Arawhata Wetlands
– Concept Development Report

June 2023

horizons
REGIONAL COUNCIL

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Executive Summary

Horizons Regional Council (HRC) propose to construct a hybrid engineered and restoration focussed natural wetland system on an approximately 142 ha dairy farm site to the south of Punahau/Lake Horowhenua near Levin.

The Arawhata Stream, which feeds Punahau, is high in nitrogen, phosphorus and sediment, which affects the quality of the lake. The objective of the proposed wetland is to reduce the sediment and nutrient concentrations entering the lake and enhance the cultural health of the landscape.

Punahau/Lake Horowhenua is a shallow hypertrophic dune lake (Figure 1) that has degraded over many years. The lake outflows to the sea via the Hōkio Stream and has several tributaries, the majority being modified waterways that flow through vegetable cropping land, dairy farms, other rural land uses as well as Taitoko/Levin township. Groundwater accounts for more than half the inflow into the lake.

A wetland complex (the Arawhata Wetlands) has been proposed as an intervention opportunity to improve water quality for Punahau/Lake Horowhenua. This intervention opportunity has been made possible through the Horowhenua Freshwater Management Unit (FMU) Water Quality Interventions project with funding from the Ministry for the Environment (MfE).

Horizons Regional Council (HRC) engaged Jacobs New Zealand Limited (Jacobs) to participate in an options assessment, followed by development of a preferred concept to support the consent application process and Ministerial Referral application. This report has been prepared to document the concept design undertaken to date to support these processes.

The proposed wetland system will comprise the following components, constructed in a series of Phases as shown in Figure A1 and described below. Note that consent applications only seek to include Phases 1 and 2, with Phase 3 being consented separately at a later date.

Phase 1 Components

- A sediment pond located at the Kohitere Stream/site boundary, this being the southernmost waterway discharging to the site from the upstream vegetable growing area.
- Installation of a perforated pipe in the existing Kohitere and Joblins Stream channels (within the site boundary) as well as new drains along the property boundary either side of Joblins Drain, backfilled with woodchips, bark for groundwater treatment (subsurface bioreactors).
- Surface water overflow from the new sediment pond will be directed into new channels constructed at a flatter grade than the ground slope such that water from Kohitere Stream and Joblins Drain can be discharged onto the surface of wetlands between Arawhata Road and Arawhata Stream, under gravity.
- Partial planting through wetland areas. Other wetland plants such as rautahi (Carex lessoniana), wiwi (Juncus edgariae) and purei/pukio (Carex secta) will naturally establish over time (pers.comm. Roger MacGibbon, T+T).
- Potential retention of an existing groundwater pump + southern well for irrigating the wetland.
- Cleaning out/deepening of farm drains surrounding but within the site and road reserve such that groundwater is intercepted. Drain inverts will be sloped such that they still discharge into the wetland.
- Extension of the adjacent bund further south along Arawhata Stream on the western side.
- Construction of a sliding weir gate on the existing culvert in Arawhata Stream alongside the existing sediment trap (north end of the site). This will normally be shut to direct flows through the sediment trap and will include permanent fish passage.
- Placement of rip rap on the existing sediment trap outlet embankment to control water level and protect the embankment from scour.
- The existing sediment trap is to be retained and will treat all of the flow from the Arawhata Stream.

Phase 2 Components

- A small new pump will be used to irrigate water from the proposed sediment pond onto the Kohitere Stream alluvial fan in areas where it cannot flow under gravity.
- Construction of new channels at flatter grade than ground slope such that water can be discharged onto the surface wetlands from Whelans Drain.
- Significant planting in Phase 1 and Phase 2 areas
- New bund on east side of existing Arawhata Stream to contain Phase 2 wetland.

- A lower section of bund will be built at the downstream end alongside Hōkio Beach Road to discharge treated wetland flow into the main Arawhata Stream.
- New groundwater collection drains along Hōkio Beach Road and the eastern wetland site boundary will be constructed.

Phase 3 components

- Wetland planting (~7 ha) in the area to the west of the main site, part of the wider traditional Arawhata wetlands known as Paenoa Swamp.
- Diversion of channels to the west of the main wetland into the phase 3 Arawhata wetland (Paenoa swamp)
- Planting of an upland (southern) forest area of ~20 ha
- Further gap infill planting in phase 1 and 2 wetland areas
- New dispersed outlet into Punahau/Lake Horowhenua.
- Deepening of drains on neighbouring land to intercept groundwater for treatment in the wetland.

The proprietary Jacobs Treatment Wetlands Design and Analysis Model has been used to predict the removal rates for the various contaminants of most concern, those being nitrate and nitrite nitrogen, phosphorus and sediment. This model has used actual water quality data collected at a number of locations around the proposed wetland site, flow data collected from the same locations, other climate data as well as removal rates based on a large number of previous wetlands projects undertaken by Jacobs around the globe. The model predicts the following output water quality and percentage removal rates for Phase 1, Phase 2 and both combined.

Table ES-1 Water Quality Improvement Modelling Results

Phase	Description	Inflow Concentration			Outlet concentration			Average % Concentration Reduction			Overall % reduction		
One		NO2-3N mg/L	TSS mg/L	TP mg/L	NO2-3N mg/L	TSS mg/L	TP mg/L	NO2-3N (%)	TSS (%)	TP (%)	NO2-3N (%)	TSS (%)	TP (%)
	Soil Infiltration	8.70	126.81	0.70	0.7	0.00	0.4	92%	100%	50%			
	Surface flow wetlands with soil infiltration outflow	8.30	111.71	0.67	4.8	26.34	0.61	42%	76%	19%			
	Sediment Trap Outlet	4.80	26.00	0.61	2.7	8.00	0.52	45%	70%	14%	69%	94%	26%
Two	Soils infiltration	2.90	296.10	0.60	1	0.00	0.4	66%	100%	40%			
	Surface flow wetlands with soil infiltration outflow	3.80	296.10	0.90	0.3	33.37	0.28	93%	89%	68%	90%	89%	53%
One and two combined		4.30	26.14	0.84	2.8	8.07	0.74	35%	69%	12%	70%	93%	27%

The proposed Arawhata wetlands will require a range of consents to be applied for and will result in a range of effects including (but not limited to):

Consents Required

- Discharges of drainage water to water

- Land disturbance (earthworks) to construct earth bunds, excavate sediment basins, excavation for the installation of pipelines
- Damming and diversion of water
- Takes of groundwater associated with intercepted groundwater in drains and use of the existing groundwater sump and pump
- Discharges of sediment and other contaminants associated with earthworks
- Discharge to air (Dust during construction).

Potential Effects

- Positive effects
- Effects on water quality
- Effects on ecology
- Effects on air quality
- Effects on groundwater quantity and quality
- Effects on surface water quantity and quality.

A high-level cost for Phase 1 of the project has been estimated at $3,360,000 ±50%. This cost includes pre-construction activities (submittals, mobilisation, survey, site preparation, temporary fencing, stockpile/dewatering area, utility location, etc), construction activities (cut volume, fill / bund construction, dewatering, installation of collection drains including media, etc), planting cost and water collection and distribution component installation (sediment pond pump and pump station, stream diversion, drainpipes, organic backfill, irrigation line, fittings, etc). This base estimate is higher than current project budget of $2.45 M NZD (excl. GST) therefore during the next phase of design (preliminary design) it is proposed that we optimise the design to minimise costs and look for opportunities to meet the budget. This may include decreasing the area to be planted. Undertaking 3D earthworks design during detailed design will also help to develop a more accurate cut/fill volume, this being one of the larger components of the cost.

Overall, with appropriate management of construction related activities, it is expected that the wetlands will improve the quality of the groundwater and surface water discharging to Punahau/Lake Horowhenua. In time it is therefore expected that the overall quality of the Lake will improve along with the cultural health of the landscape.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to develop a conceptual wetland design in accordance with the scope of services set out in the contract between Jacobs and Horizons Regional Council ('the Client'). That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs 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 then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and revaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full, and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

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1. Introduction

1.1 Overview

The Arawhata Wetland project involves the construction of engineered treatment wetlands and restoration of natural wetlands in the Arawhata Stream catchment of Punahau/Lake Horowhenua ("the lake"), near Taitoko/Levin. Punahau/Lake Horowhenua is a shallow hypertrophic dune lake (Figure 1) that has degraded over many years. The lake outflows to the sea via the Hōkio Stream and has several tributaries, the majority being modified waterways that flow through vegetable cropping land, dairy farms, other rural land uses as well as the Taitoko/Levin township. Groundwater accounts for more than half the inflow into the lake.

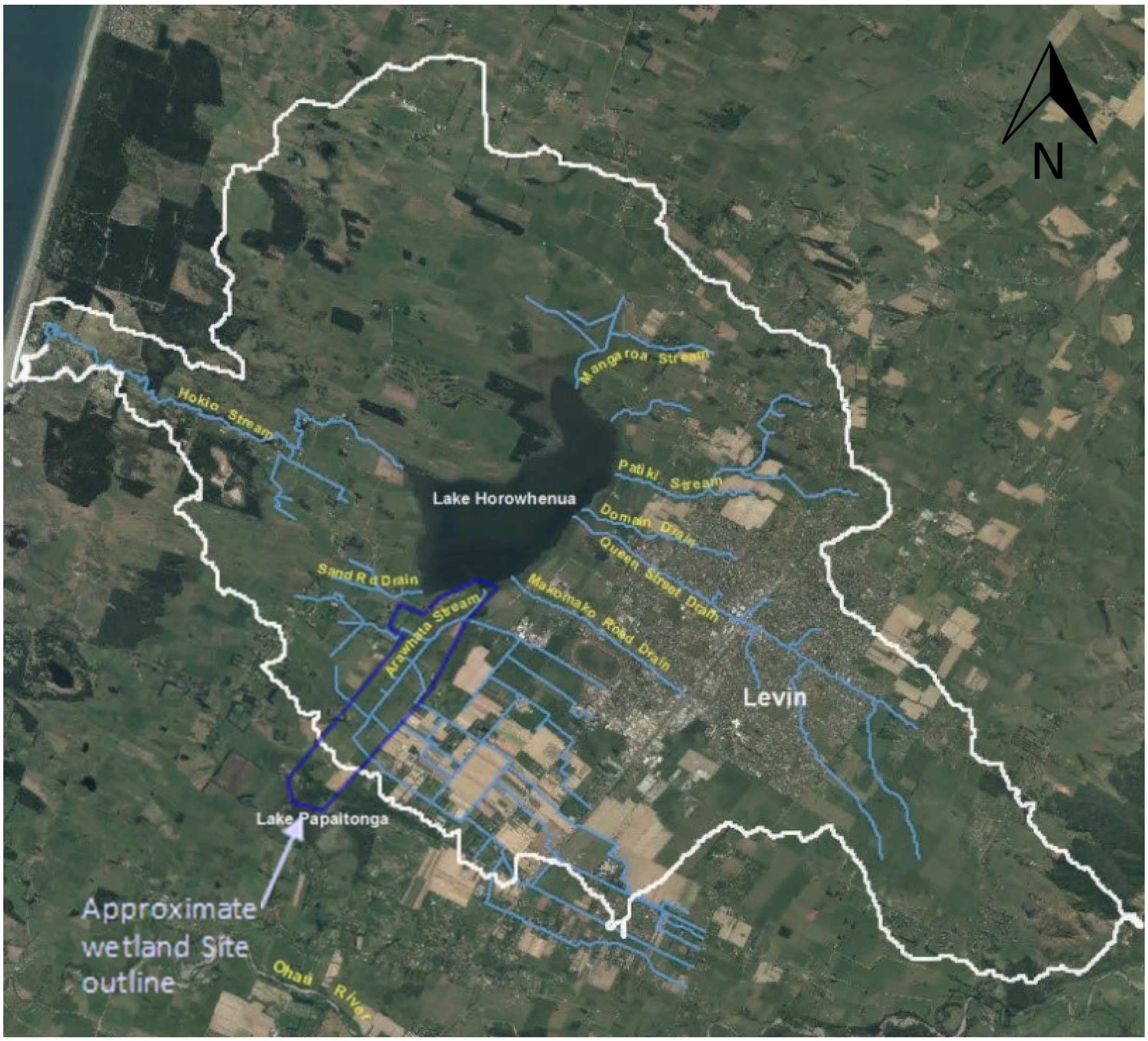

Figure 1 Lake Horowhenua, its' catchment, and the proposed wetland location

The Arawhata Stream (as well as contributing farm drains), which feeds Punahau, is high in nitrogen, phosphorus, and sediment. These contaminants have impacted the Arawhata Stream, the lake and the lakes owners, the Lake Horowhenua Trust on behalf of Muaūpoko beneficial owners, over many years including impacts on:

- Water quality
- Weed and algae growth

- Biodiversity of freshwater flora and fauna
- The health and wellbeing of its kaitiaki

Figure 1 shows the location of the proposed wetland site (“the site”). This is defined as the area within the property boundaries shown dotted in red on the attached figures (Attachment B sheets 1 to 3) but excluding the area to the north-east of the existing sediment trap.

Horizons Regional Council (Horizons) engaged Jacobs New Zealand Limited (Jacobs) to participate in an options assessment, followed by development of a preferred concept to support a Ministerial fast-track application and consenting process.

1.2 Purpose

The purpose of this report is to provide a description of the proposal, summary of the analysis and design work undertaken to date, as well as an Assessment of Effects, to support a Ministerial Fast-Track Consenting Application.

1.3 Project Objectives

The objectives of the project, as agreed by the governance group, are to:

- Contribute to the enhancement of the Mauri and water quality of Lake Horowhenua through reducing the impact of flows into the lake, in combination with other measures in the lake environs
- Reduce sediment and nitrogen loads into the lake
- Ensure that the wetland complex is culturally appropriate with Muaūpoko Mātauranga input
- Ensure the project is feasible and can be phased to align with funding available
- Enable the proposed wetland complex to provide for social amenity (kai, job creation etc.) and recreational opportunities and connectivity to other high amenity features in the local vicinity

This project has been made possible through the Horowhenua Freshwater Management Unit (FMU) Water Quality Interventions project contracted with the Ministry for the Environment (MfE).

1.4 Background

Prior to developing the concept detailed below, a feasibility design was undertaken involving a smaller part of the proposed site as well as additional land to the east. Once the full site (as discussed in this report) was purchased, an options assessment process was undertaken whereby, a range of options were identified and assessed using a Multi-Criteria Analysis approach. Input on criteria and options scoring were sought from the project stakeholders, governance group, technical specialists and tangata whenua during a series of workshops. The range of options assessed and the MCA outcomes are described in Jacobs (2022a). The outcome of this process concluded that Option 5 – “natural hybrid wetland treatment”, was the preferred option.

The preferred hybrid option, which has been developed further in this report, includes:

1. **Passive wetlands** - More natural and less engineered wetlands closer to the lake, with the focus more towards restoration, cultural revitalisation and habitat enhancement.

This approach will optimise land use to minimise pumping, matching the topography with natural wetlands, overland flow forested wet meadows, and deep settling fens. This approach will mimic nature in layout and shapes (and historic form) with components linked together with natural channels to control flow for optimised treatment and a focus to restoration. Future access and wetland education initiatives will be targeted in this area of the project.

2. **Engineered wetlands-** further from the lake, in the elevated areas of the site and closest to the vegetable cropping land use.

Engineered wetlands provide much higher levels of treatment on the same (or smaller) footprint as the passive wetlands. The appearance will be as “natural” as passive wetlands. This increased capacity is provided by increased groundwater capture and recirculation, sediment capture, and small biochemical reactors using woodchips. These engineered wetlands will require greater management into the future.

The two approaches are complementary. The increased treatment effectiveness of the engineered wetland is really an intensification of the passive wetland. The engineered approach can also remove nutrients directly from shallow groundwater via continued use of the existing pumping system. This groundwater can be passed through restored wetlands to increase treatment and support the desired hydrological regime. This has the benefit of keeping the wetlands operating at optimal flows and preventing plants from drying out in summer months.

This preferred option enables delivery of the key success criteria identified as part of the multi-criteria assessment, incorporating various cultural, social, and environmental benefits through use of different wetland types and applications, while maximising the nutrient and sediment removal across the site and in a cost-effective manner.

This has been a collaborative process and Jacobs acknowledge Muaūpoko Tribal Authority, Lake Horowhenua Trust, Kāhu Environmental staff, HRC staff, Tonkin + Taylor, and NIWA for their highly valued contributions to this project.

1.5 Scope

The scope of work for this project is outlined in the Jacobs proposal dated 22 August 2022 and summarised as follows.

1. Site visit(s) to allow the design team to familiarise themselves with the site including discussions with Dean Wilson of Lake Horowhenua Trust and Jeff Kane (former landowner) to obtain historic insight on the site
2. Review of information provided and identification of any gaps that remain, which need to be addressed to support the progression of the design
3. Design and drawing development including:
    a. Indication of where staging can occur and the overall site configuration including the size and area of each of the components and a description of the process(es)
    b. Indication of where earthworks will occur as well as the volume of earth that will be moved
    c. An outline of where interceptions of flow and diversions of flow will occur as well as proposed changes to the existing drains and the Arawhata Stream
    d. A high-level assessment of the benefits (e.g., N removal, sediment removal, etc.) that will be obtained by each of the stages
    e. High level cost estimate (±50%)
    f. Site layout drawings including a proposed site layout sketch indicting where flows will be intercepted, any changes to the drains, proposed locations of sediment traps, the locations of the engineered wetlands and areas with a restoration focus, habitat enhancement initiatives and any proposed changes to the Arawhata Stream shape
4. Preparation of a concept development report (this report) to support the development of the consenting and planning pathway and inform the governance group.

2. Existing Environment

2.1 General

The proposed Arawhata Wetlands site is located approximately 3km west of the township of Taitoko/Levin, 6km from the sea (Hōkio Beach) and between Punahau and Lake Waiwiri , as shown in Figure 1. The site is accessed via Hōkio Beach Road near the north-east side of the site.

The proposed wetland site is currently operating as a dairy farm (Kane Farm) and is therefore generally grass with some trees along the boundaries and drains.

An existing site layout plan is provided as Appendix A.

2.2 Historical Context

The project site was historically part of a wider forested wetland system and was integrated with the traditional Punahau/Waiwiri cultural landscape. It was a mahinga kai connected to Muaūpoko Pā/fortified settlements beside Punahau and Waiwiri lakes and was owned by Muaūpoko whānau until the mid-1900's. The meaning of 'Arawhata' is a 'ladder', which represents how the Muaūpoko made ladders to climb the wetland forests to obtain the sweet fruit of the kiekie, namely tirori and tawhara. The wetland site itself has been the location of inter-tribal wars between Muaūpoko and Ngāti Toa in the early 1800's and was a pathway for travel between Punahau and Lake Waiwiri via a system of tracks along higher areas (pers. comm Dean Wilson, Lake Horowhenua Trust).

Figure 2 below shows a historical map of the former extent of the wetlands in the Horowhenua area.

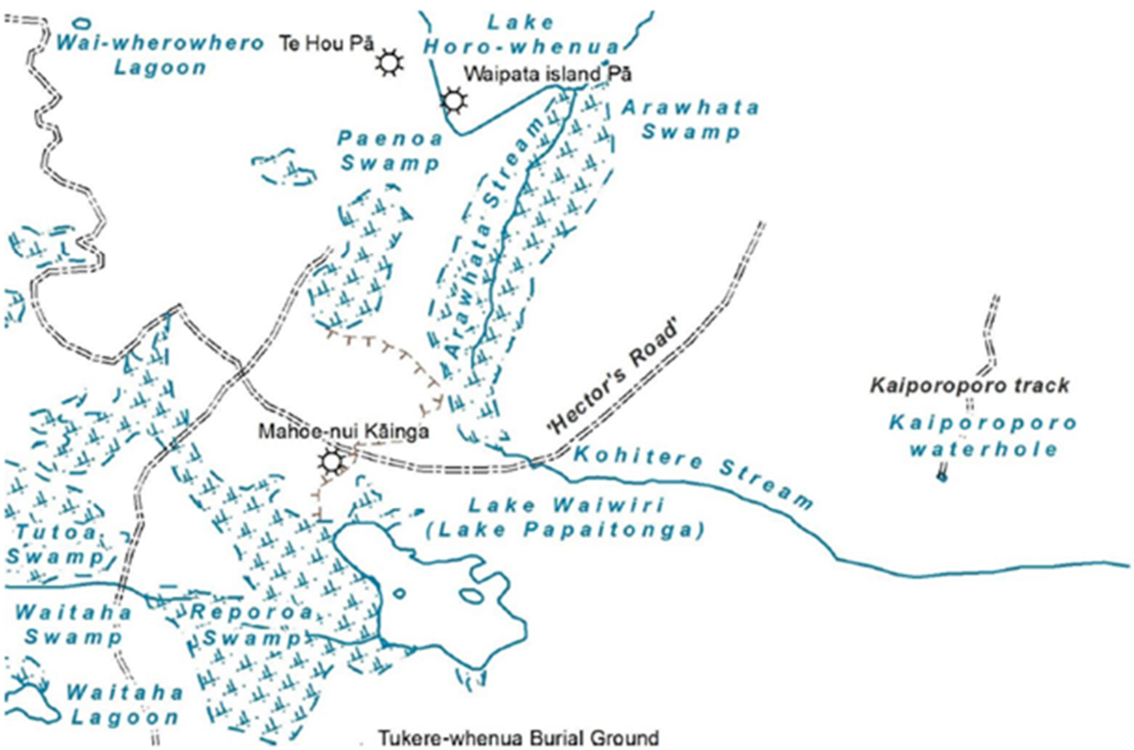

Figure 2. Historic Wetland Extent (LG Adkin, 1948)

In the early 1900's the wetland site was developed to support the booming harakeke/swamp flax trade in the area however upon Crown acquisition in the later part of the century has since been drained and converted for dairy farming. Muaūpoko whānau members still remember the harakeke swamp that once existed and these living memories have shaped this concept design. Today the project is of interest to Ngāti Raukawa who settled in the wider region in the early 1800s (Potter et al, 2017).

The degradation of Punahau has occurred over many years because of contaminant discharges (via both surface and groundwater) to the lake including from:

- The discharge of sewage from Levin township that occurred for over 30 years until 1987
- Land-use intensification in the early-mid 2000s
- Horticultural land-use upstream for many decades.

2.3 Climate

Historical meteorological data, available from New Zealand's national climate database website (CliFLO), was assessed at several weather stations within 5 km of the Arawhata wetlands site. The Levin AWS station was selected for climatic design information as it relates to the wetland design because it is located at a similar elevation to the site (15 m), it is nearby, and it has the longest data record available. Precipitation data is available between November 1990 to August 2020, whereas temperature data is between January 1972 to October 2000. More recent data will be incorporated during the next stage of design.

Average monthly temperature and precipitation data is presented in Table 1.

Table 1 Monthly temperature and precipitation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Daily Temperature (°C)	16.6	16.7	14.8	12.8	10.3	7.6	7.0	7.6	10.1	11.9	12.8	15.3
Daily Maximum Temperature (°C)	26.0	28.0	25.5	25.0	21.0	18.9	16.4	16.0	21.6	21.0	24.0	28.0
Daily Minimum Temperature (°C)	4.1	4.0	2.5	-1.3	-3.5	-6.9	-6.0	-5.2	-1.0	0.3	1.5	2.4
Mean Monthly Precipitation (mm)	66.0	79.3	65.7	84.6	91.3	102.6	94.4	88.9	93.1	97.3	92.9	96.6

Based on the historical data assessed, the site receives an average of 87.7 mm of precipitation per month with a range from 102.6mm in June to 65.7mm in March. The mean daily temperature ranges from 7.0 to 16.7 degrees Celsius (°C) over the year.

The climate is ideal for establishment and easy maintenance of a wide range of wetland plants and will support thriving micro-organism populations to provide natural water treatment.

2.4 Topography

The site is gently sloping with ground levels dropping approximately 7 m from south to north. Ground levels are shown on the Existing Site Plan (Appendix A). The eastern and southern parts of the site are higher, dropping down to the Arawhata Stream in the middle. The western part of the site is only slightly higher than the Arawhata Stream.

2.5 Soils

A soils investigation to understand soil types, depths and infiltration rates has not yet been undertaken at the project site, however general soils data is available on the Landcare Research SMaps website. This information is provided in Figure 3 below and indicates the presence of peat rich soils in the area of the former wetland. This soil needs to be retained for plant growth. The depth to alluvium is currently not known; however, data from drilling locations in the vicinity of the proposed wetland area indicate alluvium at 1-2 m below ground level.

A comprehensive shallow soil and groundwater survey is required for the site. Appendix B, Diagram 5 indicates locations of proposed soil samples.

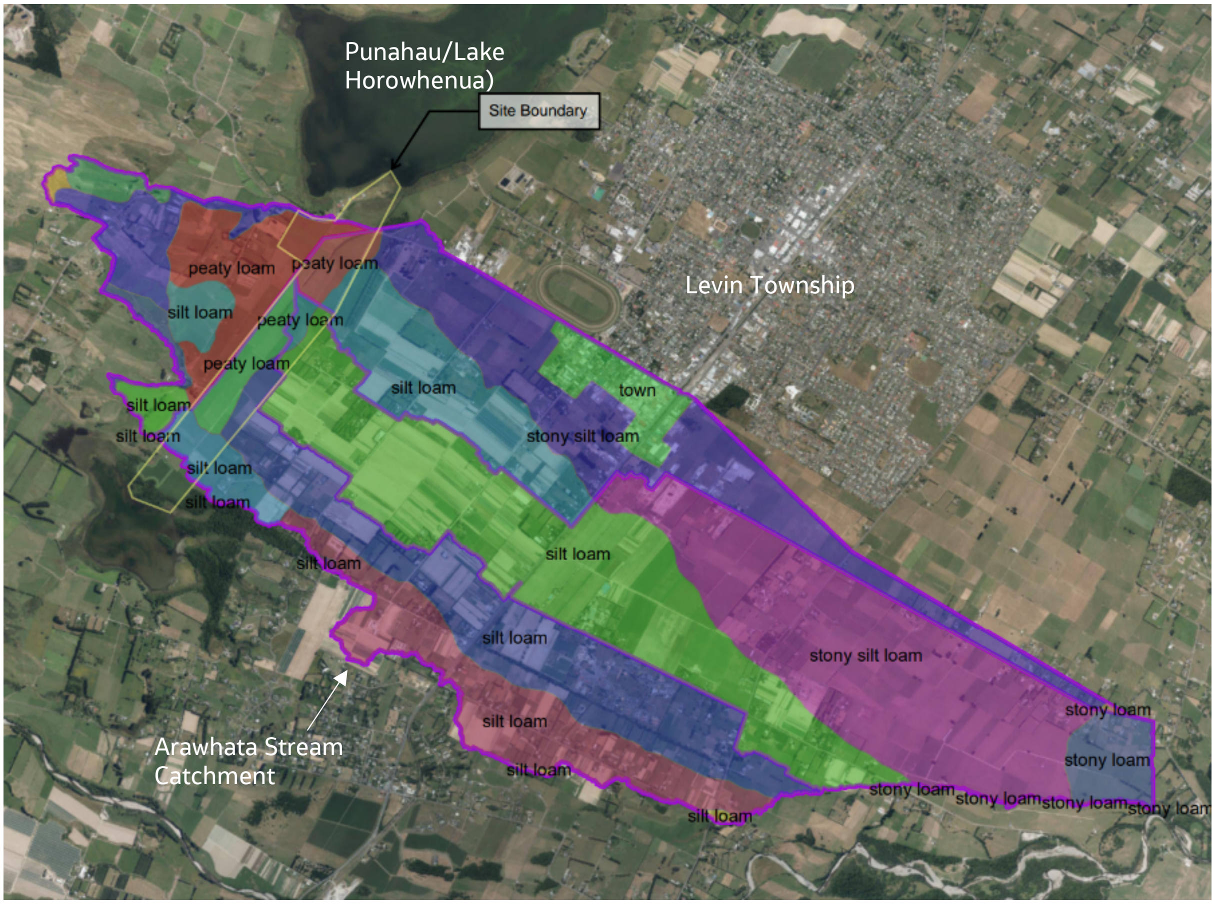

Figure 3 Arawhata Stream Catchment and Wetland Site Soils (Source: Smaps online)

2.6 Existing Surface Water

2.6.1 Streams and Drainage Network

The Arawhata Stream currently flows through the site in a south-east to northerly direction before discharging into Punahau/Lake Horowhenua. The existing project site also has an extensive network of cut drains and tile drains, some replacing natural waterways. Drains along roads/farm tracks convey water from road runoff and from upslope areas that discharge through culverts into the site at several locations.

In the northern part of the site, north of Hōkio Beach Road, there is an existing "Sediment Trap" to the west of the Arawhata Stream. This was constructed in 2017 (NIWA, 2019) to address concerns regarding sediment discharges to Lake Horowhenua. There is currently a culvert located within the Arawhata Stream alongside the sediment trap. During high flows, the capacity of this culvert means that high flows are directed through the sediment trap. In normal conditions, flows generally continue along the existing Arawhata Stream through the culvert.

There is currently one pumped subsurface drain on Kane Farm (see "F" on Appendix A Phase 1 Plan) which discharges into the Arawhata Stream.

2.6.2 Surface water flows

Surface water flows and water quality data have been recorded at five locations as shown on the Existing Site Plan - Appendix A. The names of each of these sites are as follows:

- Arawhata Drain at Kane Farm – this generally represents flow in Kohitere Stream, the southern drain discharging from the vegetable growing area)

- Joblins at Kane Boundary (Joblins Drain)
- Whelans at Kane Boundary (Whelans Drain)
- Arawhata at Dairy Track Bridge (Arawhata Stream main channel)
- Arawhata at Hōkio Beach Road (Arawhata Stream main channel)

The Arawhata at Hōkio Beach Road site has been in place since 2017 with others being installed in 2021 and 2022. A summary of the longer-term records of flow recorded at the Hōkio Beach Road site are provided in Table 2. This summary is based on hourly flow records.

Table 2 Historical monthly mean flows (m^3/s) between August 2017 and August 2022) at Arawhata Drain at Hōkio Beach Road recording station.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2017	NA	NA	NA	NA	NA	0.34	0.35	0.39	0.29	0.22	0.15	0.10
2018	0.07	0.08	0.09	0.12	0.14	N/A	0.26	0.25	N/A	N/A	N/A	0.12
2019	NA	NA	NA	NA	NA	0.17	0.22	0.36	NA	0.17	0.18	0.18
2020	NA	NA	NA	0.09	0.10	0.14	0.19	NA	NA	0.28	0.26	0.33
2021	0.34	0.20	0.18	0.14	0.17	0.19	0.31	0.43	0.39	0.26	0.20	0.44
2022	0.49	0.50	0.41	NA	NA	0.44	0.40	0.43	NA	NA	NA	NA
Average	0.30	0.26	0.23	0.11	0.13	0.26	0.29	0.37	0.34	0.23	0.20	0.23

Table 3 provides details of the shorter flow records at the "Arawhata and Kane Farm", Joblins Drain and Dairy Track Bridge sites. No data was available for the Whelans Drain at the time of this report.

Table 3 Mean Monthly Flows (L/s) at Flow Recording Stations – Dec 2021 to Oct 2022

Location	Dec 21	Jan 22	Feb 22	Mar 22	Apr 22	May 22	Jun 22	Jul 22	Aug 22	Sept 22	Oct 22
Arawhata at Kane Farm	26.5	0	19	0	1	17	40	65	64	10.1	26.5
Joblins Drain at Kane Boundary		1	5	0	0		21	27	26	6.3	
Arawhata at Dairy Track Bridge (B)		51	76	98	85	90	302	248	289		

Note (B): Data is from gauging rather than a monthly average based on hourly data.

2.7 Groundwater

2.7.1 General Description

Groundwater at the site is influenced by the location of the site within the wider Horowhenua Lakes Area. Groundwater feeding Punahau is sourced from as far away as the Tararua Ranges, east of the site.

Groundwater moves slowly eastwards from the Tararua ranges through semi-confined aquifers before upwelling at the Levin Fault, creating the lakes in the area of Punahau and Lake Waiwiri (Gyopari, 2005). Figure 4 provides a conceptual view of this system. Muaūpoko have described that their mātauranga aligns with this understanding where the iwi recognise a series of under-ground rivers and Lake Horowhenua is traditionally known to Muaūpoko as Punahau (or Waipunahau), which loosely translates to 'the freshwater spring of vitality'. The name highlights the once-abundant life-supporting capacity of the lake and Muaūpoko understanding of the lake's unique groundwater properties (pers.comm Dean Wilson, Lake Horowhenua Trust).

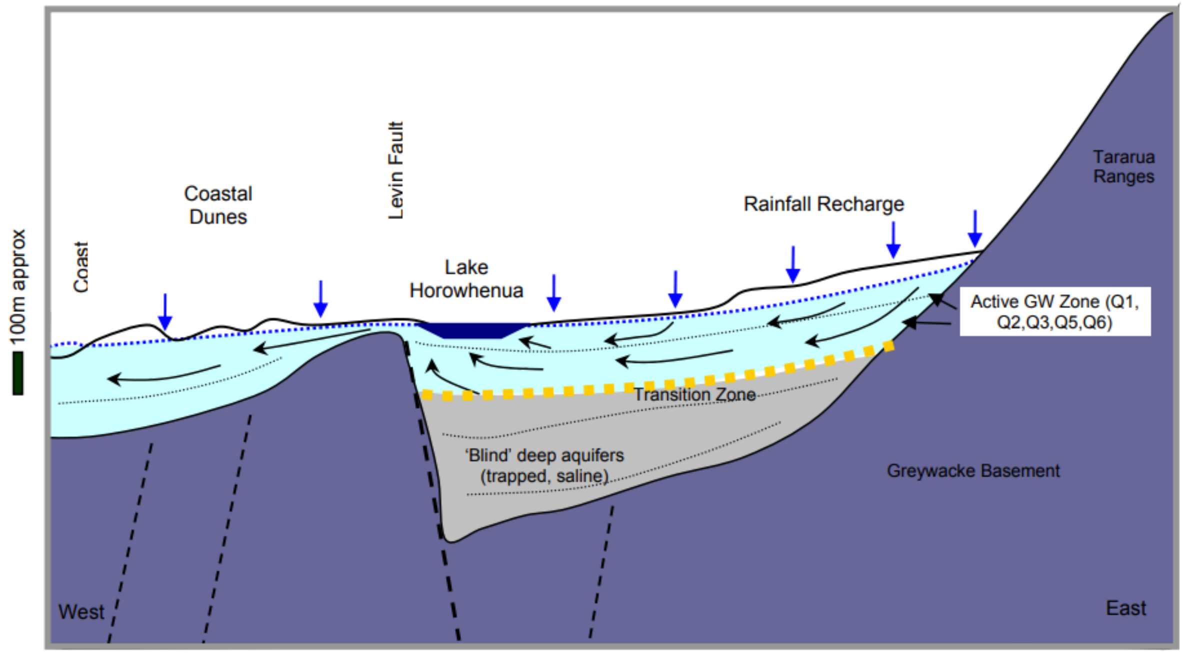

Figure 4 Conceptual Hydrogeological cross-section of the Horowhenua Lakes Area (Source: Gyopari (2005)

2.7.2 Shallow Groundwater

Shallow groundwater, sourced from rainfall percolating through soil, discharges into Punahau/Lake Horowhenua, including via Arawhata Stream and its' tributaries.

For the purposes of design, it has been assumed that the highest shallow groundwater levels at the site are at or close to the ground surface, as noted during winter site visits by the Jacobs team.

2.7.3 Existing Groundwater Pumping and Drainage Network

An existing horizontal subsurface pipe network made of wood is located in several paddocks between Arawhata Stream, Arawhata Road, and Hōkio Beach Road. The drain also extends under Arawhata Road and drains the Paenoa Swamp area. The flow from this existing drain system moves by gravity to an existing 3 m diameter manhole (labelled "F on Appendix A) and is lifted by a small existing pump that discharges to Arawhata Stream. This pump has a capacity of 50 L/s.

There is also an existing artesian livestock stockwater well located just east of the Groundwater Pump and Sump (Labelled G on Appendix A). When the stockwater well is turned off, this well continues to flow a rate of approximately 1 L/s, under artesian pressure.

There are additional wells on the site including one near the dairy shed for sanitary and washdown use, one on the highest portion of the property at the end farthest from Punahau/Lake Horowhenua, for domestic use at the house and a higher flow irrigation well also exists near the southern end of the property.

In addition, a horizontal groundwater collection drain tile consisting of perforated pipes approximately 2 m deep is used to collect an estimated 5 m^3/minute of shallow groundwater near the southern property line shared by Woodhaven Farms. This flow is expected to be relatively constant year-round.

Locations of these existing site features are provided on Appendix A.

2.8 Existing Groundwater Quality

To date no groundwater quality monitoring has been undertaken, however this will be undertaken prior to commencing the next stage of design. For the purposes of design, it has to date been assumed that shallow groundwater quality (i.e., the quality of the flow to be intercepted and treated in the wetlands) is similar to surface water quality (see below). It is however noted that samples of the water in the groundwater sump in the northern part of the site (see Appendix A for location) are low in nitrogen. It is not clear if this is localised, therefore more widespread sampling will be required to confirm this.

It is assumed that approximately half of the nutrient load from the Arawhata catchment is carried in groundwater, however this will need to be confirmed in the next stage of design. Therefore, the design includes groundwater interception and treatment. In the engineered system, extraction of regional groundwater flow is included for discharge into wetlands for treatment. It is assumed that the groundwater flow is low in turbidity and organic particles and high in nitrogen.

2.9 Existing Surface Water Quality

The *Assessment of Opportunities to Address Water Quality Issues in Lake Horowhenua* (Gibbs, 2011) states that the Arawhata Stream contributes about 50 % of the total external surface water nitrogen load to the lake at approximately 50 tons/year, although other sources suggest this may be 75%.

Water quality data has been collected at five locations within the wetland site (same sites as the flow monitoring noted earlier) as shown in Appendix A. Again, the length of record varies between sites, with the longest record held at the Hōkio Beach Road monitoring station. Other monitoring sites have recently been installed and hence records are shorter. This data has been used to determine the expected range of water quality that is expected to flow into the wetland system.

Table 4 presents the range of water quality across all five monitoring sites for selected parameters used to design the wetland system. Anecdotally, groundwater contributes approximately an equal amount of nitrogen as surface water. Phosphorus and sediment in surface water are greater than in groundwater and are contributed primarily by the main stem of the Arawhata Stream.

Table 4 Historical surface water quality data – Arawhata Stream and tributary drains (1998 – 2022) (A)

Parameter	Concentration Range			Units
	Low	Average	High	
Ammoniacal Nitrogen	<0.001	0.22	11.50	mg/L
Dissolved Organic Carbon	0.90	4.02	10.00	mg/L
Dissolved Reactive Phosphorus	0.00	0.16	0.97	mg/L
Nitrate	1.59	10.94	21.00	mg/L
Nitrite	0.00	0.02	0.16	mg/L
Total Nitrogen	1.50	6.96	31.90	mg/L
Total Oxidised Nitrogen	0.05	10.57	18.63	mg/L
Total Kjeldahl nitrogen	0.10		27.40	mg/L
Total Phosphorus	0.02	0.02	0.02	mg/L
Total Suspended Solids	0	345	3920	mg/L
Turbidity	0	346	4000	NTU

Note (A): Data in this table represents a summary across all the sites with water quality records.

3. Design Standards and Approach

3.1 Overview

The proposed wetland concept development has to date not been based on any specific design criteria or based on methods detailed in any particular design guideline. Rather, we have undertaken a detailed assessment of the site to understand how we can best utilise the topography of the site to maximise treatment. After a concept layout was developed, this was tested in the proprietary Jacobs Treatment Wetlands Design and Analysis Model (a water quality model) to understand the treatment capabilities of the proposed layout. The concept discussed in this report builds on a range of other technical assessment, options assessment and concept development work undertaken from ~2020 to present.

The following sections detail our proposed design approach to manage water quantity (flows and volumes) and improve water quality.

3.2 Water Quantity Design Approach

It is important that the proposed wetlands can function during the full range of hydrological scenarios that are likely to occur. Design of the components of the system will therefore be designed to manage the following flows:

- **Low flow conveyance** – At times there will be limited rainfall and the flows passing through the site network will be primarily sourced from groundwater. It is expected that the upper parts of the wetland will dry out during summer low flow conditions.
- **Normal flow conveyance** – When rainfall occurs, flows are conveyed into the wetlands, with the flows from Kohitere Stream going first to the sediment basin (noting that the other two incoming drains may also have sediment basins added during the next stage of design). Flows will need to spread out over the wetland to support plant growth and treatment.
- **High flow conveyance** – During larger storms, flows will still need to be stored in and pass through the wetlands, therefore velocities need to be controlled to prevent erosion and sediment managed to avoid smothering the wetland.
- **Flood flow management** – It is a requirement of the Horizons Regional Council One Plan that a 1 in 200-year Average Recurrence Interval (ARI) or 0.5% Annual Exceedance probability event is considered and managed such that flood hazard is avoided. It is therefore important that the wetland design does not make flooding worse than existing in rainfall up to including this event. It will also be important that such flows can be conveyed safely through the wetland or bypass such that the wetland will continue to function.

Refer to section 6 for a description of the hydrological modelling undertaken to date to support concept development.

3.3 Water Quality Design Approach

No discharge water quality criteria have been set for the wetland system however the overall aim of the project is to provide the best possible treatment such that the discharge (groundwater and surface water) to Punahau/Lake Horowhenua is improved and in turn lake water quality is also improved.

To determine the expected discharge quality from the proposed wetland system, water quality modelling has been undertaken using a proprietary Jacobs Treatment Wetlands Design and Analysis Model to determine the expected reduction of selected contaminants, based on the range of historically recorded flows and water quality data as well as predicted 2- year ARI flows.

The results of water discharge quality modelling are detailed in Section 7 and Appendix C.

4. Design Parameters

4.1 Rainfall

Hydrological modelling to inform concept design to date has been based on time series rainfall records sourced from NIWA's Cliflo website (see section 2.3). This approach was used to predict flows through the site based on historical data and for calibration of the model.

In addition, design rainfall depths and intensities have been extracted from NIWA's High Intensity Rainfall Design System (HIRDS) V4 in order to understand design peak flows (flows that may not have been seen in the historical record. The HIRDS V4 rainfall intensities are provided in Table 5 below. Note that this table does not include any allowance for climate change in the rainfall intensities presented. See section 4.2 for further discussion.

Section 6 provides designs of the hydrological modelling undertaken.

Table 5 Rainfall Intensities (mm/hr) sourced from HIRDS V4.

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h
1.58	0.633	44.1	28.5	22.2	14.6	9.68	5	3.25	2.08	1.3	0.978
2	0.5	48.5	31.3	24.4	16	10.6	5.44	3.54	2.26	1.41	1.06
5	0.2	63.7	40.9	31.8	20.8	13.6	6.97	4.5	2.86	1.78	1.33
10	0.1	75.4	48.2	37.4	24.4	16	8.11	5.22	3.31	2.05	1.53
20	0.05	87.8	56	43.3	28.1	18.4	9.28	5.96	3.77	2.33	1.73
30	0.033	95.5	60.8	47	30.5	19.8	10	6.41	4.04	2.49	1.85
40	0.025	101	64.2	49.6	32.1	20.9	10.5	6.73	4.24	2.61	1.94
50	0.02	106	67	51.7	33.5	21.7	10.9	6.98	4.39	2.7	2.01
60	0.017	109	69.3	53.5	34.6	22.4	11.3	7.19	4.52	2.78	2.06
80	0.013	115	73	56.2	36.3	23.5	11.8	7.52	4.72	2.9	2.15
100	0.01	120	75.9	58.5	37.7	24.4	12.2	7.78	4.88	2.99	2.22
250	0.004	140	88.2	67.8	43.5	28.1	13.9	8.85	5.53	3.38	2.5

4.2 Climate Change Scenarios

Flood flows used for design of conveyance through the proposed wetland will need to include an allowance for climate change in the rainfall intensities. To date, an appropriate climate change allowance has not been agreed with Horizons for design purposes however it is anticipated that local precedent will be referred to. The Palmerston North City Council Engineering Standards for Land Development require that climate change allowances for RCP 6.0 for 2081 to 2100 are used.

4.3 Design Flow Calculation

Peak flows and hydrographs for the concept development undertaken to date were generated using HEC-HMS hydrological modelling software using the SCS Unit Hydrograph runoff routing method. Design hydrographs (peak flows and overall volumes) were compared to flows recorded at the Hōkio Beach Road flow recorder to calibrate the HEC-HMS model. See section 6 for further discussion.

5. Description of the Proposal

5.1 Overview

The proposed wetland system (project) is made up of a range of components (activities) detailed in the following sections. It is proposed that the wetland be constructed in three phases, with Phases 1 and 2 being consented first. A further consent application for Phase 3 will be completed at a later date.

Conceptual layout plans of each of the construction phases are provided in Appendix B. The configuration of each wetland unit within the overall wetland system will be confirmed in the next stage of design, however each will be designed to allow gravity flow from south to north as currently occurs.

All wetland units will be designed to encourage the upwelling of groundwater into the deep zones (fens). Each deeper zone will be an unlined excavated impoundment. The layout requires minimal earthwork by configuring the wetland units parallel to the contours with drop from contour band to contour band with overland flow through wet meadow wetlands between deeper water emergent wetlands.

Section 5.6 provides detailed information about the wetland components. An overview of components provided in sections 0 to 5.5 below.

5.2 Mātauranga a Muaūpoko Input to Design

Throughout the optioneering and design process, mātauranga a Muaūpoko has been provided and integrated into the design. This input will continue during the next stages also. The governance group (including Ngāti Raukawa) made the decision in early phases that Muaūpoko would take leadership in providing mātauranga input to the project. Five criteria were used as part of the earlier MCA option selection process. Table 6 below details how this input has been incorporated in the design or how it is intended to be during later design stages.

Table 6 Methods for incorporating mātauranga a Muaūpoko into the Wetland Design

Criteria /Matauranga Māori Input	How this has been incorporated
Supports the traditional connections of Muaūpoko with the natural character of the landscape, including recreation of the shape, depth, and planting of Arawhata stream, wetlands, open water and connecting waterways	This will be done during the next stages of design.
Enables cultural expression opportunities through design	During the next stages of design, input will be gathered in terms of how this can be incorporated including in the shapes of wetland components. In addition, access to the site will be provided in the Phase 3 wetland (or earlier) by way of a trail through the site. The exact location and further enhancements including signboards, viewing areas etc. will be considered in the future.
Enables Muaūpoko kaitiaki to freely access their ancestral lands and to participate and make decisions in the project	Access will be provided through the site.
Creates habitat for taonga species and mahinga kai including the kotuku and watercress	During the next stage of design, plant species will be decided upon based on the hydroperiod (length of time and depth of flooding throughout the year) of each part of the wetland. It is anticipated that both mahinga kai (food) and rongoa (medicine) species will be used widely throughout, and that the species list will be developed with Muaūpoko Mātauranga input.
Minimises risk of disturbing Muaūpoko tupuna who lost their lives in the Arawhata area	The concept presented in this report has sought to utilize the existing landform to support the construction of the wetland and to minimise unnecessary earthworks. An archaeologist and/or iwi representatives will be invited to be present during earthworks to guide the construction team on how to manage any accidental discoveries of artefacts or bones.

5.3 Phase 1

Phase 1 of the wetland includes the following elements as shown on Figure 5 and Appendix B – Phase 1 Plan:

- A sediment basin located where the southern farm drain (Kohitere Stream) enters the site, this being the highest flow drain (Labelled (A) on Figure 5 and Appendix B). See section 5.6.1.
- Existing farm drains entering the site from the vegetable growing areas (Kohitere Stream and Joblins Drain) will discharge into new wetland inlet channels which will be constructed flatter than the ground slope, such that flows will discharge onto the ground surface further downslope. This way the flow can be directed overland and through a series of surface wetlands on the western side of the existing Arawhata Stream (C). See section 5.6.2.
- The proposed sediment basins will overflow under gravity into the new wetland inlet channels (D).
- The existing Kohitere Stream and Joblins farm drains (taking surface and groundwater) as well as new drains along the property boundary adjacent to Joblins drain (H), will have a perforated pipe placed in the invert, then will be backfilled with woodchips, bark, and soil. These will provide groundwater flow treatment (B). See section 5.6.3.
- Partial planting of the wetland areas (E).
- Retention of the existing groundwater sump and pump (F) as well as the artesian stockwater well for potential irrigation of the wetland/treatment of groundwater (G). A decision as to whether these pumps will be used will be made once further modelling has been undertaken. See section 5.6.7.
- Cleaning out and deepening of existing farm waterways discharging into Arawhata Stream such that groundwater is intercepted. Some of this flow will discharge into the wetlands (where grade is available) and some will discharge into the Arawhata Stream (I). See section 5.6.11.
- Extension of the bunds along the Arawhata Stream west side (J). See section 5.6.10.
- The existing culvert alongside the existing sediment trap (north of Hōkio Beach Road) will be fitted with a slide gate to redirect flows through the sediment trap, rather than along the main Arawhata Stream to the lake (K). See section 5.6.12.
- The addition of riprap on the slope of the existing sediment trap outlet to control water levels and protect the embankment (L). See section 5.6.9.
- Retention of the existing "sediment trap" north of Hōkio Beach Road (M). See section 5.6.12.

Phase one of the project will flood surface flow wetlands between the Arawhata Road and a low bund along the existing channel of Arawhata Stream (solid brown line on Figure 5). This area is shaded orange on the Phase 1 plan.

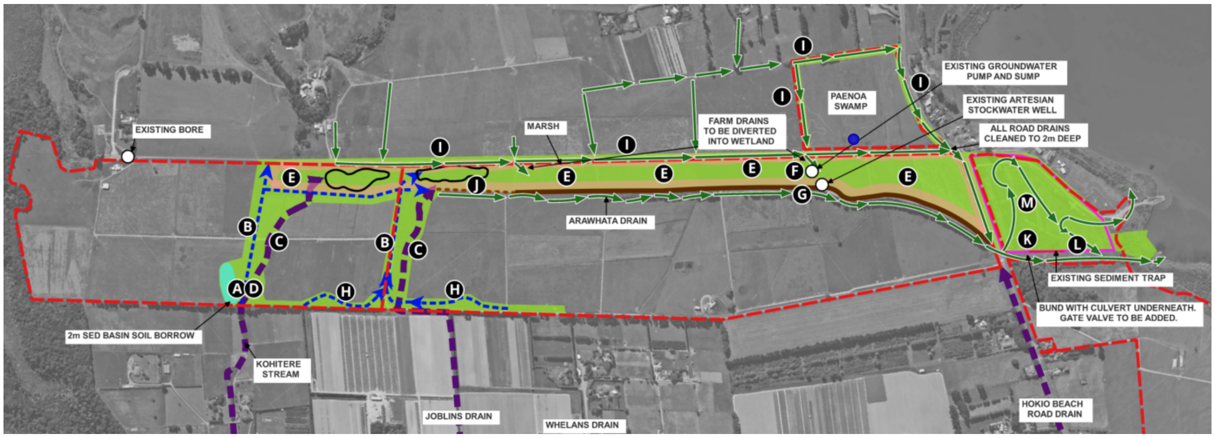

Figure 5 Arawhata Wetlands Phase 1 (see Appendix B for larger version and legend)

5.4 Phase 2

Phase 2 of the wetland includes the following elements as shown in Figure 6 and Appendix B – Phase 2 Plan:

- The existing Whelans drain will discharge into new channels which will be constructed flatter than the ground slope such that flows will discharge onto the ground surface further downslope. This way the water can then flow overland, and through a series of surface wetlands on the eastern side of the existing Arawhata Stream (Labelled (C) on Attachment 2).

- Further planting of both the Phase 1 and 2 areas (E).
- Installation of a small new pump to irrigate sediment pond water onto the Kohitere Stream alluvial fan where it cannot flow under gravity (O).
- A new bund on the eastern side of Arawhata Stream to contain the Phase 2 wetland (J).
- A lower section of riprap lined bund will be constructed at the downstream end of the Phase 2 wetland to discharge treated wetland flow into the Arawhata Stream (N).
- New groundwater collection drains along Hōkio Beach Road and the wetland site boundary (H).

Phase 2 will primarily involve the establishment of wetlands on the east side of Arawhata Stream in the paddocks surrounding the existing dairy facilities (wastewater pond and milking sheds) which will all be removed. The primary flow into Phase 2 will be from the Whelans Drain through the site. The drain will be split so part of the flow passes through the existing channel during high flow events. This existing drain will be blocked at the north-western end so flow will pond and overflow into the wetlands. The remainder will be diverted into a wide channel/swale that will have a relatively flat invert to gradually bring the water to the surface where it will discharge into a created surface flow wetland.

The existing discharge of Whelans drain into Arawhata Stream will be blocked so that all flow will pass through the restored wetlands along the south side of Arawhata Stream. The wetlands discharge will enter Arawhata Stream only at the Hōkio Beach Road culvert, having flowed over a lower section of riprap lined outlet bund. Phase 2 flow will pass through the sediment trap wetlands before discharge to Punahau/Lake Horowhenua.

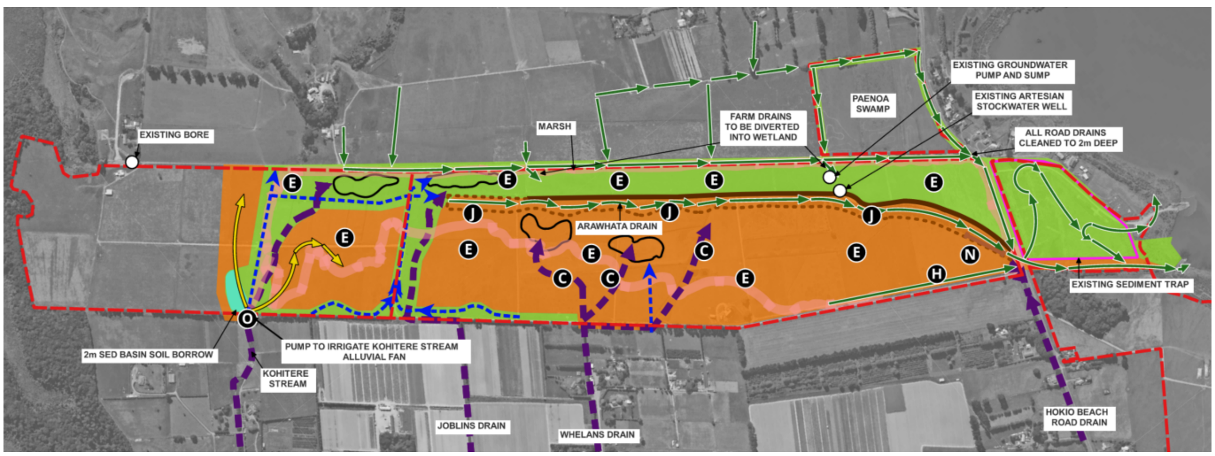

Figure 6 Arawhata Wetlands Phase 2 (see Appendix B for larger version and legend)

5.5 Phase 3

Phase 3 of the wetland complex includes the following elements as shown on Figure 7 and Appendix B – Phase 3 Plan:

- Construction of wetlands and planting of plants on the western side of the Phase 1 wetlands in an area referred to as Paenoa Swamp (R).
- An additional outlet from the existing sediment trap north of Hōkio Beach road to create a more dispersed discharge to Punahau/Lake Horowhenua (S).
- Further infill planting of the Phase 1 and 2 wetlands (E).
- Planting of the upper area of the site with forest (Q).
- Construction of a walking trail and cultural signage between Punahau/Lake Horowhenua and Lake Waiwiri (to the south of the site) (T).
- Deepening of drains on neighbouring land to intercept groundwater for treatment in the wetland.

The final phase of restoration of the Arawhata Wetlands will add new water quality treatment in the historic location of Paenoa Swamp, to the west of the main wetland area. The surface water drains from upslope (to the west of Arawhata Road) agricultural fields will be diverted into the swamp to restore hydrology and to be treated in the wetlands. The swamp appears to not have a surface water discharge in historic documents and likely discharged through infiltration to groundwater prior to entering the Lake, historically connected to wider Arawhata complex. This hydraulic connection will occur if surface flow is added to the swamp and may be adjusted by use of the existing subsurface drainpipe that currently conveys water to the pumped sump south of Arawhata Road.

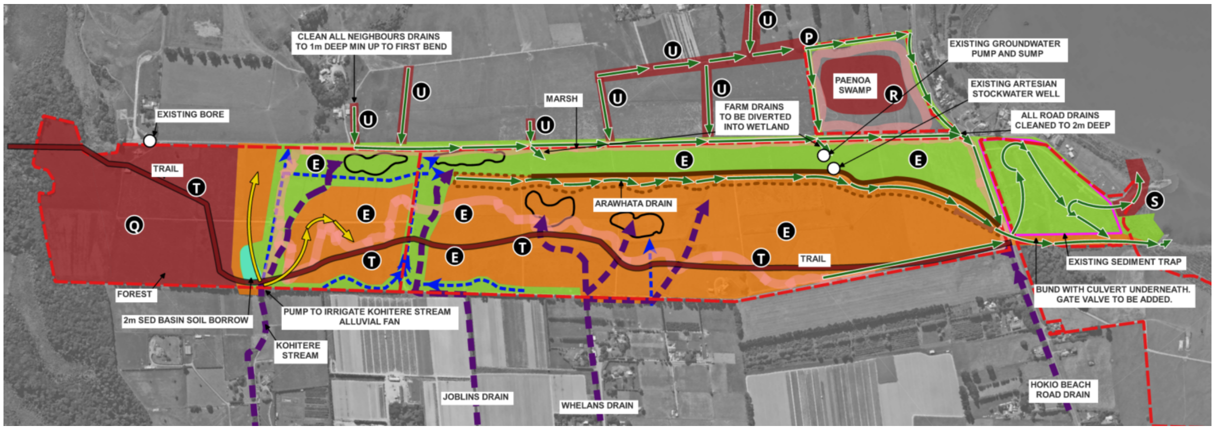

Figure 7 Arawhata Wetlands Phase 3 (see Appendix B for larger version)

5.6 Wetland System Components

5.6.1 Sediment Basin (Phase 1)

The proposed Phase 1 sediment basin (labelled A in the Phase 1 Plan) is proposed to be located where the agricultural drain in the historic location of Kohitere Stream enters the site. This stream has the highest flow and sediment load of the three main drains entering the site.

The proposed sediment basin will be designed to remove sediment laden with phosphorus prior to entering the wetlands. Removing the sediment prior to the wetland will mean that much less sediment will enter the wetland, thus reducing potential maintenance over time or overwhelming of the plantings. The sediment basin will however need more regular maintenance (removal of the sediment build up).

The sediment basin will overflow under gravity into the wetland inlet channels (see below).

5.6.2 Wetland Inlet Channels (Phase 1 and 2)

Where each of the three main channels enter the wetlands (Kohitere Stream in Phase 1, Whelans and Joblins Drains in Phase 2 –"C" on plans), this flow will discharge into a new shallow and wide channel/swale that will gradually become shallower as it flows across the site (the grade of the channel invert will be flatter than the ground surface hence it will slowly become shallower) and conveys water to the surface flow constructed wetlands.

Where the Kohitere Stream enters the site, it will first flow into the sediment basin, then will discharge into the wetland inlet channel before conveying flow to Phase 1 wetlands between Arawhata Road and Arawhata Stream. The Joblins and Whelans inlet channels will discharge into the Phase 2 wetlands, to the east of Arawhata Stream.

The flow carried in the proposed inlet channels will be restricted to that which is conveyed in the upstream drain network (upstream drains will not be modified), the capacity of which is not currently known, plus any overland flow that happens to discharge into the new inlet channels. The flow capacity of the proposed wide shallow wetlands inlet channels will however be much larger than the existing Arawhata Stream, therefore not impacting the flow carrying capacity of the system.

The Kohitere Stream and Joblins Drain represent most of the surface water flow that enters the Arawhata Wetlands and Phase 1 will treat more than half of this total surface water flow that currently discharges to Punahau/Lake Horowhenua as surface flow in Arawhata Stream.

Flow from agricultural drains to the west of Arawhata Road including the Paenoa swamp will be redirected into the wetlands where gravity allows,

5.6.3 Subsurface Groundwater Treatment Bioreactors (Phase 1 and 2)

Approximately half of the nutrient load from the Arawhata catchment is expected to be carried in groundwater. The existing deep main channel of Arawhata Stream that follows the lowest part of the site was historically deepened to drain the wetland for agricultural use. In the southern portion of the site (downstream of the Kohitere Stream inlet), the deep stream channel appears to not have existed in historic documents (refer Figure 2). It is proposed that in Phase 1, the initial section of drain (where Kohitere Stream enters the site) will be filled in to prevent direct inflow to this existing channel in the future. The remaining existing drain will have a perforated pipe installed in the base. The drain will then be partially backfilled with organic matter from wood chips and bark that is covered with about 1 m of soil and will act as a bioreactor. The organic matter will leach carbon into the groundwater in the drain to assist with removal of nitrogen. The perforated pipe will discharge into the Arawhata Stream, further north, as a large spring of low turbidity water that will become the headwaters of the stream.

The existing Joblins Drain will also be filled for the initial section where flow enters the wetland site in Phase 1. The existing channel running west across the site will have a pipe installed which will discharge into the Phase 1 wetlands alongside Arawhata Road. Again, this channel will be backfilled with a wood chips and bark. This groundwater treatment bioreactor will be extended along the eastern site boundary (along Woodhaven Farm (north and south of Joblins drain) to collect further groundwater for treatment in the bioreactor and phase 1 wetlands.

A similar groundwater collection and treatment system with gravity flow will collect water from a subsurface groundwater pipe (see Appendix A – Existing Site Plan) that currently discharges to a surface drain near the milking sheds and flows directly to Arawhata Stream in a surface drain ditch. This groundwater source will be routed in a subsurface perforated pipe surrounded by organic matter and will flow by gravity to a created wetland on the east side of Arawhata Stream for treatment.

See Appendix B – Sheet 11 for a cross-section of these bioreactors.

5.6.4 Groundwater Collection Channel (Phase 2)

An existing groundwater drainpipe (See Appendix A – Existing Site Plan) that surfaces at the property boundary and flows into Whelans drain will be captured and conveyed to the constructed wetlands using a subsurface groundwater treatment bioreactor (see section 5.6.3).

5.6.5 Treatment Wetlands (All phases)

The proposed treatment wetlands will consist of large, planted ponding areas that fill and drain during and after rainfall events. These will largely consist of the existing paddocks with new and existing bunds to contain the ponding. Areas of open deeper water will be excavated at the end of the wetland inlet channels (Black outlines on Phasing plans). This will provide a location for further settling of sediment prior to flows passing through the shallower vegetated areas.

The created wetlands on both sides of Arawhata Stream will link to existing lower (northern) areas of the site that represent the location of the historic Arawhata Wetlands. Water will flow on the surface of the existing paddocks converting them into surface flow wetlands and into the lower elevation areas near Hōkio Beach Road which will have deeper water and will be emergent surface water wetlands.

Within the proposed wetland areas, minimal earthworks are proposed.

Existing Drainage/Stream Network Modifications

It is proposed that all agricultural drains and waterways will discharge into surface flow wetlands located on both sides of Arawhata Stream and no waterways will discharge directly into Arawhata Stream except the Hōkio Beach Road drain. The surface water wetlands will discharge to Arawhata Stream just upstream of the Hōkio Beach Road culvert and all flow will pass through the existing sediment trap wetlands near the lake shore. The deep channel of Arawhata Stream will convey only treated groundwater and water treated in surface wetlands that seeps into the ground and enters as springs in the channel from the higher elevation wetlands along both sides of the channel. It is anticipated that the Arawhata Stream channel flow will be slow and low in turbidity.

Existing east-west orientated drainage channels and small separation bunds between each paddock will be retained to redistribute flow in the wetlands to reduce the potential for flow to short-circuit and will force the flow to run parallel to the contour bunds or infiltrate and seep into the Arawhata Stream channel in seeps and springs or upwelling into stream beds (hyporheic discharge) or up well in the next lower wetland section. Each existing drain will have about 10 m of length filled in on both ends so that no flow can exit the drains directly to Arawhata Stream or the perimeter drains. The drains will fill with water and become deep zones perpendicular to the wetlands flow path (south to north). The flow through soil will increase the microbial diversity that is in contact with the water providing treatment.

Permeable Bottom Layer

The wetland bottom layer will consist of non-compacted native in-situ soil as a permeable layer to promote the upwelling or percolation of groundwater into and out of the wetland system.

Wetland Water Level

The water surface of the wetland will be quite variable but will average from about 0.5 m deep to just above the surrounding groundwater elevation during most seasons. Water level will vary in each part of the wetland according to the existing ground surface topography as it did historically before farming. Site visits have indicated that the wetland topography has not been levelled or changed by agricultural use but only drained by drainage channels and by the deepening of the Arawhata Stream. Allowing the water to flow on the existing land surface will provide the best conditions for restoring the historical wetland that previously occupied the hummocky irregular land surface. The lowest elevation areas, constructed wetlands, and the areas adjacent to Hōkio Beach Road will be deeper emergent marsh wetlands with water levels consistently near 0.5 m deep.

After hydraulic modelling has been undertaken, the heights of bunds will be determined such that expected water levels within the wetland will be appropriately contained such that water will not leave the site during the largest design storm (100-year event). The 200-year event will also be considered in the next stages of design.

5.6.6 Wetland Planting (All phases)

The proposed wetland areas will be planted used a range of locally sourced plants appropriate for the location within the wetland, with different species higher up in the wetland (areas which are more often dry) compared to lower down (regularly flooded areas). Initially during Phase 1, a smaller number of plants will be planted, however during Phases 2 and 3, further planting will occur. Wetland Irrigation (Phase 2)

The southern-most waterway Kohitere Stream) that enters the site was historically a stream with a relatively large catchment. This stream has historically deposited sediment and created an alluvial fan where the flow entered the wetlands. The area of the fan is at an elevation above the deep agricultural drain and cannot be flooded by the gravity flow with drain water. In Phase 2, this area is proposed to be returned to a shallow braided flow alluvial fan with water pumped by a low-head pump from a proposed sediment pond (at the site boundary) using a perforated (pipe with adjustable gates) pipe that will spread water across the alluvial fan for overland flow into created wetlands. This will restore the hydrology of what was likely a meandering braided channel fan in the past.

5.6.7 Existing Groundwater Pumping and Treatment (All Phases)

The existing subsurface pipe network and associated groundwater pumping system (F on Phasing plans) has a potentially high value to provide additional flow into the wetlands in the lower portion of the site to maintain flows, especially during dry seasons. The discharge from this existing system will be moved to the wetland surrounding the existing sump and no other changes will be made. Groundwater extracted from this area will include a component of recycled water that infiltrated through the bottom of the wetland and is captured in the drainage network to be brought back to the surface and retreated which will further reduce nutrient concentrations and result in better treated water being discharged to the lake.

In Phase 3 it is proposed that the use of the existing groundwater sump and pump system be re-evaluated to determine if it should be abandoned in place as part of the Paenoa Swamp restoration. The continued use of the sump pump will increase the amount of water that passes through the bottom of the swamp to allow more water to be treated. The ideal hydrology for the swamp can be adjusted by adjusting the rate of groundwater pumping and will be determined in more detail on a later phase of design.

5.6.8 Wetland Outlets (All phases)

All flow from the Phase 1 wetland will exit the wetlands by overflowing a riprap lined lower section of bund into the roadside drain alongside Hōkio Beach Road, and then to Arawhata Stream. Similarly, another lower section of rip-rap lined bund will be constructed to drain the Phase 2 wetland, discharging directly to Arawhata Stream.

5.6.9 Bank Protection (All Phases)

Bank protection, stabilisation, and erosion control measures will be implemented for the banks and channels of the wetlands subject to excessive shear forces. Riprap will be used only in areas near hydraulic control structures such as the discharge from the wetlands, sediment basin, sediment trap and culverts. All other channels and banks will be protected by vegetation plantings.

5.6.10 Surface Stormwater Flow Control/Diversion Bunds (Phases 1 and 2)

The wetlands will be separated from Arawhata Stream with a ~0.5 m high bund to keep storm flows from overtopping the wetlands and reducing the potential for washing out settled solids. A portion of the existing Arawhata Stream has an adequate existing bund on the western and it will likely not need to be modified. The northern section of the Arawhata Stream (the section to be retained) will have a bund added on both sides that will be more meandering and curved to follow what may have been a meandering deep zone through the northern wetlands historically. The existing Arawhata Stream channel will not be relocated but the riparian area along the existing stream will likely be enhanced, becoming much wider, with the new low bund (Phase 2) spaced further from the channel and in a meandering alignment. The bunds will prevent agricultural drain water that enters the site from flowing directly into the Arawhata Stream channel and rapidly moving off site without treatment as it currently does. The bunds will cause all surface drain water to flow parallel to the main channel on both sides (western in Phase 1 and both in Phase 2) and enter the channel via seepage under the bund (which will not specifically be prevented) or at the northern end of the wetlands at Hōkio Beach Road where all flow will enter the roadside drain then Arawhata Stream. The wetlands will be designed to allow controlled overflows between the wetland cells (layout to be determined during the next stage of design) into the next downstream wetland during storm flows.

A bund will be constructed along the southeast side of the Arawhata stream full length of the channel to limit agricultural drain water and surface runoff from the catchment area to the southeast entering the Arawhata Stream channel directly.

5.6.11 Perimeter Drain and Farm Drain Deepening (Phase 1)

The existing road drains along Arawhata Road (east side, labelled "I" on the Phase 1 plan) and around the perimeter of the area to the west of Arawhata Road will be made deeper. A bund will be constructed on the wetland side of the drains along Arawhata Road to divert surface water runoff from the upstream catchment area (areas west of Arawhata Road) to the road drain where it can pass through the perimeter bund into the wetlands at several locations. The road drain flow will be conveyed along the road far enough to arrive at a lower elevation where it can discharge into the wetlands without allowing the wetland water level to back up the off-site drains.

By deepening these road drains, this will mean that additional high-nutrient groundwater will be intercepted and can be treated in the wetlands.

5.6.12 Existing Sediment Trap and Lake Outlet (All Phases)

After flows have passed through the wetland, they will then pass through the existing Hōkio Beach Road culvert then through the existing sediment trap wetlands between Hōkio Beach Road and the lake. The agricultural drain that flows along Hōkio Beach Road (east of Arawhata Stream), and all water collected in the road drains, will continue to pass through the sediment trap wetlands also. The existing culvert in Arawhata Stream (downstream of Hōkio Beach Road) that was built to divert flow out of the stream channel and through the sediment trap wetlands is normally open. However, in Phase 1 it will have a downward opening weir gate installed to control flow levels and the gate will normally be closed. Hydraulic modelling will be used to confirm that this addition will not result in any adverse effects and to determine when this gate will need to be opened during flood flows.

During Phase 3, it is proposed that a new dispersed discharge to the lake is constructed. A new channel will be constructed at a flat grade with multiple discharge points such that a dispersed (rather than point-source) discharge is achieved.

The expected improved quality water will discharge from the final segment of the main Arawhata Stream. It will disperse and percolate into the lake and ground through the wetland sections, which will act as infiltration beds, and from the outlet of the final open water area in the sediment trap wetlands.

5.6.13 Pathway/Trail (Phase 3)

The historic pathway (actual location unknown) between Punahau/Lake Horowhenua and Lake Waiwiri will be restored in Phase 3. It is proposed that this be located across higher ground, as would likely have occurred in the past. Alternatively, the existing and proposed stopbank tops could also be used for this walkway. Additional features will also be added including information kiosks, boardwalks etc

6. Hydrological Modelling

6.1 Description of Modelling

During previous concept design work (Jacobs, 2021), Jacobs undertook hydrological modelling of the site to obtain design peak flows. Calibration was also undertaken based on historical rainfall records and recorded flows. This modelling will need to be updated during the next stage of design in order to undertake hydraulic (flood) modelling such that the effects of the wetland can be quantified.

Table 7 shows the design peak flows for different rainfall events for each of the contributing sub-catchments obtained from the hydrological model (catchments shown in Figure 8) using rainfall from HIRDS v4 (see section 4.1) for the 100-year, the 10-year, and the 2-year Average Recurrence Interval (ARI). The methodology described in NIWA (2018) was used to develop cumulative rainfall hyetographs (graph of rainfall distribution during a rainfall event) for different storm durations to obtain the critical storm duration for each rainfall event and for each sub-catchment.

Design flows were used for sizing of wetlands during concept design and will be used for aspects of the design during the detailed design phase, as described below. We will also consider how a 200-year ARI storm event can be managed during the next stage of design, given the Horizons One Plan requires this (See section 3).

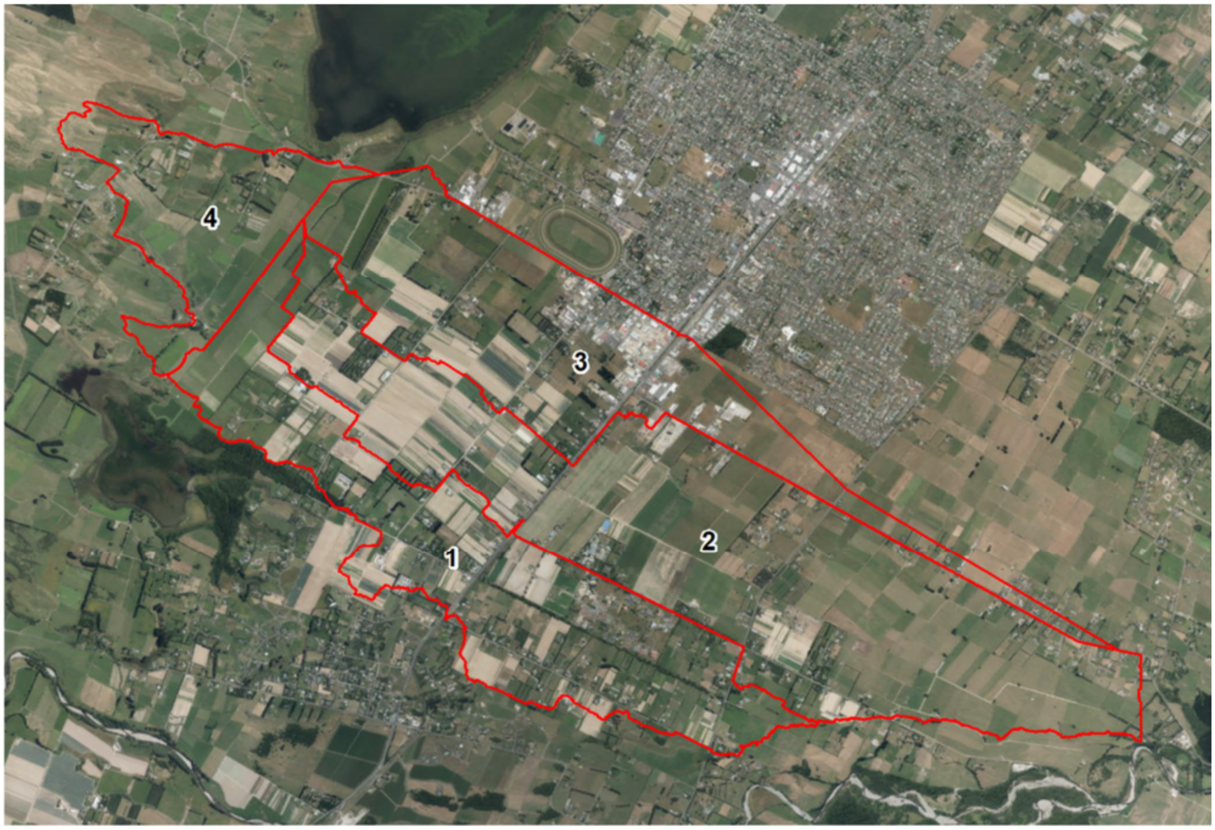

Figure 8 Hydrological Modelling Subcatchments

Table 7 Modelled design peak flows (m^3/s) generated by each subcatchment

	Catchment				
Rainfall Event	1	2	3	4	Combined (a)
100-year ARI	9.25	9.28	4.99	2.35	21.50
10-year ARI	0.70	0.69	0.39	0.10	1.63
2-year ARI	0.25	0.44	0.23	0.13	1.10

ARI = Average Recurrence Interval Note: (a) This is the combined peak flow from all catchments upstream of Hōkio Beach Road.

The wetlands will be designed for the following flow conditions.

6.2 Low Flows

The proposed design will seek to mimic status quo discharge flows during the dry period. Distributing the existing flow over a much larger wetland footprint will increase evapotranspiration and infiltration to a point that drain water discharge to the lake could be minimal during the low flow period. Groundwater will be captured in the new subsurface perforated drainpipes along the eastern boundary of the site and added to the higher parts of the wetland complex to increase the discharge to the lake with clean treated water even during the lowest flow months.

Groundwater from the existing groundwater pump sump that currently discharges directly into the Arawhata Stream channel will be discharged into the wetlands for treatment and to improve hydrology. The rate of groundwater pumping will be variable with the highest pumping rates during the dry season and the lowest groundwater pumping rates during the wet season.

The artesian livestock stockwater bore will no longer be pumped but will be allowed to flow into the wetlands by natural artesian groundwater pressure.

To date groundwater flow into the wetland area was estimated during options development using a baseflow separation approach that is detailed in Jacobs (2021). Whilst not a hydrogeological modelling approach, the Arawhata catchment is quite unique in that all surface water and a significant component of shallow groundwater flow appears to emerge into the Arawhata Stream. For the purposes of this report, it has been assumed that the baseflow component of the Arawhata Stream is the shallow groundwater component that requires treatment.

Under these conditions, the model calculated a groundwater baseflow into the Arawhata Stream from seeps and springs of 200 L/s, or 17,280 m^3/day.

It is anticipated that the addition of subsurface drainpipes along the eastern boundary adjacent to irrigated vegetable farms will increase the groundwater capture and flow by about 100 L/s. The existing groundwater sump pump (F on the Phase 1 plan) discharges approximately 50 l/s to Arawhata Stream and this groundwater flow will continue to be pumped but will discharge into the wetlands for treatment.

Note that this method of groundwater flow estimating is appropriate for a concept level design only and a more accurate groundwater flow model will be developed (by others) in the next stage of the project and will provide an input to the hydraulic (flood) modelling.

6.3 Normal Flows

Peak flows associated with a 2-year ARI storm event will be used for sizing of the normal base flow conveyance facilities e.g., the wetland inlet channels (total flow of ~1.1 m^3/s), with flows spread across the channel inverts. In addition, the treatment function of the wetland will be designed for up to this flow, with the highest removal rates occurring in events up to this size. It will therefore be important that the flows are spread out across the full wetland width during such flows to maximise treatment.

The additional flow in the 10-year ARI storm event will flow over the full width of the inlet channel (at a greater depth that the 2-year event) and only cause slightly higher flow velocities through the wide surface area of the channel and the wetlands system and will also not cause significant damage to stopbanks. The flow in the inlet channels will however depend on the capacity of the upstream offsite drains (currently unknown) and whether they will convey this full flow to the sediment basin (Kohitere Stream) and wetland inlet channels.

6.4 Flood Flows

The proposed wetlands will be designed to convey flood flows in up to a 100-year ARI storm event (~21.4 m^3/s) noting up to a 200-year event will be considered in the next stage of design.

In flood conditions, flow will arrive at the wetlands partially in the upstream drainage channels, and partially overland (when flows exceed channel capacity). Flows that are discharged into the wetland inlet channel may then need to overflow out of the inlet channels into the phase 2 wetland area (noting this area will not be developed until phase 2 but this overflow will still need to occur in phase 1), therefore the banks of the inlet channels will need to have lower sections where overflow can purposefully occur.

The design concept intentionally does not recommend fabricated water control structures, in order to be as passive and natural as possible, which has the additional benefit of minimizing maintenance on structures after high flow events.

Existing road culverts and offsite drain channels will be used even if they are not sized for the 100-year event. The vast volume of the wetlands will help to buffer the peak flows so that the flow that must pass through the Hōkio Beach Road culverts will be reduced from the peak that would occur if the wetlands were not developed. The wetlands perimeter bunds will be sized to contain the 100-year event flows and discharge them at the Hōkio Beach Road culvert at a flow rate equal to the current 100-year ARI storm event flood flow rate without the wetlands so that downstream flooding will not be increased by the wetlands. It is worth noting that there is limited understanding of drain capacities in the catchment (especially in flood events) and this area require surveying and further investigation.

7. Water Quality Modelling

The proprietary Jacobs Treatment Wetlands Design and Analysis Model was used to estimate the improvement in water quality that will be achieved with construction of the Arawhata Wetlands as described in this report. The two major components to the flow through the wetlands are subsurface groundwater flow and surface water flow from agricultural drains.

In the model, it is assumed that subsurface flow treatment occurs via treatment with organic carbon when the groundwater passes through the existing drains that will be backfilled with wood chips and bark to aid in removal of nitrogen. The model also assumes that treatment occurs when water flows through the upper two meters of soil (e.g., rainfall infiltrating through soil) before being collected and then discharging into the surface flow wetlands.

Groundwater flows are large but have only recently begun to be measured. Similarly, the quality of groundwater has only begun to be measured recently. For this level of concept development, it was assumed that the groundwater flow that can be captured is 20% of the total flow that is measured at surface flow monitoring points and that the water quality is the same as surface flow. The monitoring points are only in surface flow channel therefore this cannot be proved without further monitoring and water quality sampling. However, field observations have confirmed that a significant component of the total measured surface flow is made up of groundwater that is shallow and upwells into drains and channels. These drains and channels flow even when surface flow into the site has ceased.

The major component of flow discharging to the lake is surface flow from agricultural drains that enter as surface flow (during/after rainfall) and remain on the surface. This flow will be treated in constructed and naturally occurring wetlands that will form when the flow is diverted from the agricultural drains from the vegetable growing areas (Kohitere, Joblins and Whelans drain) are conveyed such that they can discharge onto the soil surface.

The primary contaminants causing water quality issues in Lake Horowhenua are nitrate and nitrite nitrogen, as well as phosphorus and sediment. Therefore, the modelling was focused on these contaminants. Other water quality parameters are measured and will be modelled in the next phase of design.

The summary of water quality improvements predicted by the model is presented in Table 8.

The overall reduction in nitrate and nitrite nitrogen after Phase 1 and Phase 2 are constructed and mature, is predicted to be 70%. The removal of phosphorus in the mature system (after Phase 1 and 2) is predicted to be about 30%. The Phase 1 groundwater treatment is predicted to remove about 90% of the nitrogen and 50% of the phosphorus but this is only based on treating 20% of the total flow in Phase 1. The restored wetlands are predicted remove 93% of the incoming total suspended solids that cause the turbidity in the stream and lake. Table 8 presents the subdivision of treatment by component of each phase. Note that it has been assumed that groundwater inflow quality is similar to the surface water quality, however sampling is required to confirm this.

The overall Phase 1 wetlands treatment will remove 69% of the nitrogen and 26% of the phosphorus and 94% of the total suspended solids or turbidity on over 90% of the total flow that discharges to the lake. The remaining approximately 10% of the total flow passes through Phase 2 wetlands and has a larger land area per unit of flow which results in better treatment. The Phase 2 wetlands remove about 90% of the nitrogen, 53% of the phosphorus and 89% of the total suspended solids from the flow that passes through them. However, only about 10% of the total flow receives this level of treatment. In the next phase of design, the flows may be split to load the land area more uniformly for a better-balanced treatment by diverting part of the flow from the Joblins drain into Phase 2. The total reduction in nutrient loads to the lake will be similar with better balancing and should be slightly improved. Balancing treatment amongst multiple wetlands and phases requires many iterations of modelling that were not included in this concept development phase.

Appendix C provides an overview of the modelling and assumptions.

Table 8 Water Quality Improvement Modelling Results

Phase	Description	Description	% of Phase flow	Avg Inflow m^3/day	Avg Outflow m^3/day	Inflow Concentration			Outlet concentration			Average % Concentration Reduction			Overall % reduction		
One						NO2-3N mg/L	TSS mg/L	TP mg/L	NO2-3N mg/L	TSS mg/L	TP mg/L	NO2-3N (%)	TSS (%)	TP (%)	NO2-3N (%)	TSS (%)	TP (%)
		Soil Infiltration	20%	2310	1195	8.70	126.81	0.70	0.7	0.00	0.4	92%	100%	50%			
		Surface flow wetlands with soil infiltration outflow	100%	10434	9537	8.30	111.71	0.67	4.8	26.34	0.61	42%	76%	19%			
		Sediment Trap Outlet	100%	9537	8398	4.80	26.00	0.61	2.7	8.00	0.52	45%	70%	14%	69%	94%	26%
Two		Soils infiltration	20%	139	0	2.90	296.10	0.60	1	0.00	0.4	66%	100%	40%			
		Surface flow wetlands with soil infiltration outflow	100%	555	148	3.80	296.10	0.90	0.3	33.37	0.28	93%	89%	68%	90%	89%	53%
One and two combined			100% of both phases	9685	8546	4.30	26.14	0.84	2.8	8.07	0.74	35%	69%	12%	70%	93%	27%

8. Consents Required

8.1 Overview

The proposed Arawhata Wetlands project will require a range of consents to enable construction. It is possible that consenting of the project could follow the traditional consenting process, or via the Covid-19 Fast-Track process.

The following sections set out:

- A summary of the elements of the design required to support a Fast-track referral application (including references to earlier parts of this report providing further detail)
- The consents that are likely to be required under the relevant planning regulations
- Information to provide support for the Fast-track consenting process
- A description of the anticipated and known adverse effects.

8.2 Consents Required

8.2.1 Overview

Construction and operation of the proposed wetlands will require Horizons to apply for a range of consents. Whilst not exhaustive, the following provides a list of the consents that are likely required. A more detailed assessment is expected to be undertaken by the project planners once concept design has been undertaken and an application is being prepared.

8.2.2 Consents under the Horizons Regional Plan

The following consents are expected to be needed under the Horizons Regional Plan (HRC, 2014) One Plan, 2014 including later amendments):

- Discharges of drainage water to water
- Land disturbance (earthworks) in order to construct stopbanks (bunds), excavate sediment basins, excavation for the installation of pipelines
- Damming and diversion of water – it is proposed that the main Arawhata Stream flow originating near the south-east corner of the site (Kohitere Stream inlet) as well as other farm drains from the vegetable growing area, be collected (damming) and diverted into a range of locations including a series of wetlands.
- Reclamation of the existing Arawhata Stream channel in the southern part of the site (downstream of the Kohitere Stream inlet) and converted to a groundwater treatment bioreactor.
- Discharges of sediment and other contaminants associated with earthworks
- Discharge to air (Dust during construction)
- Interception and taking of groundwater associated with drain lowering, discharges from the existing pump into the wetland and dewatering of excavations to construct structures.

8.2.3 Consents under the Horowhenua District Council Plan

- Earthworks in a Flood Hazard Overlay area- this shall not exceed 20 m^3 per 12-month period

Note that currently 20 m^3 limit is not breached however detailed design may end in higher earthworks volumes hence the need to apply for consent.

It is also possible that a consent will be required for activities likely to occur within the setback distances of the gas pipeline identified on the HDC Planning maps (see Existing Site Plan – Appendix A). A minor volume of earthworks will be undertaken to construct the proposed bund on the eastern side of the existing Arawhata Drain to create the wetlands. In order to construct this bund, some excavation will occur to provide solid foundations, with most of the earthworks being above ground fill. Given that the gas pipeline in this location is buried, it is expected that any effects on the gas pipeline can be managed.

9. Assessment of Environmental Effects

9.1 Overview

Note that this is not a full description of the effects, as would normally be required for a consent application as these cannot be confirmed until later in the design process once gaps are all filled. This section does however provide a qualitative description of likely effects based on our experience with such projects.

This section focusses primarily on water quantity and quality related effects as well as some construction related effects. Our assessment of these effects is based on the Options Assessment (Jacobs, 2022a) and Concept Development work (Jacobs, 2022b) undertaken to date, which have been based on available data. Data collection (water quality, flows, soils etc) is still ongoing, and this will be used to undertake a full quantitative analysis of effects during the next stage of the project. For the purposes of this report, a qualitative description is therefore generally provided.

Note that the proposal will also result in a range of other potential effects not addressed in detail here. These will be addressed by other subject matter experts in other supporting documents. Effects are likely to include:

- Cultural Effects: Cultural Impact Assessments (CIA's) are being undertaken to inform the project by Muaūpoko and Ngāti Raukawa. It is anticipated that the physical effects related to cultural health of the project will be primarily positive given the project objective is to improve the water quality of the lake and to restore this natural wetland. The iwi will advise through the CIA's on the spiritual, traditional and cultural implications of the project.
- Visual and Landscape Effects: The proposal will restore a natural wetland of cultural significance and hence is expected positive. There will be temporary visual impacts during construction due to the presence of construction equipment, stockpiling of soil and earthworks.
- Noise: Construction equipment is likely to generate noise during the construction period.
- Ecological Effects during construction and operation.
- Geotechnical Effects related to lowering drain invert levels (on Horizons land and within the road reserve) to intercept groundwater for treatment in the wetlands, including:
  - Drain Bank Stability - For drains that are lowered, battering of the drain banks may be needed to maintain their stability. The need for this battering will be determined after soils investigations have been undertaken.
  - Consolidation Settlement - Lowering of the water table could potentially result in consolidation settlement depending on the soil type. It is not anticipated that this will result in adverse effects on grazing lands.

Note that section 9.3.6 discusses other effects related to the lowering of the drains.

9.2 Potential Positive Effects/Benefits

9.2.1 Overview

The construction of the Arawhata Wetlands is proposed to improve water quality in Punahau/Lake Horowhenua. As such, the proposal is expected to have a range of significant benefits as well as some adverse effects which can be effectively managed via the design of the wetland system and implementation of a construction management plan including erosion and sediment control measures.

This qualitative assessment is based on the conceptual design and assessment undertaken to date by our multi-disciplinary design team and our previous experience with wetland projects both in New Zealand and around the world. A more detailed analysis of the actual and potential effects will be completed for the purposes of the consent application once concept design, further data collection and assessment is completed.

This section focusses on the effects of Phases 1 and 2 as these are what is proposed to be consented.

9.2.2 Phase 1 (Sediment Basin + diversion of flows to wetland area + planting + wood chip trenches)

- Reduction in sediment inputs to the Arawhata Stream and downstream system resulting from treatment in the sediment basin (sedimentation) and diversion of flows into wetlands for treatment (sedimentation).
- Improvements to water quality due to treatment of surface water in the wetland areas and groundwater in wood-chip trenches. Woodchips, and bark will provide a carbon source for the conversion of nutrients in groundwater to other chemical forms. Overall expected levels of nutrient removal are 69% reduction of nitrates and 26% reduction in phosphorus after Phase 1 is complete. A 94% removal of sediment is expected from the proposed Phase 1 wetland. More detailed information on expected removals is provided in Attachment 4.
- Removal of dairy cows from the site, hence reduction in effluent sourced nutrients and sediment discharges due to movement of cows around the site.

Note that the existing Sediment Trap will continue to provide additional treatment. This will be enhanced by additional planting and the modification of the existing outlet culvert such that flows pass through the trap normally, rather than passing through the outlet culvert directly to the lake.

9.2.3 Phase 2 (Additional planting, wetland area expansion)

Phase 2 will result in additional improvements to water quality due to additional wetland areas being developed as well as increased planting. Our preliminary modelling shows that after Phases 1 and 2 are constructed there will be a 70%, 93% and 27% reduction in nitrates, sediment, and phosphorus, respectively. More detailed information is provided in Attachment 4.

9.3 Potential Adverse Effects

9.3.1 Effects on Surface Water Quality

9.3.1.1 Sediment

During the period in which earthworks will be conducted to construct the wetlands, it is possible that discharges of sediment could occur, especially during periods of rainfall. Such discharges of sediment may result in sedimentation of the bed and banks of the Arawhata Stream and other farm drains within the site, in turn potentially smothering vegetation within the drain, reducing light transmission to plants, as well as higher than normal/current sediment discharges to Punahau/Lake Horowhenua. The risk of these effects is likely to be temporary and will be minimised through erosion and sediment control measures. The risk of sedimentation effects will also reduce after the site is stabilised and planted post construction.

It is proposed that the discharge of sediment will be minimised and actively managed by the contractor employing a range of erosion and sediment control measures appropriate for the site soils (including for example, use of silt fences and sediment ponds) and the works being undertaken during favourable weather conditions. The construction methodology and erosion and sediment control measures will comply with good practice standards. All works will be undertaken in accordance with approved Construction Management and Erosion and Sediment Control Management Plans.

9.3.1.2 Nutrients

The overall purpose of the proposal is to reduce nutrient concentrations in the Arawhata Stream and the lake however, to achieve this overall benefit, some localised increases in nutrient concentrations are possible, as noted below.

Much of the vegetation currently growing in the Arawhata Stream and farm drains are a result of the high nutrient load in the waterways and groundwater, sourced from nitrogen and phosphorus generating activities in the area. Changes to surface water quality (reductions in nutrients), as a result of the wetland, are likely to reduce the abundance of such vegetation and this should therefore be seen as a positive effect, in combination with reestablishment of more beneficial waterway plant species over time. It is, however, likely that such effects will occur over the longer term as wetland plant species as well as micro flora and fauna establish over time within the wetland, post construction.

The existing stream channel will be preserved and will capture groundwater and water treated in groundwater collection pipes laid in organic media backfill (woodchips). The stream flow will be clearer and lower in nutrients than it has been historically. The surface water that enters the site will receive wetland treatment, prior to discharge to the Arawhata Stream channel at the Hōkio Beach road culvert. All water that leaves the site will also flow through the existing sediment trap before entering the lake, which will provide further nutrient removal.

Where the existing farm drains and waterways (on Horizons land and within the road) are to be cleaned and deepened, it is anticipated that groundwater will be intercepted and discharged to surface water. This groundwater can be higher in nutrients than the surface water therefore has the potential to reduce surface water quality. Where there is sufficient grade, it is proposed that this channel flow is discharged into the proposed wetlands for treatment. However, this will not be possible in the northern part of the site where there is insufficient grade. Localised (in the sections of channel not flowing to the wetlands) increases in nutrients may therefore be possible, however by the time the combined flow enters the lake, the overall effect will be a significant reduction in nutrients discharging to the lake (refer also to section 7 for overall removal rates).

9.3.1.3 Contaminated Materials/Soils

Discharges from contaminated materials/soils during earthworks are less likely but may consist of contaminated material exposed during construction, and potentially discharges of oils, greases and petrol/diesel from vehicles or earth moving equipment.

Discharges from potentially contaminated materials/soils will be managed by undertaking (currently underway) a search of the Horizons HAIL (contaminated site) register and consequently any required desktop and in field investigations. Any contaminated areas that are identified will be managed based on the contaminants present, to mitigate any impacts. In addition, accidental discovery protocols are also expected to be included in consent conditions. Discharges of any oils/greases/petrol/diesel will also be managed by way of best practice construction methodologies and consent conditions which, as a minimum, will exclude maintenance and refuelling of vehicles and equipment within a set-back distance of waterways/lakes.

Overall, the surface water quality entering the lake will be improved by the wetland proposal, although there may be the potential for some temporary adverse effects during the construction period. These effects will be managed through, as far as practicable, avoidance and minimisation of run-off and discharges during construction.

9.3.2 Effects on Surface Water Quantity and Flows

The proposed wetlands will potentially have effects on surface water volumes, flows, velocities, and water levels. These effects are expected to be slightly different during the different flow conditions i.e., low flows versus storm flows, and summer versus winter.

It should also be noted that at this site, surface water and shallow groundwater are interconnected in the top 1-2m of soil, with water moving between the two depending on rainfall and the operation of the wetlands (new channels bringing water to the surface plus irrigation from the sediment basin).

It is anticipated that flow velocities through the site (during both low flows and storm flows) will be slower due to the flow passing through wetlands. Due to the grade of the site and storage of flows within the wetlands (on the surface and in the soil beneath), it is expected there will be a reduction in peak flows overall. The flow rate in Arawhata Stream in the upper reaches will be reduced given most drain water that enters the site will be diverted into wetlands rather than flowing directly into the stream channel. Flood levels are expected to be the same if not slightly lower within the site and surrounding farmland (see below for further discussion).

It is proposed that farm drains on Horizons' land and in the road reserve will be cleaned out and the inverts lowered (to 1-2 m below ground surface) such that shallow groundwater and water that seeps out of the wetlands is intercepted and drained. The perimeter of the site near Hōkio Beach Road and along part of the eastern boundary of the site will have a new shallow groundwater collection drain installed. A portion of the eastern boundary will have perforated subsurface pipes installed to collect groundwater and convey it to surface water wetlands for treatment. Initially, after the creation of new drains and deepening of others (and into the longer term) we anticipate there will be higher surface water flows as a result of intercepting more groundwater. This may be noticeable during low flow conditions however this will not likely be noticeable during storm flows. In summertime, there may be a reduction in peak flows and flood levels due to lower groundwater levels providing additional storage capacity in soils prior to runoff occurring. Overall, the impact of intercepting groundwater, will likely be an increase in low flows but no increase in peak flows (or a small reduction in summer).

Overall, the volume of water (groundwater and surface water) entering the lake will be essentially unchanged. The storage provided by the wetlands will buffer peak flows during storms, but the total volume of the storm will still be discharged, albeit over a longer period.

9.3.3 Effects on Ecology

Earthworks and any resulting discharges of sediment and other contaminants may have potential effects on instream/lake ecology (fish and invertebrates). Additional sediment could potentially smother fish and invertebrates, clogging fish gills, reducing light transmission as well as build-up of more toxic contaminants in the flesh of fish. It is proposed that industry standard construction management practices including erosion and sediment control will be implemented such that these effects will be mitigated and minimised. It should also be noted that construction activities and hence the effects will be temporary in nature.

The proposal will also reduce the extent of existing fluvial (stream/drain) habitats by converting these into a fen/wetland system.

It is expected that a more detailed habitat/ecological assessment (including confirmation of species present) will need to be undertaken by an ecologist to confirm such impacts, however with appropriately sized, installed and monitored erosion and sediment control measures during construction, we anticipate that these effects will be minimised.

9.3.4 Effects on Air Quality

It is possible that earthworks will result in discharges of dust during construction as a result of wind at times when soils are exposed or when soils are being moved around the site. Discharges of dust beyond the site boundary could potentially impact neighbours. It is anticipated that dust management will be included in the Site Erosion and Sediment Control Plan/Environmental Management Plan and that measures will be proposed and implemented to minimise such discharges including dust suppression (water sprayed onto exposed soils) when wind and hence dust may be an issue.

9.3.5 Effects on Groundwater Quantity and Quality

9.3.5.1 Effects on Deep Groundwater

Groundwater moves under the site of the Arawhata Wetlands in a profile that has been described by the previous landowner as a deep aquifer that provides drinking water and water for domestic and milking shed uses, and a shallow aquifer that is perched just below the ground surface most of the year. The deep aquifer provides some artesian pressure as it upwells (refer section 2.7.1) given the existing artesian livestock water bore (labelled G on Phase 1 plan in Attachment 1) on-site flows out of the well casing above the ground surface when it is not being pumped. The pump cycles off and on many times per day and within minutes of cycling off, the well casing fills with groundwater and flows out the top. This is an indication that the deeper groundwater may be protected from any contamination or deep percolation of surface water or the perched shallow groundwater. The well outflow without pumping is approximately 1 L/s. The outflow from the well is at an elevation that will always be above the water level in the wetlands so no surface water will enter the well. It is anticipated that this borehole well will be left undisturbed with the artesian flow being discharged by artesian head into the Phase 1 wetlands that surround the well. This decision will however be made once further modelling (water quality as well as hydrological/hydrogeological) has been undertaken at the next stage of the project.

It is also anticipated that the groundwater sump and pump (labelled F on the Phase 1 plan – Attachment 1) will discharge groundwater into the wetlands for treatment and for irrigation, however this will also be decided once further modelling has been undertaken.

There are additional wells on the site as noted in section including one near the dairy shed for sanitary and washdown use, one on the highest portion of the property at the end farthest from Lake Horowhenua, for domestic use at the house and a higher flow irrigation well also exists near the southern end of the property. These other existing wells are planned to be preserved but not used.

The overall effect on deep groundwater will be a reduced use with no change to the groundwater quality.

9.3.5.2 Effects on Shallow Groundwater

The shallow groundwater is currently intercepted in drains, waterways and in the deep channel of Arawhata Stream. Several springs and seeps are also visible along the toe of the slope on the south end of the wetlands. The restored wetlands will continue to collect shallow groundwater and will convey it to the surface for treatment in wetlands. The total volume of shallow groundwater under the site is not defined but is estimated to be large. The percentage of groundwater that is intercepted by the wetlands will be small and will consist of only water within 2 m of the ground surface.

The shallow groundwater under the site that has been monitored contains as much, if not more, nitrogen as the surface drain water. It is therefore possible that any interconnection with shallow groundwater as a result of the proposal will maintain or improve its' quality.

It is anticipated that the wetlands will discharge treated surface water through the base, back into the shallow aquifer (as it is not proposed to line the wetland) and will maintain a high water-table similar to the existing condition but with reduced nutrient levels due to the treatment provided.

9.3.6 Other potential effects

In addition to the effects noted above, the following effects may also occur as a result of the lowering of drains (Phase 1 and 3) to intercept groundwater for treatment in the wetlands:

- Health and Safety issues arising from deeper invert levels- the drains will be deeper than existing (approx. 0.5-1.5m deep currently) therefore safe egress (should someone need to enter or if they fall into the drain) will need to be considered when designing these modifications (e.g., slightly battering the side slopes). Battering of the drain side slopes/banks will slightly reduce the paddock size.
- Increased duration of drains being wetted – These drains are anticipated to be wet for most, if not all, of the year, due to these collecting and conveying groundwater (potentially they dry out in the peak of summer for a brief period). Initially (post construction) it is anticipated that the deepened drains will have higher and more sustained flows as the surrounding area drains (could be months to a year depending on the soil types). In the long term, once the system has re-equilibrated and depleted the water in storage, there will be a sustained increase in flows and wetted duration due to the additional interception of throughflow. If the drain inverts are below seasonally low groundwater levels, then year-round wetting and flow can be expected. This would need to be quantified through modelling supported by field investigations. There are however no anticipated adverse effects of these drains being wetted for longer given they are present for drainage purposes.
- Potential impacts on the use of the surrounding land for grazing - By deepening the drains (on Horizons land and in the road reserve), this will potentially draw down the groundwater level. Given the low lying and generally wet nature of the pastures, reducing the groundwater level is anticipated to improve the ability of the surrounding land (areas of land owned by other parties) to be used for grazing as it will be drier due to lower groundwater levels.
- Effects associated with adding the gate to the culver alongside the existing sediment trap. Flood modelling will confirm impacts however it is likely that this gate will need to be opened in high flows to reduce impacts.

10. Earthworks Volumes

The volumes of earth that will need to be moved for each phase are summarised in Table 9 below, noting these are rough order volumes and that a more accurate volume estimate will be determined using 3D earthworks modelling of the proposed wetland during the next stage of design.

Table 9 Earthworks volumes

Phase	Cut Volume	Fill Volume
One	~12,000 m^3	~ 1300 m^3
Two	~8000 m^3	~1000 m^3

11. High Level Cost Estimate

A high-level cost estimate has been prepared for the wetlands concept. The cost estimate has been prepared using standard costing techniques and NZ rates by the Jacobs ANZ Cost Estimation Team.

Costs are high level preliminary cost estimates. A cost is provided, and a range of ±50% to account for uncertainty and the conceptual nature of the design. Increased certainty in costs requires a detailed design process. It is evident that earthworks and planting are the largest contributor to project costs. Detailed design would improve on the accuracy of the earthworks calculations by:

- Developing the earthworks design in 3D, allowing for accurate cut and fill balance estimates.
- Providing soil and geological data allowing informed decisions on the re-use of soils onsite.

The preliminary cost estimate is presented below in Table 10.

Table 10 Preliminary cost estimate

Item	Base Cost Estimate (excl. GST)	-50%	+50%
Pre-construction activities (submittals, mobilisation, survey, site preparation, temporary fencing, stockpile/dewatering area, utility location, etc)	$710,000	$355,000	$1,065,000
Excavation & earthmoving – Construction Activities (cut volume, fill / stopbank construction, dewatering, installation of collection drains including media, etc)	$970,000	$485,000	$1,455,000
Planting costs (Plant purchase and installation)	$1,232,000	$616,000	$1,848,000
Water collection & distribution (sediment pond pump and pump station, stream diversion, drainpipes, organic backfill, irrigation line, fittings, etc)	$448,000	$224,000	$672,000
TOTAL	$3,360,000	$1,680,000	$5,040,000

It was advised by Horizons that the remaining budget is currently $2.45 M NZD (excl. GST). The base estimate is currently over this amount therefore during the next phase of design (preliminary design) it is proposed that we optimise the design to minimise costs and look for opportunities to meet the budget. This may include decreasing the area to be planted.

12. Recommendations

We make the following recommendations for next steps in the project. It should be noted that the work covered in this report is based on a range of assumptions related to the data available at the time. The further work below will allow more accurate design and understanding of the treatment ability of the proposed wetland.

Data Collection and Collation:

- Soil survey (physical and chemical) across footprint of site (test pit, hand auger to 1 m and machine borehole to 3 m plus infiltration testing)
- Detailed topographical survey, including full extent of existing Kane Farm drainage network
- Piezometric survey across catchment
- Installation of piezometers for the collection of longer-term groundwater water level data
- Groundwater quality survey in the catchment, to delineate vertical and horizontal extent of high nutrient concentrations in groundwater
- Further collection of surface water quality data

Design and Modelling

- Complete a 3D model of the proposed site using Civil 3D or similar software to improve and refine cost estimates for earthworks
- Update the hydrological modelling previously undertaken
- Build, calibrate and run a hydraulic model (flood model) to understand water quantity effects
- Update the water quality modelling based on the above work and incorporating new water quality data from site.
- Development of a groundwater flow model (to be undertaken by others) for the Arawhata catchment to provide confirmation of baseflow/inflow estimates of groundwater into the site
- Research suitable contractors (earthworks, hydro-mechanical) and subcontractors (native hydro-seeding experience)

13. Conclusion

The Arawhata wetland system has been proposed to achieve a range of positive outcomes for the Project. Based on work to date, it is anticipated that the proposed wetlands will yield significant positive effects for the lake as the project progresses.

Some potential adverse effects, primarily during construction have been noted, but these are expected to be limited to the construction period. These construction effects can be managed as they occur through industry best practice construction management (erosion and sediment control) alongside consent conditions such that the impact is no more than minor.

14. References

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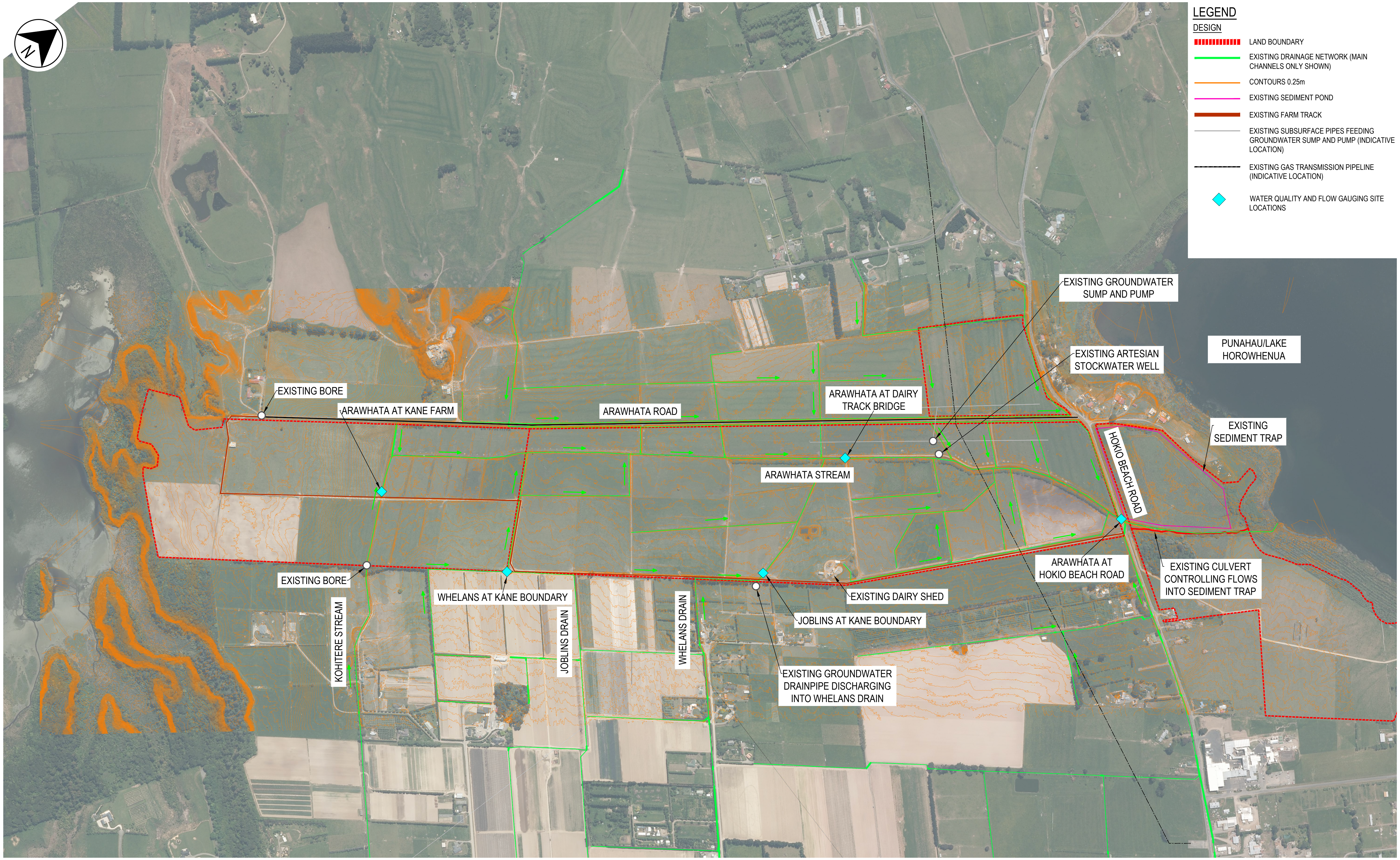
Appendix A. Existing Site Plan



PLAN - ARAWHATA WETLAND
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SCALE 1:5000 (A3)

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Appendix B. Design Diagrams and Drawings

Diagram 1: Phase 1 Wetland Plan

Diagram 2: Phase 2 Wetland Plan

Diagram 3: Phase 3 Wetland Plan

Diagram 4: Arawhata Soil Sampling Plan

Drawing #IA273100-002: Arawhata Wetland-Plan – Cross-section Locations

Drawing #IA273100-003: Arawhata Wetland-Cross Section C (Part 1)

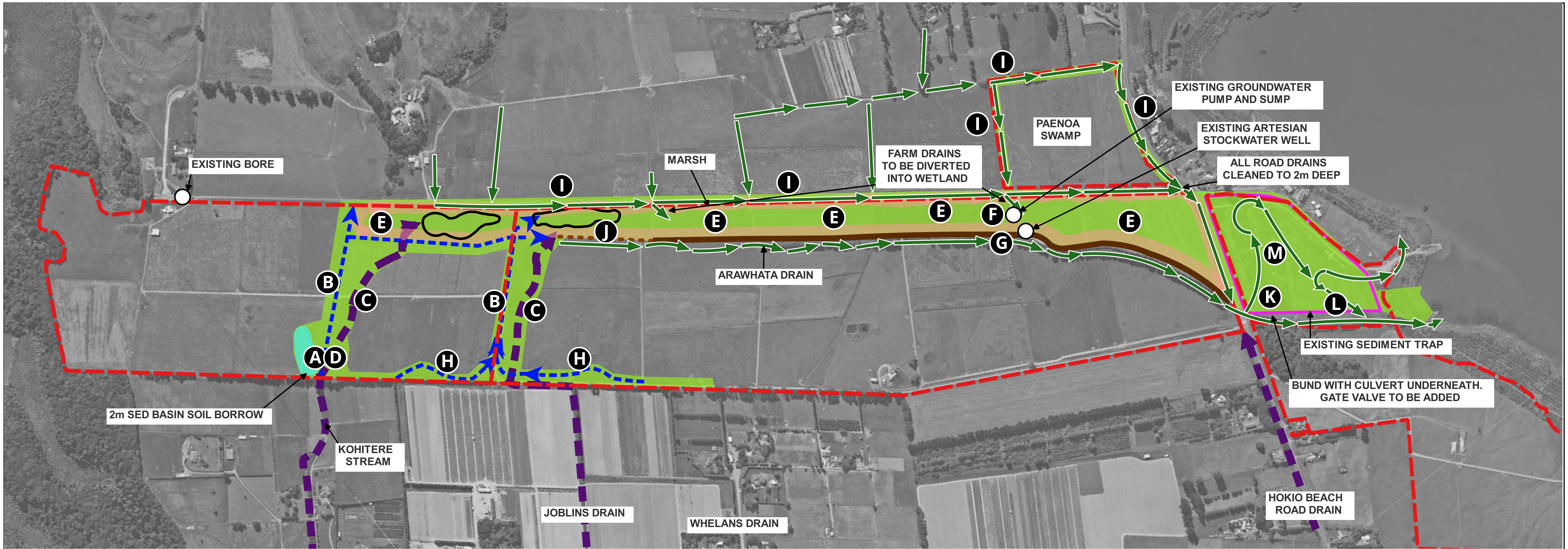
Drawing #IA273100-004: Arawhata Wetland-Cross Section C (Part 2)

Drawing #IA273100-005: Arawhata Wetland-Cross Sections D and E (Part 1)

Drawing #IA273100-006: Arawhata Wetland-Cross Sections E (Part 2) and F

Drawing #IA273100-007: Arawhata Wetland-Cross Sections C (Part 3), H and I

Drawing #IA273100-008: Arawhata Wetland-Typical Details



Legend

- Land Boundary
- Deeper cut wetland areas
- Proposed Stopbank
- Existing Stopbank
- Component Label - Phase 1
- Existing/new channel farm drains
- Subsurface perforated drain pipe laid in invert of existing/new drains then drain backfilled with wood chips, bark and hay
- Channel taking flow from drains in vegetable growing area to feed into wetland
- Approximate edge of wetland wetted area
- Sediment Basin

Construction Phases

- Phase 1

N

NZGD2000
Scale: 1:8500

0 200 400 m

Phase 1 Components

- Sediment Basin construction at Kohitere Stream/site boundary (A – see plan for location)
- Installation of perforated pipe in existing Kohitere and Joblins Drain channels (within the site boundary) and drains as well as new drains along the property boundary either side of Joblins Drain, backfilled with woodchips/bark/hay for groundwater treatment (Blue dashed arrows). (B)
- Construction of new channels at flatter grade than ground slope such that water can be discharged onto surface of wetlands from Kohitere stream and Joblins Drain. (purple arrows) (C)
- Surface water overflow from sediment trap directed into new channels (purple) under gravity. (D)
- Partial planting through wetland areas. (E)
- Retention of existing groundwater pump + southern well for irrigation (F)(G)
- Plants for phase 1 need to be purchased.
- Collection of groundwater along the boundary either side of Joblins Drain (H)
- Cleaning out/deepening farm drains and roadside drains such that groundwater is intercepted. Invert to still be sloped and discharged to either Arawhata Stream or the Phase 1 wetlands. (I)
- Extension of stopbanks along Arawhata Stream west side. (J)
- Construction of sliding weir gate on culvert in Arawhata Stream alongside the existing sediment trap. This will normally be shut to direct flows through the sediment trap. (K)
- Add rip rap on slope of the existing sediment trap outlet to control water level and protect embankment. (L)
- Sediment trap to be retained as is (M)

Arawhata Wetland
Diagram 1: Construction Phase 1

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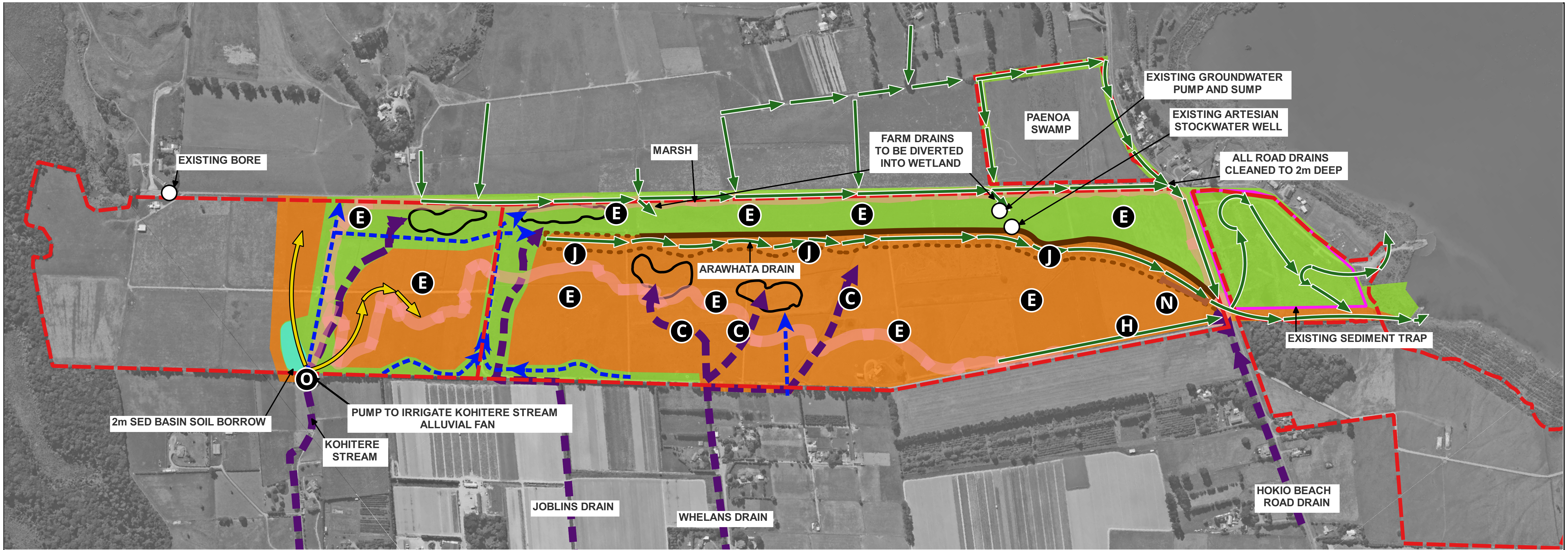

Legend

- Land Boundary
- Deeper cut wetland areas
- Proposed Stopbank
- Existing Stopbank
- Lower Section of Stopbank
- Component Label - Phase 2
- Surface irrigation perforated pipe to irrigation Kohitere stream alluvial fan
- Existing/new channel farm drains
- Subsurface perforated drain pipe laid in invert of existing/new drains then drain backfilled with wood chips, bark and hay
- Channel taking flow from drains in vegetable growing area to feed into wetland
- Approximate edge of wetland wetted area
- Sediment Basin

Construction Phases

- Phase 1
- Phase 2

N

NZGD2000
Scale: 1:8500

0 200 400 m

Phase 2 Components

- Construction of new channels at flatter grade than ground slope such that water can be discharged onto surface of wetlands from Whelans Drains. (C)
- More planting in Phase 1 and Phase 2 areas (E)
- New bund on east side of existing Arawhata Stream to contain Phase 2 wetland. (J)
- A lower section of bund/stopbank will be built at the downstream end alongside Hokio Beach Road to discharge treated wetland flow into the main Arawhata drain. (N)
- New groundwater collection drains along Hokio Beach road and wetland site boundary. (H)
- Installation of small new pump to irrigate sediment pond water into Kohitere Stream alluvial fan in areas where it cannot flow under gravity. (O)

Arawhata Wetland
Diagram 1: Construction Phase 2

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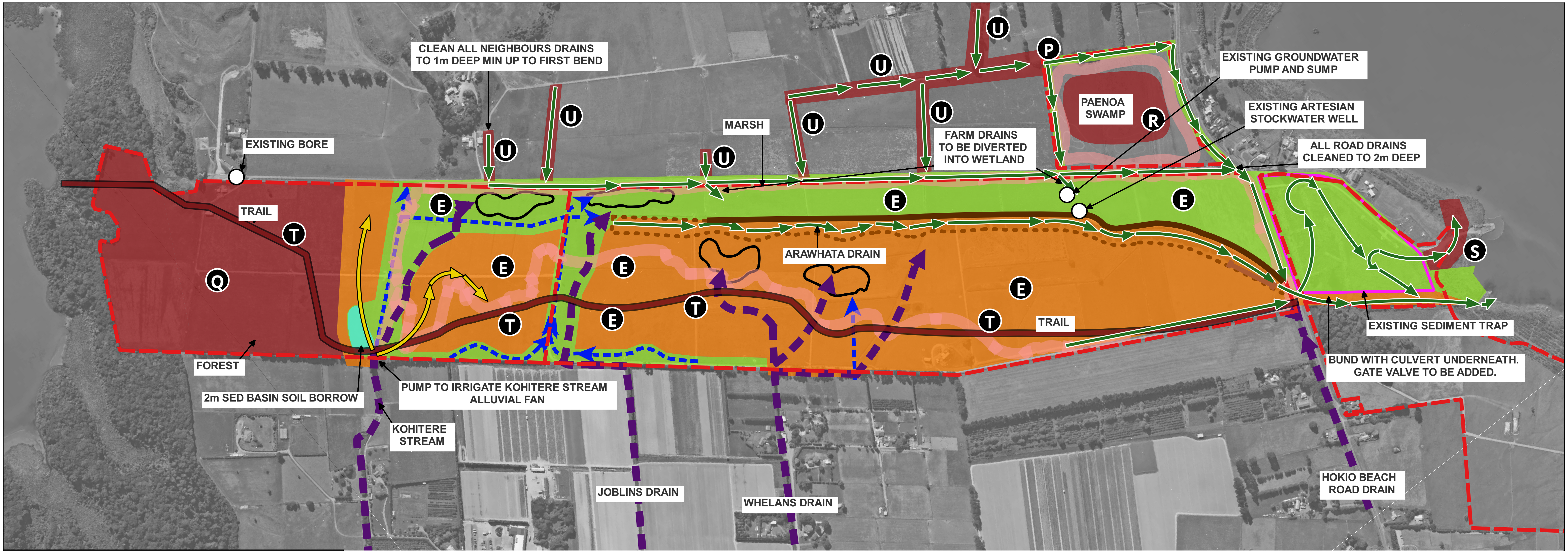

Legend

- Land Boundary
- Deeper cut wetland areas
- Proposed Stopbank
- Existing Stopbank
- Lower Section of Stopbank
- Component Label - Phase 3
- Surface irrigation perforated pipe to irrigation Kohitere stream alluvial fan
- Existing/new channel farm drains
- Subsurface perforated drain pipe laid in invert of existing/new drains then drain backfilled with wood chips, bark and hay
- Channel taking flow from drains in vegetable growing area to feed into wetland
- Approximate edge of wetland wetted area
- Sediment Basin

Construction Phases

- Phase 1
- Phase 2
- Phase 3

Phase 3 Components

- Planting in Paenoa Swamp (R)
- Divert – channels in western area into Paenoa swamp (P)
- Planting upland (southern) forest area (Q)
- Further fill in wetland areas with more planting (E)
- New dispersed outlet into Lake Horowhenua (S)
- Construction of walking trail (T)
- Cleaning out/deepening of drains on neighbours land such that groundwater is intercepted. Invert to be sloped and discharged to either Arawhata Stream or the Wetlands (U)

Arawhata Wetland
Diagram 1: Construction Phase 3

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Legend

- Land Boundary
- 27 groundwater piezometers 3m deep. Monitor depth to water and water quality monthly
- 41 soil samples. Most paired with Piezometers and could come from piezometer boring core.

N

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Arawhata Wetland
Sampling Points Location - Plan

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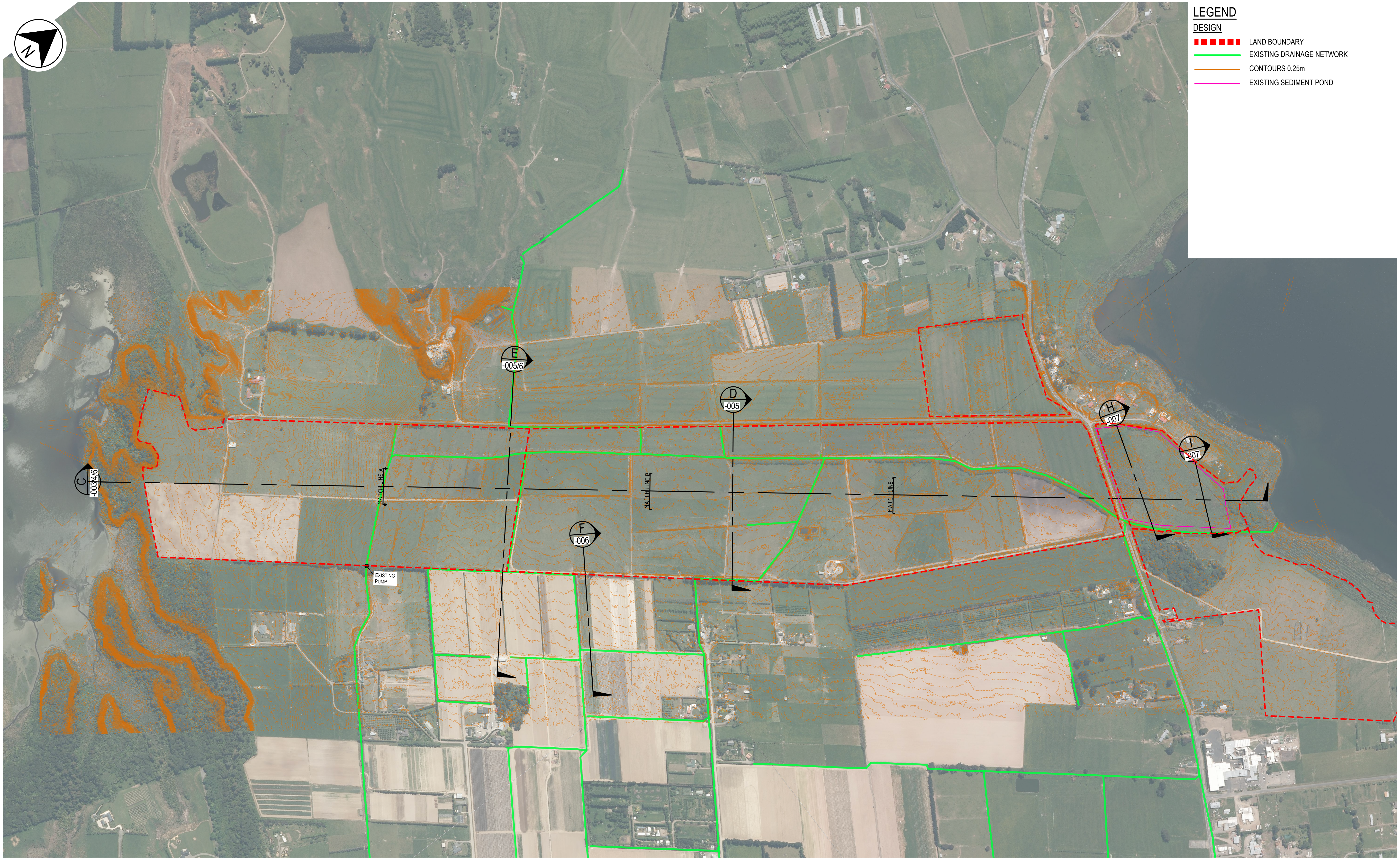

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SCALE 1:5000 (A3)

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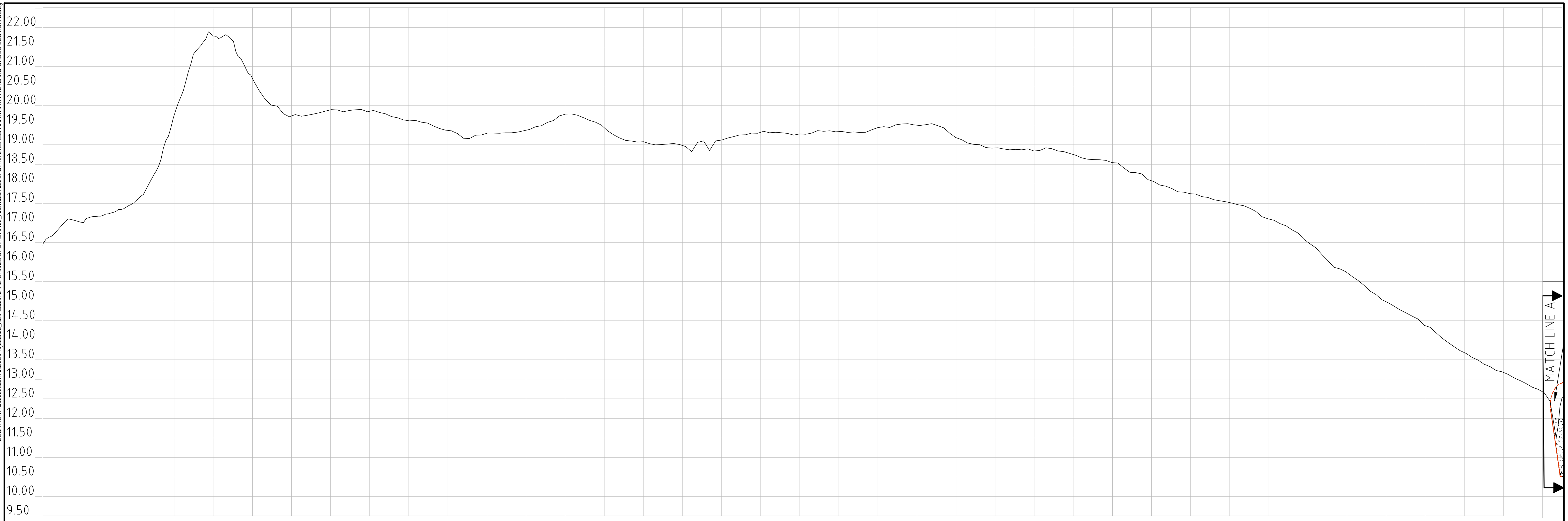

LEGEND

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EXISTING GROUND PROFILE

DESIGN

PROPOSED GROUND PROFILE

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VERTICAL SCALE 1:50 (A3)

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HORIZONTAL SCALE 1:1000 (A3)

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SECTION C -
SCALE 1:1000H 1:50V

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TITLE
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LONGSECTION C

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LEGEND

EXISTING — EXISTING GROUND PROFILE

DESIGN — PROPOSED GROUND PROFILE

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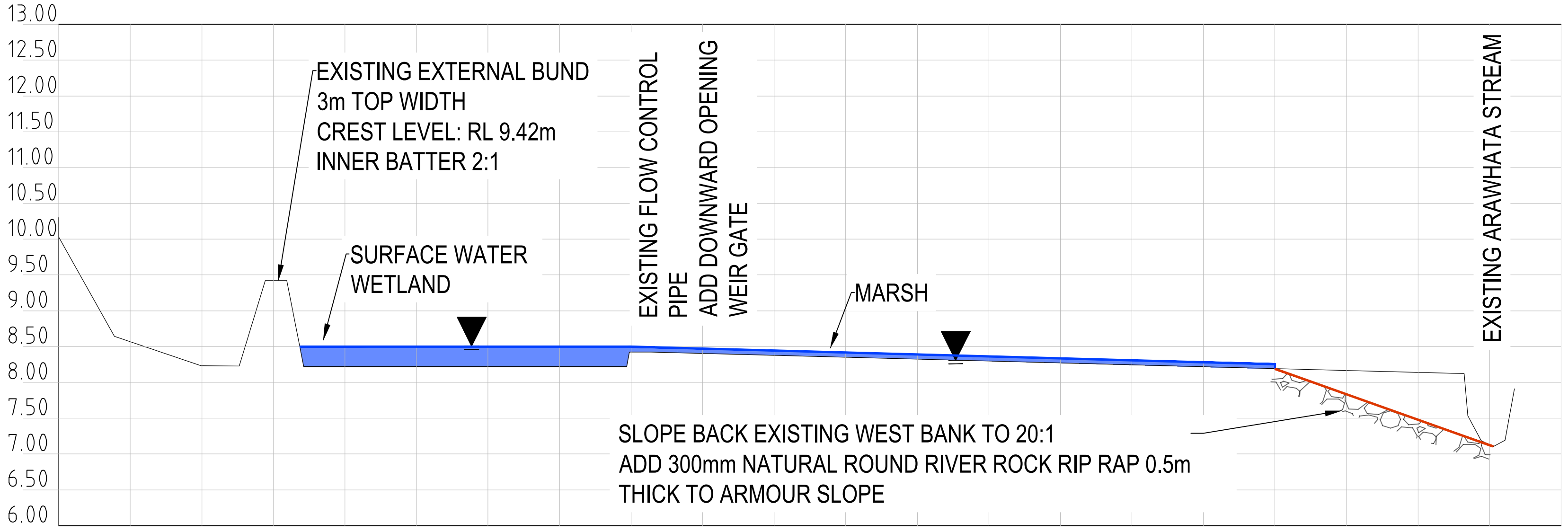

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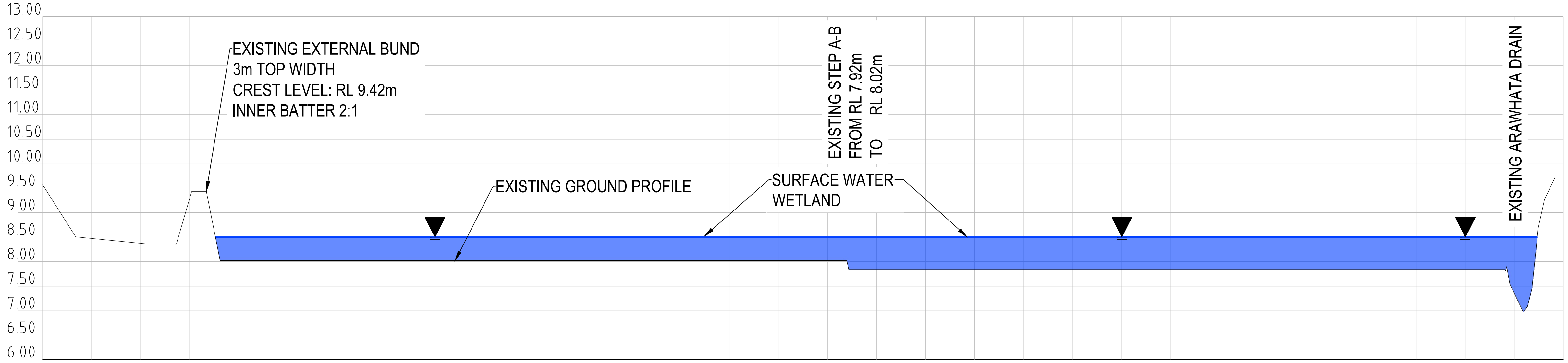

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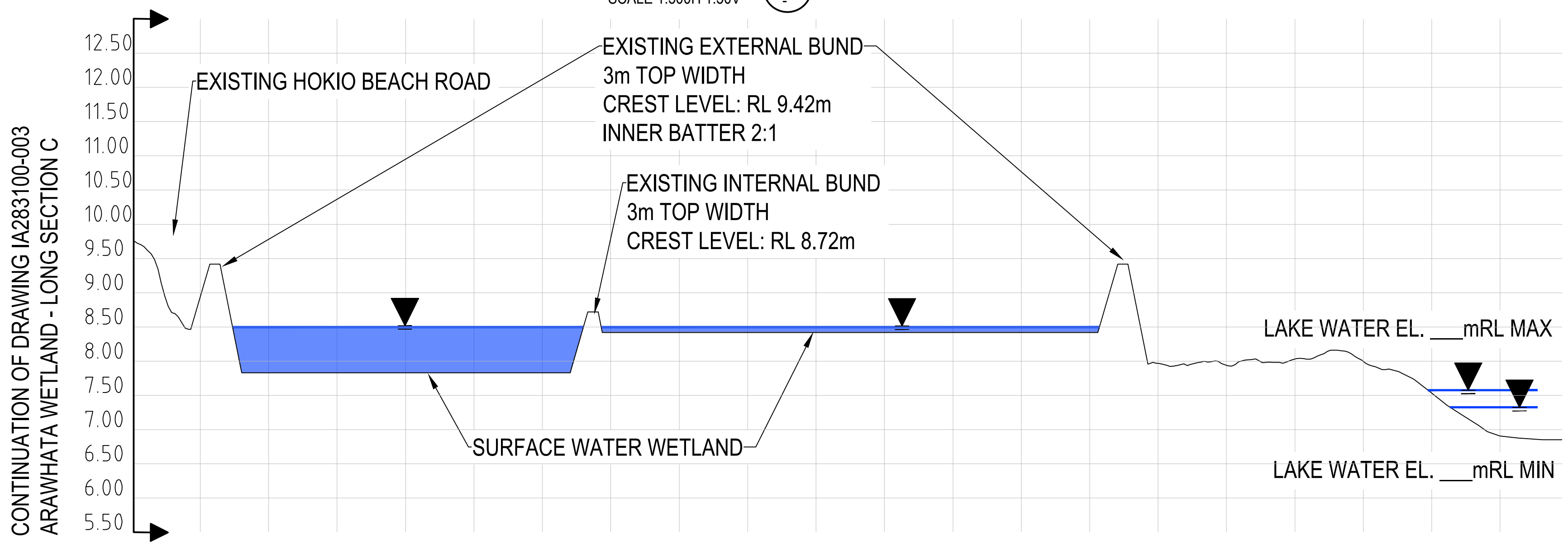

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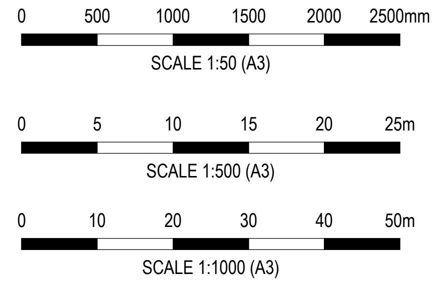

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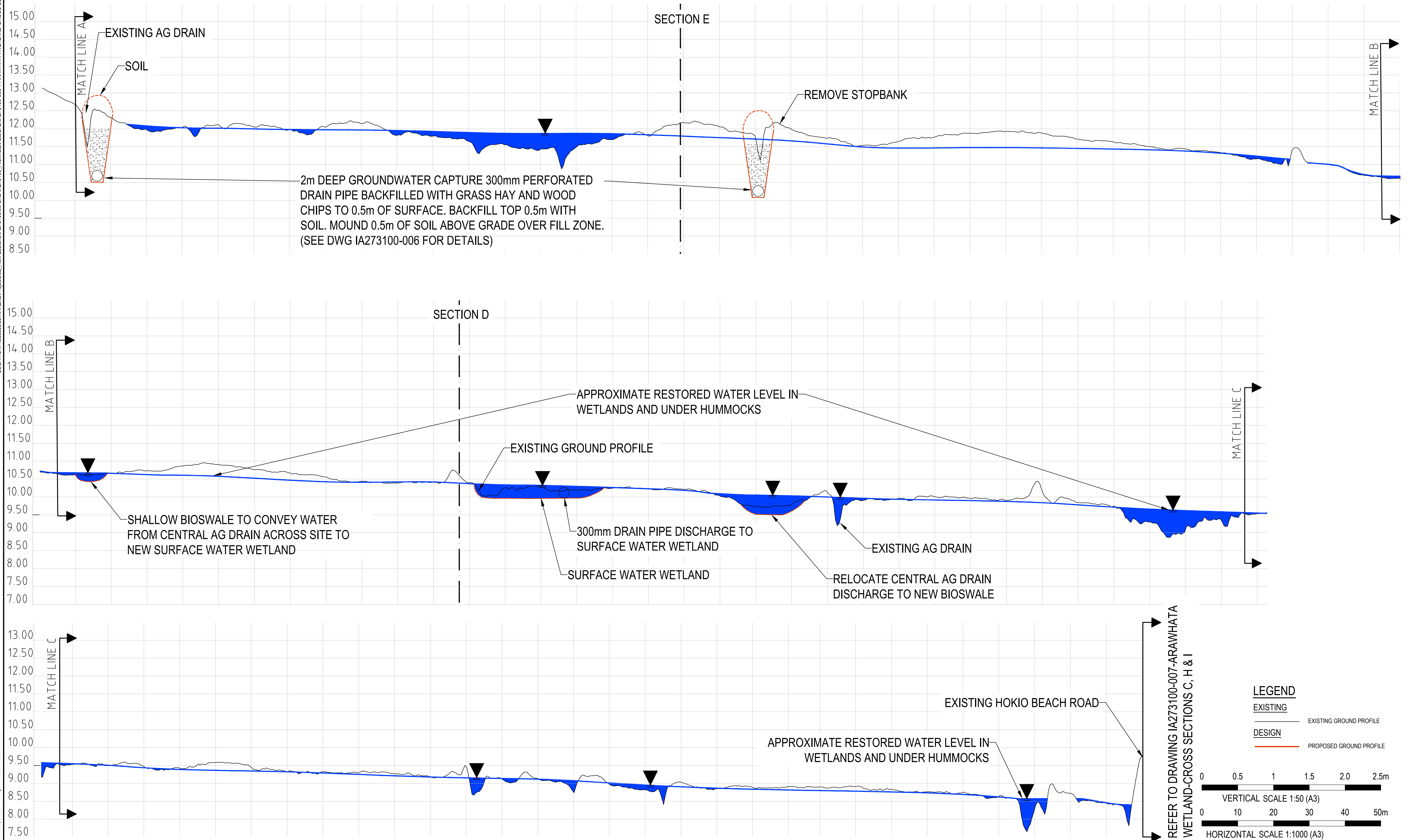

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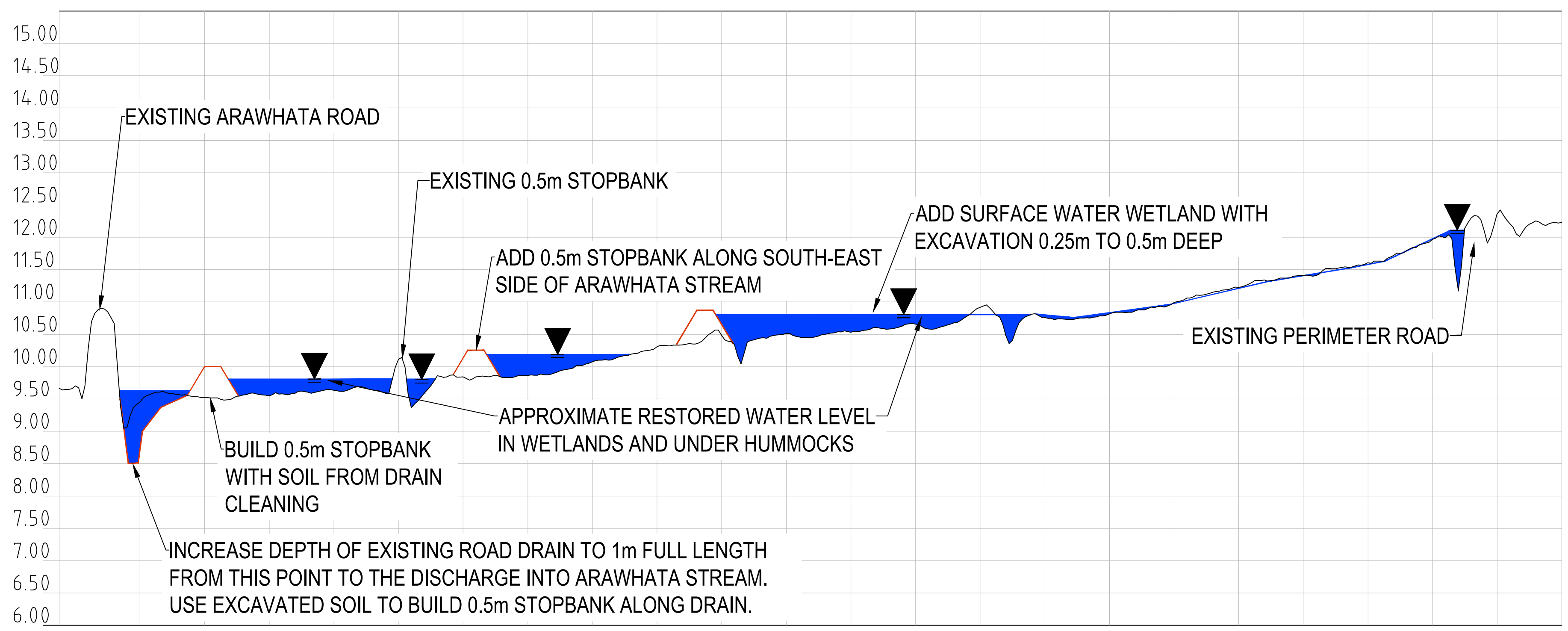
LEGEND

EXISTING

EXISTING GROUND PROFILE

DESIGN

PROPOSED GROUND PROFILE



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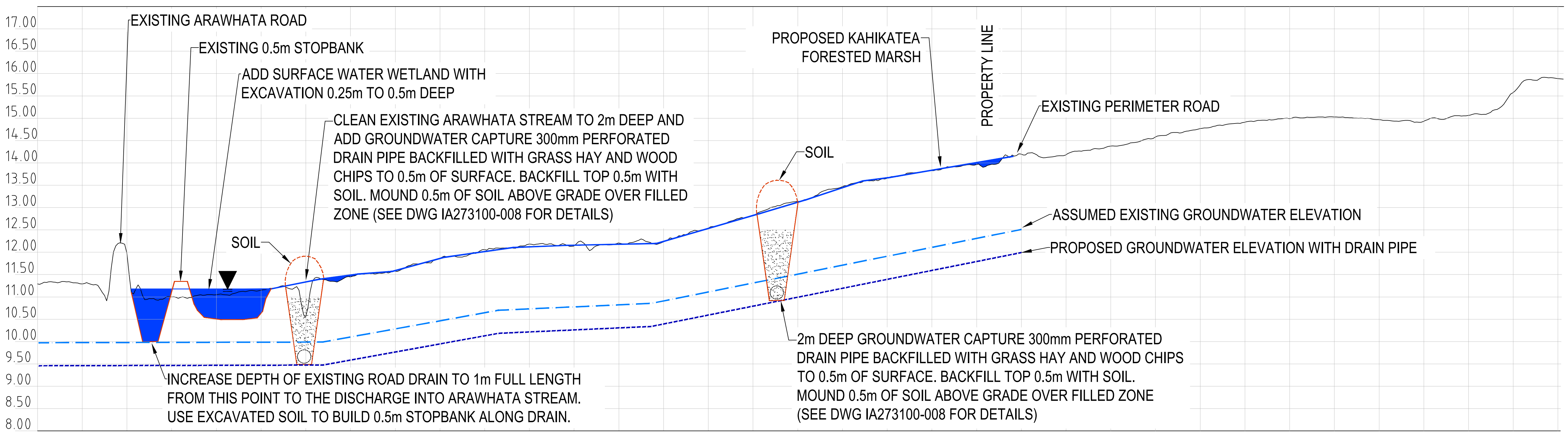

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HORIZONTAL SCALE 1:1000 (A3)

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TITLE: ARAWHATA WETLAND
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SCALE: AS SHOWN
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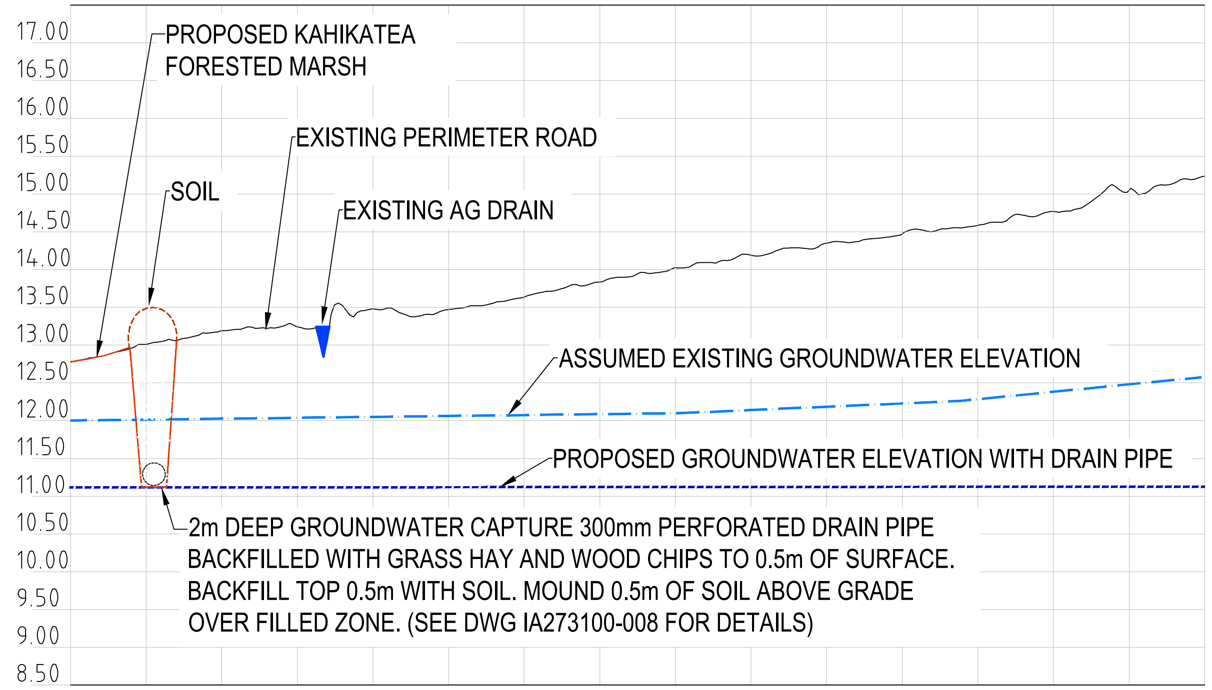
LEGEND

EXISTING

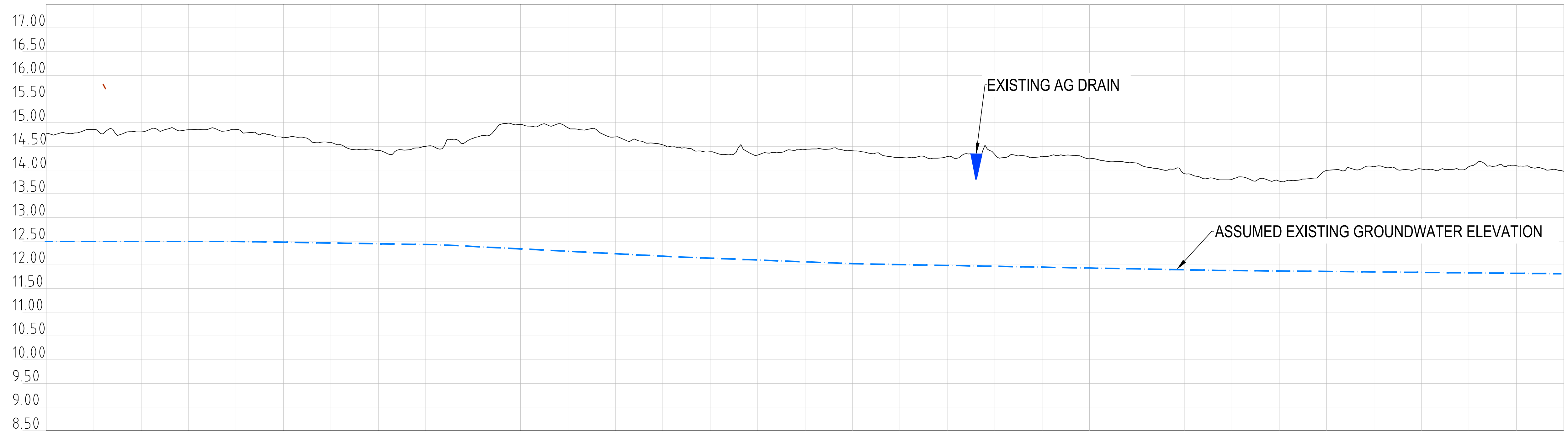
EXISTING GROUND PROFILE

DESIGN

PROPOSED GROUND PROFILE



SECTION F
SCALE 1:1000H 1:50V



SECTION E
SCALE 1:1000H 1:50V

0 500 1000 1500 2000 2500mm
VERTICAL SCALE 1:50 (A3)

0 10 20 30 40 50m
HORIZONTAL SCALE 1:1000 (A3)

KANE FARM WETLAND - CROSS SECTIONS F & E

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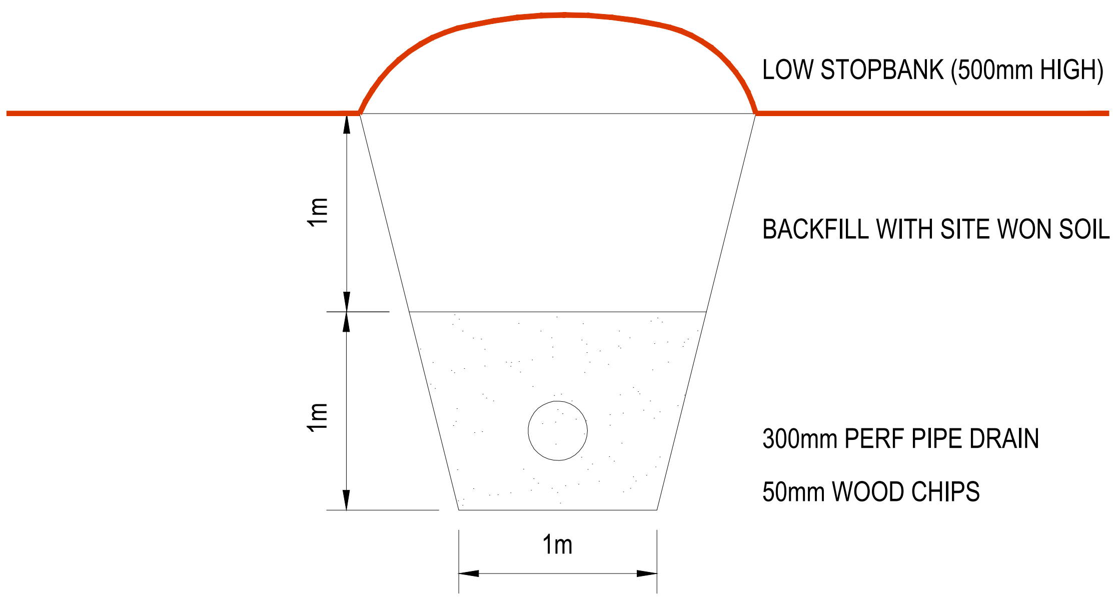
DESIGNED	DESIGN REVIEW	DATE	DATE
MM	MM		

TITLE: KANE FARM WETLAND CROSS SECTIONS F AND E

SCALE: AS SHOWN | DRAWING No: IA273100-006 | REV: 0



TYPICAL DRAIN SECTION
NOT TO SCALE

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TITLE TYPICAL DETAILS

SCALE N.T.S. DRAWING No IA273100-008 REV 0

DATE: 1/11/2022 6:15:54 PM NAME: ZUCCO, CLAUDIA
LOCATION: \\Jacobs.com\ANZ\IE\Projects\02_New Zealand\IA273100\06 CAD\IA273100_Arawhata\AutoCAD\IA273100-008-ARAWHATA WETLAND-TYPICAL DETAILS.dwg

Appendix C. Water Quality Modelling Description and Assumptions

The wetlands water quality evaluation was conducted for several configurations of proposed wetlands using the proprietary Jacobs Treatment Wetlands Design and Analysis Model. The model used the monthly average flow rates and water quality data from the five monitoring, to determine nutrient removal through the wetlands cells.

Input parameters for the wetlands modelling included historical and calculated design inflows to the wetlands, local climatic conditions, an assumption of infiltration characteristics typical of wetlands, and the proposed layouts of the wetlands, discussed in Section 5. Climate data for precipitation, air temperature, and Penman Evapotranspiration were obtained from 1990 through 2020 from the Levin AWS Metservice (to be updated at detailed design with more recent data).

The proprietary Jacobs Treatment Wetlands Design and Analysis Model was used to identify the water quality improvements that can be obtained through the wetlands for water flowing through Phase 1, Phase two and the Hokio Sediment Trap, individually and together. The water quality parameters modelled included nitrate-nitrite as nitrogen and phosphorus, which are parameters of general and specific interest. The model utilises a robust database as well as specific field tests related to treatment performance for these typical parameters. Phosphorus reductions with alumina additions is modelled using low and high reduction factors to bracket anticipated performance of the wetlands.

Model parameters and assumptions, including the areas of the wetlands, the flow volumes going through the wetland areas, and the constituent loads to the wetlands as well as projected load outflows and percent reductions are provided in section 7.

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