Project Number: 1-13085.03

Hihi Options Review

11 March 2020

CONFIDENTIAL

Contact Details

Andrew Springer

WSP
Level 3 The Westhaven
100 Beaumont St
Auckland 1010
+64 9 355 9500
+64 27 563 9859
andrew.springer@wsp.com

Document Details:

Date: 9 March 2020
Reference: 1-13085.03
Status: Draft

Prepared by
Andrew Springer

Reviewed by
Larey-Marié Mulder

Approved for release by
Eros Foschieri

Document History and Status

Revision	Date	Author	Reviewed by	Approved by	Status
Draft	9 March 2020	A Springer	L Mulder	E Foschieri	

Revision Details

Revision	Details

Contents

Disclaimers and Limitations

This report, '**Hihi Options Review**' has been prepared by WSP exclusively for Far North District Council in relation to consideration of issues and selection of preferred option for upgrade of Hihi WWTP, and in accordance with the ACENZ Short Form Agreement for Consultant Engagement, with Far North District Council, Dated 3 February 2020.

The findings in this Report are based on and are subject to the assumptions specified in the Report and discussions at stakeholder workshops. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

1 Introduction

In 2010 the Hihi wastewater treatment plant (WWTP) was identified for plant upgrade. However, this investment has been deferred until the current long-term plan. The Hihi WWTP has been identified as having deteriorating assets, with the main treatment reactor having been structurally condemned. WSP, as WSP Opus, undertook in 2018 a process review of the site and identified many issues including condition of all concrete tanks, process capacity and performance. From this several options were developed to address environmental needs and customer demands.

This report summarises the

- The evaluation processes used,
- The issues and associated risk to FNDC,
- Options considered,
- Evaluation and selection of options,
- Costs and indicative layouts for the solution(s) considered, and
- A recommendation for the preferred solution with budget costs.

1.1 Background Information

Hihi is located on the Southern Edge of Doubtless Bay in Northland. The main village sits on an Isthmus between Doubtless Bay and Mangonui Harbour and as having two beaches, is a popular retirement and holiday destination. The village consists of residential housing and a campground. All properties are served by roof tank water supply, so water usage is low for the catchment. See Figure 1 and 2 for location of Hihi and the Hihi WWTP. Figure 3 shows the existing Hihi WWTP with site designation boundaries.

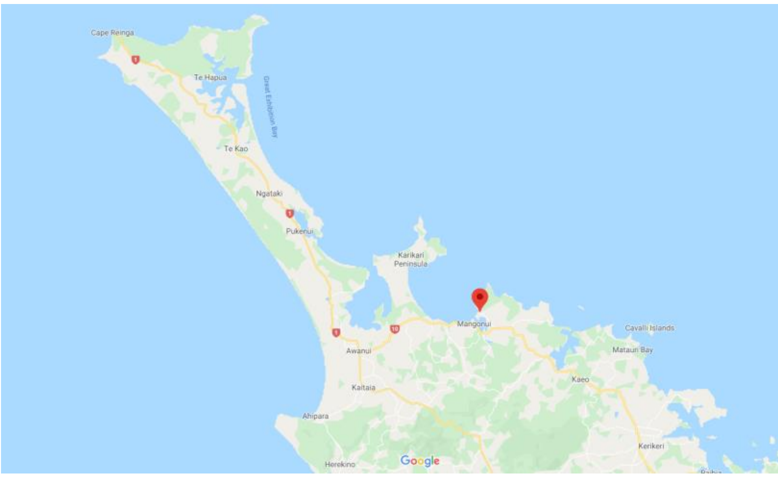

Figure 1: Location of Hihi, Northland.

Figure 2: Aerial Photograph of Hihi Community

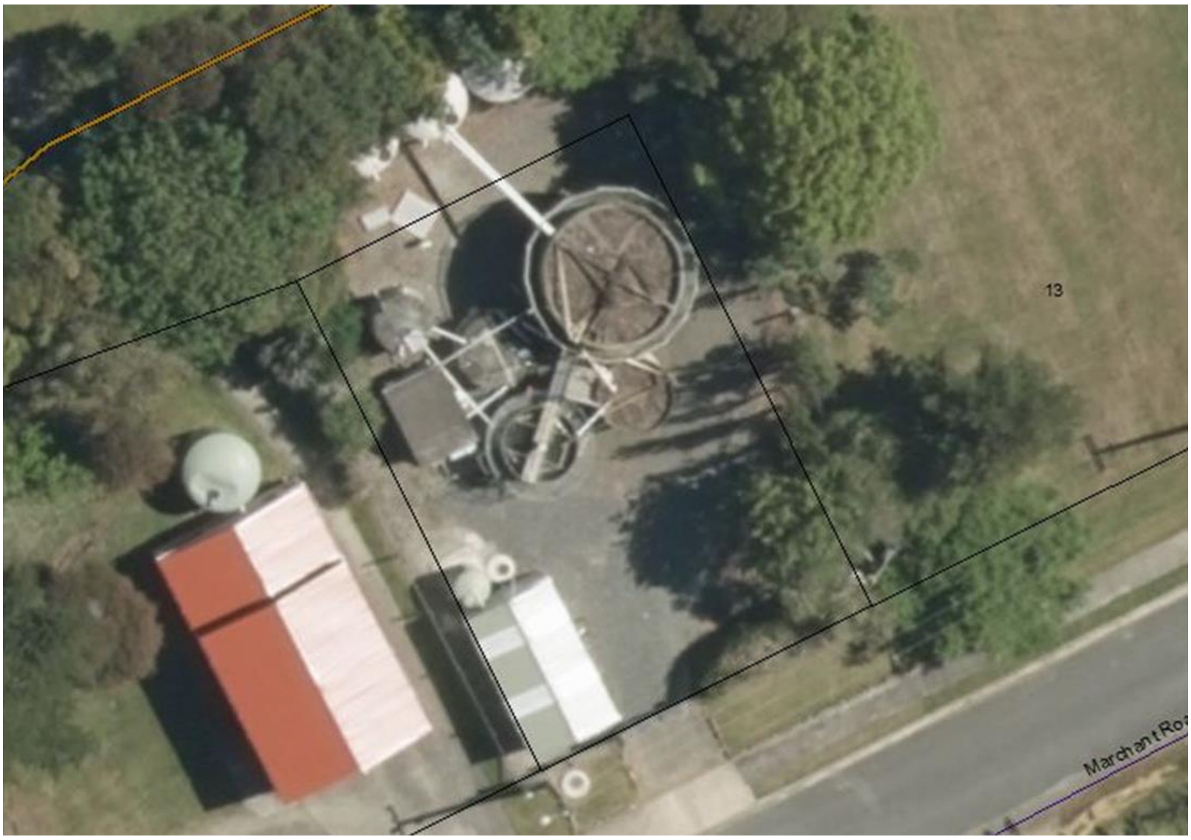

Figure 3: Existing Hihi WWTP showing site designation boundary.

1.2 Project History

The Hihi WWTP was originally installed as a temporary installation, so was designed with the least expensive approach possible. The plant is now at 30 years old and assets are deteriorating. This deterioration has been ongoing, and several investigations have been undertaken in relation to this. Only recent studies are included in the list below.

1990	Hihi Wastewater Treatment works was constructed.
May 2014	Fraser Williams identified poor structural condition of main treatment reactor and advised that even with repair only 3 to 5 years additional life of tank would be attained.
October 2018	Site visit and observations memorandum (WSP Opus)
February 2019	Basis of Design (WSP Opus)
March 2019	Conceptual Design Options Report (WSP Opus)
November 2019	Structural Assessment (WSP)
December 2019	Business Risk Assessment Workshop with FNDC stakeholders
January 2020	Options Workshop with FNDC stakeholders
March 2020,	Options Study Report

Reports associated with the above key steps are presented in this report as Appendices.

2 Basis of Design

2.1 Flow and Load

WSP (as Opus) undertook a site assessment and flow and load review in 2018/19 for FNDC. These are presented in Appendix A. From this data a Basis of Design has been developed. This was presented to FNDC in February 2019. This is attached as Appendix B. This section is a summary of these investigations and reports.

Flow data has been analysed to assess the expected future flows. These are summarised in Table 1 below. There is a marked difference between peak flows (85 m^3/d) in December/ January and off-peak periods (35 m^3/d) due to differences in seasonal population.

Influent concentrations to the Hihi treatment works have only been measured at peak loads coinciding with plant overloading. This gives a maximum design load.

Future flow and load are not expected to change significantly as the catchment is now close to full development. Land at the edges of the community is generally too steep for housing.

Loads are estimated on average concentration times flow.

Table 1: Flow and load data for the Hihi WWTP.

Parameter	Units	Off Peak DWF	Peak DWF	Peak WWF	Load [kg/d] Off Peak	Load [kg/d] Peak
Flow	m^3/d	35	85	750	-	-
BOD	g/m^3		491		17	42
TSS	g/m^3		604			51
COD	g/m^3		983		34	84
TKN	g/m^3		140		5	12

As expected for a small wastewater treatment plant, routine sampling of influent is not undertaken. Only 2 samples have been taken since 2015 for crude sewage and these coincide with peak population and operational issues on the site.

This data is characteristic of a high holiday population and water supply from roof tank.

Historically the catchment has seen high levels of infiltration and ingress, but remedial work undertaken over years ago has reduced this to a manageable level.

2.2 Population

The resident population given in the 2013 census is 170 people. Data from flow and incoming wastewater shows that peak population is over 500 people..

The census shows that the resident population is largely middle aged to retired. Several properties are Baches and not fully occupied. Typically, off season, 2 persons will occupy a property but at peak holiday periods, population will increase to 4-8 people per property. This gives from residential dwellings an estimated doubling of population. Additionally, the campground will operate seasonally and is connected to the wastewater system. Exact population data cannot be confirmed without specific load studies, requiring continuous flow recording and 24-hour composite samples over an extended period.

Since 2013, the catchment has grown as remaining sections have been developed and it is noted that the catchment plots are fully developed.

This population presents challenges to the existing works that has insufficient process capacity for peak population.

2.3 Future Consent Requirements

A resource consent is in place for the Hihi wastewater system with conditions for the wastewater effluent and odours on the receiving environment and neighbours. This consent includes both the wastewater treatment works and the wetland sites. Water and effluent quality parameters are principally at the point of discharge to the stream, with the exception of E. coli that is measured after the UV system at the WWTP.

The current resource consent for the Hihi WWTP is largely compliant for all parameters and conditions. However, at times, the ammonia concentration entering the watercourse is non-compliant, and dissolved oxygen (DO) can also be depleted. These events coincide with peak plant loadings.

The resource consent is to be renewed in 2023. To develop and compare options on a like for like basis an estimate of expected effluent quality targets has been made. At this stage it is not known exact standards to be applied, so it is assumed that to meet the current standard all year a consent at the treatment works discharge shall be;

BOD	10 mg/l	Average	20 mg/l	90%ile
TSS	15 mg/l	Average	25 mg/l	90%ile
NH3-N	1.5 mg/l	Average	5 mg/l	90%ile
E coli	< 200 Median		< 1000 Maximum	
Total P	not determined.			

Should total phosphorous be determined as required, this may be managed by the addition of alum salts to remove phosphorous by chemical means. This approach can achieve Standards of < 1 mg/l may be achieved by this method, provided a filtration process is present.

3 Options Development

3.1 Business Risk Assessment Workshop

A Business Risk Assessment Workshop was undertaken on 4 December 2019 at Kaikohe with the stakeholders from FNDC and Broadspectrum as operators and maintainers of the Hihi WWTP. Figure 4 shows the existing Hihi WWTP configuration, this layout with the information and Section 2 was used as background for the workshop. This enabled capture of all known issues and stakeholder buy-in to the project direction and outcomes. This workshop explored all the issues at the Hihi WWTP and wetlands sites. The output of these risks is presented in Figure 5. Descriptions are only provided for the red high-risk items in Figure 5.

To prioritise these issues, a risk assessment was made using business risk. This is presented in Appendix F as part of the Business Risk Assessment Workshop, 4 December 2019, WSP.

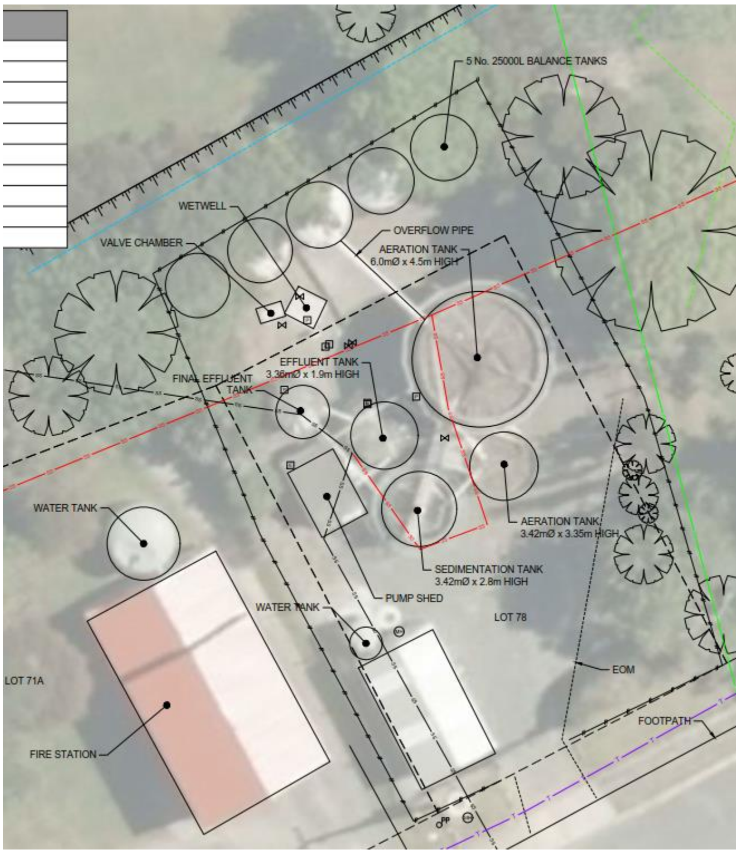

Figure 4: Existing configuration of Hihi WWTP.

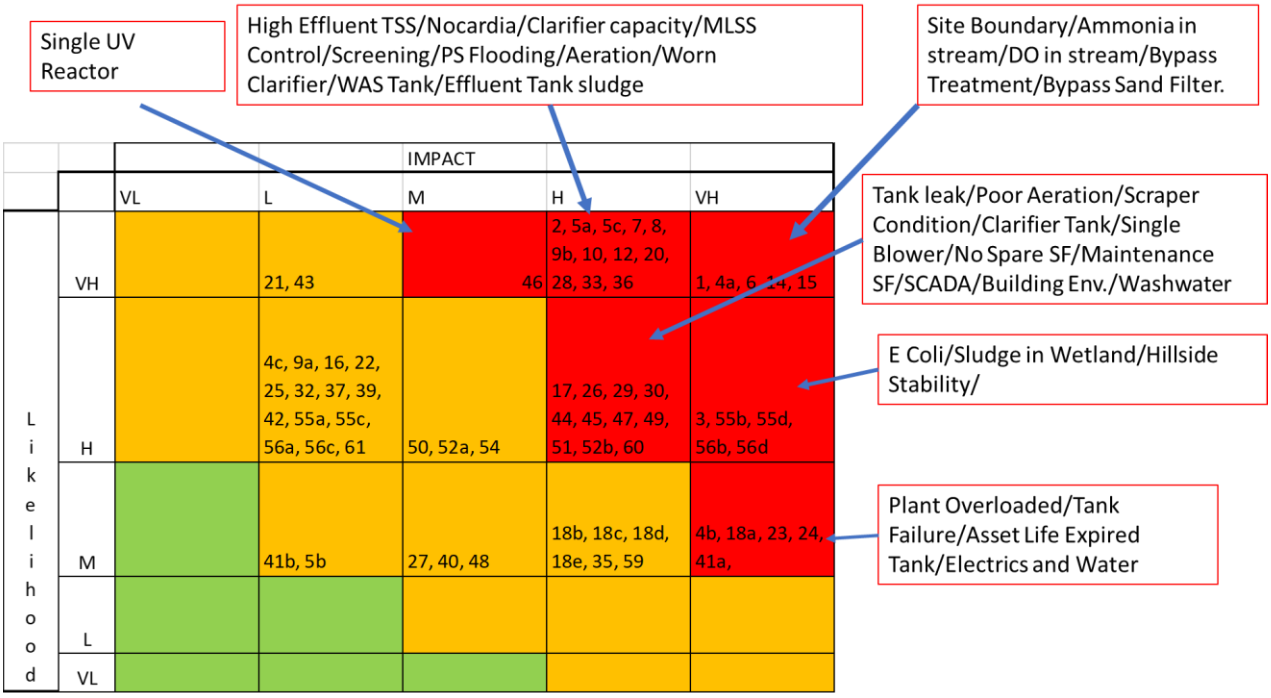

Figure 5: Root Cause Business Risk Overview

Likelihood

Likelihood was scored as:

VH	Very High	almost certain, is occurring now either intermittently or continuously or will occur within 1 year.
H	High	likely, may occur now intermittently, but not continuously, or will occur within 5 years
M	Medium	probable, will occur within 5 – 10 years, occasional
L	Low	unlikely, will occur within 10-20 years, Infrequent
VL	Very Low	rare, will occur > 20 years

Impact

Risks considered included Business risk impacts of:

- Compliance,
- Safety,
- Customer Nuisance,
- Pollution,
- Prosecution, and
- Reputation.

Full scoring of all issues and Risks is presented in Appendix F

The key issues were identified as:

- The original WWTP at Hihi was constructed 30 years ago for a lower population approximately 200 people. It has insufficient flow and load treatment capacity for current demand with peak population of 400-600 people.
- The plant is not robust against seasonal variation and suffers poor solids settlement (Nocardia filaments) and insufficient nitrification as a result.
- Peak flows to the site were designed at 2.5 l/s but current treatment pumps deliver approximately 4 l/s. Additionally storm pump will operate in high wet well conditions. Flooding occurs in very high flows as all pump capacity is exceeded. Peak flow to works of 8 l/s is estimated.
- The consent conditions for ammonia and dissolved oxygen are exceeded periodically in the stream.
- To deal with high flow deficiency, flow bypasses secondary treatment and sand filtration against the consent conditions.
- Poorly disinfected effluent is discharged in bypass conditions to the wetland and will pass through the stream to a popular bathing beach.
- The WWTP extends outside of the lawful designated area, so does not meet planning requirements.
- The assets constructed 30 years ago were “low budget solution” and have reached the end of their asset life. This includes key tanks and mechanical scraper mechanism of the clarifier.
- Structural failure has occurred of an internal baffle in the main reactor. The concrete tanks are leaking in several places. Significant Leaks will require at least a 2-week shut down of the whole plant to “patch repair”. Catastrophic failure will take the whole plant out of service until a new plant can be built (estimated minimum of 6 months) and will require tankering of all flows in this time.
- Many assets have poor accessibility that limits maintenance. This accessibility impedes removal of assets without major work and as no standby on critical assets will require a whole works shutdown. As example, to change the blower the roof of the blower building must be removed, and no secondary treatment is possible in this time.
- There is insufficient standby equipment to provide continuously high-quality effluent.
- The wetland requires maintenance as it has been impacted by the shortfalls of the plant and sludge carry through.
- Land slips are known at the wetland site and there is evidence of further recent movement in the bank. This will impact on treatment and cause loss of wetlands with consequential impact on stream, stream ecology and bathing beach.
- The site is known to cause nuisance odours and noise to the community.

3.2 Options Workshop

An options workshop was held on 16 January 2020 with key FNDC Stakeholders and Broadspectrum as operator and maintainer. Minutes of this meeting are attached in Appendix G.

3.3 Long List Options

A long list of options was considered at the Options Workshop.

The options considered were:

- Activated Sludge Plant (ASP),
- Moving Bed Bioreactor (MBBR),
- Membrane Bioreactor (MBR),
- Transfer to Mangonui Catchment, and
- Repair main reactor only.

3.3.1 Activated Sludge Plant

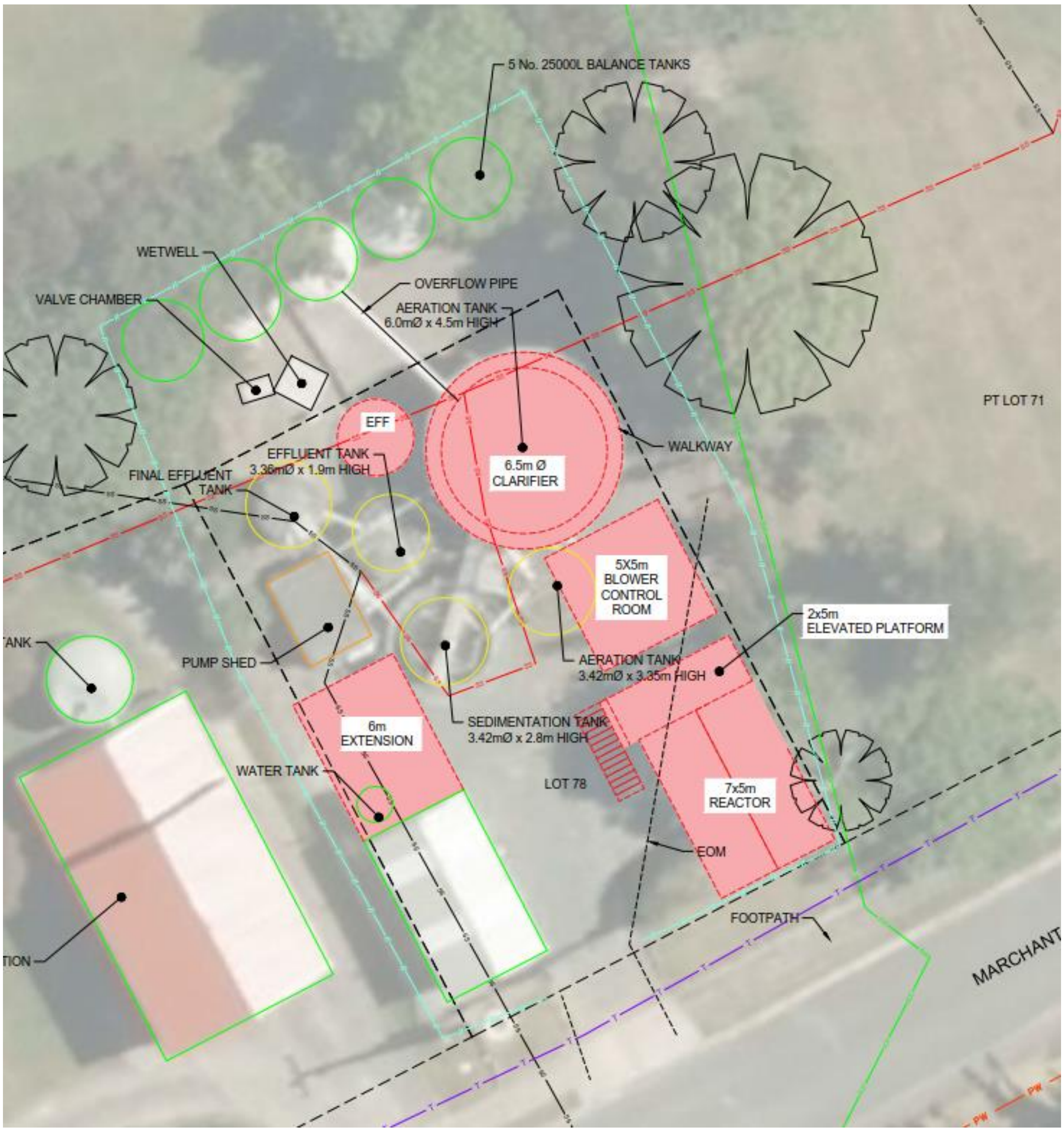

Figure 6: Activated Sludge Plant Option (Pink Structures.

This option includes;

- Replacement of inlet pumps to 8 l/s, with new rising main and flow meter
- Elevated inlet mechanical screen,

- 2 of 7m x 5 m x 4 m activated sludge reactors with anoxic zones, return activated sludge (RAS) system, access
- 1 of 6.5 m diameter flat bottom clarifier with scraper
- RAS and waste activated sludge (WAS) system
- WAS tank
- Effluent Tank
- New transfer pumps
- Additional sand filters in building
- Additional or larger UV.
- Building for Blowers and controls.

3.3.1.1 Construction

To construct this option, it is necessary to sequentially build and have temporary flow paths on the site. For short periods only, flows can be stored in the storm balance tanks enabling critical change overs to occur without removal of wastewater from site.

This plant can only be built off peak season when flows and load are lower.

Steps for construction;

- Removal secondary reactor tank. Temporary feed clarifier from main tank.
- Construct reactor slab and new blower building.
- Install all reactors and associated mechanical and electrical (M&E) equipment.
- Temporarily feed from new reactor to clarifier, with feed from existing pump station.
- Decommission existing main reactor and base slab.
- Prepare ground and install new clarifier.
- Connect clarifier to reactor and new effluent tank.
- Temporary over pump from effluent tank to existing sand filters.
- Remove old blower room, pumps WAS Tank and clarifier.
- Extend sand filter building for new pumps and sand filters.
- Connect effluent pumps to sand filter system
- Upgrade pumps at inlet to new flow rate of 8 l/s.

3.3.1.2 Advantages

- This is a conventional activated sludge solution, known to operations
- Can be built in limited footprint of designation.
- Improved aeration efficiency should lower or not increase energy costs.

- Reduced sludge from site as control available
- Achievable construction programme
- Could be largely modular for removal from site to new location if sea level rises
- Improved quality of effluent
- No bypassing of secondary treatment at high flows.
- Assets Maintainable

3.3.1.3 Disadvantages

- Changing Seasonal conditions that grow Nocardia will persist. Making plant unstable
- No resistance to Nocardia
- Requires sequential construction. (See above) with increased construction risks and duration
- Does not address wetland issues.
- Sand filter access not addressed

3.3.2 Next Steps

This option, due to similarity to existing process and proven ability to meet consent requirements is taken forward for option evaluation and costing.

3.3.3 Moving Bed Bioreactor

Moving Bed Bioreactors are used for treatment of wastewater (see option layout in Figure 7). They consist of an aerated tank with plastic floating media (see Figure 8). This media forms the support for a bacterial population and is retained in the reactor by mesh screens. Aeration is provided by coarse air, required for treatment and for media movement. This is a fixed film system so does not require a RAS to recirculate biomass.

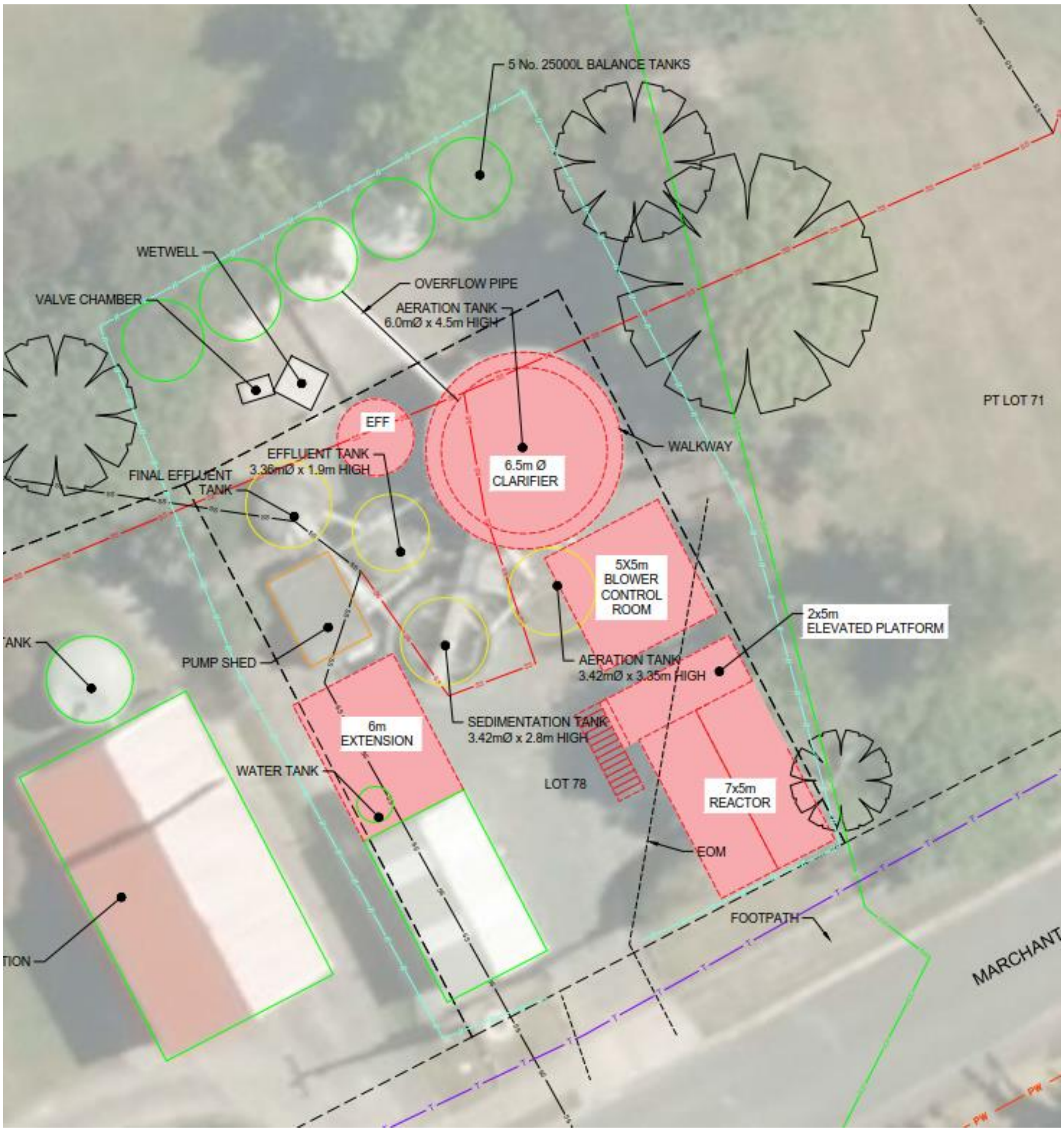

Figure 7: Moving Bed Bioreactor Option

Figure 8: Typical Moving Bed Media

This Option includes;

- Replacement of inlet pumps to 8 l/s, with new rising main and flow meter
- Elevated inlet mechanical screen,
- 2 of 7m x 5 m x 4m Moving Bed reactors with anoxic zones,
- Recycle system
- 1 of 6.5 m diameter flat bottom clarifier with scraper
- WAS system
- WAS tank
- Effluent Tank
- New transfer pumps
- Additional sand filters in extended building
- Additional or larger UV.
- Building for blowers and controls.

3.3.3.1 Construction

To construct this option, it is necessary to sequentially build and have temporary flow paths on the site. For short periods only, flows can be stored in the storm balance tanks enabling critical change overs to occur without removal of wastewater from site.

This plant can only be built off peak season when flows and load are lower.

Steps for construction;

- Removal secondary reactor tank. Temporary feed clarifier from main tank.
- Construct reactor slab and new blower building.
- Install all reactors and associated mechanical and electrical (M&E) equipment.
- Temporarily feed from new reactor to clarifier, with feed from existing pump station.

- Decommission existing main reactor and base slab.
- Prepare ground and install new clarifier.
- Connect clarifier to reactor and new effluent tank.
- Temporary over pump from effluent tank to existing sand filters.
- Remove old blower room, pumps WAS Tank and clarifier.
- Extend sand filter building for new pumps and sand filters.
- Connect effluent pumps to sand filter system
- Upgrade pumps at inlet to new flow rate of 8 l/s.

3.3.3.2 Advantages

- This is a proven technology using plastic media suspended in the tank.
- Not susceptible to poor settlement due to Nocardia.
- Biofilm adjusts rapidly to changes in loading
- Solids to clarifier are lower than mixed liquor suspended solids (MLSS), so less prone to blanket loss at high flows.
- Can be built in limited footprint of designation.
- Production of less sludge than activated sludge
- Achievable construction programme
- Could be largely modular for removal from site to new location if sea level rises
- Improved quality of effluent
- No bypassing of secondary treatment at high flows.
- Assets Maintainable

3.3.3.3 Disadvantages

- Increased aeration energy to meet demand of coarse aeration.
- Can produce very fine poor settling solids in light loading conditions.
- Requires sequential construction. (See above) with increased construction risks and duration
- Does not address wetland issues.
- Sand filter access not addressed

3.3.3.4 Next Steps

This option has been considered, but as it is new technology to the area it may create operational issues.

The costs for the plant have been estimated as higher than an activated sludge plant, as it is essentially an activated sludge plant with plastic media. Aeration is inefficient and increased aeration energy will be required.

No additional benefits were identified that differentiate this solution from an activated sludge process.

For these reasons, the option for moving bed bioreactor has not been progressed.

3.3.4 Membrane Bioreactor

The membrane bioreactor (MBR) is a version of activated sludge plant. Unlike a conventional activated sludge plant, the removal of solids is by membrane. This is usually around 0.1 µm pore size, so actively filters bacteria and some viruses and the treatment solids. This means that the plant can run at higher mixed liquor suspended solids (MLSS) concentrations, or biomass concentrations than a conventional plant and this results in a compact plant.

The MBR can be supplied as packages or a bespoke system using modules of membranes and treatment tanks.

All require fine screening to < 2 mm as blockage may occur.

The solution identified in Figure 9 is for a module membrane system external to the reactor. Flow is recycled from the membrane to the head of the plant, like a RAS from the clarifier. Effluent is guaranteed to be low in bacteria (< 1 E Coli/100ml,) and as suspended solids is < 1 mg/l, associated BOD, and nitrogen and phosphorous can be reduced.

Figure 9: MBR Treatment Option

To clean the membranes a cleaning system is required. With modular membranes as shown, this will require a continuous back scour of air, and periodic back flush with hypochlorite. Volumes used are very small on this scale of plant, with chemicals being supplied in 20 litre containers. Flat sheet membranes often do not require regular cleaning and may be cleaned by back flow of hypochlorite in the membrane about twice each year. Additional building footprint is required to allow for chemical storage and dosing systems.

This Option includes;

- Replacement of inlet pumps to 8 l/s, with new rising main and flow meter
- Elevated Inlet 2mm mechanical screen,
- 1 of 6m x 4m x 5m tank with anoxic zones, RAS system, access
- 2 membrane modules and cleaning system (if required)
- WAS system
- WAS tank
- Effluent Tank
- New transfer pumps
- Building for controls, blowers and membranes.
- Removal of Sand filters, and UV

3.3.4.1 Construction

To construct this option, it is necessary to sequentially build and have temporary flow paths on the site. For short periods only, flows can be stored in the storm balance tanks enabling critical change overs to occur without removal of wastewater from site.

This plant can only be built off peak season when flows and load are lower.

Steps for construction;

- Removal secondary reactor tank. Temporary feed clarifier from main tank.
- Construct reactor slab and new blower building.
- Install all reactors and associated mechanical and electrical (M&E) equipment.
- Install new effluent tank, with transfer pumps
- Decommission existing works.
- Upgrade pumps at inlet to new flow rate of 8 l/s.

3.3.4.2 Advantages

- This is a proven technology although not familiar to FNDC
- Not susceptible to poor settlement due to Nocardia.
- High Biomass adapts rapidly to change in load
- No solids loss

- No need for sand filters and UV
- Can be built in limited footprint of designation.
- Shorter construction programme as limited decommissioning and phasing required.
- Could be largely modular for removal from site to new location if sea level rises
- Very high quality of effluent. MBR can achieve:
    - < 1 mg/lBOD
    - < 1 mg/l TSS
    - < 5 mg/l NH_3 and
    - < 1 cfu/100ml E. coli
- No bypassing of secondary treatment at high flows.
- Assets maintainable
- Lower operator attendance required as automated and robust

3.3.4.3 Disadvantages

- Similar power requirement as existing works,
- Periodic chemical cleaning,
- More technical plant to manage, and
- Does not address wetland issues, although wetland could be bypassed due to high quality.

3.3.4.4 Next Steps

This option has been taken forward for costing and consideration as it produces consistently a high quality of effluent, not impacted by fluctuation in population and not impacted by Nocardia. A reduction in operational cost is expected due to lower operator attendance.

3.3.5 Transfer to Mangonui

Consideration was given to a transfer away option. Mangonui is 1.7 km from Hihi and could receive flows by pumping under the Mangonui Harbour (see Figure 10). This distance for a 125mm pipe is achievable by directional drilling from a new pump station at the Hihi WWTP.

Concerns have been raised on the impact of the Hihi transfer on Mangonui and East Coast Bays network. Although only 30 m^3/d in dry weather, an increase in peak flow of 8 l/s will probably require additional upgrades in Mangonui and through to Taipa. This network is already known to be struggling with peak flows and treatment capacity at Taipa.

The estimated costs of transfer are lower than the cost of upgrade at Hihi, but as there will also need to be a contribution to upgrade the network and Taipa WWTP soon, this is unlikely to be beneficial to the community as costs.

Mangonui residents are expected to be resistant to the transfer, particularly as increased odour may arise.

To facilitate a new harbour crossing a resource consent and AEE will be required. Other communities in New Zea;amd have objected to pipelines under harbours based on possible leaks that may impact harbour ecology and shellfish. Therefore, it is expected that for approval for a harbour crossing this application will go to environment court. To gather data and follow consenting process is anticipated that this process could to take 3 to 5 years.

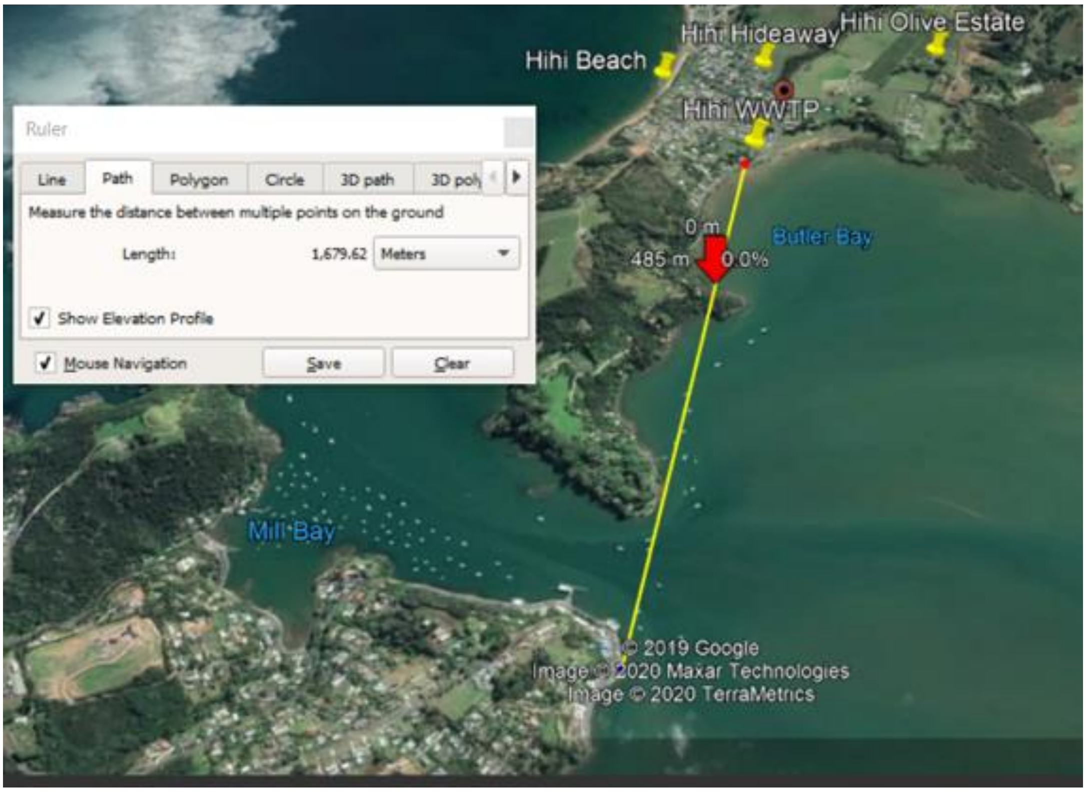

Figure 10: Option for Pipeline transfer to Mangonui

This solution will consist of:

- New transfer Pump station at Hihi WWTP.
- Gravity connection from existing sewer to new transfer pump station.
- Rising main from Hihi to Mangonui and connection chamber.

- Odour control management at Hihi (preventative) and odour treatment at point of discharge.
- Potential upgrades to Mangonui catchment including pump station upgrades and sewer upsizing.

3.3.5.1 Advantages

- Removal of Hihi WWTP, leaving only control shed (existing sand filter building) and pump station well
- Within site designation
- Return of site to reserve, recognised as favourable to neighbours.
- Removal of wetlands and associated risks
- Removal of all risks from existing plant.
- No need for Hihi WWTP consent renewal

3.3.5.2 Disadvantages

- New Resource consent required for pump station and harbour crossing
- Unable to deliver in timescale of this project (up to 5 years for consent approval)
- Upgrades in Mangonui have additional costs to community
- Increase risk of odours at Mangonui
- Removal of flow may leave no flow in receiving stream, impacting on fish and ecology

3.3.5.3 Next Steps

This option is discounted as the whole costs of transfer including Mangonui improvements are not cost beneficial to the community of Hihi. Additionally, the project timeframe of upgrade within 2 years will not be achieved with resource consent applications and expected objection to harbour crossing potentially delaying this option for 5 years or more.

3.3.6 Main Reactor Refurbishment

A discussion was held on the refurbishment of the existing main reactor. No other upgrades were considered.

To complete this work the main reactor will be out of service for 4 to 6 weeks resulting in all flows being removed from site by tanker. Over this period an average flow of 80 to 100 m^3/d will need to be managed and higher in wet weather with approximately 8 to 10 tankers everyday (and up to 50 in wet weather). This will not be logistically possible as there are insufficient road tankers in this region to support this activity 24/7 for the duration.

FNDC has identified in the Long Term Plan a replacement of the Hihi WWTP and this solution will not address that plan commitment that has previously been agreed by the community.

This works will require:

- Drain Tank and clean debris
- Remove baffle from reactor.
- Replace in tank aeration and move outlet pipe
- Sika product seal tank

3.3.6.1 Advantages

- Solution is cheap
- Can be built in timeframe of project

3.3.6.2 Disadvantages

- This tank is life expired and this work will increase asset life by at most 5 years before other leaks and damage appear.
- No maintenance risks are addressed
- No replacement of reactors, clarifiers, or other assets
- No additional capacity is provided
- Effluent resource consent will not be met.
- Customer nuisance will continue
- Flows will bypass treatment in high flow conditions, not as consented.
- Plant will be outside of designation
- No improvements to wetland or sand filtration
- Health and safety issues will not be addressed

3.3.6.3 Next Steps.

Although considered as low cost this solution does not address the critical business risks identified and will not meet consent, site designation and health and safety requirements. This option cannot be continued as fails to meet project needs.

4 Option Evaluation

4.1 Project Constraints

The following were considered as constraints for the Hihi WWTP upgrade and formed the basis for evaluation of options.

Affordability.	The Hihi catchment serves only 200 residents, so cost is a major concern for the community.
Land	The operational site is in a prime waterfront location in reserve. It is larger than the designated operational site, which needs to be addressed. The solution should fit within the existing designation
Neighbour	Overlooked and in close proximity to neighbours, the site is subject to noise and odour complaints. Future upgrades need to improve this for the community
Inundation/Climate Change	Being located on the foreshore, less than 1 m of sea level rise will see high tides in the site. Consideration may be given to robustness of design (e.g. electrical components above flood level) and the ability to move the plant at a later stage to an alternative location
New Consent Conditions	Currently unknown, but tighter standards are expected that will address ammonia and oxygen levels and bacterial standards. Possible total Nitrogen and Phosphorous standards are considered (at the workshop) to be unlikely, but can be accommodated in the design of the plant if needed
Amenity	The area is used for recreation, both on the foreshore and the recreational reserve around the site. Return of utilised areas (not designated) will increase the amenity for the community.
Land Use	The ideal situation for the neighbours is a new plant elsewhere, but this has been identified as very high capital cost as must include land purchase, resource consenting, transfer network and new treatment process.
Nuisance.	The proximity and history of the site in the community leads to odour and noise complaints that can be managed in the future plant
Time	The main reactor has been condemned and is not expected to last for more than 2 years without significant risk of catastrophic failure. Solutions need to be timely to address this key driver of the project
Construction Programme	The programme needs to consider duration as a key issue. Location in a holiday area will require construction off season, with limited space available on site. Sequential demolition and construction will be needed. Build off site techniques will be encouraged to meet timely delivery
Maintenance/Operations	Long term the plant must be fit for purpose, suitable for regular maintenance of all equipment. Typical asset life should be > 40

	years for the structures. This includes addressing single point of failure equipment and accessibility
Asset Life	Materials and equipment selected must be fit for purpose to meet the required Asset Life. This need to consider the impact of sea air and potentially, seawater ingress and tidal flooding (if climate change occur)>
Wetland Condition	To meet cultural needs a discharge to land, or in contact with land will be required. This need be fit for purpose and not cause nuisance, or deterioration of effluent in passing
Quality.	Effluent quality shall meet the consent, even at peak loading times
Safety	All plant shall be reasonably practicable safe for operation and maintenance of all equipment and assets. This shall include access, confined space avoidance, lifting of equipment and personnel hygiene
Whole life costs	Whole life cost is essential as the community will pay for capital expenditure and operational costs

These constraints are tabulated below in Table 2, with each option considered.

4.2 Comparison of Options

Table 2: Comparison of options with consideration to the listed contstraints.

Options	Repair	Activated Sludge Plant	Pump to Mangonui	Moving Bed Bio Reactor	Membrane Bio Reactor	Notes
Constraints						
Affordability	✔	✔ Check Cost	X	✔	X- Check Cost	Affordability limited to $4M
Land	✔	✔	✔	✔	✔ ✔	
Neighbour	✔	✔	✔ ✔	✔	✔	
Inundation/Climate change	X	X	X	X	X	Existing site conditions does not support
New Consent	X	✔	✔	✔	✔	
Amenity	✔	✔	✔	✔	✔	
Land Use	X	✔	✔ ✔	✔	✔	
Nuisance	X	✔	X	✔	✔	
Time	✔	✔	X	✔	✔	Design and construction in less than 2 years
Construction Programme	✔	✔	✔	✔	✔	
Maintenance operations	X	✔	✔	✔	✔	
Asset Life	X	✔	✔	✔	✔	
Wetland	X	X	✔	X	X	V High Quality may bypass wetland if consent permits
Quality	X	✔	✔	✔	✔	
Safety	X	✔	✔	✔	✔	
Whole Life Cost	X	✔	✔	✔	✔	

From the options considered at the options workshop, no option satisfactorily meets the demands of climate change and sea level rise inundation of the site. It was considered that a new site will be required in the future, but to meet current project needs, preference is for a modular, movable treatment solution that can be relocated.

The repair option did not meet many criteria and cannot be considered as suitable for site needs.

Almost all the option solutions for Hihi WWTP have a substantial risk from the wetland site. This requires desludging, replanting and stabilisation of the embankment. The failure of this embankment will flood the pond, bypassing the treatment, potentially washing out of sludge, and divert the stream. An allowance in solution costing has been made in the detailed cost estimate. Only pumping to Mangonui removes the risk from the wetlands as no flow will be discharged, but this option cannot be completed in the project constraint time scale of 2 years.

5 Detailed Options Evaluation

From the long list further evaluation has been done on the Activated Sludge and Membrane Bioreactor options.

5.1 Footprint

Early indications are that the options can be constructed within the site designation as above ground structures. This will enable removal of assets in the extension area. However, the inlet pump station (PS) is assumed to be retained. This is outside of the designation, and FNDC will need to consider whether its best value to construct a new PS after the works is constructed within the boundary, or modify the designation to accommodate.

Final Layout diagrams for the preferred short list options are presented in Appendix I

5.2 CAPEX Estimates

Capex estimates are budget costs estimates and reflect costs associated with similar projects and supplier budget cost estimates (see Table 3). Cost Estimate break down are provided in Appendix J.

Table 3: Indicative capital and operating cost estimates for the activaled sludge, and MBR options.

Option	CAPEX	Opex Change
Do Nothing	$20k **	$20k *
Activated Sludge	$5.21	No Change
MBR	$5.33m	No Change
Nominal Wetland Remediation and bank stabilisation	$700k	
Total Budget	$6.03 m	
* Additional costs of reactive maintenance will continue to increase. A nominal value is used.		
** Annual capitalised maintenance cost estimate to manage failing assets excluding structural failure		

Opex costs for both solutions are as for the existing works costs and have not been analysed at this stage but are discussed below.

Both options, have improved automation that will reduce operator attendance. Also, by use of more efficient aeration, aeration energy will decrease, offsetting additional power demands from sand filters (activated sludge option) or membrane cleaning (membrane bioreactor option).

Both options produce similar quantities by weight of sludge to be removed from site. This total volume is expected to be lower than current for the activated sludge plant as there will be improved control on wasting but reduced further for membrane bioreactor as the sludge is more concentrated, so having a lower volume.

Chemical usage for the membrane system is required but have not been estimated. This will vary depending on membrane system selected. However, chemical cost per year may be < $2k per year for a flat sheet membrane, or < $5k per year for a hollow fibre system. These shall be evaluated in detail during preliminary design but are dependent on the membrane system selected. Both options will have an increase in instrument maintenance requirement, with approximately 24 hours per year required, which is offset by the reduction in operator attendance for routine control checks.

Do nothing, which is not a preferred choice for this site, will see an increase in operational costs as maintenance increases with deteriorating assets and periodic capitalised reactive works required.

Overall there is no notable change to operational costs associated with this treatment plant replacement.

A comparison has been undertaken for the Membrane Bioreactor with a packagedsupply from Smith and Loveless. This was a budget quotation and not fully conforming. However, the cost comparison with correction for civils aspects, site integration, project on costs etc. is directly comparable with the WSP estimate. (S&L corrected $5.36m, WSP MBR, $5.33m).

6 Recommendations

Both options show very similar capital cost and have very little operational cost differences. Both options can be constructed within the site designation. With the accuracy of cost estimation, it is not possible to select between these options on price alone. Therefore, the following discussion considers the main risk areas for the plant.

6.1 Operability

Both options can be operated and maintained with reasonable skilled operators. Both plants will be impacted by seasonal changes in flow and load, but due to the membranes, the quality from the membrane system will not be impacted by the growth of filaments like Nocardia that are known to occur at this site. This means when filaments occur, less operator intervention is required for a membrane plant and a higher effluent quality achieved always than possible with the activated sludge plant.

6.2 Performance

The activated sludge plant can achieve very high effluent standards. However, in changing load conditions performance may dip, particularly on ammonia and suspended solids. Disinfection is dependent on the UV performance which will vary with suspended solids concentration.

The membrane system will, due to the membranes, have a higher biomass that improves robustness against load changes, and ensures that very low solids pass to the effluent with suppliers guaranteeing typically < 2 mg/l. This same mechanism ensures disinfection standards with no additional process.

A risk associated with warm conditions and full removal of ammonia to nitrate is that denitrification can occur in the clarifier. This is particularly the case when there are long retention times in the clarifier and the bacteria present deplete oxygen levels. The result is rising sludges that can challenge tertiary treatment processes. In the activated sludge solution, as the clarifier must be sized for peak wet weather flow, the low levels of flow seen at the site in dry conditions will cause excess retention time. In summer this is approximately 16 hours, and this duration increases in off peak conditions to over 24 hours. Rising sludge due to denitrification in this tank is almost certain. Excessive retention without oxygen in a clarifier can also lead to sludge floc breakdown, resulting in loss of treatment. This is likely to impact on ammonia removal for the activated sludge plant and increased sand filter washing.

6.3 Safety

Both solutions will be new build for the treatment works. These will be built to current standards of safety with safety in design processes being undertaken in conjunction with designer, FNDC and Far North Waters personnel.

During construction the phased activities in the confined space required to build increase significantly the risk of injury. The activated sludge option requires demolition of reactor and then construction of reactor and new clarifier on a live site. The membrane option will be built alongside the live site so has less risk and shorter programme.

6.4 Resilience to Future Changes of Consent

The Hihi WWTP resource consent is due for renewal in 2023, and this will not be known until after the construction of the wastewater plant. This means that should a difference in consented parameter occur, additional expenditure may be required for the activated sludge plant and less for the membrane plant.

Should there be a standard for BOD (currently only dissolved oxygen in the stream) or a standard for total suspended solids, this may be lower than the expected quality from sand filters, whereas a membrane plant will require no change. Should a change in ammonia be required, then the membrane plant can be operated with higher DO set point and increased biomass. However, the activated sludge plant is limited by solids load to the clarifier, and additional tank capacity may be required.

A total nitrogen standard will require both plants to have minor modifications to anoxic zone, which can be accommodated by internal baffle wall changes and recycle pumping. However, as some nitrogen is related to solids, the membrane plant will be less likely to require modification as this fraction is removed completely

Phosphorous will be considered if the discharge may cause eutrophication (increase in plant and algal growth due to elevated levels of nutrients). This can be accommodated for both systems by the additional of ferric salts or alum salts to the reactors and capturing the resultant metal phosphate salt in the solids fraction. To accommodate this a conservative loading to the activated sludge plant is required to enable a 20-30 % increase in treatment solids that arise from the chemical addition. The membrane system is intended to operate at 5,000-6,000 mg/l solids will also operate at much higher concentrations of 8,000-10,000 mg/l with no detriment.

Some coastal discharges are being required to consider impact on shellfisheries, or other areas for local gathering of seafood from wastewater discharges. Examples of Clarks Beach and Snells Beach have identified the need for membranes and UV disinfection to reduce bacteria and viruses. The activated sludge option would need to then consider replacing sand filters with membranes, or substantial increased power in the UV system, making the new UV system redundant.

The membrane plant will therefore produce a very high quality of effluent and unlikely to have any additional capital changes required from the renewal of the resource consent, whereas the activated sludge could require additional capital spend.

6.5 Sea-level and Alternative Future Sites

Sea-level rise is a significant risk to the plant as it is adjacent to the Mangonui Harbour. Much of the site is only 0.5 m above sea level. Both options can be designed to be resilient for occasional tidal events by raising electrical equipment above floor level and keeping critical components either as submersible in design or above water levels. This applies to both options.

Should sea-level rise cause saltwater to enter the network, occasional high levels of salt will be detrimental to the activated sludge plant as osmosis causes break down of the treatment biomass floc structure and loss to effluent of solids. However, as the membrane plant prevents any solids loss, quality is maintained, and treatment continues. Both plants may have secondary issues with foaming, which can be managed by an increase in free board on the reactors.

It is considered, depending on rate of sea level rise, that an alternative treatment site may be required in future. The activated sludge plant can be constructed as modular tanks that can be relocated. However, the size of the clarifier prevents a modular build and relocation. The membrane system is totally modular and may be relocated to alternative sites.

6.6 Programme

The complexity of installation to work around the existing plant means that the project programme for the activated sludge plant may be 3 months longer than for the membrane solution. This carries increased project costs and risks.

6.7 Recommendation.

The membrane bioreactor option is the most robust and adaptable solution for future performance needs and resource consent demands as well as the most operationally consistent performance. It can be constructed in approximately 3 months less than the activated sludge solution and so reduce site costs and safety risks associated with construction.

It is recommended that a membrane bioreactor be taken forward for the capital scheme.

A budget estimate for the Membrane Bioreactor of $5.33 m should be allowed, with a nominal additional cost of $700 for wetland remediation and bank stabilisation. Total project budget of $6.03m.

Appendix A Site Visit Findings Memorandum. October 2018

Appendix B Hihi WWTP Design Basis, February 2019

Appendix C Hihi WWTP Conceptual Design Options March 2019

Appendix D Fraser Thomas Structural Assessment, May 2014

Appendix E Hihi WWTP Main Reactor Structural Assessment December 2019

Appendix F Business Risk Assessment Workshop Report, December 2019

Appendix G Minutes of Option Workshop, January 2020

Appendix H Hihi Options Workshop Slides, January 2020

Appendix I Site Layout Drawings

Appendix J Budget Estimates for Options

wsp.com/nz