WETLAND 1 AT THE DRURY SOUTH PRECINCT – OPPORTUNITIES WITHIN THE FLOODPLAIN

***Andrew Hope** (Senior Civil Engineer, Tonkin + Taylor)*
***Benjamin Loh** (Senior Landscape Architect, Boffa Miskell)*
***Jade Huffadine** (Civil Engineer, Tonkin + Taylor)*
***Mark Lewis** (Senior Landscape Architect, Boffa Miskell)*
***Peter Norfolk** (Design Manager, Tonkin + Taylor)*
***Sam Courtier** (Project Engineer, Stevenson Mining Ltd)*

ABSTRACT (500 WORDS MAXIMUM)

A new 361 hectare commercial and industrial precinct, located south of Drury, will manage stormwater via a treatment train approach. In addition to raingardens, tree pits and swales, a large centralised wetland will treat 115 hectares of runoff from the new development. This wetland is unique as a large (approximately 3.5 hectare), complex (GD_01 sinuous design) wetland, located within the active floodplain of a major stream and adjacent to a significant ecological area. This provided a number of design challenges and opportunities. The wetland location within the floodplain is tightly constrained in all directions by the Hingaia Stream, balance of the flood plain area to the west and by the proposed commercial area to the East.

This project challenged our thinking processes and explores a different design method embracing hydrological, cultural and physical challenges. Instead of working through the conventional process - Survey- Analysis-Design (SAD) - we adopted a more creative / unique design process. By introducing a metaphor into the design process at an early stage, we began with an idea rather than a problem. This design method not only enables us to design a stormwater treatment system that meets the design challenges but a system that functions as a mosaic of terrestrial, wetland and aquatic habitats which will support an ecosystem of insects, birds and fish.

The team of Drury South Crossing, Tonkin + Taylor, Boffa Miskell, Ngati Tamaoho artists, Stevenson Mining, and Watres Consulting collaborated to deliver the modelling, design, and construction of the wetland. This paper outlines the project outcomes and lessons learnt from designing a treatment wetland in a sensitive floodplain environment using a non-conventional design process whilst incorporating cut slopes, large water retaining infrastructure and floodplain mechanics into one stormwater system. Discussion on the construction challenges of delivering this complex wetland geometry in very poor ground is also included

KEYWORDS

Wetland, nonlinear design, conceptual metaphor, cultural input, floodplain, sinuous design, machine control

PRESENTER PROFILE

Benjamin Loh:

Benjamin is a Landscape Architect with Boffa Miskell (BM) since 2015. Benjamin was trained as a specialist in WSUD under the Singapore government's Active, Beautiful, Clean Waters Programme. He has a number of publications in urban stormwater and has won numerous international design awards for his water sensitive projects.

Andrew Hope:

Andrew Hope is a Senior Civil Engineer & project manager with Tonkin + Taylor (T+T) since 2008. Andrew has a wide range of experience across the civil discipline and presently focuses on infrastructure development including stormwater, wastewater, water supply, dry services and large scale earthworks.

1 INTRODUCTION

The Drury South Precinct (DSP) is a 361 ha subdivision which will include approximately 178 ha of land for industrial and business activities such as manufacturing, wholesale trade, construction, transport and storage activities located in Drury, South Auckland. Along with the provision of industrial and business activities, the primary design elements of the Precincts include a broad and connected public open space and recreational network that responds to ecological, cultural, and landscape values of the area.

Stormwater management for the DSP will be delivered using a treatment train approach. Figure 1 below shows a schematic of the stormwater treatment train identified for the DSP. A stormwater wetland located at the end of the train will provide water quality treatment and detention of stormwater runoff from impervious surfaces for Stage 1 of the DSP development, prior to being discharged via a green outfall into the receiving environment (the Hingaia Stream).

The proposed wetland landscape, technical design and construction has a number of challenges and opportunities covered in the subsequent sections. These include:

- Providing amenity for recreational and ecological benefit as well as reinforcing strong cultural and historic relationships between people and nature
- A provision of habitats for a range of taonga (culturally important) plants, animals, birds, insects, and micro-organisms
- Reducing the effect of downstream/upstream flooding by allowing the wetland to function as an integral part of the floodplain and overtop in sufficiently large events to provide additional flood capacity and storage
- Overcoming the challenges of high groundwater combined with sensitive low strength soils beneath the water retaining embankment and cut slope at the rear of the wetland
- Providing sinuous bathymetry to encourage a longer flow path and increase the contact time with wetland vegetation

The solutions have been designed to meet the physical constraints of the site and the desires of the various stakeholders.

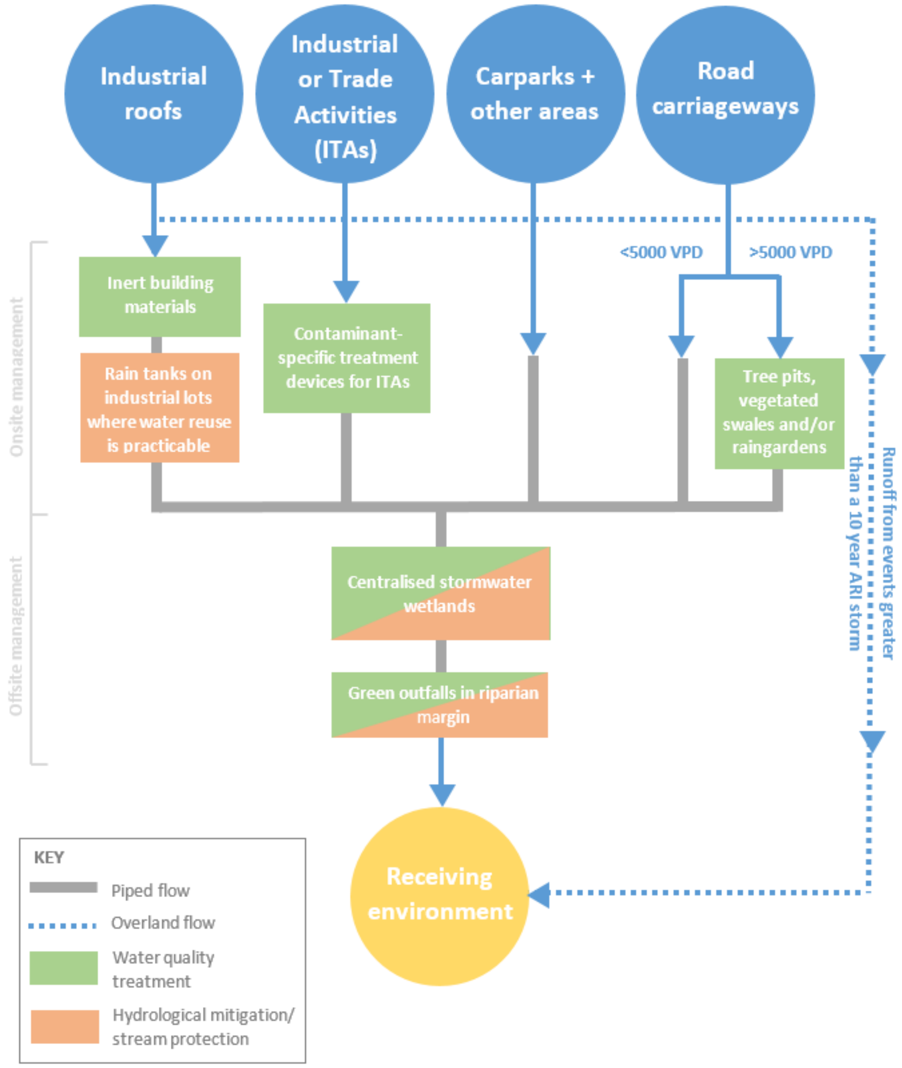

Figure 1: Schematic of the treatment train for the Industrial Precinct

1.1 THE EXISTING SITE AND CATCHMENT

The site is located in the low lying land of the Drury Basin and contains the confluence of two large streams; the Hingaia Stream and the Maketu Stream. The site occupies 6.5% of the wider Hingaia Catchment (shown in yellow in Figure 1.1 below) with Wetland 1 positioned in the west of the site (shown in blue).

The topography is generally characterised as flat to gently rolling and becomes more undulating towards the foothills of the Hunua Ranges located on the eastern side of the site. Generally the site grades in a north-westerly direction towards Drury creek and the existing Drury industrial area. The elevation of most of the site varies between 10 m RL and 20 m RL.

The current land use in the DSP area is predominantly farming (agriculture) and horticulture with some lifestyle dwellings. Vegetation on the site is mainly grazed rank pasture grasses and exotic tree species used for hedging and shelter belts. There is very little original or indigenous vegetation left, and that which is remaining is highly fragmented.

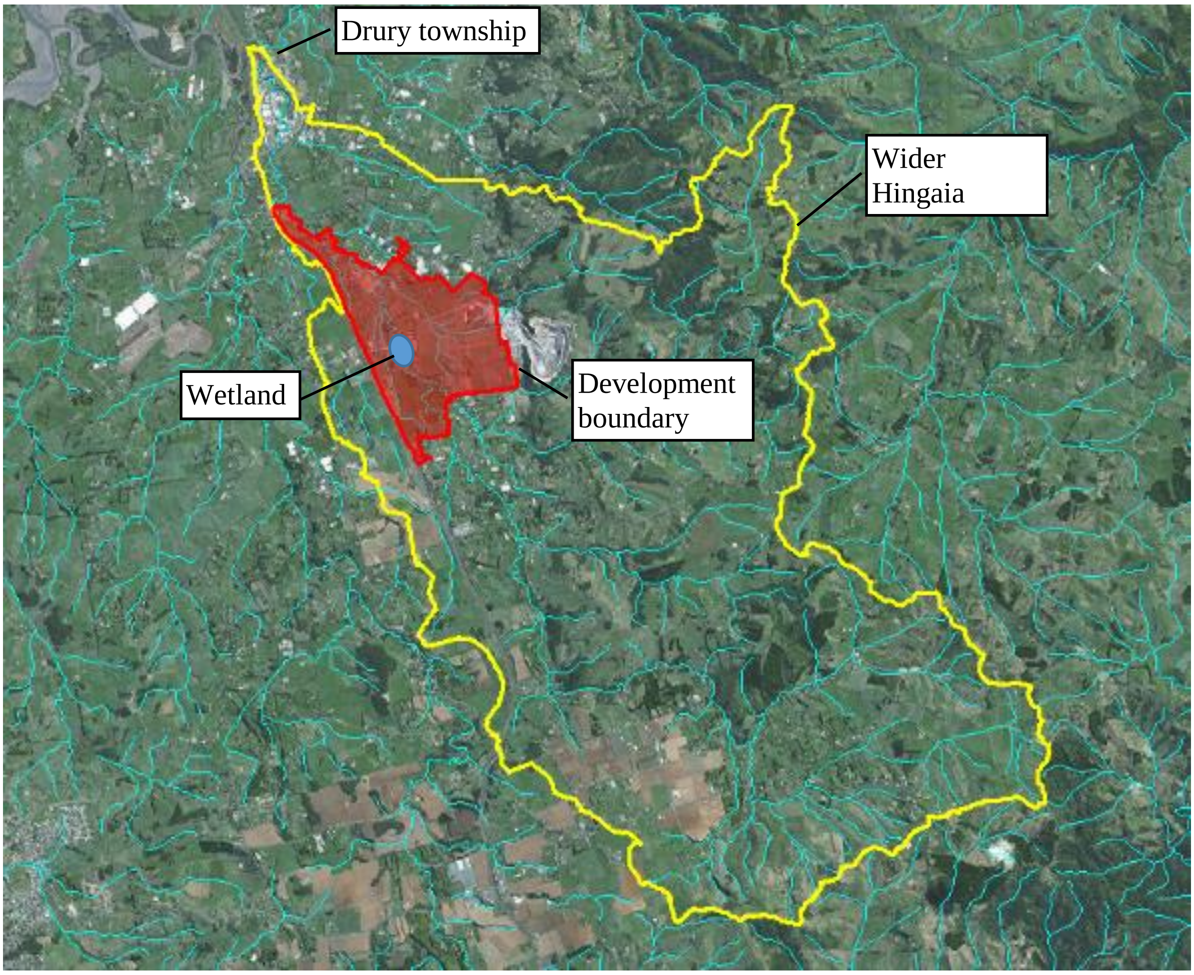

Figure 1.1: Hingaia catchment

1.2 WETLAND OR NOT

Raingardens and swales were considered as an alternative to centralised wetlands for providing water quality treatment. However, the central treatment wetland at the bottom of the catchment allowed for certainty of stormwater treatment when the layout of industrial lots and their associated treatment train would have been unpredictable until they were tenanted.

From an ecosystem perspective, floodplain wetlands were entirely in keeping with lowland environments of higher order meandering streams. From a landscape perspective the large-scale wetland environments were in balance with the large-scale industrial land use.

Additionally the centralised wetlands in this case allowed for optimal land use. A key advantage of the wetland approach over alternatives such as raingardens and swales is that wetlands can be located in the floodplain. Therefore they can be integrated within the green corridor and jointly used as floodplain and public open space on land that cannot be used for development.

1.3 IN AN ACTIVE FLOODPLAIN

Within the DSP there is a significant existing floodplain associated with the Hingaia, Maketu and Quarry Streams. Auckland Council's classified overland flowpaths and extent of the 100 year ARI floodplain are available on Auckland Council Geomaps and are shown in Figure 1.3 below.

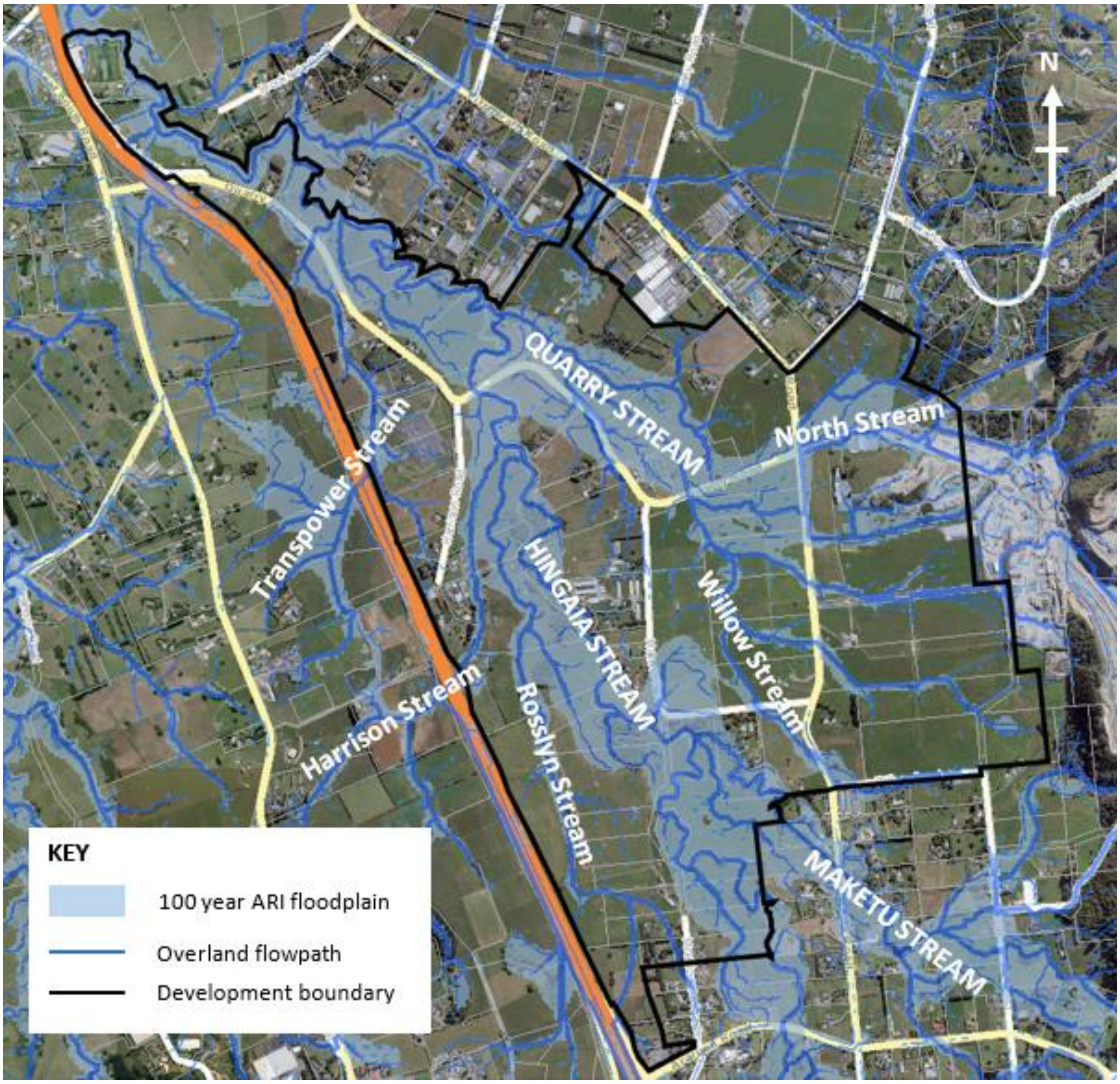

Figure 1.3: Existing 100 year ARI floodplain and overland flow paths (Auckland Council Geomaps)

The Wetland is located within and along the eastern edge of the flood plain so it features as part of the overall floodplain design for large storm events. For events greater than the 10 year ARI storm, the wetland is designed to allow overtopping and thereby provide additional flood capacity and storage within the floodplain.

The wetland location within the floodplain is tightly constrained in all directions by the Hingaia Stream, the flood plain area to the west and the proposed commercial area to the East. In addition further constraints are imposed by the proposed relocation of Transpower line pylons to be situated at the northern and southern ends of Wetland 1 and the wastewater pumping station situated at the northern end. Both of these facilities are to be constructed at levels placing them above the 100 year flood levels.

The proposed wetland solution has been designed to provide the required capacity for the contributing catchment within these physical constraints and to meet the desires of various stakeholders. The design makes efficient use of the available area to maximise the size of the wetland sufficient to treat its contributing catchment area.

2 LANDSCAPE DESIGN OPPORTUNITIES

The key landscape opportunities were:

- A stormwater wetland that also provides reserve and visual amenity for recreational and ecological benefit
- The integration of blue (stormwater wetland) and green infrastructures (surrounding landscape features) with pond embankments designed deliberately with both a formal and a natural (stream) side
- Establishment and reinforcement of strong cultural and historic relationships between people and nature, as wetlands are spiritually significant and closely linked to the identities of the tangata whenua (people of the land) (Sargent et al., 2005)
- A provision of habitats for a range of taonga (culturally important) plants, animals, birds, insects, and micro-organisms

2.1 MOVING BEYOND SURVEY-ANALYSIS-DESIGN (SAD)

This project sought an exploratory design method. Instead of working through a conventional process, Survey- Analysis-Design (SAD), the team adopted a design method that was led by a metaphor, which was in itself inspired by the cultural values ascribed to the Hingaia Stream environments by Mana Whenua. This design method was intended to aid creativity and reduce predictability and rigidity.

By introducing a metaphor into the design process at an early stage, it acts as a catalyst and springboard for fresh and inspired ideas. Metaphor, in this project, simplifies complex issues by condensing separate elements into a single meaningful idea.

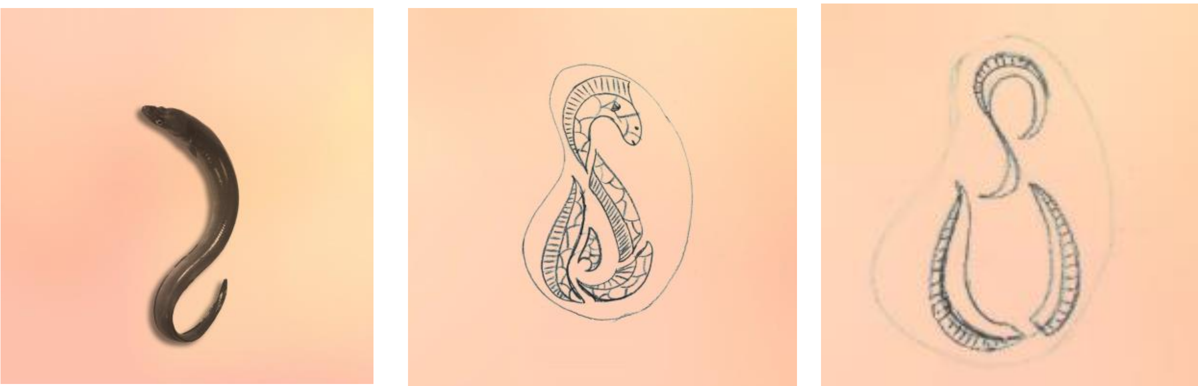

Figure 2.1: Tuna, a design metaphor (from Ngati Tamaoho) used to generate the design of Wetland 1

Figure 2.2. The major features (mound, forebays) are refined and drawn by hand

2.2 PROTECTING AND RESTORING AQUATIC & TERRESTRIAL HABITATS

The wetland is located within the Manukau Ecological District (ED), which is characterised by gently rolling hill country of low relief, with broad valleys and river flats in places. The wetland treatment system will provide a mosaic of terrestrial, wetland and aquatic habitats that will support an ecosystem of insects, birds and fish. As well as providing stormwater treatment, and thereby protecting downstream environments, the protected Hingaia Stream will also continue to function as an ecological network that connects to the wider landscape (matrix).

This project seeks to restore wetland ecosystem functions currently not found in the floodplain by establishing an ecological connection to the Hingaia Stream. The wetland will be integrated with the revegetation occurring along the stream corridor.

2.3 IWI CONSULTATION

Iwi feedback for the overall stormwater management of the site was received from representatives of Ngati Tamaoho, Ngati Te Ata and Ngai Tai ki Tamaki. The following concerns relating to the wetland were noted and have been addressed:

- Requested that wetland designs allow for two forebays due to the fact that the wetlands are the sole water quality treatment for carparks in the Industrial Precinct.
- Requested that the proposed "green outfall" concept was retained in the final stormwater management approach
- Requested whether flooding from recent large rainfall events have been monitored as this could be reflective of future weather events. Tonkin + Taylor confirmed that the recent flooding events were monitored and used by Auckland Council to validate the flood model.
- Requested that the all land uses were encouraged to use reuse water tanks throughout the development. Although the Unitary Plan does not require reuse tanks on-site, the SMP will seek to encourage their use where there is opportunity and they are practicable.
- Sediment loads generating during site construction affecting the performance of raingardens installed within the roads. Although this is primarily an enforcement matter as all site works are required to install appropriate erosion and sediment controls, monitoring of device performance will be addressed as part of the Network Discharge Consent (NDC).

2.4 DESIGN FORM

As noted earlier, the landscape design of Wetland 1 is grounded in symbolism and metaphor. The abstracted shape of the tuna, or long-fin eel, was originally inspired by Ngati Tamaoho as a result of the collaboration between landscape architect and mana whenua to express the cultural values of the project area. The metaphor remained constant, but its tangible form evolved by adapting to suit the site and to become a functioning stormwater wetland.

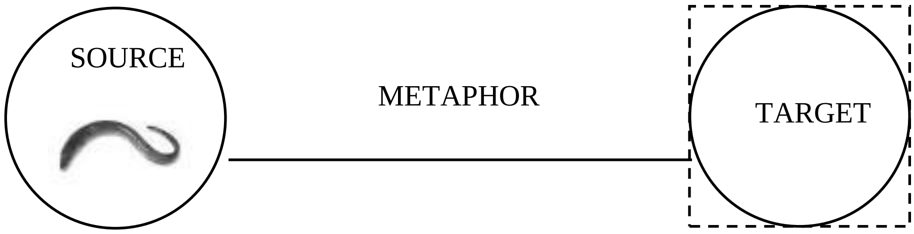

Figure 2.4. A model of cross-domain mapping (Lakoff, 1990)

After a series of workshops between the designers and engineers, the physical expression of the tuna metaphor, such as the geometry of the forebay, becomes evident. The major features and lines are refined and transferred to a digital terrain model.

Figure 2.5. The applied concept with basic structure of the metaphor

Terrain is critical in developing landscape design and shaping it involves both aesthetic and functional considerations (Goncalves, 2018).

This is an active process of modifying the form in response to the new design criteria; and each change is immediately translated into a new surface with both visual and technical data.

The final digital model was tested and further fine-tuned by the engineer, to ensure that the wetland design met the hydrological requirements.

Once the terrain of the wetland was finalised, the planting composition was developed to consider:

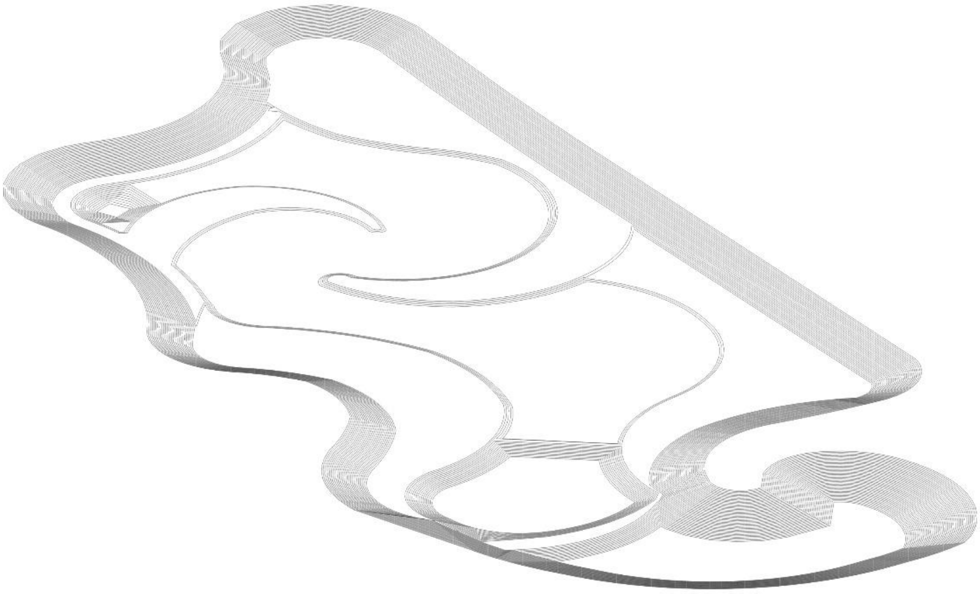

Figure 2.6 The early basic 3D model of Wetland 1

- Boundary and frame
- Perceived and experienced spaces
- Movement through and around the wetland
- Views into and out of the wetland
- Focal and resting points
- Vitality and rhythm
  - Simplicity and economy
  - Water treatment
  - Water passage
  - Flood flows
  - Erosion control

Figure 2.7 Wetland forebay and pedestrian path

3 TECHNICAL CHALLENGES

The wetland's location within an active floodplain, large size of the contributing catchment and the complex aesthetic form adopted posed a number of key technical challenges which included:

- Reducing the effect of downstream/upstream flooding by allowing the wetland to overtop to provide additional flood capacity and storage
- Overcoming the sensitivity of the cut slope to the high groundwater levels in the slope and the low strength soils beneath the water retaining embankment
- Providing sinuous bathymetry to encourage a longer flow path and increase the contact time with wetland vegetation
- Extending large diameter inlet pipes out into the first forebay
- Providing a large outlet structure (over $20m^2$) which is both sympathetic to the wetland form and efficient in time and dollar cost

3.1 THE DESIGN BRIEF

The following design objectives have guided the wetland design:

- Provide a stormwater quality treatment and hydrological mitigation function in the stormwater wetlands as a component of the overall stormwater treatment system.
- Incorporate the wetland areas as part of attractive open space areas that enhance the landscape and cultural values of the DSIP through visual public amenity and protecting the natural character.
- Incorporate naturalised wetland planting that creates diverse aquatic and terrestrial habitats for existing and potential wildlife species.
- Use design principles that align with the water sensitive design philosophy presented in Auckland Council's Guidance Document 04[1] (GD04).
- Consider the nature and sensitivity of receiving environments with the aim to minimise effects on these environments.

In addition to the stormwater objectives above there was a key focus on geotechnical elements such as stability, erosion resistance, settlement, and seepage management to ensure industry accepted standards were met.

The final wetland layout is shown in Figure 3.1 below.

[1] Auckland Council Guidance Document 2015/004 – Water Sensitive Design for Stormwater, dated March 2015.

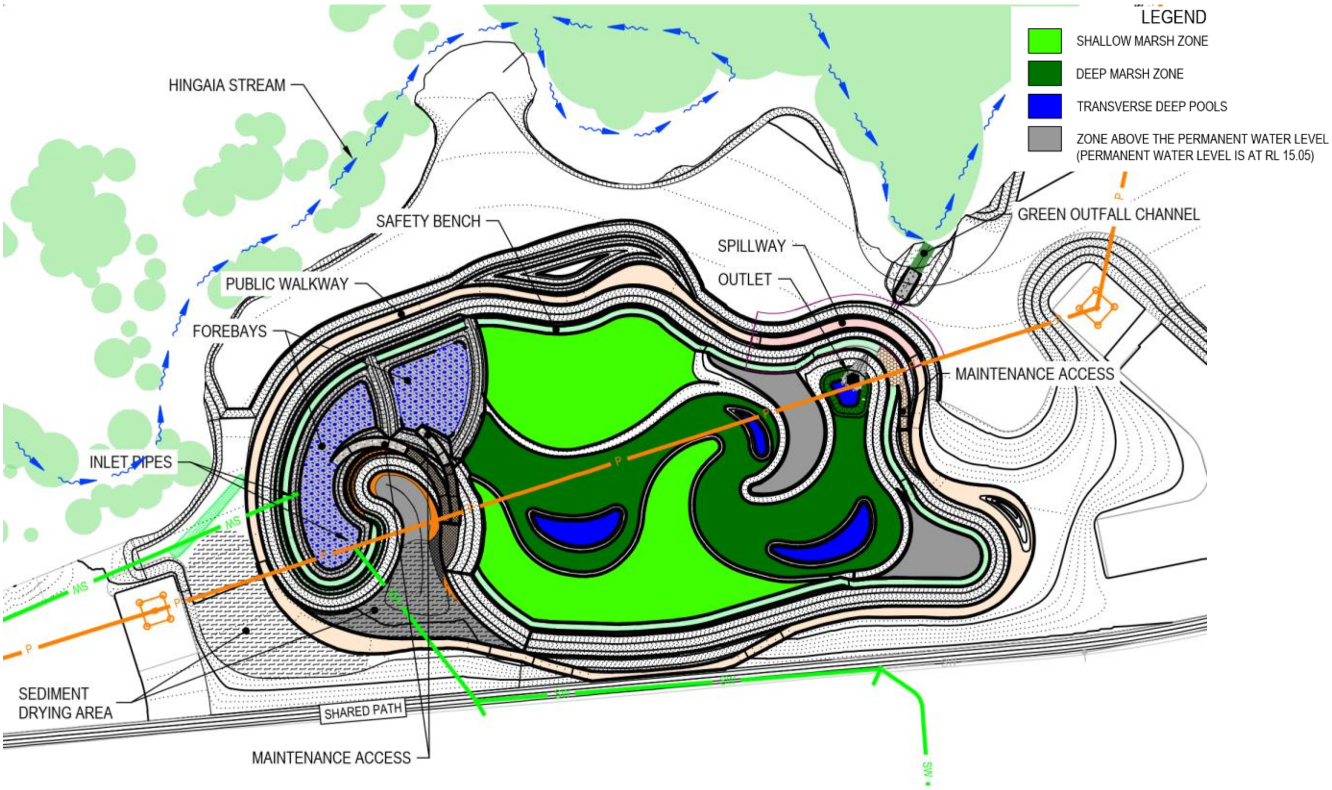

Figure 3.1 Wetland layout

3.2 DESIGN CRITERIA

The wetland design has been undertaken in accordance with the following design guidance (in order of precedence):

- Auckland Council Guidance Document for Stormwater Management Devices in the Auckland Region (GD01).
- Auckland Council Guidelines for stormwater runoff modelling in the Auckland Region (TP108).
- Technical Report 2013/018 Hydraulic Energy Management: Inlet and Outlet Design for Treatment Devices.

For the embankment portion of the wetland the recommendations of the New Zealand Society on Large Dams (NZSOLD) Dam Safety Guidelines (2015), and the Building Act 2004 were adopted.

3.3 FLOODPLAIN/WETLAND FUNCTIONALITY

Extensive modelling of the catchment, and in particular the neighbouring Hingaia Stream, has been undertaken as part of the overall project flood mitigation. One of the key performance requirements for the Wetland is to enable flooding from the Hingaia Stream to overtop the emergency spillway and enter the wetland during events greater than the 10yr ARI storm. This is to reduce the effect of downstream/upstream flooding by providing additional flood capacity and storage within the Wetland.

Therefore, the requirement for the embankment to "overtop" to receive floodwater from the Hingaia Stream during events greater than the 10yr ARI storm, has driven the consideration of crest level freeboard.

Error! Reference source not found. Shows the depth of water above the spillway invert level during a 100 year flood. The graph shows that during this flood the level in the wetland rises to 300 mm above the spillway invert approximately 12.5 hours into the storm. The level then begins to lower before the Hingaia Stream level to the west reaches the spillway invert and the flow begins to reverse back into the wetland. The peak water level in the Hingaia during the 100 year flood has been calculated at RL 18.4 m. This level fully submerges the crest of the Wetland (except for a small area of landscaping near the centre of the embankment).

In practice, it is expected that a significant flood would cause a rise in Wetland 1 and the Hingaia Stream with minimal lag between and likely result in drowning out of the spillway as the flood plain becomes submerged. The net effect will be reduced velocities (and therefore also reduced scour erosion) on the spillway than would be expected based on the height of water over the spillway shown on the graph below.

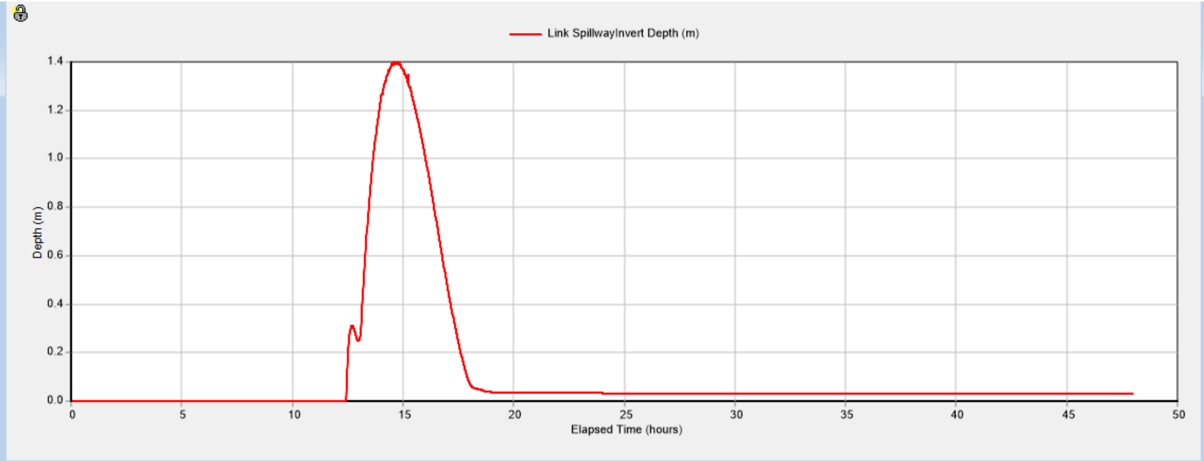

Figure 1.2: Depth of flow over the auxiliary spillway during a 100 year flood.

3.4 STABILITY

The Wetland comprises a cut batter on its eastern perimeter and an earth bund dam on its western perimeter. On the eastern side the Wetland will abut the elevated in-situ ground to the east. The cut slope to the east forms a significant length of the wetland perimeter and supports a shared path/cycleway, buried pipe services, and a commercial / mixed use development area.

During the preliminary slope stability analyses two key issues arose, these were; the sensitivity of the cut slope to permanent high groundwater levels in the slope and the low strength soils beneath the embankment. Early workshopping with T+T specialists, Peer Reviewer (RILEY), the project owner, and constructor has shaped the final design approach for the wetland embankment.

An early decision was made that the embankment would be formed completely with engineered fill, rather than shaping in-situ material, for the following reasons:

- The relatively poor characteristics of the in-situ material and variability in layering meant that stability and seepage control issues would require significant engineering to overcome
- High in-situ groundwater levels raised concerns for temporary stability of the embankment

- The scale of excavation required to lower the neighbouring ground for the floodplain enhancement meant that it was likely to be more efficient to lower the entire area as part of the bulk earthmoving contract.

In addition, the poor characteristics of the material (variable and saturated) meant that re-use as engineered fill for the embankment through conventional treatments (such as drying, discing and blending) was not considered practical given the space and time constraints. All excavated material was therefore agreed to be cut-to-waste for reuse elsewhere on the project and all required fill imported.

During foundation treatment discussions with the design and construction teams, an approach of constructing a foundation treatment zone that could also be used for safe machine access during construction was agreed and developed into the detailed design to overcome the inherently weak and saturated nature of the foundation soils. The granular treatment can be pushed ahead of the compacting equipment to eliminate the need for heavy traffic directly on the softer soils, and, the embankment can be staged to enable temporary use of the treatment zone for construction vehicles

Although not considered to be a large dam as defined in the NZ Building Act, the design of the embankment has still been Peer Reviewed by an independent consultant with significant experience in dam design.

Consequently the design of the embankment is robust and defensible, incorporating cumulative contributions from different design features to add to the serviceability and integrity of the dam over and above the minimum standards that are commonly adopted.

A robust and simple drainage system was developed to lower the groundwater along the back face (eastern) slope of the wetland and provide a buttress to improve existing ground stability as shown in Figure 3.3 below. This solution came out of an initial workshop as being favoured by the construction team. Analysis indicates that this treatment will enhance the slope, thereby achieving normally accepted factors of safety. The drainage and buttress zone geometry has further considered safety during construction by ensuring sufficient width to enable construction machinery to traverse along the slope (safer) rather than perpendicular to the slope (less safe).

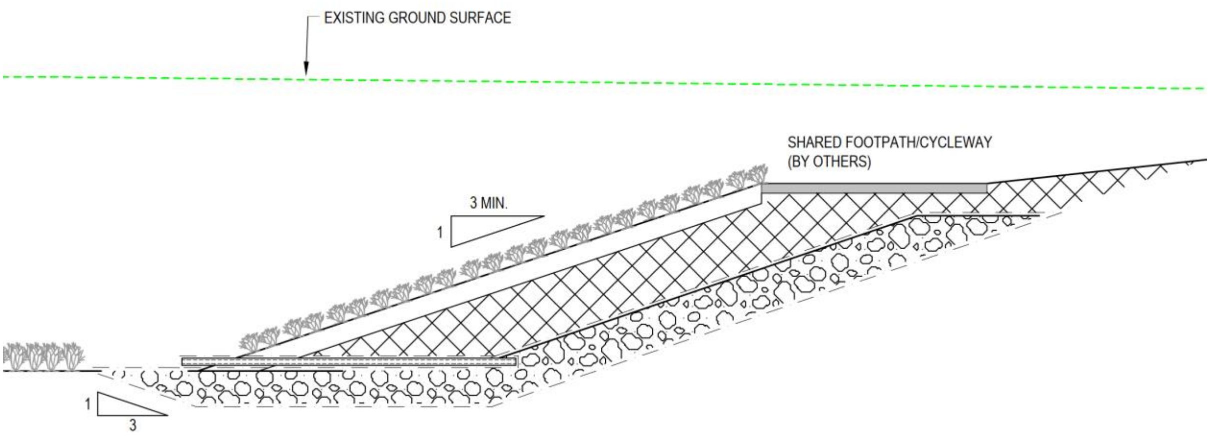

Figure 3.3: Cut face drainage system

Ease of maintenance and reduction in the need for operating within the wetland or on the slopes has been considered. Key features that have been incorporated include:

- Continuous “daylighting” of the drainage blanket along the toe of the eastern slopes to reduce the risk of blockage and therefore minimise maintenance required.
- Erosion protection to be achieved using hardy wetland appropriate vegetation. This is consistent with the landscaping objectives and is expected to require less maintenance than comparable erosion protection systems such as reinforced grass, reno/gabion mattresses or rip rap that can require more regular spraying and/or tidying up.

3.5 WETLAND SHAPE

Sinuous bathymetry has been adopted for the Wetland to encourage a longer flow path and increase the contact time with wetland vegetation. Several shallow marsh, deep marsh and transverse deep pool zones have been adopted for the wetland to support vegetation growth, provide shade for temperature control, provide biological uptake of nutrients and added habitat complexity.

The normal permanent water level is 15.05 mRL, controlled by a large orifice in the hexagonal outlet manhole. This permanent level is below the typical ground level outside the wetland bund that ranges from approximately 15.5 to 15.6 mRL. The maximum storage at the auxiliary spillway level is 58,900 m3.

Due to the large flows expected to enter the Wetland from the upstream network and also from the Hingiaia overtopping the bund crest, the inlet point of the Wetland has been designed as a two-forebay system arranged in series. The first forebay provides energy dissipation for the incoming flows, reducing the risk of resuspension of sediment in the second forebay and capture of coarse sediment and other debris. The second forebay is designed to provide additional capture of suspended sediment before the water enters into the main body of the wetland.

The forebays and forebay bunds will be lined with a layer of rock riprap up to the permanent water level to prevent scour and provide a hardened stabilised platform for maintenance access and cleanout of the forebays. The rock riprap for Forebay 1 and the forebay bunds is to have a D50 of 350 mm and a thickness of 700 mm filled with GAP65 in the interstitial spaces. The velocities within Forebay 2 are expected to be lower, with no pipes discharging into Forebay 2, therefore the risk of scour is significantly reduced. Forebay 2 will be lined with D50 100 mm with a minimum thickness of 350 mm filled with GAP65 in the interstitial spaces. The purpose of filling the interstitial spaces is to provide a hard and relatively smooth layer for cleaning sediment out of the forebays.

3.6 INLETS

Flows into the wetland are via two pipes, 2400mm and 1800mm diameter respectively, with overland flow from the development bypassing the wetland and running into the floodplain. For hydraulic and safety in design reasons these inlet pipes are on plinths extending 7-10m into the primary forebay. As a result they discharge directly into the deepest water and are difficult for members of the public to access.

Plinths were required to be relatively quick and easy to construct as well as tolerate potential settlement without concentrating movement at a few pipe joints resulting in pipe damage. The plinths comprise two layers of interlocking concrete mass blocks dry stacked (like lego) on an aggregate pad. The pipe sections are placed on top and a concrete cradle is boxed around the base of the pipe and poured insitu with polystyrene spacers inserted into the concrete at each joint for flexibility.

3.7 OUTLET

The outlet structure operates in both directions in events greater than the 10 year ARI due to the floodplain mechanics. For lesser events a weir length of up to 14m was required which presented cost and construction issues. To remain sympathetic with the wetland form, a rectangular structure was discounted and so the structure would either need to be custom made on site at significant time and dollar cost or precast and brought to site in sufficiently small components to be practically transportable. In the end a hexagonal structure was selected comprising readily transportable precast panels with stitch joints mounted in a poured insitu base.

To control blockage and for safety a custom steel grating sized at over $20m^2$ will be workshop fabricated in 6 sections and assembled in place. For aesthetics a cladding of aluminium panels may be fitted over much of the grating at a later date with laser cut designs which have been checked for blockage and flow constraints.

4 CONSTRUCTION CHALLENGES

This section discusses the key construction challenges which are:

- Wetland geometry comprising complex curves with no straight lines
- Sensitive ground conditions with elevated groundwater levels severely limiting access thus requiring final levels to be achieved in a single cut
- Complex control systems required to verify excavation in real time to prevent rework while minimising the need for survey personnel working around the hazardous equipment
- Carefully staging filling to provide limited access back across the sensitive ground

4.1 METHODOLOGY

The construction of the wetland presents a significant challenge, which requires a specific design methodology as well as the use of modern machine control systems to ensure its success.

Saturated, sensitive clays are found approximately 2-3 meters below existing ground. While being relatively strong insitu, once stressed, these clays quickly lose all strength and are no longer trafficable. This means the final 2-3 meters of cut to subgrade level needs to be completed in one cut rather than a series of shallow cuts. This would typically not be a problem on its own, however the design of the wetland is quite complex, composed of a variety of complex curves with no straight lines, and many elevation changes across its extents. This excavation needs to be completed to a high level of accuracy to ensure it performs in line with the design specifications. An excavation this complex would normally be done in multiple stages, with surveyors staking out shallow, consistent cuts across the site for the excavators to dig down to, before the surveyors then stake out the next shallow cut to be excavated until the final subgrade depth is achieved across the site. To excavate down to the subgrade level in one cut across the entire wetland the excavator operator needs to have access to the entire design at any given time. The only way to achieve this is with the use of 3D machine control systems.

Rework of an area due to the excavation being completed to an incorrect level is extremely difficult, costly, and time consuming due to the sensitive clays present. To minimize the risk of having to rework any areas, minimize operator confusion, and assist the operator to excavate to the tight tolerances required two separate machine control 3D models are generated for the wetland.

The first model to be used is the subgrade model, containing the lowest levels of excavations required across the entire extent of the wetland, allowing for topsoil thicknesses, aggregate or rock backfill thicknesses, and areas requiring undercutting and refilling using engineered fill. This allows the operator to dig to the design shown on their screen rather than try to interpret pdf plans and cross sections in order to work out what vertical offsets to apply in each location.

The topsoil is stripped and the first 1-1.5 meters of cut is completed using CAT 627 motor scrapers. From this point on excavators and articulated off road trucks are used. Due to the size of the excavation, approximately 200,000 m3, significantly larger excavators are required than the 20 to 30 tonne machines typically fitted with machine control systems. A variety of different sized excavators are used, including 50 and 90 tonne machines, all fitted with full 3D GPS machine control systems. The excavators sit on the solid ground above the sensitive clays, where they can reach down the finished subgrade level and load out the excavated wet clay onto articulated dump trucks, ranging in size from 30 to 45 tonnes. A 15 tonne (CAT D7) dozer with low ground pressure Apex tracks and GPS machine control assists the excavators to achieve the subgrade design levels. Using the machine control, the excavators are able to bulk excavate and complete the final trimming simultaneously, forming the complex curves and detailed elevation changes to a very high level of accuracy without requiring any survey set out. Completing this cut in one pass ensures the sensitive clays are not overstressed.

Once the excavation is completed, the subgrade model is deleted from the equipment and the final design model is uploaded. The final design model provides the finished levels across the wetland accounting for any topsoil, rock armouring etc. By deleting the subgrade model and uploading the finished design model after the excavation is completed, the risk of operators getting confused and working of the wrong model is eliminated.

The first step of building the wetland back up from the subgrade excavation is to place a layer of geofabric where the wetland bund walls will be constructed. Weathered greywacke, forming the foundation for the wetland bund walls, is then pushed out using dozers, starting from either end working toward the middle. This creates an access track around the outside of the wetland, ensuring heavy equipment does not have to track directly on the soft clays underneath. From this access track topsoil, riprap, aggregate, and engineered fill can be placed into the interior of the wetland, completing the construction of the wetland base while simultaneously extending access for heavy equipment as work progresses towards the centre. Finally, the wetland bunds are constructed from engineered fill along with the inlet and outlet structures, footpaths, and other finishing details.

Figure 4.1: Wetland excavation using 3D machine control systems

4.2 QUALITY CONTROL

A variety of different survey equipment is used on site to monitor quality control and assist with monthly volume calculations. Hand held rovers are used to perform spot checks, ensure machine control systems are properly calibrated, as well as to quickly measure undercuts and fills. Total stations are used for work requiring high precision, such as the installation of the concrete level control beams in the wetland emergency spillway. The excavators and dozers equipped with 3D machine control can be set to record their working levels continuously, creating an asbuilt surface of the deepest elevation they have cut to. This can be used for quality control checks as well as assisting with monthly volume calculations. Lastly, aerial drones using photogrammetry are used to fly the site for monthly volume calculations. This method very quickly creates a highly accurate 3D model of the site while having no impact on equipment production and ensuring that no personnel are put at risk from entering active heavy equipment work areas or other hazardous zones.

5 SAFETY IN DESIGN

Safety in design was considered early in the design process to eliminate or minimise the risks of death, injury or illness to those who will construct, operate and maintain the wetland. The goal is to eliminate hazards wherever possible.

The key safety in design elements incorporated into the design are:

- Safe machine access during construction
- Protection of the cycleway/commercial land above the wetland
- Ease of maintenance
- Discouraging access into the outlet pipes

One of the key geotechnical considerations identified during preliminary design was the inherently weak and saturated nature of the foundation soils over the Wetland footprint. During foundation treatment discussions with the design and construction teams an approach of constructing a foundation treatment zone that could also be used for safe machine access during construction was agreed and developed into the detailed design. The granular treatment can be pushed ahead of the compacting equipment to element the need to traffic this equipment direct on the softer soils, and the embankment can be staged to enable temporary use of the treatment zone for construction vehicles.

The weak, saturated soils are also present on the eastern cut slopes of the Wetland, with expected high groundwater levels. This area abuts the rising ground to the east and is considered to be non-critical with regard to the operation of the wetland. However, early stability assessments identified potential risk to the upslope cycleway, road and commercial land due to the unfavourable existing geology. A robust and simple drainage system was therefore developed to lower the groundwater in the slope and provide a buttress to improve existing ground stability. Analysis indicates that this treatment will enhance the slope, thereby achieving normally accepted factors of safety. The drainage and buttress zone geometry has further considered safety during construction by ensuring sufficient width to enable construction machinery to traverse along the slope (safer) rather than perpendicular to the slope (less safe).

Ease of maintenance and reduction in the need for operating within the wetland or on the slopes has been considered. Key features that have been incorporated include:

- Continuous "daylighting" of the drainage blanket along the toe of the eastern slopes to reduce the risk of blockage and therefore minimise maintenance required.
- Erosion protection to be achieved using hardy wetland appropriate vegetation. This is consistent with the landscaping objectives and is expected to require less maintenance than comparable erosion protection systems such as reinforced grass, reno/gabion mattresses or rip rap that can require more regular spraying and/or tidying up.

To drain the wetland for maintenance the outlet chamber has a valved 450mm diameter low level outlet pipe. For safety the key for the valve is permanently installed and extends up to grating level where it is locked off to allow valve operation without requiring access into the outlet chamber.

The large diameter of the outlet pipes could be enticing to some people, particularly children. Extension of the outlets into the forebay was done as a means of discouraging entry because people will have to wade out into the forebay, which will be permanently under water, in order to gain entry.

6 CONCLUSIONS

Landscape:

This project demonstrates how a foundational metaphor can be used in the non-linear landscape design process as a springboard for the imagination. In this process, the metaphor embodies and incorporates the hydrological, cultural and physical challenges and transports them into creative design. Landscape architecture need not rely on the traditional Survey-Analysis-Design process as the only course of action. Incorporating creativity early in the process can inspire solutions that are exciting, imaginative and effective.

Technical:

To reduce the effect of downstream/upstream flooding the Wetland has been designed to overtop providing additional flood capacity and storage. Extensive modelling of the catchment, has been undertaken as part of the overall project flood mitigation.

A foundation treatment zone that could also be used for safe machine access during construction was agreed and developed into the detailed design to overcome the inherently weak and saturated nature of the foundation soils. The granular treatment can be pushed ahead of the compacting equipment to eliminate the need for heavy traffic directly on the softer soils, and, the embankment can be staged to enable temporary use of the treatment zone for construction vehicles.

To overcome the sensitivity of the cut slope to the high groundwater levels in the slope and the low strength soils beneath the cut slope a robust drainage system was developed to lower the groundwater in the slope and provide a buttress to improve existing ground stability.

To retain the design water volume of 58,900 m3 while founding on low strength soils the embankment design incorporates cumulative contributions from different design features to add to the serviceability and integrity of the dam over and above the minimum standards that are commonly adopted.

Construction:

To prevent excavation rework which is extremely difficult, costly and time consuming, due to the sensitive clays present, two separate machine control 3D models were generated for the wetland and loaded into the 3D GPS machine control systems where the works are monitored in real time.

Safety:

To ensure that no personnel are put at risk from entering active heavy equipment work areas or other hazardous zones aerial drones using photogrammetry are used to fly the site to very quickly create highly accurate 3D models of the site while having no impact on equipment production

To maximise ease of maintenance and reduction in the need for operating within the wetland, outlet chamber and on the slopes a number of specific design decisions were made.

ACKNOWLEDGEMENTS

The authors acknowledge and thank all those who have contributed to this wetland project including Ngati Tamaoho artists, representatives from Ngati Tamaoho, Ngati Te Ata and Ngai Tai ki Tamaki, Drury South Crossing (the client) and Stevenson Mining.

REFERENCES

Goncalves, A.R. (2018) Stop drawing start modelling: From design intentions to landform in landscape design. Articles and Digital Terrain Modelling.

Lakoff, G. (1993) The contemporary theory of metaphor. In A. Ortony (Ed.). Metaphor and Thought (2nd ed., 202-251). New York: Cambridge University Press.

Sargent, C., Hole, S. and Leggett, K. (2005) Wetlands for Education in the West Coast Tai Poutini Conservancy. New Zealand Government - Department of Conservation.

Auckland Council GeoMaps