without intervention. These observations are consistent with those of water authorities, shires and landcare groups in the region. Control of sediment including sand and silt particles from catchment areas and the Kalkallo basin area is expected to be possible with sound erosion and sediment control strategies. Control of clay dispersion will involve treatment and covering and reduce or eliminate contact between fresh water and dispersive soil surfaces, with engineering measures to compliment these practices.

3. General recommendations for the catchment

3.1 Primary soil management principles

Control of sediment including sand and silt is widely practiced through traditional erosion and sediment control practices. The dispersion of clay and erosion by stormwater is recognised however practices for control are limited with few practical options for adoption in waterway and wetland environments. Many options exist at the point source where construction activities or site disturbance may occur. Amelioration of clay and reducing or eliminating the risk of sodic and dispersive clay from erosion is difficult.

The following dispersive and soil management principles are critical to adopt:

1) **Restrict development and construction impacts on steeper slopes**

   Runoff and erosion potential are proportional to slope. Development and construction should be avoided where slopes are steeper than 5% or 1 metre of rise over 20 metres.

2) **Treatment and stabilisation of sodic and dispersive soils**

   - Treatment with gypsum, or another form of flocculant or calcium ameliorant, inhibiting dispersion.
   - Treatment with organic materials to bind soil particles together and reduce clay loss of structure from slaking and dispersion, leading to transportation upon wetting.
   - Engineering measures to reduce or eliminate freshwater contact and flow velocity.
   - Anchorage, using environmental methods including tree plantings, shrubs, grasses or aquatic plants and their root systems to protect the soil surface, bind soil aggregates together and support them to withstand forces from adverse soil chemistry or from water flow.

3) **Covering soils and eliminating exposure**

   Covering or shrouding sodic and dispersive soil, ensuring fresh water cannot become in direct contact with an unstable, exposed, dispersive surface with a lack of organic matter. Covering remains a favored option even following treatment and stabilisation.

   - The more exposed and uncovered dispersive soils become, the higher the risk of erosion and the greater the need for covering and/or treatment.
   - The Kalkallo basin is a large area expanding approximately 380 hectares across an agricultural landscape. Following full amelioration of all topsoil, the most practical option for providing cover of dispersive and sodic soils is to retain all topsoil containing organic matter and reuse as a protective cover or shroud.
   - Topsoil is also critical to secure plant growth. Very few species of plants will establish in typical dispersive or sodic subsoils of this region. Subsoils are hostile from sodicity, salinity, high boron, high calcium carbonate and high pH levels. Options for vegetative growth are limited without topsoil cover.

3.2 Management of erosive and dispersive soils in catchment areas

Recommendations for catchment areas follow similar recommendations as applied by Jacobs (2020a, 2020b) covering sodic soil assessments for the Beveridge North West and Shenstone Park Precinct Development Areas, with further additions to suit this project and improvements in knowledge.

Management principles and options for catchments include:

- **Undisturbed sites within catchments:**
  - Nil disturbance or removal of topsoil and surface organic matter until necessary.
  - If soils are already dispersive and subject to erosion, treat with gypsum while land is in transition from agriculture to urban development.
  - Maintain surface groundcover and actively growing biomass from native or introduced pastures or crops, providing root anchorage.
  - Carry out slashing or mowing of groundcover. Avoid chemical spraying. Propagation of grass seed is important for site stability, if sites remain vacant for several years.
  - Avoid removing trees. Their root systems provide important anchorage both vertically and horizontally throughout soil profiles.
- **Disturbed sites – large scale surface disturbance:**
  - Staging developments to avoid large-scale exposure to sodic and dispersive soil erosion risks in any one area.
  - Selection of design options for buildings and structures that minimise disturbance, including pier or pile foundations as opposed to trenching.
  - Restricting commencement of works and site disturbance for as long as possible, ensuring works are carried out within a minimal timeframe.
  - Controlled measures for treatment of dispersive soils on-site during works:
    - Gypsum or ameliorant treatment of bare and exposed soil surfaces along with stockpiles.
    - Topsoil cover, daily or weekly, over bare areas.
    - Placement of organic matter use of organic materials on finished surfaces to soften the impact of rainfall, filter runoff and aid the generation of seed or turf.
    - Use of geotextile barriers for soil protection where gypsum and topsoil management options are not available.
    - Minimise activity ahead of rainfall events or during rainfall.
    - Topsoiling, seeding or planting of bare areas or re-topsoiled areas following works (areas around buildings and structures).
  - Control of turbid stormwater and sediment which leaves work sites:
    - Drainage banks and stormwater control.
    - Sediment fences on all drainage lines to disrupt water flow and increase tortuosity.
    - Runoff basins at a street and/or subdivision level, to impound all turbid runoff and prevent discharge of untreated water into waterways.
    - Stormwater treatment (refer to Section 4.2.1 Stormwater treatment options).
  - Roads and access:
    - Gypsum or ameliorant treatment of exposed dispersive soil, either topsoil or subsoil.
    - Placement of geotextile barriers on top of topsoils for construction of roads and tracks.
    - Placement of non-dispersive material, either on top of geotextile or on top of undisturbed soil to provide a wearing surface. This includes sands and gravels, non-clayey.
    - Where topsoils must be removed if they are creating access problems, strip topsoil and immediately gypsum treat bare subsoils before a trafficable surface is installed to form tracks and roads.

- **Trenches, culverts and drains (adapted from Jacobs 2020a, 2020b)**
  - Avoid the use of trenches for the construction of services as they may intercept and collect stormwater.
  - Timeframes for works should be kept minimal to prevent ingress of rainfall or stormwater.
  - Where trenches are used, dispersive soil must be adequately stabilised with hydrated lime (subsurface treatment) and gypsum (topsoil cover) to limit dispersion and erosion. Loose fill will erode even if non-dispersive.
  - Consider alternative trenching techniques that do not expose dispersive subsoils including horizontal or directional drilling, with use of grouting to fill in voids and reduce tunnel erosion risks.
- **Tributary drainage lines and depressions outside of waterways (catchment to waterway zone):**
  - Ensure these remain grassed for as long as possible.
  - Complete works within tight timeframes to minimise exposure of bare soils to rainfall.
  - Stormwater flow should be conveyed within stable, non-erodible drainage lines, lined with geofabric, anchored and rock armoured, or stabilised with other materials including asphalt or concrete.
  - Install earthen detention dams to contain and treat turbid runoff and collect coarser sediment including silt and sand.
  - Prior to waterway discharge, construct water energy dissipators or to remove energy from water.
  - Avoid works ahead of forecast rainfall or during rainfall.
- **Waterways:**
  - As discussed under Section 4.1 ‘Recommendations for design of stormwater assets in the Kalkallo retarding basin‘.

4. Specific recommendations for the site to inform the design of stormwater assets

4.1 Recommendations for design of stormwater assets in the Kalkallo retarding basin

The following is a summary of the types of stormwater assets that may be designed within Kalkallo Basin:

1) Waterways passing through the basin.
   - Low flow channels carrying more frequent flows
   - Broader waterway channels carrying less frequent high flows
2) Sedimentation ponds upon waterway entry into the basin
3) Wetlands, both seasonal or permanent.

The following are important considerations that need to be worked through in the design of stormwater assets:

1) Review of water flow within each section of waterway entering the Kalkallo basin. Each section of waterway should be assessed for erosion risk.

Water flow characteristics within each segment requiring review:

- This should consider a range of flow rates, up to and including ARI 1 in 100-year flow rate (m3/s)
- Velocity (m/s), Boundary Shear Stress

Channel, waterway or basin:

- Width
- Depth
- Batters
- Slope

Erosion control measures, specifically those that address dispersive and sodic soil should increase proportional to the risk of erosion. The primary soil management principles for planning in assessing dispersive soil exposure risk include stabilisation and covering. These techniques must increase proportional to the risk.

Engineering measures to protect and manage soil coverings and water flow within dispersive and sodic soils must also increase proportionally to the flow volume, velocity and shear stress. Ground covers need to be designed to be resistant to scour. Appendix B provides further information on critical shear stress thresholds for a range of substrate conditions and vegetation types. Where vegetation forms a part of the surface treatment, plant selection also needs to consider vegetation species and community water regime requirements.

2) Basin depth and exposure to dispersive and sodic soils

Risks of exposure of dispersive and sodic soils increases proportional to the depth of excavation. For basin excavations within waterways, sediment ponds and seasonal wetlands, all depths of excavation should be minimised. This also reduces the risk of exposure, level of stabilisation, covering and engineering required. The lowest risk material to manage across the site is the topsoil, with risks of sodic and dispersive soil increasing significantly with subsoil exposure.

Management and design considerations:

- Topsoils should be accurately mapped on an intensive grid across the site. This should be no less than 1 site per 50 x 50-metre square, or approximately 0.25 Ha grid (approximately 1 per acre). A 3-dimensional plan of topsoil thickness can be prepared with volumes calculated. This material is critical to preserve, ameliorate and reuse carefully as a protective shroud over highly dispersive and sodic subsoil.
- The depth of all cuts forming the basin floor and other infrastructure should be assessed. Where possible, the depth of cut and risk of exposure should be kept as minimal as possible.

3) Geotechnical considerations

Concerns relating to the placement of infrastructure in sodic and dispersive soils run parallel to their engineering characteristics and classification. As soil reactivity increases so too does the soils clay content. In the Kalkallo region, dispersion and sodicity risks apply in clay soils and almost run parallel with increasing clay content. On highly reactive soils, several elements of clay behavior impact soil condition and capacity to bear structures with minimal or nil ground movement. The sodicity status of a soil plays a role in this process when clays saturate, with particles that detach and push apart from each other. Allowable bearing pressures in clay are expected to be low. Deep, wide footings are recommended to spread load and these should be well reinforced.

4.2 Recommended stormwater treatment options and soil ameliorants

4.2.1 Stormwater treatment options

- **Flocculation or coagulation.** This process involves applying a salt and dropping the suspended clay fraction out of water.
- **Detention.** This process involves holding water in detention under low or nil energy conditions, using gravity to allow suspended clay to drop out. This process does not provide a solution for removing suspended clay.
- **Filtration.** This option allows larger particles and foreign matter to be removed. Filtration does not provide effective removal of suspended clay.
- **Aeration.** This option provides oxygen to water supplies, improving the rate of breakdown of organic materials within water.

4.2.2 Soil chemical ameliorants

Soil chemical ameliorants are favoured for short-term stabilisation of soils on construction sites. Ameliorants include:

- **Gypsum [$CaSO_4$]**, primarily for stabilising dispersive topsoil or subsoil not intended for construction or geotechnical use. Gypsum flocculates soil and increases soil permeability, rendering materials less favourable for compaction and geotechnical use. Gypsum significantly reduces dispersion of clay and turbidity of runoff.
- **Hydrated Lime [$Ca(OH)_2$]**, primarily for geotechnical use. When slaked in water, hydrated lime stabilises soil cations by supply of calcium (reducing or eliminating dispersion and sodicity) and increases soil strength. Hydrated lime is the favoured soil chemical ameliorant for stabilisation of soils in civil and geotechnical works such as around pipes, structures, roads, trenches and any works requiring compaction upon reinstatement. Hydrated Lime treatment is not a standard amelioration technique on large-scale soil stabilisation projects such as retarding basins.
- **Agricultural Lime ($CaCO_3$)**, primarily for acidic topsoil amelioration. Standard agricultural lime will provide minor soil stability however the solubility is low and immediate response is poor. Agricultural lime could be used to support an improvement in plant growth within the basin and by adjustment of soil pH, however the effect on soil stability is expected to be low or negligible in the short term by comparison with gypsum.
- **Others**, Liquid soluble calcium, Liquid gypsum, Liquid lime.

4.2.3 Soil physical ameliorants and treatment

Soil physical ameliorants are favoured for long-term structural stability of soils for reducing erosion. Their effectiveness is varied depending on the nature of the ameliorant and how effective it is for protecting dispersive soils from direct contact with fresh water and erosion, or slowing down water flow. Before or after topsoil covering and shrouding, soil physical ameliorants include:

- Topsoil spreading, or use of better soil to protect sodic soil. Using sandy topsoils, non-dispersive, sodic soils including subsoils can be covered. Should topsoils be dispersive or sodic, they should be ameliorated prior to use. Sandy topsoils are preferred for protective covering and shrouding for the following reasons:
  - The sand fraction, often angular with a range of particle sizes, provides good lodgment and locking of particles, with resilience to dislodgement.
  - Larger particle size and weight to clay, therefore they are less likely to become suspended and entrained in overland or concentrated flow of drainage water.
  - The sand fractions show little to nil chemical reaction with fresh water.
  - The gypsum requirement for stabilising sand-dominant topsoils is significantly less than clay-dominant topsoil.
  - Sand also provides a wearing surface.
- Geotextile fabrics and mattings that provide sodic soil protection, shrouding, plant root growth, shoot growth and assist with plant propagation.
- Organic matter. Used as a protective shroud on topsoils, improving soil physical structure and biological condition. Hydro-mulching is a form of stabilisation using organic matter. Organic matter is not suitable for stabilisation of soils for civil or geotechnical works unless it is a final layer of protection used for shrouding. Options include straw, woodchips, biosolids. Care must be taken to ensure use of organic materials within wetlands and waterways does not impact dissolved oxygen levels, or the Biochemical Oxygen Demand (the amount of dissolved oxygen required by aerobic organisms to break down organic material).
- Seeding of sites to fast-growing species such as grasses, or application of instant turfs. Deeper rooted species should also be planted but will require greater management to become fully established.
- Structures, beaching and other rock control measures will slow down flow and dissipate energy, however they are indirect options for controlling dispersive soil.

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Appendix A. Literature review

Merrifield Central Channel Soil Stabilisation. By Robert H.M. van de Graaff. March 2018.

Introduction

The report outlines the intention of the study is to investigate the apparent major instability of clay soils surrounding the Merrifield Central Channel when exposed to water. This channel is part of an urban design and is intended to remove stormwater. Site was visited on the 8th February 2018.

Background information on the soils

Soils have formed from minimal weathering, where base cations have not leached away with rainfall. Cations have accumulated in lower portions of the soil profile along with their chloride, carbonate, and sulphate occurrences. Consequently, with the increase in cations and salts, the EC levels rise with depth.

The report also notes that salts are constantly added with rainfall and there is a comment and formula confirming that rainwater chloride concentration of soils is proportional to distance from the ocean. The report indicates that topsoils are acidic but have improved structural stability. Notes state that topsoil organic matter will bind soil together while subsoil will spontaneously slake.

The report indicates that when water is highly saline, clay particles are attracted to each other by flocculation and exist as larger soil units. Dispersion is also inhibited.

The comments by Dr. Van De Graaff appear accurate in the assessment of soil chemistry and consequent effects on physical properties.

Investigations

Purpose was to determine whether and how much gypsum and/or other calcium compounds may be added and mixed with the soil to prevent excess slaking and clay dispersion. A total of six sites were samples from the banks of the Merrifield Central Drain across various sections of banks (batters). Four of these samples were comprehensively analysed by SWEP laboratories. An additional twelve sites were sampled by Golder Associates with testing carried out by ALS laboratories.

The investigation and number of tests appears to have provided enough evidence to confirm the extent of sodicity and provide recommendations accordingly.

Results and Recommendations

The results of comprehensive testing of Dr. Van de Graaff's samples and those of Golder Associates are summarised below.

- Average Exchangeable Sodium Percentage (ESP, measure of sodicity):
  - Van De Graaff: 19.8%.
  - Golder Associates: 21.8%.
  - The trigger for a sodic soil is 6%. The soils are highly sodic.
- Average EC (salinity):
  - Van De Graaff: 709 uS/cm.
  - Golder Associates: 711 uS/cm.
  - The results confirm the samples are of moderate to high salinity. This level of EC is not expected to be high enough to inhibit dispersion.
- Dispersion index:
  - Van De Graaff: All samples were recorded at 16, very high.
  - Golder Associates: 11 out of 13 results recorded 16, very high.
- Exchangeable Calcium:
  - Van De Graaff: 6.2 meq/100g, very low for clay soils.

- Golder Associates: 6.2 meq/ 100g, very low for clay soils.
- Exchangeable Potassium:
  - Van De Graaff: 0.6 meq/ 100g, acceptable.
  - Golder Associates: 0.4 meq/ 100g, acceptable.

Results confirm that the soils are saline, highly sodic and low in calcium, normal for clays in this region. The report notes that the EC of the samples collected is too low to prevent clay from dispersing when in contact with fresh water including rainfall. A recommendation of 20 t/ Ha is provided for the top 20cm of soil, an equivalent of 10 tonnes/ Ha/ 100mm of soil, or 1% weight to volume. There are also notes that the low Ca:Mg ratio will also increase the tendency for dispersion.

Leachate derived from gypsum application and movement of salts was not deemed to be a problem, based on the view that groundwater is already saline and leachate will not have further significant effect.

The report recommends application of gypsum in stages to allow rainfall to dissolve it and move it into the profile. The recommended amendments and mode of incorporation were transmitted by email communication and summarised as follows:

- Apply a lime/ gypsum mix.
- Rip the clay of the final floodway profile to 300mm.
- Allow ripped clay to dry.
- Mix gypsum in by harrowing – maybe twice before reshaping.
- Indicates this could be done with a rotary hoe.
- Recompacting required with a swamp dozer working laterally across the channel, so the track cleat imprints are perpendicular to the downslope flows. The impressions will provide a key for the topsoil application.
- Report indicates from previous comment that topsoiling would occur over the exposed sodic subsoil.

These techniques all appear to be viable techniques for mitigating erosion on sodic soils and mitigating impacts of sodic soil on waterways and infrastructure.

Other comments in email communication:

- Channel / batter failures on the south side of Donnybrook road occur where there is no treatment of finished batters, no appreciable vegetation and geotextile had been impacted by lateral rilling. Flow had eroded the channel base and ripped out the geotextile.
- Doesn't believe that the primary flow channel can be stabilised with this process as they are too steep.
- The primary flow channel would require shotcrete to provide protection with rock armour.
- Topsoiling of channel batters is necessary over ameliorated subsoil.

Other comments and summary of notes:

These recommendations are sound for managing dispersive clays. Further recommendations using this technique could include more tailored and specific gypsum application by prilled or liquid sources, along with other complimentary practices including seeding and harrowing. The capital gypsum application on areas of high risks of sodicity and dispersion is a starting point.

Very high rates of gypsum have proven sustainable in pasture growth even where EC levels rise from the application of calcium sulphate salts. This rise in EC and associated rise in EC of water is expected to peak in the short term as gypsum dissolves, then diminish over time. The impacts of elevated EC on water from gypsum salts at peak times is unknown. General indications from literature are that the EC rise in water and soil from gypsum has minimal impact on aquatic flora and fauna.

Merrifield Central Waterway – Geomorphology Report (Brizga & Seymour, 2018).

Site

Merrifield Central Waterway, a major tributary of the Kalkallo Basin.

Introduction and Scope

To provide geomorphological advice in relation to the design of the proposed Merrifield Central Waterway. The report addresses the need for a constructed channel to accommodate increased flows in the creek resulting from urbanisation of the upstream and local catchment areas. The scope specifically indicates that soil chemistry will be addressed.

Objectives:

- Provide an assessment of the existing geomorphology of the site and proposed Merrifield Central Waterway and the implications of flow increases expected to occur as a result of catchment development, and
- Advice on opportunities for establishing a stable morphology for the Merrifield Central Waterway to safely carry the increased flow.

Methodology and data review

This included a site inspection and field assessment of the current geomorphology of the proposed waterway, existing drains and the upstream waterway covering all factors influencing stability.

This investigation used previous geotechnical investigations by Golder Associates and a soils report commissioned during this investigation by Van de Graaff (previously reviewed) to provide baseline data regarding soil physical and chemical condition. These reviews confirmed that the soils are prone to slaking, dispersion and soil erodibility.

The report outlines the Merrifield development zone and another smaller urban catchment to the south of Donnybrook road which drains into the Merrifield Central Waterway. It is understood that other catchment drainage from around this area also flows into the waterway.

Field observations

Figure 5 of the report shows poorly drained soil subject to waterlogging, however the area is under pasture cover and drainage water appears clear or of a low level of turbidity. Figure 6 is a photo of bank erosion on the batter of an existing drain near Donnybrook Road. It is unknown if this drain is connected to the Merrifield Central Waterway. The erosion in this image appears to be a combination of severe rill erosion or tunnel erosion.

Figures 7, 8, 9 and 10 and 18 are photographs of drainage channels supporting the Merrifield development. These drains are conveying highly turbid water which appears typical of low-flow, low salinity drainage water in contact with dispersive soil. These images also show significant slumping and erosion on the batters of these channels. All batters appear to be relatively steep in the order of 1.5:1 through to 3:1 horizontal to vertical grade. Figure 7 may show signs of topsoiling over batters however this is not evident in Figures 8-10.

Figures 11 and 12 are photographs of the Warratah Estate channel which has been lined with geotextile. It is unknown if geotextile was applied to this channel solely to reduce erosion risks with a modelled flow velocity of 1.8 m/s, or if sodic and dispersive soil influenced the decision. According to the report, this channel did not have any exposed subsoil ameliorated prior to applying geotextile. Failure has resulted with sloughing, tearing and movement of the geotextile downslope and downstream. Furthermore, the report indicates that layers of geotextile had poor lapping and it is not known if the geotextile was adequately anchored.

Design Parameters

Approximately 8 metres of fall occurs along the channel path, creating high potential flow velocity. Flows were expected to increase as the level of development continues. A waterway corridor reserve width of 70 metres is provided, with the Merrifield Channel cross section width of 60 metres. Urban catchments will have sediment traps or ponds installed. The report notes that water emanating from these catchments is expected to be of high turbidity entering the waterway.

The report references Melbourne Waters constructed waterway guidelines (2009) in achieving waterways that mimic local, natural stream flows as far as practicable. The waterway also needs to meet local aesthetic, amenity, and public safety requirements.

Section 3.3 discusses modelled hydraulic loading, or water pressure on the Merrifield Central Channel, with some uncertainty of the actual hydraulic loading. The report notes that the design seeks to lower stream power to below 100 Nm2 as far as possible to reduce erosion.

Subsurface Conditions and Soils

Much of this has been covered in the review of Dr. Van De Graff's report. This report summarises subsurface formation as:

- Topsoil, extending to 0.3m.
- Residual basaltic clay, extending from the base of the topsoil to weathered rock.
- Weathered basalt encountered at depths of 1.4-3.8 metres.

The report notes the depth of bedrock is variable and bedrock cannot be relied upon for channel bed erosion control.

Basaltic clay is ferruginous at depth and the degree of ferruginisation increases with depth. The report notes that these results suggest evidence of a seasonal water table at 2.0 metres, however this was not observed.

Table 2 in the report provides a summary of results from the Van de Graaff report. These results are summarised in Van de Graaff report review.

Geomorphological issues noted to be addressed in the design of the waterway

Bank erosion risks from high rainfall:

- Stream flows
- Overbank flows
- Overland flows
- Raindrop splash

Bank erosion impacts from high rainfall:

- Rill erosion
- Tunnel erosion
- Fluvial scour
- Undercutting
- Bank collapse

Geomorphological issues to be addressed in the waterway design to prevent channel erosion:

1) Bank erosion. Control measures include:
   a) Rock protection over a heavy polyfelt geosynthetic fabric and bedding material to prevent natural clays under fabric from erosion
   b) Complete vegetation cover on banks and in the channel, except in rock areas using sedges and semi-aquatic species.
   c) Prevention of overland and overbank flows apart from around defined inlet points
2) Bed controls
   a) Concreted rich structures (riffles) and deep cut offs
   b) Natural rock
3) Channelisation and flow confinement
4) Loss of channel capacity due to aggregation
   a) Sediment ponds will require stabilisation.

Design responses to geomorphological challenges
▪ 1 year ARI channel: ▪ Large rock edging   ▪ Linear aquatics and semi-aquatics along the channel   ▪ Shotcrete batters   ▪ Sub base treatment with gypsum to 300mm.   ▪ 200mm of topsoil to be treated with jute master behind rocks and planting for a minimum of 1.5m wide or to the toe of the batter. ▪ The base of the primary channel to be rocked with 400mm dee of rock graded 50-350 laid on 100mm deep 40mm NDCR on a min 4mm poly felt liner ▪ Keep channel velocity below 1.0 m/s ▪ As flat batter slope as possible (grade 6:1 horizontal to vertical grade). ▪ Batters to be fully cross scoured with 200-300mm of topsoil as per Van de Graaff report ▪ No overland flows onto banks ▪ Broad flat floor with banded sedges bands, cross-floor grade of 1:35-1:40 ▪ Cut off bars where required, concrete with rock cemented on top. ▪ Bedform diversity from riffles, pools and runs ▪ 600mm freeboard ▪ Overland flow entries via controlled structures. ▪ Integration of landscaping as part of the structural response and ensure that no wet points are created by paths or similar to minimise risk of soil erosion and tunnelling. ▪ Semi-aquatic plantings including sedges along the waterway edge and channel floor. ▪ Cross-channel planting bands to be jute mastered. ▪ Grassed floor areas of Kikuyu and Couch Grass. ▪ Clean-boled trees at pools with sedges on slight rises to primary channel level.
Longitudinal grade floodway treatments
▪ Relatively flat to keep flows below 1.0 m/s, rock armoured, felted geotextile application keyed in and lapped to prevent movement. ▪ Concrete cut off-s at 50 metre intervals if no natural rock is evident. ▪ Riffle structures ▪ Gypsum treatment at 20 t/Ha in accordance with recommendations by Van de Graaff (2018) using a dozer. ▪ 200mm of topsoil applied and watered in. ▪ Interim grassing.
Cross-sectional grades and treatments
▪ Floodway channel with batters of 1:6 horizontal to vertical, on floodway's with floors of 1:40 floor grade. ▪ Shotcrete-battered 1:1 primary channel. Primary channel to have a rock edge over geotextile. ▪ Primary channel edge treated using a combination of large fitted and placed rocks in a double layer with compacted backfill of 40mmdia rock and coarse sand mix. ▪ Felted geotextile laid against shotcrete treatment. ▪ Topsoil placed over the edge of the treatment and compacted/rolled. ▪ Light weed mat.

Access tracks
▪ No formed tracks required. ▪ All temporary tracks to have fibre geotextile laid and rock placed on the surface, then removed upon completion.
Sediment ponds
▪ Connected into main channels via pipes. ▪ Base of machine access ramps of sediment ponds ben below natural water level, to be concreted to aid desilting. ▪ Remainder of comments here are somewhat unclear without plans in hand. ▪ Upper safety benches and submerged marsh zones will need to be treated with gypsum and topsoiled as per Van de Graaff (2018).
Summary of report
The report is quite general and lacks scientific detail. Several of the references to bank erosion, water flow, soil sodicity, erosion and other factors are not as comprehensively detailed as they could be. This may be all that was asked of the report. Geomorphological elements of the design of channels, which were the intended purpose of the report is lacking in references. Rock will slow down flow velocity and reduce the 'entrainment' of dispersed water, however it will not necessarily reduce the dispersion of clay. Dispersion of clay is reduced or eliminated by: ▪ Stabilisation of dispersive soil (clay fraction) by gypsum treatment and soil cover. ▪ Covering stabilised soil with a protective shroud that eliminates freshwater contact. The report indicates that high sodium concentrations in some of the soil samples indicate that local soil water and groundwater is likely to be affected by salinity. The report recommends keeping a pilot channel in the centre of the waterway, rather than meandering within the waterway. A meandering channel was not recommended due to potential erosion on the outside of the bends of the channel. No gypsum recommended for topsoil. This will be critical given that topsoils are expected to be dispersive. Establishment of grasses is proportional to soil condition and the presence of topsoil. Topsoil is necessary in all areas for site rehabilitation. Native and introduced vegetation, including aquatic vegetation require reasonable topsoil to establish and develop. Based on experience, any area of water flow on a dispersive surface of more than 1.0 m/s will lead to erosion. Revegetation success will be proportional to what the plants are growing in. Comments on deep rooted species are left open to interpretation, no species recommended. Mowing not recommended for management is unusual – a one pass mow with wheel tracks is unlikely to cause surfaces to erode if carried out when dry and accessible. River Red Gum and Grey box will be hard to establish.

Kalkallo Retarding Basin Geotechnical Assessment Report. GHD, May 2019.

The GHD report has been reviewed and is mostly related to deeper soil conditions for geotechnical use. A summary of the report is listed below. Fieldwork carried out in March 2019 and reporting in May 2019.

The investigation included 15 boreholes to 4.4-5.0 metres below ground level, 5 test pits and 5 dynamic cone penetrometer tests to depths of 0.45-2.4 metres below ground level.

A generalised geotechnical model was provided in Table 2. This lists the conditions as:

- Unit 1. Topsoil - CLAY (OH). 0.5-1.1 metres.
- Unit 2. Colluvium - CLAY (CH), traces of sand, pale brown with orange mottling, becoming orange brown. 0.5-1.1 metres.

- Unit 3. Residual newer volcanics. CLAY (CL), gravelly and sandy, orange brown, fine to medium grained sand and subangular gravel. 1.3-4.8 metres.
- Unit 4. Newer volcanics. BASALT, dark grey. 2.2-4.5 metres.

Reports discuss soils as clays. Table 4 summarises the results of moisture content, Atterberg limits and Emerson Dispersion Class for all tested samples. Of the 20 samples tested, all recorded an Emerson Class of 1 or 2, indicating that full or partial dispersion occurred upon immersing in fresh water.

The report discusses dispersive and reactive soil and classifies material in the upper horizons of the Kalkallo basin accordingly. The report indicates that these soils are susceptible to piping failure from cracking. Linear shrinkage tests confirm that the soil will shrink by up to 20% upon drying.

The report notes that compaction is critical to achieve. The report notes that soil stockpiles should not exceed 1:2 grades and a height of 2.0 metres with temporary erosion and sediment control measures.

Section 6 summarises recommendations as follows:

- Soil improvement by lime stabilisation, compacted to 95% of standard maximum dry density. This is a standard measure that should be practiced for all soil around pipes, structures and where materials require stabilisation within embankments. It is not practiced on broad-scale application such as detention basins, many hectares in size because of practicality or cost. It could be considered, however soils forming the floor of basins will respond more cost-effectively to gypsum.
- Use of Geosynthetic clay liners, such as ECOSEAL, with all soil used as backfill in trenches treated with lime.

The report is unclear on the type of lime for use in stabilisation. Hydrated lime is required. Ag Lime should not be used. The report also does not specify rates for stabilisation. There is no mention of use of gypsum in the report. This is not unexpected given that gypsum is not a standard material for use in geotechnical applications.

The report notes that protection of earthworks is required due to the highly dispersive nature of the soils present on the site. To manage the issue of dispersive soils, the report recommends to keep vegetation clearing to a minimum and install drainage measures to control runoff.

A high proportion of earthen storage dams and channels in the Riverine Plain of south-eastern Australia, north of the Great Diving Range, are built on and from dispersive and sodic clays. When adequate control measures are in place during earthworks, storages and channels are of a low risk of erosion and failure. Control measures include compaction, topsoil shrouding, lime stabilisation of soils within banks and around structures, gypsum stabilisation of the surface shroud and several other design batters around banks and batters.

Jacobs Independent Peer Review of the Brizga & Seymour (2018) report.

This report was carried out by Jacobs in a request by Melbourne Water to review current design proposals for construction of the Merrifield Central Waterway, specifically geomorphological issues and the management of dispersive soils. Elements of review include:

- Design parameters
- Hydrology
- Hydraulics
- Subsurface conditions and soils
- Geomorphological issues
  - Bank erosion. Control measures include:
  - Bed controls
  - Channelisation and flow confinement
  - Loss of channel capacity due to aggregation
- Design response to geomorphological issues
  - Longitudinal grade and floodway treatments

- Cross sectional grade and treatments
- Construction and maintenance track access
- Sediment ponds
- Revegetation
- Constructability

Jacobs provided design solutions to some elements of the proposed design. The main design solution relates to the use of seasonal wetlands and the configuration, hydraulic behaviour and surface treatment of soils forming both seasonal wetlands and a low flow channel.

Conclusions of the report include changes to the design by Brizga and Seymour, which include:

- Clearer demonstration of and the design of drawings that show that rock chutes, bed and banks will be effective in providing a stable channel configuration. It needs to be demonstrated that rock chutes and armouring in different areas of the channel will withstand expected shear stresses. This is agreed. The Brigza and Seymour report provides several references to options however the specifics around these measures is not overly detailed. No drawings were provided.
- Strategic locating of rock chutes, then using rock mulch to protect clear from erosion, rather than full rock treatment. Agree.
- Avoidance of the use of concrete in sodic soils as this is inflexible, prone to undermining and susceptible to failure if dispersion occurs. The use of bentonite geofabric and rock treatments is recommended to provide a more flexible structure, which will resettle if dispersion was to occur. Agree.
- Construct the channel in sections and stages to manage erosion risks. Agreed. The notes prepared indicate that each section of waterway entering the Kalkallo Basin should be reviewed for design specifications, with treatment options increasing proportional to the erosion and exposure risk.

The main missing item here is discussion around topsoil management. The Brigza and Seymour refer to topsoiling and also to revegetation, however the importance of topsoiling and correlation between topsoiling and revegetation success is not made clear in the report. Use of topsoil, stabilisation and management of topsoil are critical factors.

SESL Kalkallo Retarding Basin – Soil Science Investigation

Site
Kalkallo Basin
Purpose
▪ Understand the extent of, and risks associated with the site soils ▪ Identity management strategies for possible future uses of the site ▪ Determine if there is excess land within the designated retarding basin that could be developed for other purposes, and ▪ Assess topsoils to determine the potential re-use quantities of biosolids as a soil ameliorant.
Methodology
▪ Assessment of 38 sites in a grid fashion, 1 per 10 Ha. Each site reflected a grid point where sub samples were collected by sampling every 5 metres and composite sampling 0-10cm, 40-50cm and 90-100cm. All investigation was limited to the top 1.0 metre. ▪ Laboratory analysis.

- Laboratory chemistry: pH (water), pH ($CaCl_2$), EC, organic matter, nitrate, phosphorus, potassium, calcium, magnesium, sulphur, iron, boron, manganese, copper, sodium, chloride and cation exchange properties.
- Topsoil physical properties including texture.
- Subsoil chemical properties, including pH (water), pH ($CaCl_2$), EC, potassium, calcium, magnesium, sodium and cation exchange properties.
- Subsoil physical properties, including soil texture and dispersion.

Findings

1) Sodic soils identified on the site.
2) Risk of dispersion is currently low due to long-term site stability.
3) Soil conditions do not vary widely across the site with clay textures dominating.
4) Topsoils are generally slightly to moderately acidic in water and EC is low.
5) Organic matter in the topsoil is moderate; organic matter was not tested in subsoils.
6) Sodic conditions increase with depth.
7) Soils are amenable to improvement with gypsum and biosolids; and
8) There is a natural detention basin on the site with potentially redevelopable land around the periphery.

Additional findings

- Soils found to have both vertic and non-vertic properties
- Low-lying and central sections as darker soils with greater shrink-swell capacity.
- Profiles in the north and west of the site were paler in colour and dis not exhibit the same degree of shrink-swell and were not vertic.

Test results are as follows as extracted from the report:

Analyte	Topsoil	0.5 metres	1.0 metre	Comment
pH (assume water)	6.0	7.3	8.1	Normal for clay soils.
EC (dS/m)	0.1	0.28 (High)	0.98 (High)	Acceptable to 0.5m, very high at depth. Results are normal and expected.
Sodium % (ESP)	6.0 (High)	13.5 (High)	21.5 (very high/ extreme)	High in the topsoil, very high at depth, increasing down the profile, expected for colluvial and alluvial or volcanic clays in this region.
Chloride (mg/kg)	80	365 (High)	1200 (very high / extreme)	Acceptable in the topsoil, sharp increase with depth. Surprising the EC is not higher at 0.5m with 365 mg/kg of chloride. Subsoils should be viewed as saline.
Cation Exchange Capacity (CEC)	20.5	30	47	All results are relatively high. Normal for clay soils.

Comments regarding the findings

1) Sodic soils identified on the site.	Sodic soils are widely found in the region and results are as expected, with results consistent with literature including Jeffery (1981) and others. Literature covers differing geology including colluvial deposits and newer volcanics. These conditions were also found by Jacobs during recent investigations in the area of Beveridge North-West and Shenstone Park.

	Even at low levels of sodicity or where soils are deemed non-sodic, dispersive conditions often prevail given low EC levels along with the influence of exchangeable potassium (Rengasamy & Marchuk, 2010). This occurrence was also noted in the Jacobs Beveridge North-West study. Comment - Although the site is deemed stable and erosion risks deemed low, as soon as the site is disturbed the opposite observations are likely to be noted following rainfall. This occurrence has been observed in the field in this region on other construction sites subject to rainfall.
2) Risk of dispersion is currently low due to long-term site stability.	Risk of dispersion was deemed low by SESL, but the risk of dispersion will increase with the removal of topsoil and disturbance of subsoils. Based on experience and literature from this region, this assessment is likely to be of high accuracy. The risk of dispersion should be broken down into two forms of disturbance with associated risk: ▪ Undisturbed: Low risk, as noted by SESL. ▪ Disturbed: High to very high risk. With disturbance there is usually movement or scraping of topsoil, exposing both non-sodic and sodic, or dispersive subsurface topsoil or subsoil clay. With disturbance comes the movement or loss of organic matter which provides significant stability. Stability is derived from organic carbon and long-term pasture growth. Applied organic matter may provide some stabilising effect, however it may not be as effective as the pasture and organic matter already present on the site.
3) Soil conditions do not vary widely across the site with clay textures dominating.	Given the test results and observations, it is highly likely that soil conditions do not vary widely and there is a dominance of clay soils. Should this be the case, amelioration and soil management strategies for construction works within the basin will need to be of the highest quality. Of interest is the presence of clay-dominant conditions from the surface to depth (uniform profiles), or whether soils show surface textures lighter than clay (clay-loams, deemed gradational). The presence of any duplex soils with a sharp contrast between the A and B horizon are also important to ascertain. From the report I have not been able to locate topsoil texture recordings, although they were noted as collected. This is particularly important to understand if soils, although classed as vertic / clay-dominant, evince textural change between the A1 and B1 horizon where a topsoil layer is defined. Even where topsoils are clay-loam over clay, the identification and approximate depth of topsoil allows more detailed recommendations to be made concerning site management.
4) Topsoils are generally slightly to moderately acidic in water and EC is low.	Topsoils are likely to be acidic as found along with EC levels. These conditions confirm that soils are likely to disperse at lower ESP levels than they would if the EC level were higher. The results for pH confirm that the soils are low in calcium as found in the soil test pack by SESL. Results confirm that all options for application of calcium ameliorants to soils are available, including Agricultural Lime or Gypsum.
5) Organic matter in the topsoil is moderate; organic matter was not tested in subsoils.	Organic matter levels were not averaged or summarised in the report. The comment that organic matter levels in the topsoil are moderate (section 1 Topsoil analysis) has been reviewed by checking soil test results. Tests of topsoils show that most 0-10cm samples recorded organic carbon levels of 2-4% (corresponding organic matter levels of 3.4-6.8%). It is agreed that these levels are moderate. Organic carbon and organic matter levels will decline with the movement of topsoil and stockpiling. For use of topsoil for finished surfaces of the retarding basin or waterways, topsoil will require

	shifting and replacement over a short timeframe with seeding soon following placement.
6) Sodic conditions increase with depth.	Sodic conditions increase with depth as found in the test results. The results confirm that levels start on the surface averaging 6%, the trigger for a sodic soil. These increase to 13.5% at 0.5m and 21.5% at 1.0 metre. These are highly sodic but not unusual for soils of this type. For this project it is critical to limit depth of excavation or soil movement where possible, as the sodic soil exposure risk increases with depth. Shallower material requires less ameliorant than deeper material.
7) Soils are amenable to improvement with gypsum and biosolids; and	Soils will be amenable to improvement with ameliorants including gypsum and biosolids. Of importance is the ability to also use Agricultural Lime and other available forms of organic matter. Although Lime is not soluble, it is a good source of soil calcium which is low in EC and takes pressure off the total reliance on gypsum as a chemical ameliorant. Biosolids are a very attractive ameliorant to stabilise soils based on their carbon content at approximately 20%. The ability to stabilise soils is proportional to the high carbon content by comparison with other sources of organic matter such as straw. The risk with biosolids relates to metal contaminants which may become mobile under anaerobic conditions. Experience with old biosolids stockpiles from Melbourne Water confirms that contaminant levels exceed the maximum thresholds for fill, triggering Category C or B waste. Movement of contaminants is unlikely to be a favoured option. Biosolids with low contaminant levels are an attractive material for stabilising soils. Straw and woodchips are also other attractive materials to stabilise soils or act as materials to compliment revegetation of disturbed sites.

Other comments regarding the report:

The report comments on how the Blackman Creek Dam was stabilised during failure and notes that soils were treated with gypsum along with infilling water. This is not standard practice. Gypsum is a salt and flocculates soil, creating a 'fluffing' effect. Gypsum is purposely used in agricultural and environmental management for improving infiltration and water movement, rather than slowing it down. These conditions are not favoured on embankments. For the Kalkallo site, dispersive soils which are appropriately compacted to specification are likely to seal and hold water, restricting water movement through banks. Gypsum is only used on the surface shroud to minimise rill erosion.

The report notes that the low relief of the site 'means that water velocities will seldom be high' and 'low energy water would not drive transport of dispersed soils'. I see this as incorrect as dispersed clay once reacted with water causes clay to displace into suspension. Even at low energy or nil energy conditions, dispersive soil entrained in water will transport with further runoff.

Report indicates that innovative engineering solutions would be encouraged on soils of the site. No solutions were provided.

Report confirms that very high calculated rates of gypsum are necessary.

Report notes that soils are currently stable.

Sodic and dispersive soils will aid the sealing and clogging of soil pores forming the embankment of the basin. There is not expected to be losses of water to deep soil percolation.

The subsoils are saline however this should not impact use of the site as a retarding basin and wetland.

Because of the scale of the site and project, gypsum will need to be relied upon for stabilisation of any topsoil removed or disturbed. Subsoil stabilisation, although needed, is less likely because of logistical issues and cost.

All information reviewed in this document places weighting on appropriate topsoil management, ensuring the surface of the site can be stabilised during and upon completion of works.

Appendix B. Geomorphological flow criteria

Boundary shear stress is commonly used to predict sediment mobilisation (Gordon et al. 2004). A useful rule of thumb is that the critical shear stress (measured in N/m^2) to initiate mobilisation is equivalent to the diameter of the particle measured in millimetres (Gordon et al. 2004). This rule of thumb applies to round particles, with flat shaped particles requiring half the tractive force for movement (Newbury & Gaboury 1993).

There is also a theory of 'equal mobility', that states that all grain sizes move at nearly the same discharge. This theory predicts that, rather than the entire bed becoming mobile at a particular threshold discharge, the bed selectively and progressively unravels from different locations as discharge increases. The amount of shielding, packing, or imbrication in addition to the particle size can influence the potential mobility of sediments (Gordon et al. 2004).

An analysis of the potential for modelled flows to scour channel surfaces can be made with reference to published information on critical shear stresses for scour and incision for a range of sediment textures and vegetated surfaces (Table B.1). The minimum shear stress to impact the least hard of grasses (i.e. poorly established bunch grass) is 80 N/m^2. It generally appears that critical shear stresses in the range 100-200 N/m^2 will remove most in-channel vegetation.

Table B.1 : Critical shear stresses leading to scour and incision for a range of sediment and vegetated surfaces.

Sediment	Mean grain size, D^{50} (mm)	Critical Shear Stress (N/m^2)	Source
Silt	0.016-0.0625	~0.065-0.11	(Hanson & Simon 2001, Hawley & Vietz 2015, Julien 1998, Simon & Thomas 2002)
Soft clay	-	5	
Stiff clay	-	50	
Sand	0.0625-2	~0.11-0.47	
Gravel	2-64	~1.26-53	
Cobbles	64-256	~53-223	
Boulder	>256mm	>223	
Vegetation type		**Critical Shear Stress (N/m^2)**	**Source**
Aquatic swampy vegetation		105	(Prosser & Slade 1994)
Tussock and sedge		240	(Prosser & Slade 1994)
Disturbed tussock and sedge		180	(Prosser & Slade 1994)
Bunch grass, 20-25cm high		184	(Prosser et al. 1995)
Bunch grass, 2-4cm high		104	(Prosser et al. 1995)
Bunch grass		80-170	(Hudson 1971, Reid 1989)
Bermuda grass		110-200	(Hudson 1971, Reid 1989)
Buffalo grass, Kentucky bluegrass		110-200	(Hudson 1971)
Buffalo grass		110-180	(Reid 1989)

As assessment of thresholds for the removal of macrophytes can be made with reference to an application of work by Groeneveld and French (1995). Based on a macrophyte stem diameter of 11.9mm, two thresholds are reported on as representing a 95% or 99.9% chance of stem rupture. The thresholds are reported as a discharge required for the product of flow depth and velocity to exceed either 0.152 (Qm95%) or 1.52

(Qm99.9%). Velocity was assumed to be the cross-section mean and depth was maximum channel depth. While this relationship is specific to ***Scirpus acutus***, it would be expected to apply to robust macrophytes with moderate resistance to hydraulic stress such as Typha and Phragmites. This relationship has been applied to evaluate the potential impacts of flow management on Typha establishment along the Little Murray River (Gippel 2014).

It has also been reported that macrophyte abundance generally peaks at 0.3-0.5 m/s (Riis et al. 2008) and that 1 m/s is an upper limit of velocity above which macrophytes are few or absent (Chambers et al. 1991). It has also been noted that ***Typha*** spp. are not found in water deeper than 2 m (Greening Australia 2007).

Appendix B. – Options Report and Matrix Analysis

KALKALLO BASIN

Option Analysis

2.0 | Draft

March 24, 2021

Melbourne Water



Kalkallo retarding basin - design of stormwater assets in dispersive soils

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Appendix A. – Options Analysis

Appendix B. – Matrix Output

Important note about your report

The purpose of this report and the associated services performed by Jacobs, Spiire and South East Soil & Water (SESW) is to document the outcomes of a Basin Designs – Options Analysis, Task 3 of *the Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils* project. The purpose of this task is to outline the potential water quality and hydraulic conveyance options available to Melbourne Water to enable the preferred asset configuration within the Kalkallo Basin to be determined. The work has been conducted in accordance with the scope of services set out in the contract between Jacobs (Australia) and Melbourne Water.

In preparing this report, Jacobs, Spiire and SESW has relied upon, and presumed accurate information provided by Melbourne Water and/or other sources as referenced in the report. Except as otherwise stated in the report, Jacobs, Spiire and SESW has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, the observations and conclusions in this report may change.

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This report has been prepared on behalf of, and for the exclusive use of, Melbourne Water subject to, and issued in accordance with, the provisions of the contract between Jacobs and Melbourne Water.

1. Introduction

1.1 Background

This report documents the outcomes of a Basin Designs – Options Analysis, Task 3 of *the Kalkallo Retarding Basin – Design of Stormwater assets in dispersive soils* project. The purpose of this task is to outline the potential water quality and hydraulic conveyance options available to Melbourne Water to enable the preferred asset configuration within the Kalkallo Basin to be determined.

The current concept design/strategy for the Kalkallo retarding basin (per the current DSS) proposes three large wetlands, a series of constructed waterways and an upgrade of the existing retarding basin functionality. This project is a study that aims to minimise disruption to the sodic soils that have been identified within the southern catchment areas feeding the basin as well as providing a design of scheme water treatment assets to address the sodic soils within the basin itself.

1.2 Report structure

This report documents the methodology and results of an options analysis undertaken for the Kalkallo Basin project, with the distinct goal of determining the best solution to accommodate the sodic soils within the upstream catchment and within the basin site.

The steps to narrow down the available options were completed via a two-step process:

1) An options analysis collating a full range of scenarios that may apply to the site with the resulting suitability providing a basis for the next step (Refer to Section 2 for details on options analysis),
2) Ranking the resulted options within a matrix framework based on Melbourne Water (MW) objectives outlined in the project brief, and other key drivers to help quantifiably assess the best option combinations to be adopted for the site (Refer to Section 3 for details on assessment matrix).

The information presented herein is based on a review of documentation and internal technical discussions between the combined Jacobs, Spiire and South East Soil & Water team.

2. Option Analysis

The options analysis process was used to collate design scenarios applicable for the Kalkallo Basin project. This step required the review of existing information, an ideas generation meeting amongst technical staff from different disciplines within Jacobs and Spiire, collating all potential design/construction methods for the site and formal documentation provided in the tables in Appendix A.

The advantages and disadvantages of each scenario were assessed, with other general comments provided to determine whether an option was suitable for the site. The process narrowed the multitude of scenarios and assisted in finding any commonalities to inform the ultimate recommendations. Scenarios/strategies were assessed based on the following categories:

- Administrative tools and pre-design assessments
- General principles for working in sodic soils (site specific)
- Design Options: Best practice water quality treatment
- Design Options: Stormwater conveyance
- Design Options: Retardation
- Construction considerations
- Ongoing considerations and maintenance
- Other Considerations – Options/Opportunities

An overview of the key findings of the options analysis has been presented in Table 1, which outlines the most appropriate options for the site. Note that Table 2.1 does not include a number of options listed in the initial options analysis, as they were deemed unsuitable for the site. A more detailed/thorough overview listing all options, the advantages and disadvantages of each option and assessing their applicability, has been provided in Appendix A.

Table 2.1: Options Analysis Outcome

Objectives	Suitable methods, strategies and options
Administrative/Pre-Design/Miscellaneous tools Key considerations: ▪ These are tools that can be developed/utilised by MW, with the express goal of assisting or prompting designers to consider sodic soils (i.e., prior to design). Failures can occur when improperly designing water assets within sodic regions. These tools/options will likely be more suited for future sites within the catchment (or even other catchments)	▪ Testing of pre-existing turbidity of stormwater discharging into/out of the site (A1)* ▪ Pre-development advice to include sodic soil requirements/considerations within sodic regions (A3) ▪ Mandate a soil test for every site within sodic regions, to determine the proportion of exchangeable sodium in soil (A4) ▪ Preparing specialised standard drawings for waterways/wetlands for sodic areas (i.e. addendum to original design manuals) (A5)
General principles and options for working in sodic soil - specifically in Kalkallo Basin drainage reserve. Key consideration:	▪ Restrict development in steep areas (G1) ▪ Treatment of sodic soils with calcium-based ameliorant (G2) ▪ Treatment of soil with physical ameliorants (G3) ▪ Treatment of sodic soils with organic material (G4)

Objectives	Suitable methods, strategies and options
▪ These options present general design principles that should be employed within the Kalkallo Basin drainage reserve	▪ Reducing or eliminating freshwater contact with sodic soils (including rainfall) (G5) ▪ Retention and reuse of all topsoil containing organic matter (G6) ▪ Topsoil use for plant growth. Importation of suitable/high quality topsoil (G7) ▪ For any structures – assess and provide options that reduce disturbance (G9) ▪ Areas of topsoil to be mapped throughout the site, prior to design/construction (G10) ▪ Reduce all excavation depths (G11)
Design Options/Considerations: Best Practice Water Quality Treatment Key considerations: ▪ Stormwater quality treatment options should aim to treat stormwater as per standard stormwater quality objectives. ▪ Water quality assets should consider turbid and potentially saline runoff. ▪ Turbid flows are expected in larger stormwater events. ▪ The large receiving catchment will change over time. During construction, it is expected that turbidity of water will be at its worst in the short-term, then slowly become more stable long-term as the catchment is developed (i.e. post-construction).	▪ Constructed Wetland (Standard) (WQ1) ▪ Constructed Wetland (Alternative) - would include alternative design principles e.g., higher extended detention, alternative plant selection (WQ2) ▪ Test "Pilot" Wetland Construction (for research purposes) (WQ4) [could be integrated into other options below i.e. WQ6] ▪ Modular wetland design (full wetland constructed in parts) (WQ5) ▪ Splitting large wetlands into several smaller wetland cells (WQ6) ▪ Large sediment pond to treat incoming suspended solids. (Potential location for future flocculation) (WQ7) ▪ Adopting local, salinity hardy and /or turbidity resilient plants for terrestrial and aquatic planting (WQ12) [Can be utilised in other options above] ▪ Turbid water sheeting through paddocks and vegetation (WQ14) ▪ Leaving the site largely untouched, or minimising construction (i.e., light touch approach) (WQ15)
Design Options/Considerations: Water Conveyance Key considerations: ▪ Water Conveyance options relate strictly to the conveyance of flows throughout the site. ▪ All options must consider the need to convey large magnitude of flow throughout the site Some consideration should be given to ecology, community outcomes and amenity for the site	▪ Earthen constructed/planted waterway (Standard) (WC1) ▪ Earthen constructed/planted waterway (Alternative) (i.e., using alternative design approaches, cross sections, longitudinal grades etc.) (WC2) ▪ Sediment basins into entrance of waterway (WC3) ▪ Lined waterways (i.e., concrete lined) (WC4) ▪ Grade control and reduced batter slopes (WC5) ▪ Specifying use of calcium-based ameliorants to stabilise disturbed areas (WC6) ▪ Minimising construction footprint (WC7) ▪ Non-degradable geofabric to protect any steep batters/sensitive areas (WC8) ▪ Reverse grade channels to reduce low flow velocities and increase vegetation (WC10)

Objectives	Suitable methods, strategies and options
	▪ Leaving the site largely untouched/minimising construction (i.e. light touch approach) (WC11)
Design Options/Considerations: Retardation Key considerations: ▪ Any option will relate to the need to upgrade the existing retardation capabilities of the site, to allow for the future increase in developed flows. ▪ Allowance for flood immunity and maintaining current 1% AEP flood level within the site (231.4 m AHD). ▪ Stormwater retardation to maintain existing discharge rates to downstream waterbodies/creeks.	▪ Leaving the site largely untouched/minimising construction (RB2) ▪ Favouring deep bulk earthworks and reduced surface area disturbance, to provide storage volume (RB3) ▪ Favouring shallow bulk earthworks and increased surface area disturbance, to provide storage volume (RB4) ▪ Targeting excavation in areas where there is not as much existing topsoil or biomass coverage (RB5)
Construction Considerations Key considerations: ▪ Design stormwater assets in the Kalkallo retarding basin must be appropriate to the dispersive soils and that will minimise clay dispersion during construction and operation of the assets. ▪ Retardation option must consider the scale of the drainage reserve area (380 ha) and staging of construction. ▪ The construction methodology is to consider sodic soils within an online system. ▪ Construction timing over the life of the project should be considered.	▪ Flocculation of stormwater throughout periods of construction (reducing turbidity to pre-determined value) (C1) ▪ Reducing extents of machinery movement/ minimising extent of works (C3) ▪ Not disturbing any areas until necessary (C4) ▪ Staging development of the basin, to reduce the amount of area disturbed at one time (C5) ▪ Maintain/retain actively growing biomass where possible (C6) ▪ Avoid removing trees (C7) ▪ Timely placement of organic matter/suitable topsoil, to assist in rapid propagation of grass seed (C8) ▪ Stabilising any dispersive soils and disturbed ground with Gypsum or Lime(C9) ▪ Retention and reuse of all topsoil to cover exposed sodic soils (C10) ▪ Shrouding / covering the surface with topsoil/mulch/straw etc. to stop the effect of rainfall impact on sodic soils (C11) ▪ Utilising geofabric barriers for soil protection (C12) ▪ Regular (daily/weekly) assessment of site to identify bare areas (C13) ▪ Ceasing major construction/excavation activities prior to rainfall event, where possible (C14) ▪ Design of infrastructure to consider scale of the asset, such that it can be constructed and established in a timely matter (C15) ▪ Implementation of effective bypass systems during construction (C16) ▪ Staging and timing(C17)

Objectives	Suitable methods, strategies and options
	▪ Test "Pilot" Construction (for research purposes) (C18)
Ongoing Considerations/Maintenance	▪ Flocculation - ongoing treatment of incoming water (M1) ▪ Ongoing monitoring of the site and reapplication of topsoil/shroud material where necessary (M2) ▪ Enforcing management of future construction sites (i.e., managing stormwater discharged from contributing catchments) (M3) ▪ Carry out slashing/mowing of groundcover where site remains vacant (M4) ▪ Irrigation of area using water with Gypsum/calcium additives within water (M5)
Other Considerations - Options/Opportunities	▪ Ecological enhancement opportunities (O1) ▪ Amenity for the site (O2)

*All references (e.g. A1, WQ1, M2) are used to categorise and distinguish the various options

The analysis showed that dozens of strategies can be applied to the site.

To quantify the effectiveness of each of the scenarios (i.e. listed in the above table), a matrix framework has been applied (see Section 3). In doing so, the multitude of options can be ranked to narrow down methods to be applied to the site. As part of developing the assessment matrix, the following was determined:

- Pre-design/administrative options and construction/maintenance considerations would be applied in all scenarios. That is to say, the construction, maintenance and administrative scenarios should be applied in any design option ultimately selected for the site.
- The matrix ranking system would therefore only assess and rank each of the options relating to water conveyance, water retardation, and stormwater quality components. It was determined that these three components would be ranked within a matrix system, as they are the options in which a single 'winning option' would need to be selected.

Some general outcomes that were made clearer from this process were:

- The system can be built with mitigation measures, such as chosen plants, and short-term turbidity treatment during vegetation establishment phases, to have a higher chance of survival in a higher turbidity risk environment.
- Levels of turbidity for "aesthetic reasons" will be determined by Melbourne Water but the only applicable successful method to remove dispersed clay is by flocculation. It is noted that the turbidity risk is highest at the early stages of catchment construction and over the long term, it is expected the catchment will stabilise with turbid runoff reducing.
- Construction disturbance (cut and fill) is a critical component and is to be considered early on and factored in. Topsoil mapping is a key component as it is very advantageous to reuse any topsoil available on site.
- The primary outcome of gypsum application is to condition the soil for vegetation establishment which will hold the soil together long term.
- Ongoing maintenance are major factors in all scenarios.
- The ability of an option to reduce turbidity was shown to be largely poor at determining its suitability. Nearly all options were deemed to be ineffective at removing dispersed fine clay particles in water.
- The large scale of the site was a key determining factor of whether an option is most suitable.

3. Matrix Analysis

A matrix analysis has been undertaken to quantifiably rank the multitude of options deemed applicable for the site. The methodology of the matrix process, and the results of the analysis has been provided below.

3.1 Process of Analysis

The initial analysis showed that a large variety of options could be applied to the site. Therefore, as noted above, it was determined that a matrix framework should be applied. As an outcome of the options analysis the framework groupings of the assessment matrix apply to design options relating to:

1) Water Quality
2) Water Conveyance
3) Retardation

Therefore, to encapsulate the effectiveness and risk of each option, several parameter categories were integrated within the matrix to best represent the decision-making process, with rankings and weightings ultimately based on internal technical discussions. The categories in which each of: Water Quality, Water Conveyance and Retardation, were assessed are as below:

A. Upfront costs
B. Maintenance difficulty/ongoing costs
C. Meeting construction objectives
D. Effectiveness of meeting MW objectives
E. Ability to reduce turbidity
F. Ability to function in turbid water
G. Risk of failure over time
H. Suitability for the large site (scale)
I. Environmental and community considerations

3.2 Weighting of Options

Each of the categories were assigned a weighting based on the suitability to the site, with the highest weighted parameters being: 'D - effectiveness of meeting Melbourne Water objectives', 'H - suitability for the large site' and 'G – risk of failure over time'.

The weightings (as per the table below) will be key discussion points in future correspondence and workshop discussions with Melbourne Water. Stakeholder input, namely from Melbourne Water, will be required to ensure all weightings are appropriate. It is important to understand that the figures are subject to change and will be finalised as the project progresses.

A full summary of the category rankings has been summarised in Table 3.1. Full completed outputs have been provided in **Appendix B**.

Table 3.1: Design Assessment Weightings

Design Options Assessment Category	Weighting
Category A - Upfront Costs	0.4
Category B - Maintenance difficulty/ongoing Costs	0.9
Category C - Meeting Construction Objectives/Parameters	0.3
Category D - Effectiveness at meeting MW Water quality/conveyance objectives	1.0
Category E - Ability to Reduce Turbidity	0.2
Category F - Ability to Function within Turbid Water	0.2
Category G - Risk of failure over time	0.8
Category H - Suitability for site (i.e., scale)	0.75
Category I - Environmental and Community Considerations	0.15

3.3 Initial Results/Highest Scoring Options

The top three scoring options for each of 'water quality', 'water conveyance' and 'retardation': have been presented in Table 3.2, Table 3.3 and Table 3.4.

Table 3.2: Matrix Outcome Water Quality

Highest Scoring Options		Score
Rank 1	WQ6 - Splitting large wetlands into multiple cells	19.40
Rank 2	WQ5 - Single wetland; modular construction	17.50
Rank 3	WQ2 - Constructed Single Wetland (Alternative)	17.30

Table 3.3: Matrix Outcome Water Conveyance

Highest Scoring Options		Score
Rank 1	WC2 - Earthen/Planted waterway (Alternative)	20.80
Rank 2	WC1 - Earthen/Planted waterway (MW Standard)	20.00
Rank 3	WC8 - Piped high flows	18.15

Table 3.4: Matrix Outcome Retardation

Highest Scoring Options		Score
Rank 1	RB5 - Targeting excavation in certain areas (considering areas where there is existing topsoil or biomass coverage)	18.95
Rank 2	RB4 - Favouring shallow bulk earthworks over a wide area	17.85
Rank 3	RB3 - Favouring deep bulk earthworks in a single location or area	17.55

The options above will be workshopped with Melbourne Water, as they all have merits with respect to each of the objectives outlined (full breakdown in Appendix B). Therefore, a combination of any of the above options will likely be viable for the Kalkallo Basin site.

The outputs have generally determined that a major component of the high scoring options is related to the arrangement and physical shaping of the systems. The higher scoring options deal with arrangements of the wetlands, integrating local site-specific vegetation and employing targeted bulk excavation for the retardation basin to minimise sodic soil disturbance.

3.4 Assessment of Highest-Ranking Options

An assessment of the highest-ranking options has been undertaken below. Note that these options may be subject to change, following the workshop with Melbourne Water, and the modification of any of the weightings within the assessment matrix.

3.4.1 Splitting large wetlands into multiple cells (WQ6)

This option would involve splitting the large wetlands, as currently shown in the DSS, into several smaller wetlands. This option has numerous benefits, which includes:

- Mitigating risk over the course of the project - rather than building one large asset which may fail all at once and be subject to costly re-planting/rehabilitation, this option can distribute the risk.
- Being able to integrate the construction of a test wetland (i.e. as one of the initial cells) and to assess how resilient the wetland systems will be with the incoming turbid water (i.e. as per WQ2).
- Being able to still employ alternative plant species within the wetland cells (as per WQ2).
- Increases the stability of the site and incorporating appropriate slopes that provide stable landforms.
- Ensuring that each wetland cell is a manageable size for catchment growth.

It is noted, that due to the scale of the site, splitting the wetland to manageable cells also allows flexibility in the staging of the infrastructure. Additionally, this option is consistent with the design recommendations that have been outlined in the *Sodic Soils Catchment and Site Review*.

3.4.2 Earthen constructed/planted waterway (alternative) (WC2)

This option involves the use of constructed waterways as a means of conveying stormwater throughout the site. However, employing alternative design techniques will be critical to the stability of the waterway. Some considerations for the alternative waterway design include the following:

- Employing a reverse grade design (i.e. per WC10 in Table 1, and Appendix A), to assist in plant establishment, to achieve a more rapid stabilisation of the site.
- Wider and shallower channel cross section profile compared to industry standards for hydraulic conveyance, to reduce shear stresses within the waterway.

Overall, it is envisioned that this system will become more stable over time with more biomaterials and combined with a longer-term stabilising catchment will be an excellent outcome for the site.

3.4.3 Targeting excavation of areas that have existing topsoil or biomass coverage (RB5)

In achieving retardation objectives, the volume of sodic soils disturbed by construction (the footprint) should be minimised where possible thus the redistribution of topsoil is critical as part of the design. Meeting the retardation objectives will mean there will need to be significant excavation required throughout the site.

In assessing the options, the current design consideration is to target excavation (as much as practical) within areas of the basin site that have good topsoil or biomass coverage. Targeting the excavation in areas with better topsoil coverage will lessen the risk of exposing sodic soils and will also provide increased topsoil that can be utilised onsite as shrouding.

As part of the overall excavation for the site, topsoil mapping is recommended as a first step. Undertaking mapping of the site will give a more accurate understanding of where excavation will be best suited, while also identifying areas of greater topsoil (which will be important for re-use within the site).

Earthworks must consider the erodibility of the surface materials, height and gradient of the slope created and likely vegetation of batters. If steep batters are required within the site, options for further stabilisation must be investigated (e.g. use of rock beaching, geofabric and calcium-based ameliorants).

4. Further Considerations

Some additional considerations for the site have been discussed below.

4.1 Timing Considerations and Opportunities

It is important to understand how a selected option behaves over time. Opportunities throughout the lifecycle of the project need to be considered. The design process has shown that over the longer term, the incoming catchment area will become more stable as the catchment is developed and treatment of sodic soils are implemented correctly for development sites. Therefore, designs should consider the following:

- In order to minimise long term costs, increase efficiency of infrastructure and for construction ease, it is critical to have designs prepared as early in the project as possible, with certain infrastructure showing benefits to be constructed before the commencement of the wider catchment. The greater the delay in designs, the less efficiency and cost savings can be achieved.
- Where possible, the early establishment of vegetation and WSUD infrastructure is a key component of mitigating erosion risk. The process of establishment can take 4+ years, therefore, it is beneficial to fast-track any infrastructure that requires vegetation/planting, even where construction may commence before that of the catchment.
- With the build-up of biomaterial and vegetation, the site will stabilise overtime.

4.2 Short Term Strategies

It is expected that in the short-term period the site will receive more turbid flows. Flocculation could potentially be performed in the short term. This can potentially be achieved by implementing an oversized sediment pond and larger dry out areas (as it is understood that flocculation material will produce larger amounts of sediment compared to regular expected inflow).

It is understood that the detention of water will not be very effective in removing suspended clay from water within the site, and clay dropout can only be realistically achieved if chemically treated. However, using a large sediment pond will provide a large water body to allow for flocculation opportunities in the short term. Ultimately the sediment pond can be integrated back into the regular treatment train as the catchment stabilises in the long-term (i.e. where there is no longer a need for flocculation), though will simply be oversized. Volume sizes will be based on low flow events within the expected receiving catchment during early phases of construction.

5. Next Steps

- This document will be used as technical background information for a workshop with Melbourne Water.
- Within the upcoming workshop with Melbourne Water, the following key aspects must be discussed, and adjusted where necessary:
  - The list of design options for the site or gaps in the options presented.
  - The weightings, assessment criteria and rankings of the options per the assessment matrix.
- Adjustments/alterations to the assessment matrix/options analysis, following the Melbourne Water workshop.
- Once the four top ranked options are confirmed with Melbourne Water the following tasks will be undertaken:
  - Determination of the preliminary extent of works and depths of excavation for the water quality, conveyance, and retardation assets within the basin.
  - Development of MUSIC models for the options to determine if the current treatment areas within the DSS are still valid.
  - Preliminary costings for the design options.
- Selection of the preferred option for the Kalkallo Basin to cater for dispersive soils.
- Conceptual design of the preferred design option for the site

Appendix A. – Options Analysis

Pre-Design/Miscellaneous/Administrative tools

ID	Scenario/Option	Pros	Cons	Comments	Applicable Y/N
A1	Testing of pre-existing turbidity of stormwater discharging to site	Understand the current turbidity to inform future decisions	Cost and time investment	Testing to ascertain a base level of turbidity within the catchment. May form a baseline on what level of water that can be discharged off site, during the construction phase.	Y
A2	Mapping/Categorising all sodic regions in Melbourne	Can be used as a guide for all future sites.	Not an immediate solution	Creating a database of sodic regions to inform MW decision making in future development sites. Current state wide available data is sufficient for high level assessment, with further testing required during the individual design phase.	NA to N to discuss
A3	Pre-development advice to include sodic soil requirements/considerations within sodic regions	Raise awareness in the engineering community. Force engineers to consider sodic soil environment		For Melbourne Water and Council to mandate. Will affect development stages that are managed by Council and MW. So important that both have mechanisms	Y
A4	Mandate a soil test for every site within sodic regions, to determine the proportion of exchangeable sodium in soil	Understand the extent to which a site is prone to dispersiveness/erosion etc.	Additional cost to developer	Linked to A3	Y
A5	Preparing specialised standard drawings for waterways/wetlands for sodic areas (i.e. addendum to original design manuals)	To give designers and MW a framework to design water assets through (within sodic areas)	Cost and time investment	Potential additional outcome of the project	Y

General principles and options for working in sodic soil - specifically in Kalkallo Basin drainage reserve

ID	Scenario/Option	Pros	Cons	Comments	
G1	Restrict development in steep areas	Avoids additional earthworks	Limits the potential works area	Should not construct on slopes greater than 5%	Y
G2	Treatment of sodic soils with calcium based ameliorant	Inhibits dispersion	May be cost prohibitive, due to scale of subject site.	Example: using Gypsum treatment. Would ideally be a requirement in upstream catchments as well, to reduce SS load coming into the site. Gypsum will always be the default product for treatments, as it is readily available and easy to apply. **Specific Ameliorant Options:** **Gypsum [$CaSO_4$]** - stabilising topsoil (increases soil permeability and significantly reduces dispersivity **Hydrated Lime [$Ca(OH)_2$]** - for geotechnical/construction use. Increases soil strength. Useful for works around pipes/structures/roads/paths or any work that requires compaction **Agricultural Lime [$CaCO_3$]** - for acidic topsoil pH amelioration **Liquid soluble calcium** **Liquid Gypsum** **Liquid Lime**	Y
G3	Soil physical ameliorants	Contributes to the long term stability of soils, reducing erosion	May be cost prohibitive, due to scale of subject site	Using sandy topsoils, which are preferred for protective covering or shrouding. The sand fraction provides locking of particles and provides resilience to dislodgement. Sand fractions show basically no chemical reaction with fresh water Use of larger particle size/weight of clay - less likely to become suspended Gypsum requirement for stabilising sandy topsoils is much less than clay dominant topsoils Topsoil is critical in the strategy of this project, you must work to reuse available topsoil in the area. Mapping and redistribution of topsoil. This can be done by mapping the topsoil and this will give more accurate costing on what you need to treat the soil. Testing should be completed in the area within the retardation basin. Work to reuse the soil. Proposed mapping would be 50m x 50m grid, for a 300ha area 1200 tests, will take 12 days cost 30-50k.	Y
G4	Treatment of sodic soils with organic material	Reduces loss of structure in clay. Prevents slaking and dispersion. Prevents clay transportation when wetted	May be cost prohibitive, due to scale of subject site	Binds soil particles together; would ideally be a requirement in upstream catchments as well, to reduce SS load coming into the site	Y
G5	Reducing or eliminating fresh water contact with sodic soils (including rainfall)	Inhibits dispersion	The scale of the basin may make this difficult	Shrouding the surface; to be considered in conjunction with gypsum/organic material treatment.	Y
G6	Retention and reuse of all topsoil containing organic matter	Provides suitable material to shroud sodic soil areas	May not be enough material available. Stockpiling and testing on site will be required.	Should be considered, even after amelioration and treatment	Y

G7	Topsoil use for plant growth. **Amelioration of existing topsoil**	Allows for plant growth; no need for importation costs.	More ameliorants such as gypsum/lime would be required if the site topsoil has a high proportion of clays.	Treatment of topsoil to allow for plant growth; to allow for propagation of biomass, to anchor the soils It has been noted that plant growth will be limited in the Kalkallo region, within the sodic subsoils. Subsoils for the region are high in sodicity/salinity and contain high proportions of boron ad calcium carbonate. Soils are also high in pH May use Gypsum or agricultural lime to improve site derived topsoil. Vegetation is to be re-established after treatment to stabilise the soil	Y
G8	Topsoil use for plant growth. **Importation of suitable topsoil**	Allows for plant growth; allows to bring in topsoil that is more suited to the site (i.e. sandy soils). Imported topsoils would likely require reduced amelioration requirements, compared to using in situ topsoil	Has associated importation costs. Likely more expensive than using in situ topsoil, or ameliorating on-site topsoil (to investigate)	As Above (G7). Importation may mean we can bring in more suitable topsoil (i.e. sandy topsoils), which require no, or reduced amelioration with gypsum/lime etc. Sandy loam can be used as a component but gypsum is to be preferred. Importing sand will be an extra cost.	Y
G9	For any structures - look for options that reduce disturbance (i.e. piles vs trenching)	Reduces erosion potential	Piles would be comparatively more expensive than trenching	look to avoid structures that disturb - reduce trenching where practical	Y
G10	Areas of topsoil to be mapped throughout the site	To understand which areas can be retained/left alone.	Time consuming	Mapping all topsoil areas throughout the site. Topsoil is critical to be preserved (i.e. for use as shroud over dispersive soils), and need to understand where the bulk of the topsoil is etc. There are areas which can be retained, should not be blanket stripping of topsoil.	Y - refer the technical requirements. -
G11	Reduce all excavation depths	Minimise excavation of sodic soils	Impacts future flood storage requirements within the basin	The depth of cut should be kept to absolute minimum. Risk of exposure to dispersive/sodic soils increases proportionately with depth of excavation. This option needs to be weighed up against the flood storage requirement of the basin.	Y

Design Options/Considerations: **Best Practice Water Quality Treatment**

ID	Scenario/Option	Pros	Cons	Comments	
WQ1	Constructed Wetland (Standard)	Using MW's pre-existing design guidelines. Effective at pollutant removal; easier to maintain than bioretention systems; provides great amenity;	Some of MW's design guidelines may not be suitable for sodic sites	Wetland design per the current MW design manual/guidelines. Standard plants may not thrive in a sodic region. Proper compaction of soil underneath clay liner required during construction. Deep rooted plans for shallow areas, light turbidity and plant choice critical, but establishment is key.	Y subject to further investigation re plant suitability
WQ2	Constructed Wetland (Alternative)	Same as WQ1 (though not strictly using MW's design guidelines)	Some design elements may be untested, if wetland is not designed to MW's design guidelines	Changes to some design elements of the wetlands. Some examples: Different planting species/more resilient species; Increased EDD to reduce footprint. Vegetation is critical to keep the area stable , root growth is important to hold soil together especially within the first 200mm.	Y
WQ3	Constructed Reed Beds / Bioretention	Smaller footprint compared to wetland; same effectiveness at meeting water quality objectives	Harder to maintain; generally not suitable for large upstream catchments. Not preferred by Melbourne Water.	Could be part of a combination. Smaller footprint is a good aspect of the system, but unlikely to work as a standalone treatment in such a large site. Bioretention systems are normally for smaller catchments so not applicable for this site, and the filtration may create blockages from the turbid water.	N
WQ4	Test Wetland Construction (for research purposes)	Understand what does and doesn't work with wetland design in sodic catchments. Reduces risk of constructing a full/large scale wetland. Gives a proof of concept	Cost and time investment to conduct the research.	Could partner with Academic institutions, for ongoing monitoring and research. To de-risk the site and data mine. Timing dependent	Y
WQ5	Modular Wetland Design (full wetland constructed in parts)	Reduces risk with any potential wetland failure - could be in conjunction with ID-WQ4	When fully constructed, wetland will still be very large. Will need to come back to construct later stages.	Constructing the full wetland in parts - not constructing all at once. Issues relating to keying into the existing portion of the wetland. Scale and stability of system. Feeds in WQ4. Applies to larger sodic soils.	Y
WQ6	Splitting Large Wetlands into several smaller wetland cells	Reduces risk with any potential wetland failure - could be in conjunction with ID-WQ4. Wetlands split into more manageable sizes	Diversion structures and connection infrastructure between cells required. May require several outlets to control residence time	This will allow the construction of the water quality assets in stages. With staging potentially following development within the catchment. Can be used in conjunction with WQ4	Y
WQ7	Large Sediment Pond to treat incoming suspended solids. (Potential location for future flocculation)	Will treat incoming turbid water;	May only treat course sediments and be ineffective at removing suspended clay particles	Could have a large centralised sediment basin, and having several distribution mechanisms to feed various wetland cells (somewhat similar to raingarden design philosophy). Large sediment basin can be a site for flocculation to occur. Detention of water is not highly effective in removing suspended clay - potentially making a large sediment basin ineffective in reducing turbidity on its own. There is merit in providing a large sediment pond for the short term which can be used for flocculation during the catchment development.	Y
WQ8	Using proprietary GPT type units at the outlet of each development/upstream catchment contributing to the site. To reduce turbidity of incoming water	May provide an initial treatment of incoming flows. May reduce the size for potential sediment basins	Proprietary units cannot remove highly dispersed/suspended clay (but could work in a treatment train)	Can mandate the construction of proprietary GPT units. Could reduce the footprint of sediment basins in the reserve (and thus the area of disturbance) Units unlikely to remove suspended clay within incoming stormwater	N

WQ9	Filtration of incoming water	Filtration would target larger particles and may be ineffective at removing suspended clay	High cost	This allows larger particles to be removed. However, not effective at removing suspended clay	N
WQ10	Aeration of Water	no value in removing suspended clay	no value in removing suspended clay	Providing oxygen to water supplies, improving the rate of breakdown of organic material within water. Confirmed not applicable for this site.	N
WQ11	Specialised on-site treatment plant, to remove suspended sediment	formal chemical treatment process can remove suspended clay	Extremely expensive	Unlikely to be viable from a cost perspective.	N
WQ12	Adopting local and salinity hardy plants for terrestrial and aquatic planting.	There has been successful previous projects adopting a more local plant list.	Time lead requirements	Wetlands may need a particular profile for different plant list.	Y
WQ13	Stormwater treatment for reuse	can remove volume and nutrients from the receiving waterway. Provides alternative to potable water	Expensive and an existing treatment site nearby for reuse has failed due to high turbidity.	Turbid water will require significant treatment before re-use. Neighbouring harvesting scheme has been shelved due to turbidity.	N
WQ14	Turbid water sheeting through paddocks and vegetation	Low cost	Will likely be ineffective in removing the turbid waters from the sodic soil environment.	Sheet flow through existing paddocks/biomass does remove the sediment from the moral turbid water, however it does not remove the turbidity from sodic soils as it requires a binding mechanism.	Y
WQ15	Leaving the site largely untouched with only minor works (i.e. light touch approach)	Does not disturb the current sodic soils on the site. Will retain biomass etc.	Does not meet water quality targets; does not consider how water will be conveyed from future developed catchments. May not provide suitable retardation/storage requirements for developed catchments. Site may ultimately become unstable	Will have no water quality benefits; may not provide sufficient retardation to allow for future development	Y

Design Options/Considerations: **Water Conveyance**

ID	Scenario/Option	Pros	Cons	Comments	
WC1	Earth/Planted Waterway (Standard)	Effective conveyance method of high flows (i.e. 1% AEP flows) - under normal circumstances	No guarantee of plant establishment in sodic areas, following bulk earthworks	Per the current Melbourne Water Design Manual. Gypsum to potentially assist with plant establishment	Y
WC2	Earth/Planted Waterway (Alternative)	Changing the geomorphology of a standard waterway to be more suited to sodic regions	No guarantee of plant establishment following bulk earthworks. May require larger footprint.	Wide and shallow cross section to distribute shear forces. Broader waterway to carry less shear force not to exceed a predetermined value.	Y
WC3	Sediment Basins into entrance of Waterway	May reduce WQ sizing. Reduce velocities.	Any sediment accumulated could be resuspended during large events. More space required.	This option may the primary treatment in the WQ treatment train.	Y
WC4	Lined waterways	Minimises erosion	Less naturalised; more expensive than just planting; reduced amenity	Piped waterway with overflow channel provides similar solution. Lower amenity outcome. Contrary to current MW and community expectations.	Y
WC5	Grade control and reduced batter slopes	Minimises erosion;	Potentially additional earthworks/additional cost	Ensure batters and longitudinal grade of the waterway is no steeper than a predetermined grade. Use of armoured rock riffles where grade needs to be controlled	Y
WC6	Specifying use of Gypsum to stabilise all disturbed areas	Reduces erosion/dispersion; assists with plant establishment	Can be expensive, especially at the scale of the Kalkallo Basin	Likely to be a key part of the construction process.	Y
WC7	Minimising construction footprint	Reduces areas of disturbance, and reduces risk of erosion	Limiting footprint may impact the floodplain storage available to service future development	Site is inherently stable. Reducing the construction footprint will reduce the risk of exposing unstable material.	Y
WC8	Piped high flows	Reduces water contact with dispersive soils	Trenches for pipes can be a collector of stormwater. Trenches can become unstable	Note: that where trenches are required, any dispersive soil could be treated with hydrated lime (subsurface) and gypsum (topsoil cover) to avoid dispersion/erosion. Alternatives to trenching include horizontal or directional drilling, with use of grouting to fill in voids to reduce tunnel erosion	Y
WC9	Non-degradable geofabric to protect any steep batters/sensitive areas	Minimises erosion	Can be expensive, especially at the scale of the Kalkallo Basin	Most suitable shrouding method will be decided through the construction methodology	N - Part of standard construction methodology
WC10	Reverse grade channels to reduce low flow velocities and increase vegetation.	Increase vegetation, lower shear stress and velocity.	The system will be wetter, how will this engage with sodic soil/subsoil.	Minor pooling to support vegetation growth will not be an issue. Sodic soil is affected by fluctuations of dry and wet weather, in retardation basin it will more likely be more wet all the time so not an issue. You want to create a stable environment for stable plant growth as this provides more stability.	Y
WC11	Leaving the site untouched/not constructing anything (i.e. light touch approach)	Does not disturb the current sodic soils on the site. Will retain biomass etc.	Does not meet water quality targets; does not consider how water will be conveyed from future developed catchments. May not provide suitable retardation/storage requirements for developed catchments. Site may ultimately become unstable	Will have no water quality benefits; may not provide sufficient retardation to allow for future development	Y

Design Options/Considerations: **Retardation**

ID	Scenario/Option	Pros	Cons	Comments	
RBx	Minimising retarding basin cut area and depth of cut	Minimises interaction with sodic soils	Inability to achieve floodplain storage volumes required.	May require deeper cut to achieve same storage volume. Risk of exposure to dispersive/sodic soils can increase proportionately with depth of excavation	N (not an option, just a prompt/comment)

RB1	Underground storage	No surface water- reduce surface Water	High risk of failure, expensive, high amount of excavation. Volumes too big for underground storage for this site.	Not practical for scale of site.	N
RB2	Leaving the site untouched/not constructing anything (i.e. light touch approach)	Does not disturb the current sodic soils on the site. Will retain biomass etc.	Does not meet water quality targets; does not consider how water will be conveyed from future developed catchments. May not provide suitable retardation/storage requirements for developed catchments. Site may ultimately become unstable.	Will have no water quality benefits; may not provide sufficient retardation to allow for future development. Will require flood level in basin to increase to provide flow control for future development	Y
RB3	Favouring deep Bulk Earthworks in a single location or area, to achieve RB storage volume	Will disturb a reduced surface area within the drainage reserve (as compared to option RB4)	Risk of exposure to dispersive/sodic soils can increase proportionately with depth of excavation. May encounter base rock.	deeper excavation will require appropriate compacting of soil profile and covering whether it be clay liner (for a wetland) or topsoil/vegetation (for a waterway)	Y
RB4	Favouring shallow bulk Earthworks over a wide area, to achieve RB storage volume	Risk of exposure to dispersive/sodic soils can increase proportionately with depth of excavation	Will disturb a greater surface area within the drainage reserve (as compared to option RB3)	Additional flood storage is required within the design to cater for future development. Shallow excavation may limit the available additional flood storage. May result in increase flood levels within the basin.	Y
RB5	Targeting excavation in areas where there less existing topsoil or biomass coverage	Will target excavation in areas that are inherently less stable	Might be difficult to determine where these areas are; areas deemed suitable may not provide enough retardation storage	This option can be assessed in conjunction with option G10	Y
RB6	Revegetating the entire site, potentially making it more stable	May make the site more stable, and less prone to erosion/suspending particles into water	Scale is prohibitive; will likely not impact the stability on the site (unless velocities are deemed high)	Could be an opportunity to rehabilitate the area. The existing site is stable as it stands (i.e. is there any need for rehabilitation/revegetation of non-disturbed areas)? It is understood that if velocities are kept low, increased volumes of flow onto the site should not have a detrimental impact on site stability	N (not required due to existing site conditions)

Construction Considerations

ID	Scenario/Option	Pros	Cons	Comments	
Cxx	Experienced contractor who is familiar with the proposed asset types and requirements to combat the sodic environment will be critical to success of any asset construction. Construction methodology should be key to the winning contractor bid.				NA - A comment not an option
C1	Flocculation (reducing turbidity to pre-determined value)	Reduces turbidity of incoming water	Costly; will need to be undertaken regularly/after most rainfall events. Disposal of flocculated silt/clay can also be costly. No guarantee of working - especially on large scale sites	It is noted that the much of the turbidity would come from construction sites - the catchment should remain stable as is, if untouched. Construction treatment is required to protect downstream infrastructure. During the construction phase of the development has the highest risk. could provide an interim solution whilst the catchment develops	Y
C2	On site Clarifiers (to remove incoming suspended sediment)	More reliable at removing suspended clays/particles than flocculation	More expensive than flocculation; clarifiers would need to be regularly maintained and operated manually; disposal of material can also be expensive	Only treats small amounts. Can only discharge at small flow rates. You will need a lot of them in series to treat such a large site, and they need full time operators. Very expensive not feasible at this scale.	N
C3	Reducing extents of machinery movement/minimising extent of works	Reduces disturbed areas, and potential for erosion	May limit the time of machines that can be used within a site; could increase the time of construction	This could be an effective option, but will be difficult to manage in practice without experienced contractors	Y
C4	Not disturbing any areas until absolutely necessary	Reduces disturbed areas, and risk for erosion (i.e. following a rainfall event)	May limit the amount of work that can be done concurrently. May increase the time of construction	As above	Y
C5	Staging development of the basin, to reduce the amount of area disturbed at one time	As per C4	As per C4	Will need to factor in the timing of development within the catchment	Y
C6	Maintain/retain actively growing biomass where possible	Provides a shroud over sodic soils; reduces erosion and exposure	Difficult and cumbersome to manage	Existing plants provide root anchorage; important for site stability	Y
C7	Avoid removing trees	Provides anchorage of soil profiles	May limit where we can design certain constructed assets (unlikely to be an issue for Kalkallo site)	Tree root systems provide anchorage through soil profiles. This could be included in the Specification as a condition of the site, to include buffer zones.	Y
C8	Timely placement of organic matter/suitable topsoil, to assist in rapid propagation of grass seed	Ensure that sodic soils can be protected as soon as possible.	Requirement to source all topsoil in a timely manner. Sourcing material could be limited.		Y
C9	Stabilising any dispersive soils and disturbed ground with Gypsum or Lime	Reduces dispersiveness and erosion etc	May be expensive, especially considering the scale of the site	Needs to be done as soon as soil is stripped.	Y
C10	Retention and reuse of all topsoil to cover exposed sodic soils	Cheaper than importing topsoil/other shrouding material	May be limited suitable topsoil on site	This needs to be protected on site, and reapplied as quickly as possible.	Y
C11	Shrouding covering the surface with topsoil/mulch/straw etc. to stop the effect of rainfall impact on sodic soils	Reduces direct contact between water and sodic soils. Would reduce erosion potential	Sourcing appropriate materials; potentially costly.	Shrouding of exposed areas will be critical to the success of the construction activities. The size of the basin area will require a cost efficient measure to be adopted.	Y
C12	Utilising geofabric barriers for soil protection	Reduces direct contact between water and sodic soils. Would reduce erosion potential	May be costly, especially at the scale of Kalkallo Basin	As above	Y
C13	Regular (daily/weekly) assessment of site to identify bare areas.	May prevent erosion damage, during unexpected rainfall events	Contractor commitment and ability to keep track of such things (may need to be driven by the superintendent)	Identifying any bare areas within the site, and re-shrouding the surface with topsoil or other suitable material. Having an experienced contractor is vital to the management of the site.	Y
C14	Ceasing major activities prior to rainfall event	Avoids unnecessary exposure or damage to sodic surfaces during an impending rainfall event	Superintendent must ensure compliance from contractor		Y

C15	Design of infrastructure to consider scale of the asset, such that it can be constructed and established in a timely matter	Allows assets to be under less exposure prior to establishment	Funding of asset ahead of schedule may impact s	Establishment of vegetation will provide the greatest chance of a successful asset.	Y
C16	Implementation of effective bypass systems during construction	Avoids water entering and damaging construction sites (e.g. wetland/bioretention construction areas); may design to be sacrificial and so wouldn't matter if erodes	Additional earthworks/infrastructure that may need to be decommissioned		Y

Ongoing Considerations/Maintenance

ID	Scenario/Option	Pros	Cons	Comments	
M1	Flocculation - ongoing treatment of incoming water	Removes suspended sediment from stormwater	Expensive ongoing cost - having to pay for spraying and ongoing removal of sludge. No guarantee of success.	Level/degree to which flocculation is required will depend on what NTU reading will need to be achieved. Thus the importance of determining a pre-developed NTU rating for the site. EPA guidelines typically state that NTU readings must be <30, for water discharged from a construction site. This site might be an exception, if we prove the baseline catchment turbidity is greater than 30NTU Flocculation of large water bodies can be difficult. May require a boat so that the flocculant spray could reach the centre of the basin. Flocculation would almost be required after every storm event – the amount of sludge it can produce is significant, as well. May need an on-call maintenance team to continually flocculate, desilt and dispose of silt etc.	Y - maybe
M2	Reapplication of topsoil/shroud material	Ongoing protection of the sodic soils, to avoid future erosion	Requires regular monitoring of the site, following construction. Need to understand who would be responsible for undertaking the reapplication task	Limiting contact between fresh water and sodic soils is vital to reducing turbid water entering the downstream environment.	Y
M3	Enforcing management of future construction sites (i.e. managing stormwater discharged from contributing catchments)	Limits turbid water entering basin site, reduces erosion within upstream sites also.	Additional resources may be required to enforce. Funding may not be available.	May not be practical to enforce the notion that all water discharged from upstream construction sites be managed or treated to a specific NTU rating.	Y
M4	Carry out slashing/mowing of groundcover where site remains vacant	Keeps the site well maintained	Requires regular monitoring of the site, following construction. Need to understand who would be responsible for undertaking the reapplication task		Y
M5	On site Clarifiers (to remove incoming suspended sediment)	Removes suspended sediment from stormwater; more guarantee of success compared to flocculation (M1)	Expensive ongoing cost - having to pay for spraying and ongoing removal of sludge. Who would be undertaking this/engaged to be doing this work - it's almost a full time job.		N due to scale.
M6	Irrigation of area using water with Gypsum/calcium additives within water	Would theoretically ameliorate the topsoil, for ongoing stabilisation of the site	Expensive to implement - would need to integrate the appropriate infrastructure. Expensive to add liquid ameliorants to irrigation water compared to the regular application of Gypsum		N

Other Considerations/ Options/Opportunities

ID	Scenario/Option	Pros	Cons	Comments	
O1	Ecological opportunities	Enhanced ecosystem and biodiversity. Enhanced community connection.	Constraints limiting the design	Integration with Growling Grass Frogs and Golden Sun Moths	Y
O2	Amenity for the site	Making the site welcoming to the general public. Huge reserve area, which should be considered for alternative uses	Adding extra connectivity could disturb the site	What does this look like? What can the site be used for? Previous concepts have been undertaken by Spiire.	y

Safety in Design (Elements to consider during future design phases)

ID	Scenario/Option	Pros	Cons	Comments	
S1	Integrate safety benching into any permanent pool infrastructure.	Provides safer environment for future users	May conflict with the requirements for shallow batters within sodic soil environment.	This region has a potential for lower plant growth, or vegetation failure. So water bodies should be safe	Applicable at later stages of design
S2	Sodic soil area have higher risk of embankment failures.			ANCOLD assessment	Applicable at later stages of design
S3	High turbidity receiving water may slow plant establishment				Applicable at later stages of design

Appendix B. – Matrix Output

Design Options

1) Water Quality
2) Water Conveyance
3) Retardation

Cat A - Upfront Costs

	Description
1	>100M
2	50-100M
3	20-50M
4	$5-$20M
5	<$5M

Category B - Maintenance difficulty/ongoing Costs

(can all construction recommendations be met)
(what is the difficulty in achieving the construction recommendations)

	Description
1	Frequent ongoing maintenance; high cost of maintenance; high ongoing cost
2	Frequent maintenance required; medium cost to maintain; medium/high ongoing cost
3	Infrequent maintenance required; medium/high cost to maintain; medium/high ongoing cost
4	Infrequent maintenance required; low/medium cost to maintain; relatively low ongoing costs
5	Little to no ongoing costs or maintenance

Category C - Meeting Construction Objectives/Considerations

(Ease of Constructability/ability to reduce erosion/dispersion)

	Description
1	Unable to meet majority of construction objectives/parameters, or most objectives are impossible to impliment
2	Able to meet some construction objections; construction objectives are very difficult to implement
3	Able to meet most construction objections; construction objectives more difficult to implement
4	Can achieve all construction objectives; construction objectives more difficult to implement
5	Very Easily achieve all construction objectives; construction objectives very easy to implement

Category D - Effectiveness at meeting MW Water quality/ conveyance objectives

	Description
1	Provides no water quaility **AND/OR** very ineffective at water conveyance/retardardation etc.
2	Provides little to no water quaility **AND/OR** ineffective at water conveyance/Retardation
3	Mostly offers treatment train effectiveness, but does not meet best practice **AND/OR** water conveyance/retardation will be challlenging to achieve
4	Can meet MW best practice treatment **AND/OR** able to achieve conveyance/retardation objectives
5	Easily meets MW best practice treatment **AND/OR** easily able to achieve conveyance/retardation objectives

Category E - Ability to Reduce Turbidity

	Description
1	Option likely to drastically worsen turbidity
2	Option likely to worsen turbidity
3	Option unlikely to alter turbidity
4	Option somewhat likely to improve turbidity
5	Option very likely to improve turbidity

Category F - Ability to Function in the presence of Turbid Water

	Description
1	Option will be severely impacted by the presence of turbid water
2	Optionwill be impacted by the presence of turbid water
3	Option can work in in turbid water, but will require minor modifications
4	Option will be able to mostly function normally in turbid water
5	Option will be able to function normally in heavily turbid water

Category G - Risk of failure over time

(Chance of erosion/plants dying/asset failing)

	Description
1	Guaranteed Failure - Risk is impossible to mitigate
2	High risk of failure AND Risk is difficult to mitigate
3	Medium risk of failure AND Risk is difficult to mitigated
4	Medium risk of failure AND Risk can mostly be mitigated
5	Little to no risk of failure AND Risk is easily mitigated

Category H - Suitabilty for site (i.e. scale)

	Description
1	Option is not suitable for large site; will not be suitable for the site, or essentially ineffective/unsuitable or impossible to implement
2	Option is largely impracticle for implementing within a large site, though can still be implemented with difficulty
3	Option will have difficulties implementing within a large site, but is somewhat achievable
4	Option is mostly suitable for the site; can withstand magnitue of incoming water
5	Option is highly suitable for the site; can easily withstand magnitue of incoming water

Category I - Environmental and Community Considerations

	Description
1	Option has highly negative impact on environment, amenity and community objectives
2	Option has some negative impact on environment, amenity and community objectives
3	Option has no impact on environment, amenity and community objectives
4	Option has some positive impact on environment, amenity and community objectives
5	Option has highly positive impact on environment, amenity and community objectives

Design Option	Weighting
Cat A Weighting	0.4
Cat B Weighting	0.4
Cat C Weighting	0.3
Cat D Weighting	1
Cat E Weighting	0.2
Cat F Weighting	0.2
Cat G Weighting	0.8
Gat H Weighting	*0.8*
Gat I Weighting	*0.15*

- Category A - Upfront Costs
- Category B - Maintenance difficulty/ongoing Costs
- Category C - Meeting Construction Objectives/Parameters
- Category D - Effectiveness at meeting MW Water quality/conveyance objectives
- Category E - Ability to Reduce Turbidity
- Category F - Ability to Function within Turbid Water
- Category G - Risk of failure over time
- Category H - Suitabilty for site (i.e. scale)
- Category I - Environmental and Commnunity Considerations

ID	Design Option	Cat A - Upfront Costs	Cat B - Maint. Costs/ Ongoing Costs	Cat C - Meeting Construction Objectives	Cat D - Effectiveness at meeting MW Objectives	Cat E - Ability to Reduce Turbidity	Cat F - Functionality within Turbid Water	Cat G - Risk Of Failure over time	Cat H - Suitability for Large site	Cat I - Community and environmental considerations	Total Score
	Weighting	0.4	0.4	0.3	1	0.2	0.2	0.8	0.8	0.15	
EX1	**Example (High Score; excellent result)**	5	5	5	5	5	**5**	5	**5**	**5**	21.25
EX2	**Example (Low Score; poor result)**	1	1	1	1	1	**1**	1	**1**	**1**	4.25
	WATER QUALITY OPTIONS										
WQ1	**WQ1 - Constructed Single Wetland (MW standard)**	2	3	3	5	3	4	3	**3**	**4**	14.7
WQ2	**WQ2 - Constructed Single Wetland (Alternative - e.g. different plants)**	2	3	3	5	3	4	4	**3**	**4**	15.5
WQ3	**WQ3 - Constructed Reed Beds/bioretention**	3	2	3	5	3	1	2	**2**	**4**	12.5
WQ4	**WQ4 - Test Wetland**	3	3	3	4	3	4	4	**3**	**4**	14.9
WQ5	**WQ5 - Single Wetland; modular construction**	2	4	3	5	3	4	3	**3**	**4**	15.1
WQ6	**WQ6 - Splitting Large Wetlands into Multiple Cells**	2	4	3	5	3	4	4	**4**	**4**	16.7
WQ7	**WQ7 - Large Sediment Pond to treat incoming sediment (Plus Flocculation)**	4	1	3	3	4	5	4	**4**	**4**	14.7
WQ8	**WQ8 - Proprietary Water Quality Products**	4	3	3	2	4	4	4	**2**	**3**	12.55
WQ9	**WQ9 - Filtration of incoming Water**	4	3	3	2	4	4	4	**2**	**3**	12.55
WQ10	**WQ11 - On site treatment plant**	1	1	3	5	5	5	2	**2**	**2**	12.2
WQ11	**WQ15 - Leaving the site untouched/not constructing anything (i.e. light touch approach)**	5	5	5	1	3	4	4	**1**	**1**	12.05
	WATER CONVEYANCE OPTIONS										
WC1	**WC1 - Earth/Planted Waterway (MW Standard)**	4	4	4	5	3	**5**	3	**5**	**4**	18
WC2	**WC2 - Earth/Planted Waterway (Alternative)**	4	4	4	5	3	**5**	4	**5**	**4**	18.8
WC3	**WC3 - Sediment Basins into entrance of Waterway**	4	4	4	3	3	**5**	4	**4**	**4**	16
WC4	**WC4 - Lined waterways**	3	4	4	4	3	**5**	4	**3**	**2**	15.5
WC5	**WC8 - Piped high flows**	2	5	4	4	3	**5**	5	**2**	**3**	15.65
WC6	**WC10 -Leaving the site untouched/not constructing anything (i.e. light touch approach)**	5	5	5	1	3	**4**	3	**2**	**1**	12.05
	WATER RETARDATION OPTIONS										
RB1	**RB1 - Underground Storage**	2	2	3	2	2	**3**	3	**1**	**3**	9.15
RB2	**RB2 - Leaving the site untouched/not constructing anything (i.e. light touch approach)**	5	5	3	1	3	**4**	2	**2**	**1**	10.65
RB3	**RB3 - Favouring deep Bulk Earthworks in a single location or area**	4	4	3	4	2	**4**	3	**3**	**3**	14.55
RB4	**RB4 - Favouring shallow bulk Earthworks over a wide area**	4	4	4	4	2	**4**	4	**3**	**3**	15.65
RB5	**RB5 - Targeting excavation in targeted areas (considering areas where there is existing topsoil or biomass coverage)**	4	4	5	4	2	**4**	4	**4**	**3**	16.75

Appendix C. – Key Melbourne Water Correspondences

Jacobs

Memorandum

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Subject	**Kalkallo Workshop Outcomes**	**Project Name**	Kalkallo Basin Sodic Soil Review
Attention	Stephen Miller	**Project No.**	IA5000DL
From	Thomas Cousland		
Date	26 April 2021		
Copies to	**Elizabeth Smolinska**		

The workshop undertaken on the 29th of March 2021 pertaining to *Kalkallo Basin Option Analysis*, Jacobs/Spiire (March 2021), provided opportunity to discuss the options analysis and further input to the matrix analysis. The main input from the workshop came from different stakeholders within Melbourne Water. This memo provides a summary of the key outcomes from the workshop and provides various inputs which were used to update the current analysis. The additional items resulting from the workshop include:

1. Greater investigation of the 'light touch' or 'do nothing' approach as an option, to gain additional context in retaining the existing conditions as much as possible for the site and reflect or clarify the weightings accordingly.

2. Incorporating key input from Melbourne Water, regarding the weighting values per the matrix analysis, and presenting any changes to the top-ranking options.

1. Assessment of the 'Light Touch' ('do nothing') Approach

During the workshop Melbourne Water requested further investigation of the 'light touch' or 'do nothing' approach to better reflect the discussion and queries. Key discussion points to be incorporated or further clarified are as below:

- The 'do nothing' approach is to leave the site in its existing state as much as possible.
- The site is currently functioning as an existing retardation basin with existing channels and embankment. Increased storage requirements not immediately required.
- The current site has existing biomass coverage under current hydrological conditions which indicates that the site is inherently stable under existing conditions. Any proposed works may create a short-term risk of sodic soil failure during construction.
- The opportunity to further improve the organics in the soil more to improve the stability of the site was discussed. It was noted that the existing pasture is already inherently stable, without the need for additional amelioration.

- A key assessment of a 'do nothing' scenario is to determine the merits of leaving the site as is as much as possible, in relation to changes that would need to occur to the proposed scheme. A 'do nothing' approach would require removal of the formal wetland infrastructure and the additional storage capacity that the wetland infrastructure would provide in parallel. The detention requirements would likely be mitigated by increasing the embankment height of the existing system. Therefore, the main components reviewed relate to:
  - Increased ultimate flood level in the basin and the freeboard implications.
  - Water quality implications.

1.1 Retarding Basin Function/Freeboard

A key consideration of the 'do nothing' approach, is the impact on flood storage. Without touching the site to provide addition storage to service future development, the presumption is an increase in the 1% AEP flood levels within the basin. To confirm the approximate magnitude of the impact, the DCE option drawings set was reviewed to confirm the amount of additional storage required to accommodate future development. Results are presented in the Table 1 below.

Table 1: Storage requirements

Parameters	
1% AEP Flood Area	267 ha
Approximate additional storage requirement based SWS report and DCE plans.	1,311,000 m^3
Increase in ultimate 1% AEP Flood level if existing surface is not disturbed (i.e., no additional storage excavation)	490 mm

In a 'do nothing' scenario, the additional storage requirements for the retardation basin will require an increase of the embankment height and associated infrastructure to cater for future retardation requirements.

Current basin designs allows for freeboard to future lots of approximately 600 mm. As shown in Table 1, the approximate freeboard loss if the embankment height was increased to meet future detention requirements reduces to just over 100 mm. This should be discussed further within Melbourne Water to confirm whether the loss of freeboard is an outcome Melbourne Water are willing to accept, based on existing surrounding approvals. It is the project team's opinion that this reduced amount of freeboard is not acceptable.

1.2 Water Quality

The 'do nothing' approach proposes the removal of stormwater quality infrastructure requirements to retain the current stable conditions as much as possible.

The 'do nothing' approach will provide some water quality benefits as it will be a large vegetation buffer and provide infiltration, however it is unlikely to meet BPEM performance targets (most specifically TN load reduction), with quantification of load reductions difficult to ascertain in the informal treatment train. Melbourne Water has noted that ensuring site stability (i.e., achieved by retaining existing conditions within the site) and reducing turbidity is a primary concern, while stormwater quality improvement may be considered a secondary concern.

In terms of turbidity reductions, the removal of fine clays can only be completed by a chemical process (alum injection/flocculation) which cannot be modelled in MUSIC and is not part of the water quality objective requirements. The 'do nothing' process with existing vegetation will not provide significant turbidity removal from sodic soils conditions. Additionally, while retaining existing conditions within the site is inherently stable, it has been noted that construction of water quality infrastructure can also be stable, if construction and design is undertaken appropriately to accommodate sodic soils.

We also note that proposing no water quality infrastructure in order to reduce costs, sets a precedent for other DSS catchments within Melbourne, and other catchments in sodic regions (i.e., most of the norther region of Melbourne.) in achieving water quality objectives.

2. Updated weighting and Matrix Analysis

The matrix analysis has been updated (i.e., adjustments to weightings and scores) based on the workshop with Melbourne Water, and better reflects the additional context of the 'do nothing' approach. The updated weightings and collations of discussions and clarifications are presented in the table below.

Table 2: Updated weightings for matrix analysis

Design Options Assessment Category	Weighting	Updated Weightings and Clarifications
Category A - Upfront Costs	0.4	0.4 *Upfront construction cost should not be an issue – it is presumed that there will be adequate funding within the scheme.*

Category B - Maintenance difficulty/ongoing Costs	0.4	0.4 *There was some preliminary discussion in the workshop surrounding increasing this weighting but upon further analysis we have decided to maintain the current ranking.*
Category C - Meeting Construction Objectives/Parameters	0.3	**0.4** *The weighting has been increased to reflect workshop discussions of the importance of constructability.* *It is also noted that the ranking adoption has considered the following as discussed.* • *Timing of works and construction* • *Establishment* • *Constructability*
Category D - Effectiveness at meeting MW Water quality/conveyance objectives	1.0	**1.0** *The weighting considers the objectives of stormwater quality, conveyance, and retardation. The score incorporates:* • *The negotiable element of the design, i.e., the turbidity is a more important issue to deal with a previous "non-negotiable" issue such as water quality.* *The light tough approach has an increase score from 1 to 3, in this category.*
Category E - Ability to Reduce Turbidity	0.2	0.2
Category F - Ability to Function within Turbid Water	0.2	**0.3** *Of the opinion that Category F should be weighted higher. The consensus that the presence of turbid water would not be making systems any better and could potentially hamper the planting or rate of establishment (with light penetration being a key point brought up) – so*

		increasing the weighting slightly seems appropriate. *In terms of light penetration affecting plant growth:* • *Brent N noted that light penetration might not impact the planting at the depths used in MW wetlands.* • *Brent N asked the group how other assets have established in the area – Ryan V noted there were some where the planting was thriving.* • *Christian B noted that the wetlands would not be 'enhanced' by dirty water – there would at least be some impact (e.g., a reduction in light penetration, and heat/sunlight for the plants impacting establishment etc)*
Category G - Risk of failure over time	0.8	0.8
Category H - Suitability for site (i.e., scale)	0.75	0.75 The 'light tough' approach has an increased score from 1 to 3.
Category I - Environmental and Community Considerations	0.15	**0.3** *Category I weighting has increased. It is noted that environmental and communicated considerations score the same for different options for this context.* *Further discussion points:* • *Ryan V thought this needed to be higher; that there was some ecological value within the site, with seasonal grasses and shallow wetland veg.*

		• *David R. thought amenity for the community was not something he saw as a priority. With site stability without adding extra complexity to the design key to a successful outcome.*
Category J – IWMS opportunities	0.20	**0.20 – new category** *Category J has been incorporated to do with IWMS/water reuse as per Melbourne Water request to incorporate potential multiple benefits of options*

2.1 Updated rankings

The updated analysis has been provided below with amended rankings and scores. The light touch approach has now increased into to be in the top 4 of the options, but we note that the top three ranking options have remained the same as per Draft Options Analysis Report. It is noted that this is assuming that Melbourne Water is willing to compromise on water quality objectives.

Table 3: Matrix Outcome Water Quality

	Highest Scoring Options	Score
Rank 1	WQ6 - Splitting Large Wetlands into Multiple Cells	18.8
Rank 2	WQ5 - Single Wetland; modular construction	18.0
Rank 3	WQ2 - Constructed Single Wetland (Alternative - e.g. different plants)	17.2
Rank 4	WQ15 - Leaving the site untouched/not constructing anything (i.e. light touch approach)*	17.1

Table 4: Matrix Outcome Water Conveyance

	Highest Scoring Options	Score
Rank 1	WC2 - Earth/Planted Waterway (Alternative)	20.7
Rank 2	WC1 - Earth/Planted Waterway (MW Standard)	19.9

Rank 3	WC10 -Leaving the site untouched/not constructing anything (i.e. light touch approach)*	18.4
Rank 4	WC3 - Sediment Basins into entrance of Waterway	17.9

Table 5: Matrix Outcome Water Retardation

	Highest Scoring Options	Score
Rank 1	RB5 - Targeting excavation in targeted areas (considering areas where there is existing topsoil or biomass coverage)	18.5
Rank 2	RB4 - Favouring shallow bulk Earthworks over a wide area	17.3
Rank 3	RB2 - Leaving the site untouched/not constructing anything (i.e. light touch approach)*	17.0
Rank 4	RB3 - Favouring deep Bulk Earthworks in a single location or area	16.1

*The light touch approach is shown in the list of options assuming it is an acceptable outcome given the previously mentioned impact on ultimate flood levels and failure to meet BPEM targets.

3. Summary

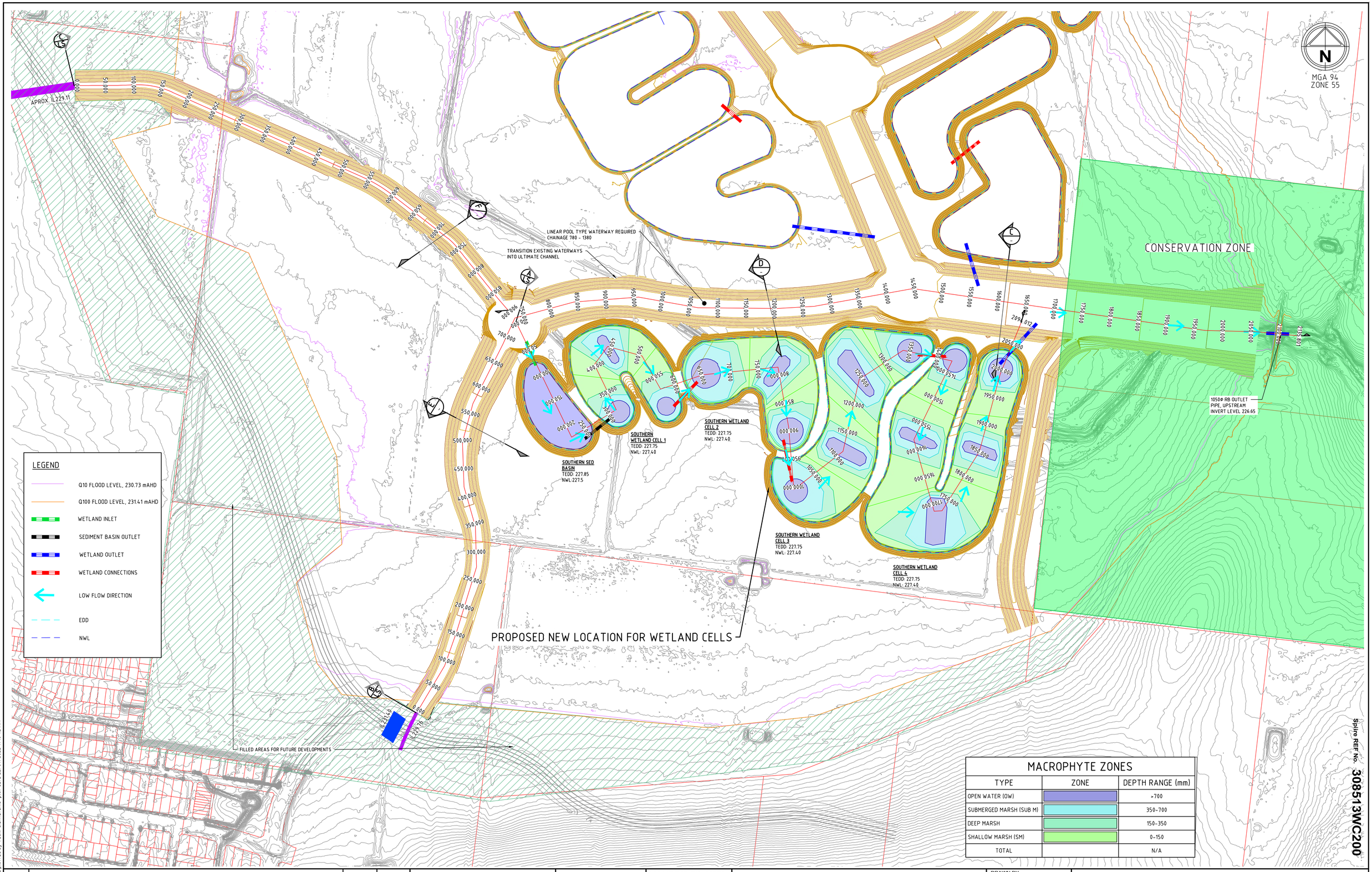
A main outcome from the workshop with Melbourne Water was the need to assess the viability of a 'do nothing', or 'light touch' approach for the Kalkallo Basin site. Investigations into the option have found the following:

- Leaving the site untouched has implications from a water quality perspective.
  - The predominant source of turbid water will be from upstream construction sites – thus leaving the site untouched will not inherently provide any assistance in reducing turbidity.
  - Not providing water quality infrastructure (i.e., wetlands), it is presumed that there will be a greatly reduced ability to treat total nitrogen entering the downstream Kalkallo Creek.
  - While leaving the site untouched is inherently stable, through the use of proper design and construction methodologies, constructing water quality assets in dispersive soils can also be stable.
  - By not providing water quality assets for the catchment, a precedent may be set for other DSSs within Melbourne.

Additionally, following the completion of the workshop with Melbourne Water, the options analysis and associated ranking matrix has been adjusted to incorporate Melbourne Water's feedback. In adjusting the assessment matrix, it has been found that the preferred options are largely consistent with the findings in the draft Options Analysis Report, albeit with the inclusion of the 'do nothing' approach within the top 4 rankings for each outcome. While the 'do nothing' approach ranks higher, it still does not outrank the other proposed options as indicated in Tables 3 to 5.

We look for Melbourne Water's final comment on the 'do nothing' approach and confirmation of the desired options for each outcome to proceed to conceptual design.

Appendix D. – Preferred Option Conceptual Layout and Sections



LEGEND

- Q10 FLOOD LEVEL, 230.73 mAHD
- Q100 FLOOD LEVEL, 231.41 mAHD
- WETLAND INLET
- SEDIMENT BASIN OUTLET
- WETLAND OUTLET
- WETLAND CONNECTIONS
- LOW FLOW DIRECTION
- EDD
- NWL

MACROPHYTE ZONES

TYPE	ZONE	DEPTH RANGE (mm)
OPEN WATER (OW)		>700
SUBMERGED MARSH (SUB M)		350-700
DEEP MARSH		150-350
SHALLOW MARSH (SM)		0-150
TOTAL		N/A

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DESIGNED **B.NEVILL**
CHECKED **T.COUSLAND**
AUTHORISED **T.COUSLAND** 11/07/2022

SHEET 1 OF 7

MELBOURNE WATER CORPORATION

KALKALLO RETARDING BASIN - CONCEPT DESIGN

LAYOUTS & CATCHMENT PLAN - SOUTHERN WETLANDS

DWG NO. 1

REV. A

File name 308513WC200.dwg layout name WC200
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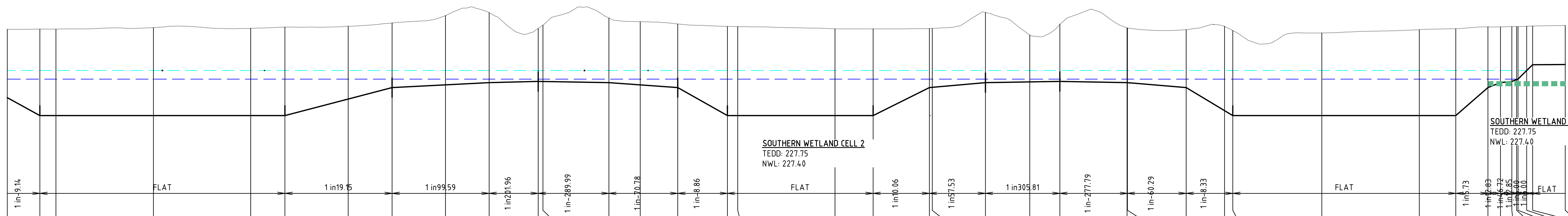
EDD

NWL

BALANCE AND TRANSFER PIPES TO BE DESIGNED AT A LATER DATE

VERTICAL GEOMETRY

DESIGN GRADELINE



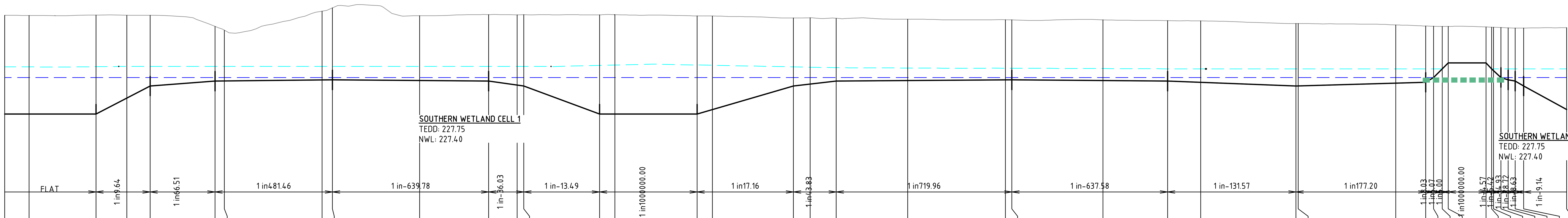
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636.689	225.900	229.453
640.000	225.900	229.456
660.000	225.900	229.515
680.000	225.900	229.484
687.024	225.900	229.534
700.000	226.578	229.572
709.043	227.050	229.706
720.000	227.160	230.013
728.962	227.250	230.135
739.060	227.300	229.483
740.000	227.297	229.616
753.560	227.250	229.911
760.000	227.159	229.759
767.716	227.050	229.666
777.901	225.900	229.564
780.000	225.900	229.559
800.000	225.900	229.466
807.821	225.900	229.463
819.388	227.050	229.478
820.000	227.061	229.480
830.894	227.250	230.142
840.000	227.280	229.209
846.184	227.300	229.653
860.000	227.250	229.504
860.074	227.250	229.499
872.131	227.050	229.431
880.000	226.106	229.570
881.714	225.900	229.395
900.000	225.900	229.292
920.000	225.900	229.430
927.526	225.900	229.469
934.119	227.050	229.544
936.685	227.250	229.544
939.021	227.300	229.553
940.000	227.376	229.557
940.306	227.400	229.559
942.058	227.750	229.571
943.308	228.000	229.584
950.000	228.000	229.605

LONG SECTION A (3/7)

VERTICAL GEOMETRY

DESIGN GRADELINE



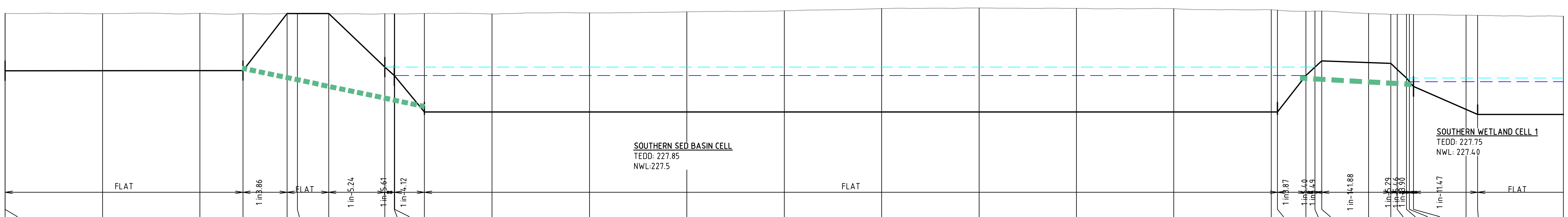
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333.686	225.900	229.962
340.000	226.555	229.958
344.776	227.050	229.956
358.079	227.250	229.499
360.000	227.254	229.340
380.000	227.296	230.121
382.152	227.300	230.262
400.000	227.272	229.938
414.141	227.250	229.984
420.000	227.087	229.970
421.346	227.050	229.975
436.861	225.900	229.973
440.000	225.900	229.980
456.852	225.900	229.929
460.000	226.084	229.924
476.583	227.050	229.841
480.000	227.128	229.850
485.348	227.250	229.830
500.000	227.270	229.790
520.000	227.298	229.771
521.346	227.300	229.768
540.000	227.271	229.767
553.225	227.250	229.735
560.000	227.199	229.725
579.540	227.050	229.612
580.000	227.053	229.612
600.000	227.165	229.558
606.119	227.200	229.514
607.726	227.400	229.504
609.500	227.750	229.497
610.750	228.000	229.497
618.489	228.000	229.474
619.632	227.750	229.465
620.000	227.682	229.464
621.528	227.400	229.456
623.021	227.300	229.439
624.457	227.250	229.429
626.183	227.050	229.432
635.000	226.085	229.447

LONG SECTION A (2/7)

VERTICAL GEOMETRY

DESIGN GRADELINE



DATUM RL 221.5

CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
0.000		230.060
0.007	227.700	230.060
20.000	227.702	230.047
40.000	227.703	230.058
48.839	227.704	230.042
57.904	230.053	230.053
60.000	230.052	230.059
66.452	230.049	230.049
77.971	227.850	230.041
79.935	227.500	230.041
80.000	227.484	230.041
86.111	226.000	230.054
100.000	226.000	230.036
120.000	226.000	230.078
140.000	226.000	230.119
160.000	226.000	230.163
180.000	226.000	230.254
200.000	226.000	230.280
220.000	226.000	230.265
240.000	226.000	230.250
260.000	226.000	230.205
261.288	226.000	230.190
267.099	227.500	230.146
268.988	227.850	230.150
270.360	228.100	230.152
280.000	228.032	230.048
284.548	228.000	230.021
285.871	227.750	230.021
287.783	227.400	230.019
288.369	227.250	230.018
289.203	227.050	230.012
300.000	226.109	229.984
302.393	225.900	229.977
320.000	225.900	229.944

LONG SECTION A (1/7)

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CHECKED T.COUSLAND
AUTHORISED T.COUSLAND 11/07/2022

SHEET 2 OF 7

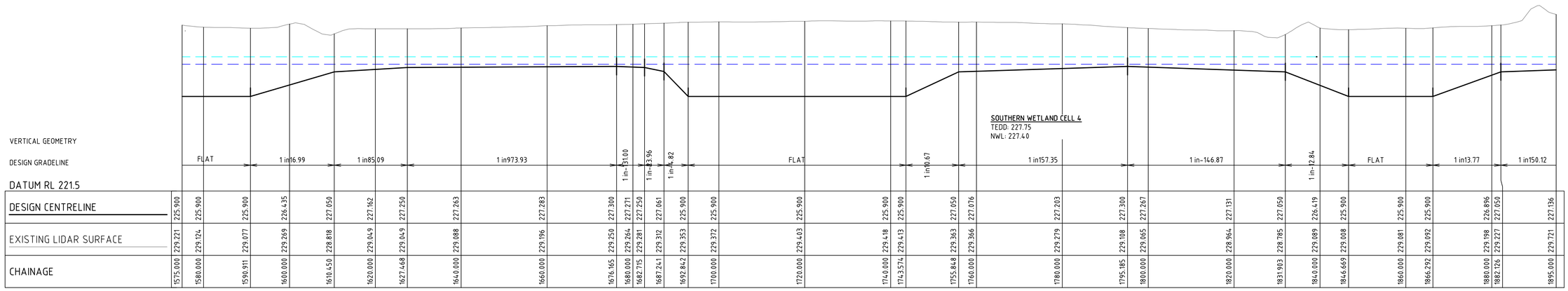
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KALKALLO RETARDING BASIN - CONCEPT DESIGN

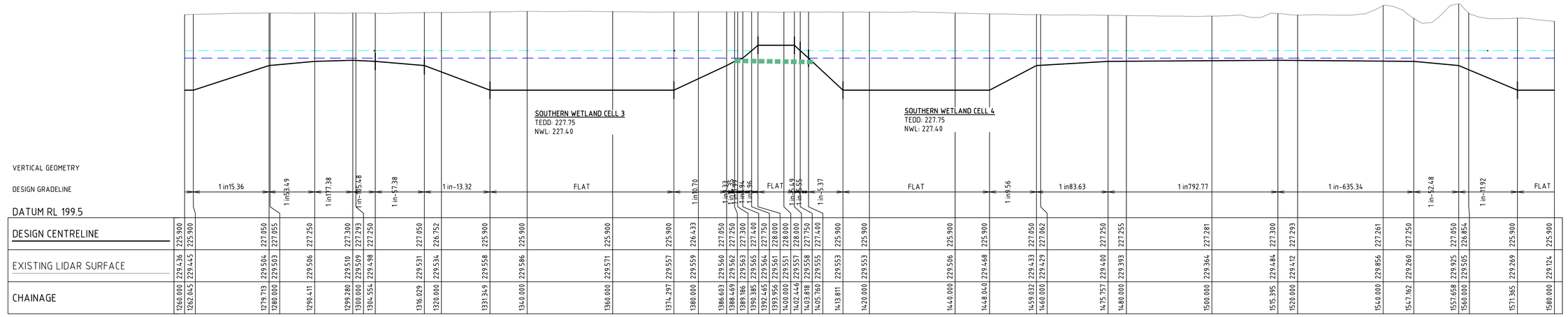
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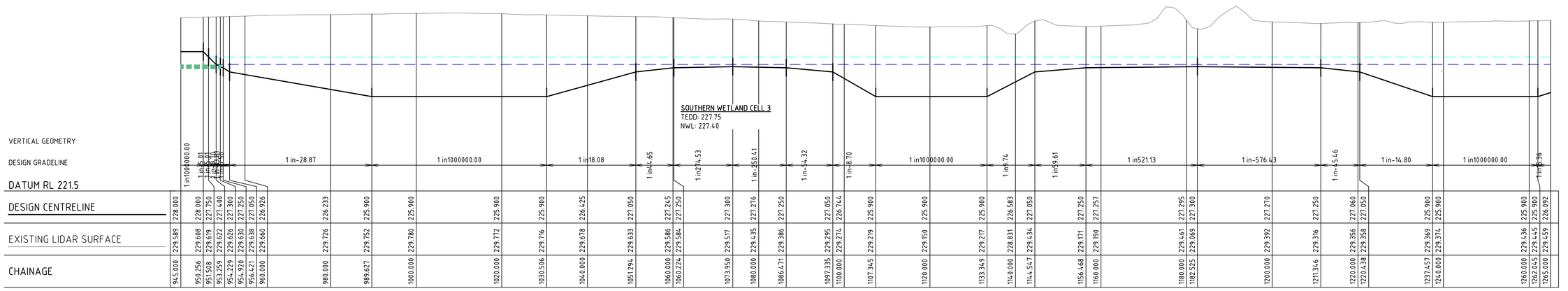
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LONG SECTION A (6/7)



LONG SECTION A (5/7)



LONG SECTION A (4/7)

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KALKALLO RETARDING BASIN - CONCEPT DESIGN

LONG SECTIONS

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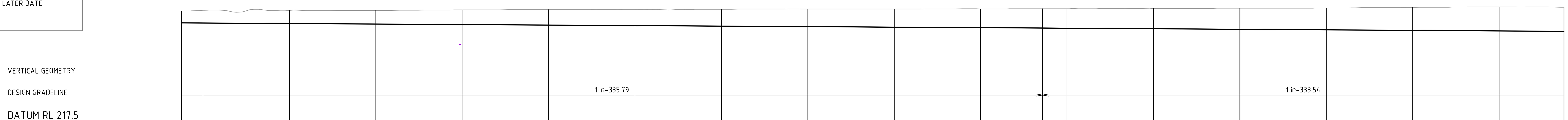
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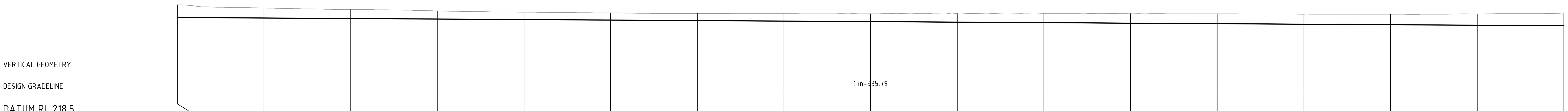
NWL

OUTLET PIPE TO BE DESIGNED AT A LATER DATE



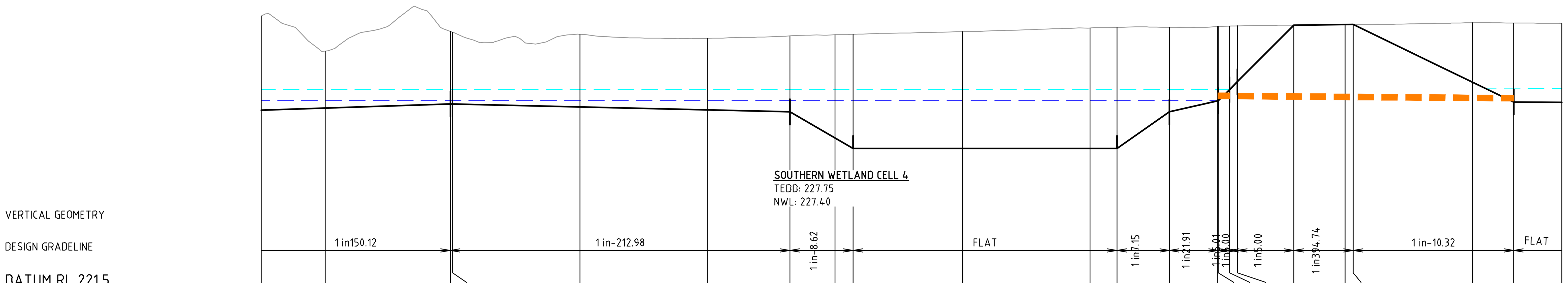
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360.000	228.681	230.267
380.000	228.622	230.319
400.000	228.562	230.345
420.000	228.503	230.355
440.000	228.443	230.398
460.000	228.384	230.418
480.000	228.324	230.412
500.000	228.264	230.440
514.307	228.222	230.456
520.000	228.205	230.455
540.000	228.145	230.505
560.000	228.085	230.520
580.000	228.025	230.534
600.000	227.965	230.606
620.000	227.905	230.669
635.000	227.860	230.627

LONG SECTION B (2/7)



CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
0.000	229.754	231.212
20.000	229.694	230.842
40.000	229.634	230.651
60.000	229.575	230.501
80.000	229.515	230.365
100.000	229.456	230.274
120.000	229.396	230.211
140.000	229.337	230.190
160.000	229.277	230.172
180.000	229.217	230.187
200.000	229.158	230.189
220.000	229.098	230.180
240.000	229.039	230.164
260.000	228.979	230.136
280.000	228.920	230.119
300.000	228.860	230.156
320.000	228.801	230.267

LONG SECTION B (1/7)



CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
1890.000	227.102	230.061
1900.000	227.169	228.957
1919.656	227.300	229.578
1920.000	227.298	229.550
1940.000	227.204	229.484
1960.000	227.111	229.359
1972.901	227.050	229.437
1980.000	226.227	229.472
1982.815	225.900	229.484
2000.000	225.900	229.568
2020.000	225.900	229.686
2024.223	225.900	229.701
2032.440	227.050	229.704
2040.000	227.395	229.730
2040.109	227.400	229.730
2041.862	227.750	229.742
2043.113	228.000	229.752
2051.966	229.772	229.771
2060.000	229.792	229.794
2061.288	229.796	229.792
2080.000	227.983	229.849
2086.459	227.357	229.841
2094.012	227.354	229.827

LONG SECTION A (7/7)

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AUTHORISED T.COUSLAND 11/07/2022

SHEET 4 OF 7

MELBOURNE WATER CORPORATION

KALKALLO RETARDING BASIN - CONCEPT DESIGN

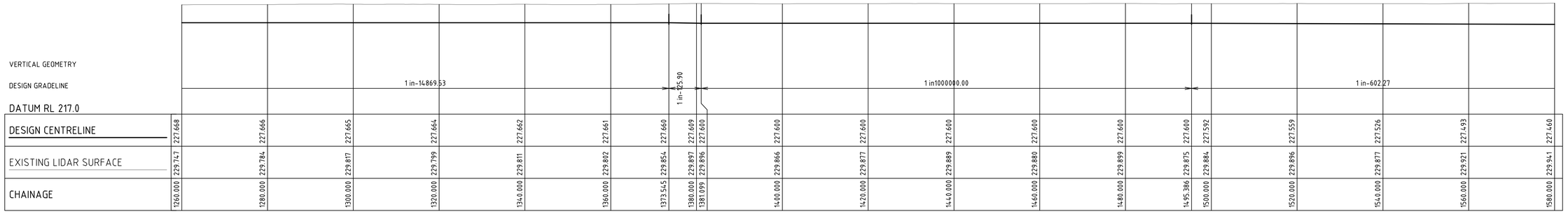
LONG SECTIONS

DWG NO. 4

REV. C

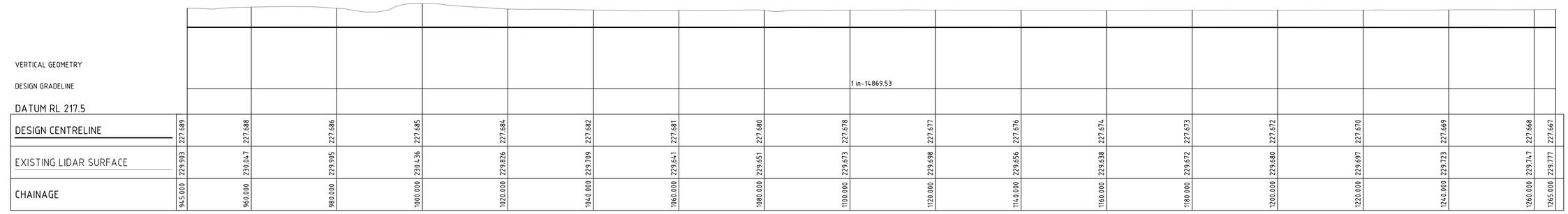
Spiire REF No. 308513WC203

file name 308513WC200.dwg layout name WC203
file location G:\30\308513\Water\ACAD plotted by Vasili Giannetakis plot date 22/07/2022 11:10:45 AM



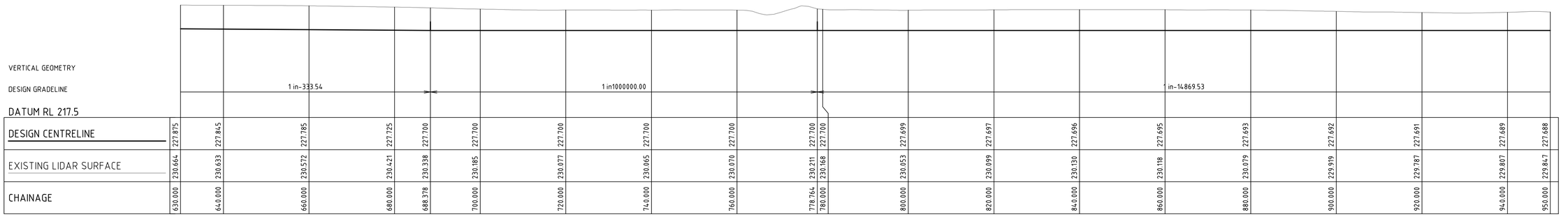
DESIGN CENTRELINE	227.668	227.666	227.665	227.664	227.662	227.661	227.660	227.609	227.600	227.600	227.600	227.600	227.600	227.600	227.600	227.592	227.559	227.526	227.493	227.460	
EXISTING LIDAR SURFACE	229.747	229.784	229.817	229.799	229.811	229.802	229.854	229.897	229.896	229.866	229.877	229.889	229.880	229.899	229.875	229.884	229.896	229.877	229.921	229.941	
CHAINAGE	1260.000	1280.000	1300.000	1320.000	1340.000	1360.000	1373.545	1380.000	1381.099	1400.000	1420.000	1440.000	1460.000	1480.000	1495.386	1500.000	1520.000	1540.000	1560.000	1580.000	

LONG SECTION B (5/7)



DESIGN CENTRELINE	227.689	227.688	227.686	227.685	227.684	227.682	227.681	227.680	227.678	227.677	227.676	227.674	227.673	227.672	227.670	227.669	227.668	227.667			
EXISTING LIDAR SURFACE	229.903	230.047	229.905	230.436	229.826	229.709	229.641	229.651	229.673	229.698	229.656	229.638	229.672	229.680	229.697	229.723	229.747	229.777			
CHAINAGE	945.000	960.000	980.000	1000.000	1020.000	1040.000	1060.000	1080.000	1100.000	1120.000	1140.000	1160.000	1180.000	1200.000	1220.000	1240.000	1260.000	1265.000			

LONG SECTION B (4/7)



DESIGN CENTRELINE	227.875	227.845	227.785	227.725	227.700	227.700	227.700	227.700	227.700	227.700	227.700	227.699	227.697	227.696	227.695	227.693	227.692	227.691	227.689	227.688	
EXISTING LIDAR SURFACE	230.664	230.633	230.572	230.421	230.338	230.185	230.077	230.065	230.070	230.211	230.168	230.053	230.099	230.130	230.118	230.079	229.919	229.787	229.807	229.847	
CHAINAGE	630.000	640.000	660.000	680.000	688.378	700.000	720.000	740.000	760.000	778.764	780.000	800.000	820.000	840.000	860.000	880.000	900.000	920.000	940.000	950.000	

LONG SECTION B (3/7)

Spiire REF No. 308513WC204

REV.	AMENDMENTS	APP'D	DATE
C	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	11/07/2022
B	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	21/02/22
A	FOR INFORMATION ONLY	T.C	28/09/21

Melbourne Water

H 1:500 SCALE @ A1 V 1:250 — 0 5 10 15 20 25 / 0 2.5 5 7.5 10 12.5

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MELWAY REFERENCE

PLAN REFERENCE 308513

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DRAWN BY **V.GIANNETAKIS**
DESIGNED **B.NEVILL**
CHECKED **T.COUSLAND**
AUTHORISED **T.COUSLAND** 11/07/2022

SHEET 5 OF 7

MELBOURNE WATER CORPORATION

KALKALLO RETARDING BASIN - CONCEPT DESIGN

LONG SECTIONS

DWG NO. 5

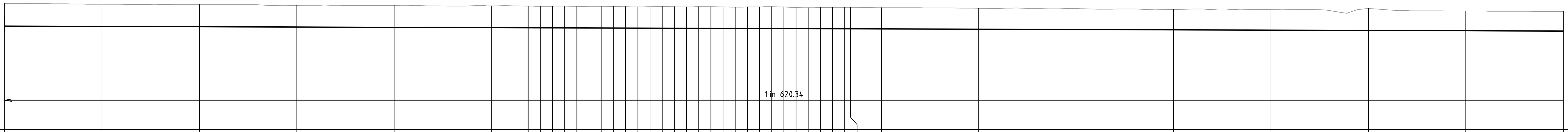
REV. C

file name 308513WC200.dwg layout name WC204
file location G:\30\308513\Water\ACAD plotted by Vasili Giannetakis plot date 22/07/2022 11:10:45 AM

VERTICAL GEOMETRY

DESIGN GRADELINE

DATUM RL 218.5



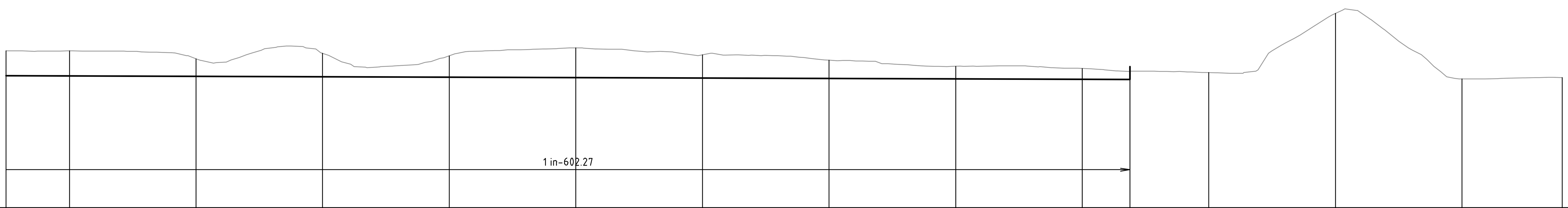
CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
0.000	229.110	231.431
20.000	229.078	231.352
40.000	229.046	231.301
60.000	229.013	231.229
80.000	228.981	231.219
100.000	228.949	231.184
107.500	228.937	231.152
110.000	228.933	231.135
112.500	228.929	231.143
115.000	228.925	231.156
117.500	228.921	231.124
120.000	228.917	231.125
122.500	228.913	231.133
125.000	228.908	231.113
127.500	228.904	231.092
130.000	228.900	231.069
132.500	228.896	231.092
135.000	228.892	231.115
137.500	228.888	231.082
140.000	228.884	231.076
142.500	228.880	231.092
145.000	228.876	231.100
147.500	228.872	231.071
150.000	228.868	231.050
152.500	228.864	231.063
155.000	228.860	231.078
157.500	228.856	231.093
160.000	228.852	231.061
162.500	228.848	231.009
165.000	228.844	230.992
167.500	228.840	231.003
170.000	228.836	231.024
172.500	228.832	231.035
173.715	228.830	231.031
180.000	228.820	230.985
200.000	228.788	230.931
220.000	228.755	230.894
240.000	228.723	230.814
260.000	228.691	230.797
280.000	228.659	230.914
300.000	228.626	230.640
320.000	228.594	230.597

LONG SECTION C (1/3)

VERTICAL GEOMETRY

DESIGN GRADELINE

DATUM RL 216.5



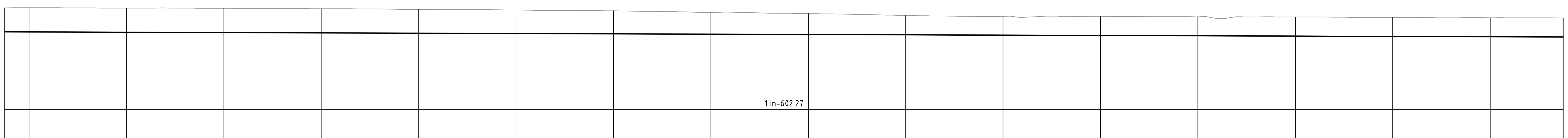
CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
1890.000	226.945	228.900
1900.000	226.928	228.901
1920.000	226.895	228.282
1940.000	226.862	228.716
1960.000	226.829	228.509
1980.000	226.795	229.141
2000.000	226.762	228.588
2020.000	226.729	228.170
2040.000	226.696	227.685
2060.000	226.663	227.518
2067.542	226.650	227.291
2080.000		227.192
2100.000		231.867
2120.000		226.686
2135.801		226.797

LONG SECTION B (7/7)

VERTICAL GEOMETRY

DESIGN GRADELINE

DATUM RL 216.5



CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
1575.000	227.468	229.930
1580.000	227.460	229.941
1600.000	227.426	229.899
1620.000	227.393	229.874
1640.000	227.360	229.829
1660.000	227.327	229.772
1680.000	227.293	229.702
1700.000	227.260	229.621
1720.000	227.227	229.448
1740.000	227.194	229.335
1760.000	227.161	229.142
1780.000	227.127	229.038
1800.000	227.094	229.047
1820.000	227.061	229.075
1840.000	227.028	228.984
1860.000	226.995	228.936
1880.000	226.961	228.910
1895.000	226.936	228.878

LONG SECTION B (6/7)

Spiire REF No. 308513WC205

REV.	AMENDMENTS	APP'D	DATE
C	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	11/07/2022
B	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	21/02/22
A	FOR INFORMATION ONLY	T.C	28/09/21

H 1:500 SCALE @ A1 V 1:250 — 0 5 10 15 20 25 / 0 2.5 5 7.5 10 12.5

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DRAWN BY V.GIANNETAKIS
DESIGNED B.NEVILL
CHECKED T.COUSLAND
AUTHORISED T.COUSLAND 11/07/2022

SHEET 6 OF 7

MELBOURNE WATER CORPORATION

KALKALLO RETARDING BASIN - CONCEPT DESIGN

LONG SECTIONS

DWG NO. 6

REV. C

file name 308513WC200.dwg layout name WC205
file location G:\30\308513\Water\ACAD plotted by Vasili Giannetakis plot date 22/07/2022 11:10:46 AM

VERTICAL GEOMETRY

DESIGN GRADELINE

1 in-620.34

DATUM RL 217.5

CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
630.000	228.094	230.193
640.000	228.078	230.631
660.000	228.046	230.319
680.000	228.014	230.252
700.000	227.982	230.244
720.000	227.949	230.210
727.500	227.937	230.234
730.000	227.933	230.234
732.500	227.929	230.223
735.000	227.925	230.217
737.500	227.921	230.206
740.000	227.917	230.199
742.500	227.913	230.198
745.000	227.909	230.200
747.500	227.905	230.203
749.661	227.902	230.201
760.000	227.885	230.183
780.000	227.853	230.160
800.000	227.820	230.368
820.000	227.788	229.784
840.000	227.756	230.110
860.000	227.724	230.078
874.675	227.700	230.068
880.000	227.700	230.068
900.000	227.700	230.075
900.242	227.700	230.075

LONG SECTION C (3/3)

VERTICAL GEOMETRY

DESIGN GRADELINE

1 in-620.34

DATUM RL 218.0

CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
315.000	228.602	230.612
320.000	228.594	230.597
340.000	228.562	230.578
360.000	228.530	230.556
380.000	228.497	230.524
400.000	228.465	230.502
420.000	228.433	230.490
440.000	228.401	230.451
460.000	228.368	230.442
480.000	228.336	230.420
500.000	228.304	230.377
520.000	228.272	230.341
540.000	228.240	230.295
545.000	228.231	230.285
547.500	228.227	230.280
550.000	228.223	230.283
552.500	228.219	230.289
555.000	228.215	230.291
557.500	228.211	230.293
560.000	228.207	230.302
562.500	228.203	230.307
565.000	228.199	230.307
567.500	228.195	230.316
570.000	228.191	230.318
572.500	228.187	230.321
575.000	228.183	230.310
577.500	228.179	230.253
580.000	228.175	230.234
582.500	228.171	230.151
585.000	228.167	230.028
587.500	228.163	229.930
590.000	228.159	229.849
592.500	228.155	229.780
595.000	228.151	229.750
597.500	228.147	229.772
600.000	228.143	229.819
602.500	228.139	229.853
603.389	228.137	229.860
620.000	228.111	230.305
635.000	228.086	230.425

LONG SECTION C (2/3)

Spiire REF No. 308513WC206

REV.	AMENDMENTS	APP'D	DATE
C	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	11/07/2022
B	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	21/02/22
A	FOR INFORMATION ONLY	T.C	28/09/21

H 1:500 SCALE @ A1 V 1:250 (0 5 10 15 20 25 / 0 2.5 5 7.5 10 12.5)

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MELWAY REFERENCE

PLAN REFERENCE 308513

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DRAWN BY V.GIANNETAKIS
DESIGNED B.NEVILL
CHECKED T.COUSLAND
AUTHORISED T.COUSLAND 11/07/2022

SHEET 6 OF 7

MELBOURNE WATER CORPORATION

KALKALLO RETARDING BASIN - CONCEPT DESIGN

LONG SECTIONS

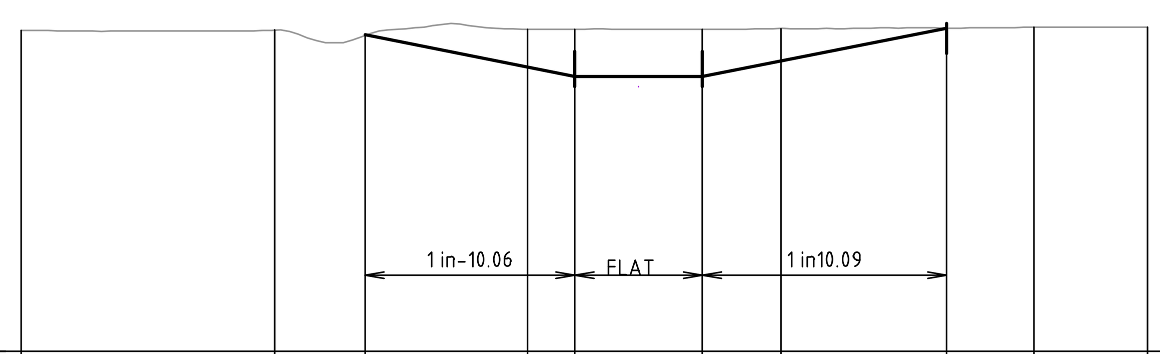
DWG NO. 7

REV. C

file name 308513WC200.dwg layout name WC206
file location G:\30\308513\Water\ACAD plotted by Vasili Giannetakis plot date 22/07/2022 11:10:47 AM

VERTICAL GEOMETRY

DESIGN GRADELINE



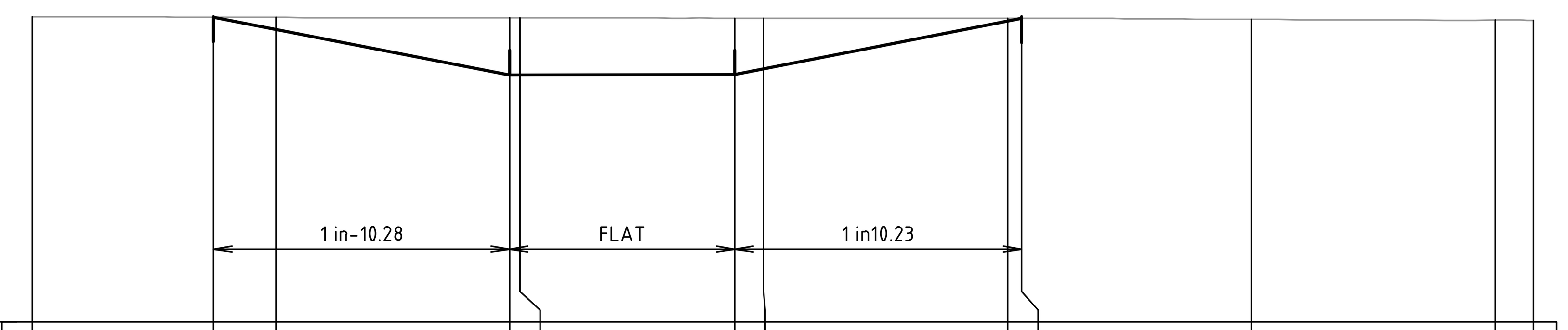
DATUM RL 217.5

CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
0.000		230.171
20.000		230.190
27.145	230.008	229.979
40.000	228.731	230.218
43.726	228.360	230.223
53.802	228.359	230.218
60.000	228.973	230.253
73.099	230.272	230.271
80.000		230.306
88.965		230.313

CROSS SECTION F

VERTICAL GEOMETRY

DESIGN GRADELINE



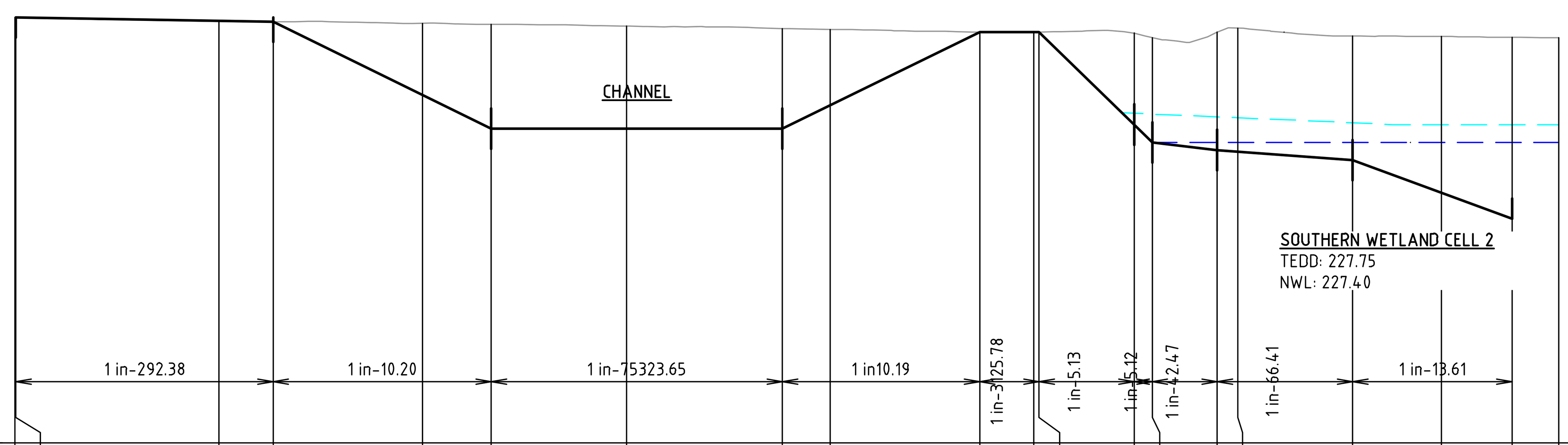
DATUM RL 218.0

CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
0.000		230.540
14.863	230.516	230.515
20.000	230.016	230.512
39.147	228.155	230.494
40.000	228.155	230.496
57.621	228.167	230.476
60.000	228.399	230.470
80.000	230.355	230.475
81.173	230.469	230.469
100.000		230.422
120.000		230.412
123.161		230.399

CROSS SECTION E

VERTICAL GEOMETRY

DESIGN GRADELINE



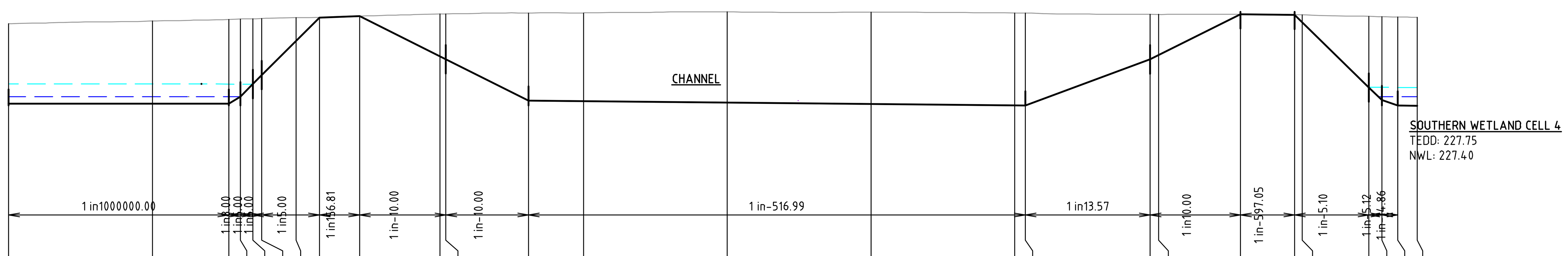
DATUM RL 221.5

CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
0.000		229.857
0.090	229.857	229.857
20.000	229.789	229.786
25.338	229.771	229.772
40.000	228.333	229.740
46.740	227.672	229.720
60.000	227.672	229.685
75.312	227.672	229.637
80.000	228.132	229.621
94.671	229.571	229.570
100.000	229.569	229.570
100.495	229.569	229.569
109.827	227.750	229.547
111.618	227.400	229.457
117.988	227.250	229.566
120.000	227.220	229.646
131.270	227.050	229.491
140.000	226.409	229.479
146.921	225.900	229.468
151.491		229.454

CROSS SECTION D

VERTICAL GEOMETRY

DESIGN GRADELINE



DATUM RL 223.0

CHAINAGE	DESIGN CENTRELINE	EXISTING LIDAR SURFACE
0.000	227.300	229.531
20.000	227.300	229.603
30.625	227.300	229.648
32.225	227.500	229.659
33.976	227.850	229.665
35.226	228.100	229.674
40.000	229.055	229.700
43.240	229.703	229.703
48.823	229.739	229.741
60.000	228.621	229.801
60.831	228.538	229.803
72.333	227.387	229.830
80.000	227.372	229.830
100.000	227.334	229.860
120.000	227.295	229.848
140.000	227.256	229.829
141.455	227.254	229.825
158.844	228.535	229.790
160.000	228.651	229.788
171.408	229.791	229.795
178.930	229.778	229.779
180.000	229.568	229.776
189.270	227.750	229.733
191.062	227.400	229.725
193.292	227.250	229.717
195.980		229.709

CROSS SECTION C

Spiire REF No. 308513WC207

REV.	AMENDMENTS	APP'D	DATE
C	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	11/07/2022
B	UPDATED IN ACCORDANCE TO MWC COMMENTS	T.C	21/02/22
A	FOR INFORMATION ONLY	T.C	28/09/21

Melbourne Water

H 1:500 / SCALE @ A1 / V 1:100

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DRAWN BY V.GIANNETAKIS

DESIGNED B.NEVILL

CHECKED T.COUSLAND

AUTHORISED T.COUSLAND 11/07/2022

SHEET 7 OF 7

MELBOURNE WATER CORPORATION

KALKALLO RETARDING BASIN - CONCEPT DESIGN

CROSS SECTIONS

DWG NO. 8

REV. C

file name 308513WC200.dwg layout name WC207
file location G:\30\308513\Water\ACAD plotted by Vasili Giannetakis plot date 22/07/2022 11:10:47 AM

Appendix E. – Preferred Option TUFLOW Mapping

KALKALLO RETARDING BASIN - FLOOD MAPPING
PROPOSED CONDITIONS - 10% AEP FLOOD DEPTHS (d_max)

NOTATIONS

File Ref: xxxxxx
Plan: W GIS xxx
Rev:
Date: 30.09.2021

Designed:
Checked:
Authorised:

Flood Results:
Data:

LEGEND

- Model Extents
- Model Outflow Boundary

Flood Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- >2.0

1:9,500

97 0 97 194 291 m

Coordinate System: GDA 1994 MGA Zone 55
Paper size A3 Landscape

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Melbourne Vic 8007
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spiire.com.au
ABN 55 050 029 635

KALKALLO RETARDING BASIN - FLOOD MAPPING
PROPOSED CONDITIONS - 1% AEP FLOOD DEPTHS (d_max)

NOTATIONS

File Ref: xxxxxx
Plan: W GIS xxx
Rev:
Date: 30.09.2021

Designed:
Checked:
Authorised:

Flood Results:
Data:

LEGEND

- Model Extents
- Model Outflow Boundary

Flood Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- >2.0

1:9,500

97 0 97 194 291 m

Coordinate System: GDA 1994 MGA Zone 55
Paper size A3 Landscape

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ABN 55 050 029 635

KALKALLO RETARDING BASIN - FLOOD MAPPING
PROPOSED CONDITIONS - 10% AEP BED SHEAR STRESS (bss_max)

NOTATIONS

File Ref: xxxxxx
Plan: W GIS xxx
Rev:
Date: 30.09.2021

Designed:
Checked:
Authorised:

Flood Results:
Data:

LEGEND

- Model Extents
- Model Outflow Boundary

Bed Shear Stress (N/m2)

- 0 - 40
- 40 - 80
- 80 - 125
- > 125

1:9,500

97 0 97 194 291 m

Coordinate System: GDA 1994 MGA Zone 55
Paper size A3 Landscape

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KALKALLO RETARDING BASIN - FLOOD MAPPING
PROPOSED CONDITIONS - 1% AEP BED SHEAR STRESS (bss_max)

NOTATIONS

File Ref: xxxxxx
Plan: W GIS xxx
Rev:
Date: 30.09.2021

Designed:
Checked:
Authorised:

Flood Results:
Data:

LEGEND

Model Extents

Model Outflow Boundary

Bed Shear Stress (N/m2)

- 0 - 40
- 40 - 80
- 80 - 125
- > 125

1:9,500

97 0 97 194 291 m

Coordinate System: GDA 1994 MGA Zone 55
Paper size A3 Landscape

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Appendix F. Site Construction Management Plan

Site Construction Management plan and EMP - Types and Locations of Environmental Protection Measures

Project Name: Kalkallo Basin Sodic Soil Review Date and Revision: 19/07/2022 – Rev 2

The following have been identified as medium environmental aspects for the site:

▪ Dispersive (sodic) soil ▪ Erosion ▪ Water quality ▪ Waste/Chemicals

These aspects shall be managed with the environmental protection measures outlined on this plan.

Management

1. Responsibilities:
- Authority: Melbourne Water
- Consultant: Spiire
- Contractor:
- Emergency Contact:
- Emergency Contact 2:

2. Communication of EMP and Construction Requirements:
- Displaying site EMP and Construction management plan on shed wall at contractor Compound
- Inductions for all Sub-Contractors & Contractors
- Toolbox Meetings
- Training Sessions
- Induction of Sub- Contractors & Visitors into EMP, CHMP and Construction Practices

3. Inspections and Maintenance:
- Monitoring of EMP protection measures after rainfall events, otherwise weekly
- Monthly inspections by consultants where significant flora or fauna may be impacted
- All environmental mitigation measures found to be defective and/or ineffective at any time,
a) are to be repaired, replaced and/or adequately improved immediately, so as to be effective & sufficient OR within a timeframe that ensures an impact cannot and does not occur; AND
b) If the defective or ineffective mitigation measure could potentially result in an environmental impact, all works must cease immediately and may not resume until the mitigation measure is repaired, replaced and/or adequately improved, so as to be effective and sufficient
- Provide a wash down bay, amenities, waste bins, chemical spill kits, first aid station ect at compound site.
- All persons using machinery within the works area must comply with hygiene protocols and complete the relevant details within the register

4. Staging of Works:
- Staging TBC

5. Informing Residents of Construction Works:
- Letter drop
- Signage
- Door knock (where applicable)
- Newspaper articles (where applicable)

6. Associated Documents:
- Flora and fauna survey and condition assessment (TBC for Kalkallo site)
- CHMP –Cultural Heritage Management Plan (TBC for Kalkallo site)

Dispersive (Sodic) Soil — Risk: Significant

Requirement: Specific requirements must be adhered to in relation to general principles for working in sodic soils.

7. Reducing extents of machinery movement/minimising extent of works.
- Minimise disturbing any areas until necessary.
- Staging construction of the basin to minimize the amount of area disturbed at one time.
- Retain existing tees/biomass wherever possible.

8. Stabilizing dispersive soil/ reducing contact with rainfall
- Suitable topsoil to aid the rapid propagation of grass seed.
- Stabilising any dispersive soil or disturbed areas with Gypsum or lime
- Reuse of all topsoil to cover exposed sodic soil.
- Providing material to shroud exposed sodic soil areas

9. Site specific methods
- Covering surface with topsoil/mulch/ straw to lessen the effect of rainfall impact on sodic soils.
- Use of geofabrics for soil protection
- Regular (daily/weekly) assessment of site to identify bare areas.
- Ceasing major construction/excavation prior to rainfall events.
- Implementation of effective bypass systems during construction.

Erosion and Sediment — Risk: Significant

Requirement: Mitigating the erosion risk as a result of sodic soil through early establishment of vegetation, appropriate construction methodology, soil protection techniques as well as short term treatment of incoming turbid water.

10. Soil physical ameliorants
- Using sandy topsoils, which are preferred for protective covering or shrouding.
- Use of larger particle size/weight of clay – less likely to be suspended
- Ad-hoc (as needs basis) use of Gypsum [$CaSO_4$] – stabilising topsoil (increases soil permeability and significantly reduces dispersity).
- Hydrated Lime [$(Ca(OH)_2$]- for geotechnical/construction use. Increases soil strength.
- Agricultural Lime [$CaCO_3$] – for acidic topsoil pH amelioration

12. Management of Runoff
- Diversion of off-site runoff away from site
- Diversion of on-site run-off away from sensitive areas (such as unstabilised soil, batters of stockpiles)
- Diversion of sediment-laden run-off into sediment retention structures
- Naturalise drainage lines as much as possible
- Outlet drains must be protected by sediment traps placed upstream of outlet points
- Working Drainage pits to be protected during construction with adequate sediment control

11. Sediment control:
- On-site clarifiers to remove incoming suspended sediment.
- Implementation of effective bypass systems during construction
- Short term strategy through implementation of flocculation – using oversized sediment pond and larger dry out areas.
Monitoring turbidity levels on site in regular intervals is important

13. Other:

Water quality — Risk: Med

Requirement: All earthworks must be undertaken in a manner that will minimise soil erosion/maintain water quality and adhere to ***Construction Techniques for Sediment Pollution Control*** (EPA 275:1991), ***Environmental Guidelines for Major Construction Sites (EPA 480: 1996) and Doing it Right on Sub-divisions (EPA 960: 2004)***

14. Drainage Management:
- Diversion of any contaminated flow generated on site to a sediment trap or settlement treatment prior to release from site of into receiving waters
- Water quality monitoring before discharging water into the wetlands/waterway to confirm discharge meets EPA requirements 30NTU or that of the receiving waters if the receiving waters is < 30 NTU.
- Monitoring of water quality of the receiving waters to be undertaken before and after discharge.

18. Dewatering:
- Reuse on site run-off water (if of suitable quality)
- Water quality objectives
- Pumping procedures
- Supervision during de-watering process
- Use of flocculants
- Treat water if necessary, before discharging
- Discharged water must have turbidity as less than or equal to the receiving waters or otherwise ≤30 NTU, whichever is lower
- Water quality monitoring to be undertaken upstream and downstream of works as directed by superintendent

15. Soil Stabilisation:
During Construction:
- Stabilising any dispersive soil and disturbed ground with Gypsum or lime
- Utilising geofabric barriers for soil protection
- Grading, excavation and construction must not proceed during periods of heavy rainfall
- Restrict excavation depth beyond what is needed.
- Avoid removing trees.
- Timely placement of organic matter/suitable topsoil, to assist in rapid propagation of grass seed.
- Mulching

19. Vehicle and Road Management:
Site Access:
- Access will be obtained from the adjacent subdivision stages or roads.
- Restrict vehicle movement to stabilised areas only
- Cover vehicle tracks and parking areas with gravel

Cleaning Vehicles:
- Install wash down area at nominated location, if not in place and if directed by the superintendent. Wash all equipment in wash down area
- Disinfection to be carried out a safe distance from water bodies to minimise the risk of chemical contamination.
- Location of wash down area is outside the vicinity of the work zone area.
- The cleaning and disinfection of equipment/machinery is to be in accordance with 'Hygiene protocols for the control of diseases in Australian frogs' (Murray et al 2011)
- Wash down area to be surrounded with bund and channel. Refer to detail on Sheet 3

Street Cleaning:
- Regular inspections
- Roads cleaned prior to rain/storm event
- Street sweepers must not be used as a primary means of sediment control

16. Stockpile Protection:
- Retention and reuse of all topsoil containing organic matter – May not be enough material available – stockpiling and testing on site will be required.
- Stockpile to be located within subdivision stages as per plan
- Diversion of run-off away from stockpile areas
- Sediment retention structures downslope from stockpiles
- Position away from drainage lines and at least 10m from waterways
- Stockpiles must be covered immediately
- Minimise the number and size of stockpiles
- Maximum of 2:1 height to width ratio; and a maximum overall height of 2m
- Any excess spoil should be removed from site as quickly as possible

17. Sediment Traps:
- The following may be utilised as a means for sediment protection: Geotextile sediment fences, grass filter strips, rock bunds, synthetic/biodegradable logs, check dams and gravel sausages
- Sediment run-off controls and drainage around construction must be completed prior to works
- Sediment controls measures must be maintained for size and capacity of 1 in 2 year storm event
- Inspect and maintain after rainfall
- Emergency sediment fencing to be available
- Filter socks installed in open channels
- Prior to the installation of sediment/silt fencing, the fencing material is to be cleaned and disinfected against vegetative and spore stages of fungi prior to installation.

20. Other:
- Topsoil must be kept separate from subsoil when stockpiling soil
- Imported soils, mulch and aggregate must be free of weeds, debris, acid sulphate and other contaminants

Waste — Risk: Low

Requirement: Litter and waste must be contained on site, before disposal in a responsible manner. Waste generation must be minimised.

21. Movement of Soil : Off-site/ On Site
- Any additional fill unsuitable or surplus to requirements will be taken to a legal site of disposal

Contaminant Status: N/A

22. Waste Minimisation Methods:
- Avoid, reduce, reuse, recycle
- Separate recyclable waste and materials from general waste for recycling (recycle bins must be clearly marked to avoid contamination of recyclable materials)
- Take care to not over order materials

23. Waste Storage and Disposal:
- Store all litter and hard waste in designated areas to prevent washing/blowing away
- Lidded rubbish and recycle bins provided close to site office
- Bins locked at the end of each workday
- Remove waste frequency
- Contain all waste material on site
- Adhere to regulatory requirements for waste disposal

24. Other:
- Worksite be litter free and removed at end of works
- Select recycled materials for use on site, where possible

Chemicals — Risk: Low

Requirement: Storage and spill management practices must be implemented to ensure that no environmental damage can result from the escape

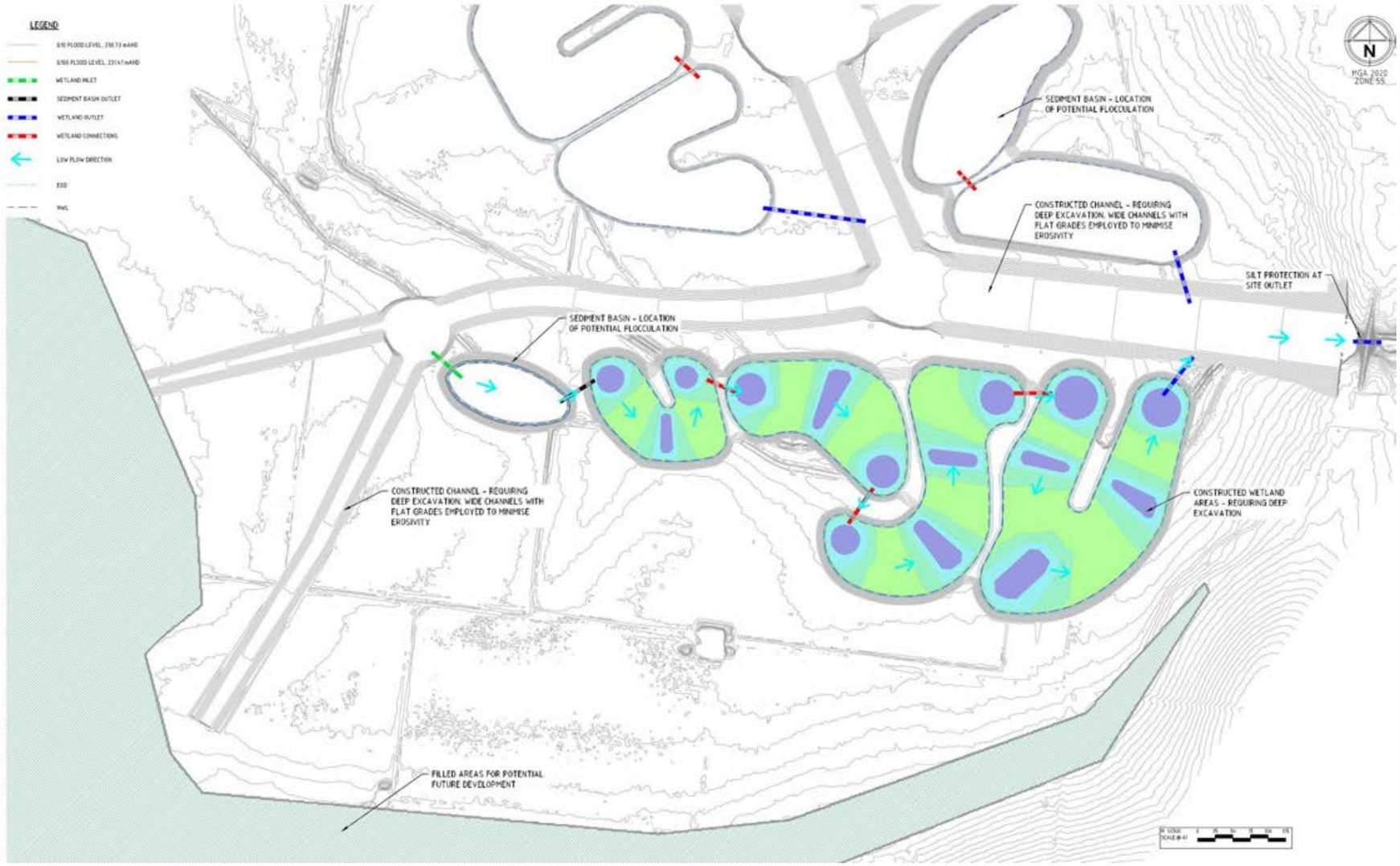
25. Storage:
- Chemicals used/stored on site:
- Designated areas (including for fuels, oils, chemicals and other hazardous materials)
- Bunding
- Impervious liners
- Minimal storage of field and other chemicals on site
- MSDS must be available for substances in store

26. Spill Management:
- Training and emergency procedures for fuel/chemical spills
- Emergency contact numbers and response flow charts distributed and displayed clearly
- Weekly inspections of management measures
- Spill kits to be kept on site
- Designated refuelling areas and site compound must be appropriately bunded and graded to a sump at the lowest point where spills collect

27. Refuelling Procedure:
- Designated appropriate refuelling points
- Bunding and liners for chemical storage must be installed
- No refuelling to occur within minimum 10m of any waterway
- All refuelling and other hazardous materials use to only occur within appropriate bunded or portable sealed bunded area
- Stormwater/rain protection measures must be installed for bunded areas
- Minimal refuelling of vehicles to occur on site and wherever possible done off site

28. Other:
- Vehicular and machinery maintenance must not occur on site
- All oily water collected from sumps, interceptors and drip trays must be disposed of at suitably licensed waste disposal facility

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- Vehicular and machinery maintenance must not occur on site
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Significant Flora/ Fauna — Risk: Med

Requirement: **All significant flora and fauna on and adjacent to the site must be protected.**

29. Yes/No. Details:
- Temporary fencing to be anchored at: (TBC)
- Buffers – (TBC)
- Relocation programs – (TBC)
- Tree protection e.g. temporary fencing around drip line – (TBC),
- Offsets e.g. removal of a tree, replaced by planting of new trees – (TBC)
- Design change – N/A
- Native vegetation to be retained and protected in accordance with Native Vegetation Precinct Structure Plan.

Weed Management:

Archaeological/ Heritage — Risk: Significant/**Med**/Low

Requirement: Places, sites and objects of archaeological or heritage significance must be protected.

30. **Yes**/No. Details:
- Inductions to all contractors and sub-contractors for cultural heritage management plan
- Procedure if further items are found: - if suspected artefact found, cordon off 20m radius, notify cultural heritage advisor, Biosis
- Collection and relocation
- Design changes
- Monitoring
- Stop works
- Protection zones