Palmerston North Wastewater
Best Practicable Option (BPO) Review

Eco-City Strategy Assessment

August 2021

PAPAIOEA PALMERSTON NORTH CITY

PALMERSTON NORTH NATURE CALLS

Prepared for Palmerston North City Council by:

Stantec

QUALITY STATEMENT

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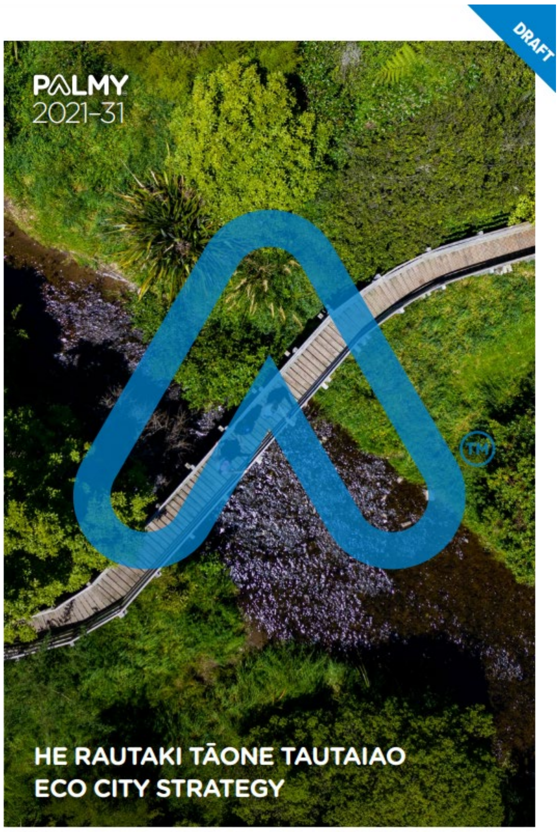
Executive Summary

This report has been prepared to assist the Council in identifying options that may be considered through the final Best Practicable Option (BPO) assessment. This assessment forms one of seven assessments being carried out, prior to confirming the BPO with Horizons Regional Council.

This Assessment has been undertaken with the involvement of technical experts, who have advised the Council on options development and assessments throughout the Project.

Each of the 11 shortlisted options has been assessed against the 11 project objectives. And a score of 1 (least aligned) to 5 (most aligned). The basis for this score is documented in the assessment (refer Table 2, Section 3 of this report).

Technical advisors and Iwi have been involved in the assessment of all options against the Eco-City Strategy. Specific work has been undertaken to identify the carbon effects from each option and related back to the City's goal of 30% carbon reduction by 2031. The technical advisors have recommended a scale of 1 to 5 be used for comparing how well options align with the various Eco-City Strategy Plans (refer Table 2).



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1 Introduction

1.1 Overview of Assessment Process

An assessment of the short list options has been undertaken to determine levels of alignment for each option, with Council's Eco-City Strategy. This assessment has been undertaken to help inform the process of determining the Best Practicable Option (BPO) for the Palmerston North City wastewater management solution. Figure 1 below illustrates how the eco-city strategy assessment integrates with the other assessments and processes involved in determining the BPO.

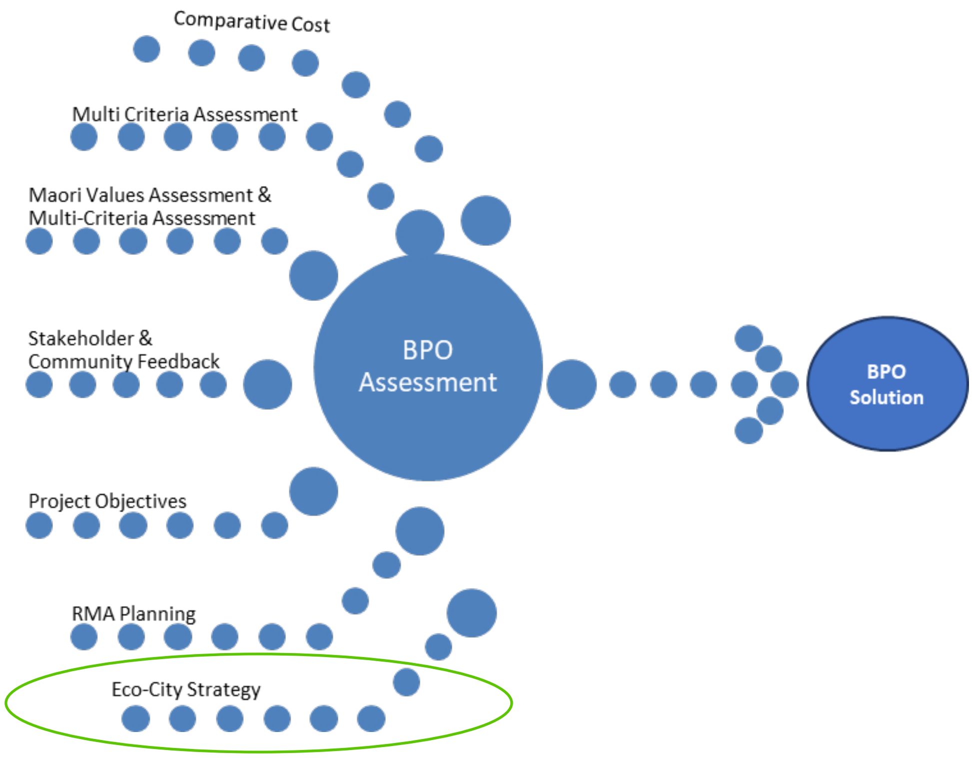


Figure 1 BPO Assessment Process

The Eco-City Strategy assessment involves considering how each of the Short List of Options aligns with the key 'Measures of Success' and 'what the Council wants to achieve' through its Strategy. An outline of the methodology used to undertake this assessment is provided in Section 3 of this Report.

1.2 Shortlist Options

The following table lists the shortlist options. Further details of the shortlist options are provided in the Shortlist Options Summary Report, May 2021.

Table 1 Options Description / Reference

Option No.	Option Summary Description
1	**R2(b) River discharge with Enhanced Treatment**
2	**R2 (b-2) River discharge with Enhanced Treatment, 75% ADWF to Land at low River flow.**
3	**Dual R+L (b) Two river discharge points, with 75% ADWF to Land low River flow.**
4	**L+R (a) 97% of the time to Land (inland)**
5	**L+R (b) 97% of the time to Land (coastal)**
6	**L+R (d-1) to Land <80m^3/s / 53% of the time to Land (inland)**
7	**L+R (d-2) to Land <62M^3/s / 43% of the time to Land (inland)**
8	**L+R (e-1) to Land <80m^3/s / 53% of the time to Land (coastal) TN = 35 mg/L**
9	**L+R (e-2) to Land <62m^3/s / 43%of the time to Land (coastal) TN = 35 mg/L**
10	**O+L / Ocean with Land**
11	**Ocean discharge**

1.3 Supporting Project Information

The following technical documents, developed to inform the shortlist options development and assessment process to date includes:

- Wastewater BPO Shortlist Options Report, August 2021
- Wastewater BPO Treatment Options Report, May 2021 & Addendum Report, May 2021
- Carbon Footprint Assessment Report, May 2021 (Appendix 1)
- Assessment of Residential Flow & Load Reduction Technology, October 2018
- Wastewater BPO MCA Comparative Assessment Report & Appendices, November 2021
- RMA Assessment Report, August 2021
- Iwi Values Report prepared by Rangitāne o Manawatū, July 2021

2 Eco City Strategy 2021-2031

2.1 Overview & Key Aspects

Palmerston North City Council has a vision of "small city benefits, big city ambition". To achieve this, the Council has adopted five goals, one of which is to be an Eco-City (Goal 4). As an Eco-City, the Council recognises the city has a role to play in the response to climate change. A goal for Palmerston North is to decrease carbon emissions and reduce ecological footprint. Council also wants to protect and enhance the natural and built environments, accommodate growth through intensification and support active transport. Council is also committed to working with partners, including Rangitāne o Manawatū and stakeholders.

Figure 2 Council's Strategic Direction, including the Eco-City Strategy (Goal 4)

Five plans sit beneath the Eco-City Strategy, describing the city's activities for the first three years of the 2021-2031 Long Term Plan. These plans include: **Climate Change, Environmental Sustainability, Manawatū River, Resource Recovery** and **Waters**. There are two drivers of the Eco-City Strategy that underpin many of the actions within it. The drivers are Community Wellbeing (Local Government Act 2002) and Climate Change (Ministry for Environment requirements). Climate Change is particularly relevant in the case of the Wastewater BPO Project. This is because the proposed options have the potential to contribute to Council's target of a 30% reduction in CO_2 emissions in Palmerston North by 2031.

2.1.1 Manawatū River & Rangitāne o Manawatū

Across each of the five plans, Council is committed to working in partnership with Rangitāne o Manawatū. In several plans, Council recognises the significance of the Manawatū River as a key cultural, environmental, and recreational resource. A key priority for the Council is to "***Respect and enhance the mauri of the Manawatū River***" and measures are identified in the Eco-City Strategy, Waters Plan and Manawatū River Plan specifically to outline how this will be achieved. Within the overarching Strategy, Council has identified the following effort will be required:

- *Understand the relationship Rangitāne o Manawatū has with the Manawatū River*
- *Increase the use of the Manawatū River environment for passive and active recreation.*
- *Increase the health and amenity of the River environment through increased biodiversity.*[1]

The Council has adopted a partnership approach to working with Rangitāne o Manawatū on the BPO Project. Representatives from the Iwi are on the Project Steering Group for the BPO Project and form part of the technical team to develop and assess options. On this

[1] Page 6, Eco-City Strategy 2021-2031

basis, the partnership between the Council and Rangitāne o Manawatū has not been assessed across the options, as there is no difference in the partnership for the different options so it will not affect comparative scoring.

2.1.2 Carbon Reduction

There is growing awareness and commitment globally to reducing carbon emissions, and New Zealand has committed to being a leader in this area. The Council is a signatory to the New Zealand Local Government Leaders Climate Change Declaration, which establishes a commitment to addressing climate change in decision making in the interest of community well-being.

Council is committed to reducing electricity, natural gas, and fuel usage, as well as reducing waste and has confirmed to the goal of reducing emissions to reduce costs, while improving air quality and other environmental outcomes. To achieve these reductions, the Council has identified the following overarching commitments:

- Foster sustainable practices and behaviours so that city residents and organisations become more sustainable.
- Develop policies and plans and work with city stakeholders to achieve the target of 30% reduction in greenhouse emissions by 2031, and continue to reduce greenhouse gas emissions from Council's own activities.

Significant work has gone into the Council understanding the emissions profile of the city. For the wastewater BPO Project, technical analysis has been undertaken to identify the potential emissions of CO_2 emissions from each shortlisted option and to determine the impact the option will have on achieving the target (30% reduction by 2031). This detailed analysis is covered in Section 3 and Appendix 1 of this report.

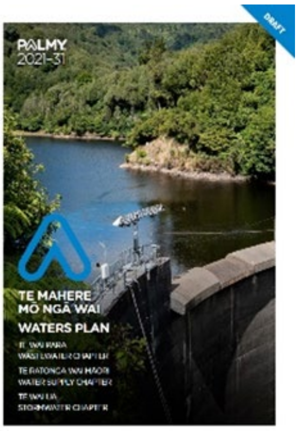
2.2 Eco City Strategy – The Five Plans

The following describes the over-arching strategic goals for each of the five plans that form the Eco-City Strategy.

Environmental Sustainability Plan

This Plan recognises links to the Waters Plan and Manawatū River Plan on the basis the Council is seeking to improve stormwater and wastewater management, thereby improving water quality of the Manawatū River and native biodiversity.

There are two parts to this Plan, comprising the Sustainable Practices Chapter and the Biodiversity Chapter. Within the sustainable practices chapter, Council identifies opportunities for individuals and organisations to contribute to sustainable practices. For the BPO Project, no matter which option is selected, Council is committed to exploring sustainable practices to reduce wastewater production (in the home and within organisations). Council is also committed to wastewater and bi-product re-use, which is addressed in the resource recovery plan assessment.



Waters Plan

The Waters Plan is made up of three chapters - wastewater, water and stormwater. For this assessment, the wastewater chapter has been reviewed to determine options alignment. The primary objectives of the wastewater plan are to manage wastewater well, enhance the mauri of the Manawatū River and avoid adverse effects on the environment.

Specific reference is made to the Wastewater BPO process and Council's commitment to seeking a new consent by June 2022. It also refers to commitments to working with Trade waste customers, Rangitāne o Manawatū and the Manawatū River Leaders Accord. In this case, options have only been assessed when relevant measures and actions allow for a comparison to be made resulting in different scores.

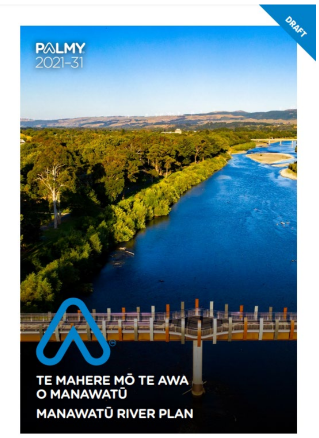
Climate Change Plan

The purpose of this plan is to understand the impacts of climate change and to reduce Council and citywide greenhouse gas emissions.

Council has developed a 'Palmy Climate Calculator', which has been used to allow council to roadmap achieving low carbon emissions by 2050. Each of the BPO Options has been assessed to determine the contribution it will have on carbon emissions (refer Section 3 and Appendix 1). We consider this analysis to be of highest priority compared with other plans and assessment and so it has been assigned a higher weighting.

Resource Recovery Plan

In accordance with the Waste Minimisation Act 2008, the Council is required to adopt a waste management and minimisation plan. This plan is the foundation of the Resource Recovery Plan and the purpose of this is to reduce the generation of waste and the impact of waste on the environment. In relation to the BPO Project, this Plan focuses on solid waste and includes targets for reducing landfill waste as well as setting priorities for residents and commercial premise to contribute to this reduction.



Manawatū River Plan

The Manawatū River Plan focuses on the relationship between Rangitāne o Manawatū and the River, as well as community engagement with the river through increased public use and increased the health and amenity of the environment (biodiversity). This Plan is interlinked with the other Eco-City Strategy plans and this is reflected in the measures and actions. The significance of the River to the Council in the Strategy is also strongly reflected in the top priorities for the Strategy.

As most of the options utilise the River to varying degrees (as a discharge location), this Plan provides helpful guidance in the options assessment process.

3 Methodology for this Assessment

3.1 Classification Process

The assessment considers the extent to which a wastewater discharge to a particular receiving environment, aligns with the relevant '*Measures of success*' and '*what Council wants to achieve*' in comparison to the other receiving environments and treatment levels. The assessment considers the balance of multiple discharges where more than one receiving environment is used in any option.

In some cases, the objectives were further interrogated and divided into subcategories within the overall objective and scored accordingly. This was done to provide greater robustness and transparency around the assessment of multiple elements. In each case the score is an average of the subcategory scores.

3.2 Scoring of Objectives

The assessment is based on a determination of the extent to which the proposed treatment solution and discharge environment, aligns with the '*measures of success*' and '*what council wants*'.

Table 2 sets out the banding/scoring used in the assessment. Section 5 of this report details the allocated scores applied to each shortlist option.

Table 2 Scoring Criteria

Level of alignment	Score
Strong alignment	5
Good alignment	4
General alignment	3
Weak alignment	2
Fails to align	1

4 Carbon Analysis

4.1 Climate Change Plan and Carbon Footprint Assessment

The goal of reducing the Council's and the community's carbon footprint is reflected in all the four plans but the primary focus of the Climate Change Plan. To understand the contribution of the wastewater BPO to achieving the target reduction a high-level carbon assessment of each of the options was undertaken. The report is referenced in Appendix 1 of this report.

4.2 Carbon Footprint Assessment

The high-level carbon assessment included consideration of both embodied (construction) and operational carbon emissions over a 50-year period [2](refer Appendix A). The total emissions (embodied + operational) are expressed as tonnes of CO_2 equivalent (CO_2-e). CO_2-e includes methane and nitrous oxide emissions from those options continuing to use the existing aerated lagoons at the Totara Road Wastewater Treatment Plant, converted to the equivalent mass of CO_2 in terms of global warming potential.

The estimated 50-year carbon emissions are presented in Table 3 and Figure 3, from lowest to highest. The net change relative to the current Treatment Plant emissions is also shown, with those options with a net reduction highlighted.

Annual operational carbon emissions ranged from 5,000 – 8,000 tonnes CO_2-e per annum (not including reduction due to carbon sequestration in trees). This amounts to around 1% of the estimated total annual carbon emissions from Palmerston North (500,000 tonnes CO_2-e p.a.).

The assessment shows that Option 1 with enhanced treatment and a 100% discharge to the river; and Option 2 with the same enhanced treatment but 75% of the Average Dry Weather Flow (ADWF) applied to land at low river flows achieve an estimated 28 and 29% reduction over the 50 year period modelled as compared to the current operation.

The three coastal land options have the lowest carbon footprint due to the contribution of carbon sequestered in the forestry plantation trees, which significantly offsets the operational carbon emissions from wastewater treatment and discharge. Ministry of Primary Industries lookup tables for pinus radiata have been used for this information.

The ocean outfall option (Option 11) has the highest carbon footprint of the shortlisted options due to:

- High embedded carbon (long pipeline); and

[2] The 50 year period is used as it align with Councils growth planning horizon and infrastructure planning requirements.

- Methane and nitrous oxide emissions (from the aerated lagoons).

If the treatment process for the ocean outfall option was changed to an activated sludge process, the annual operational carbon emissions would reduce to around 5,000 tonnes CO_2-e per annum and the 50-year total would reduce to 312,000 tonnes CO_2-e. This would represent a reduction in emissions of around 24% relative to the current WWTP operation and would improve the carbon ranking of the ocean outfall to 7th on the list.

Table 3 PNCC Wastewater BPO 50-Year Carbon Emissions

Option	TL	Embodied Carbon	Average Operational Carbon Emissions	Average Annual Sequestered Carbon	50-Year Carbon Emissions	Net Change from Current Emissions
		t CO_2-e	t CO_2-e p.a.	t CO_2-e p.a.	t CO_2-e	%
L + R (b)	3	68,700	2,340	(22,500)	-299,000	-173%
L + R (e-1)	2	67,600	8,530	(31,900)	-189,000	-146%
L + R (e-2)	2	66,300	8,470	(26,400)	-73,000	-118%
R2 (b) 2	4	7,000	2,400	-	129,000	-69%
R2 (b)	4	3,500	2,500	-	131,000	-68%
O + L	1	66,500	8,210	(12,900)	206,000	-50%
L + R (d-2)	2	21,600	8,400	-	450,000	10%
L + R (d-1)	2	22,000	8,450	-	453,000	11%
Dual R + L (b)	2	37,000	8,240	-	457,000	12%
L + R (a)	1	24,400	8,800	-	473,000	15%
O	1	63,600	8,140	-	479,000	17%

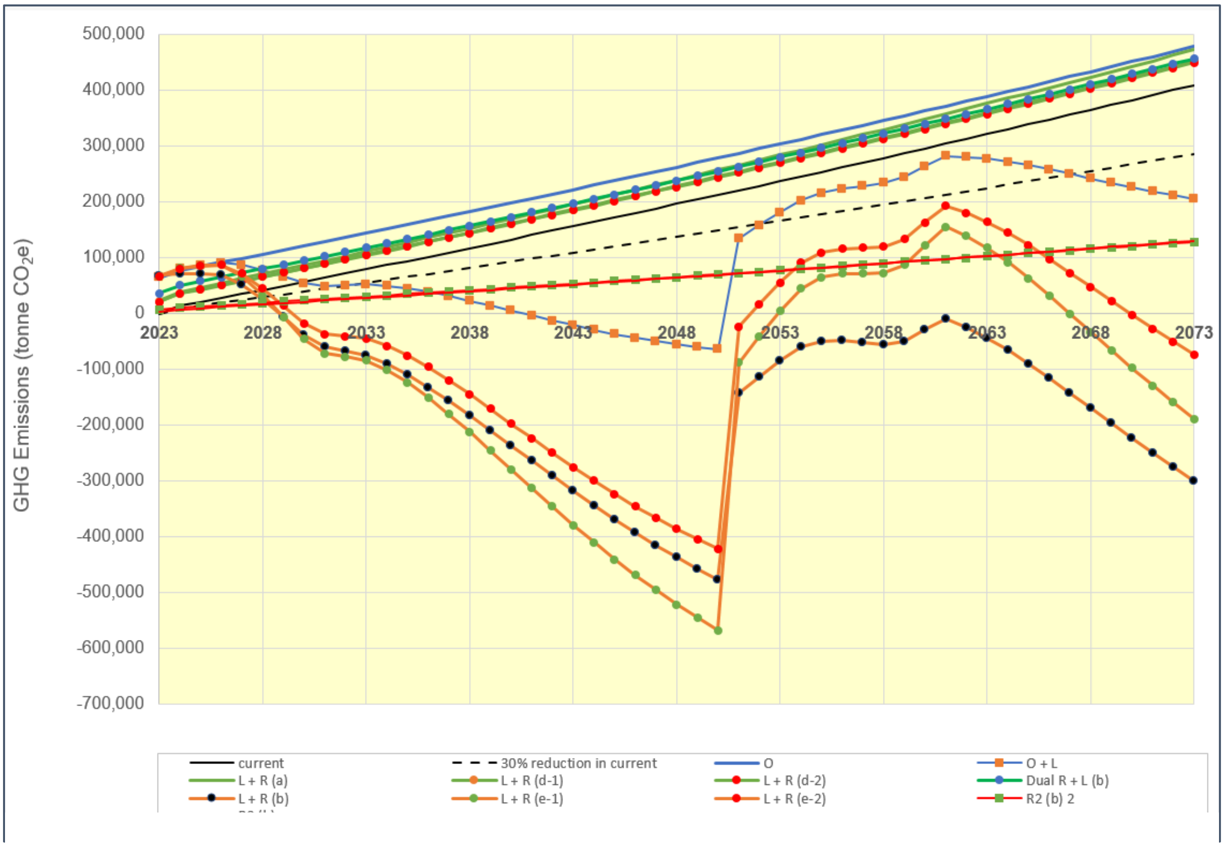


Figure 3 PNCC Wastewater BPO Carbon Emissions

4.3 Resource Recovery Plan

The purpose of the Resource Recovery Plan is to set out 10 year plan levels of service that:

- Ensure the city's solid waste is adequately and affordably managed
- Maximise the proportion of waste diverted from landfill (e.g. through recycling and composting)
- Manage hazardous waste in an environmentally responsible manner.

This Plan has a solid waste, landfill and hazardous waste focus. This focus has been used in the assessment and scoring as included in section 5 of this report.

Optimising resource recovery is an objective of the BPO Project.

Resource recovery opportunities and drivers have been investigated and compared for the short-listed options. Appendix 2 to this report includes excerpts from project work packages that cover the resource recovery assessments undertaken to date.

Once a preferred BPO solution is identified in depth evaluation of resource recovery opportunities will be undertaken and those considered practical for implementation identified. The approach followed to date and to be developed further is based on a "circular economy" philosophy where all waste streams are considered as values stream. Figure 4 illustrates this approach.

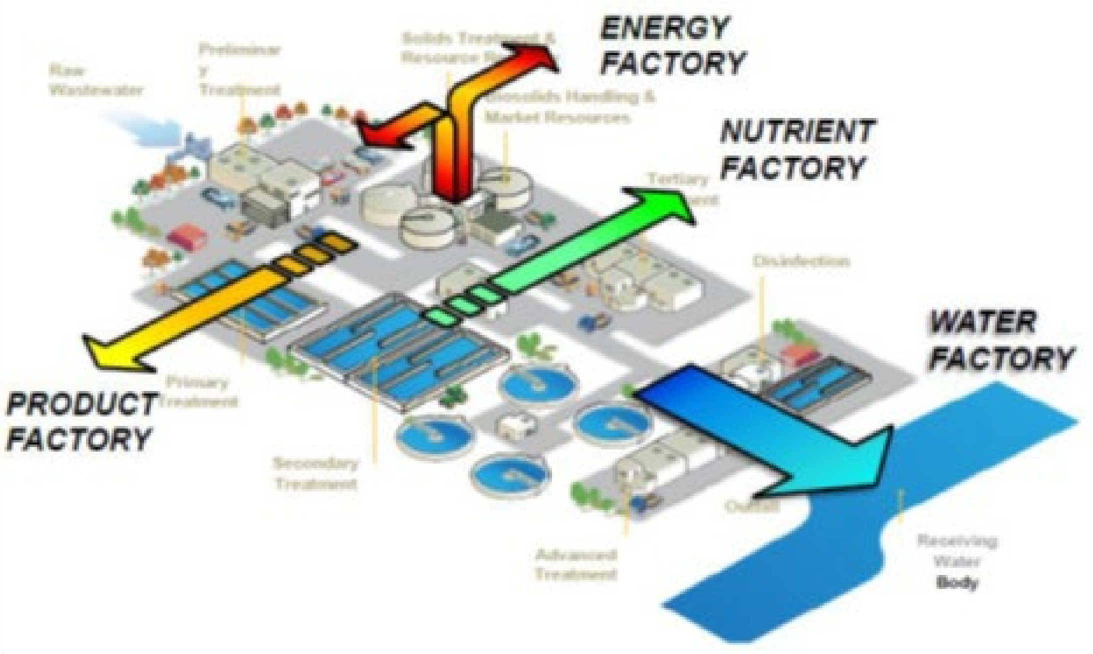


Figure 4 WWTP Resource Recovery

5 Assessment & Scoring

Table 4 below provides the assessment of options against relevant 'Measures of success' and 'what council wants to achieve', including a description of the scoring rationale for each option.

Table 4 Options against relevant Eco-City Strategy Measures and Achievements

Relevant Plan	Measures of Success	What does Council want to Achieve?	Options Assessment	1	2	3	4	5	6	7	8	9	10	11
Environmental Sustainability Plan	*Sustainable Practices Chapter* *Improvement in Council's environmental performance (e.g. per capita / average basis) in terms of:* • *Energy Efficiency* • *Water Consumption* • *Waste Generation* • *Waste Diversion* • *Carbon emissions from transportation*	*Council staff internalise best practices in sustainability in day-to-day decision making, activities and operations towards reducing impacts on the environment (air, water, and land) in a cost-effective manner.*	Not assessed on the basis there is no ability to differentiate between the options.	-	-	-	-	-	-	-	-	-	-	-
	Biodiversity Chapter: *Improvement in water quality*	*The city's urban waterways are attractive places to visit, and the mauri of these waterways is enhanced where practicable.*	The focus of this assessment is the mauri of the city's urban waterways only. Options 5, 10 and 11 have scored the highest on the basis the treated wastewater discharge will be removed from the Manawatū River. Options including large coastal land application areas will not impact on the city's urban waterways.	2	3	2	4	5	3	3	4	4	5	5
		The mauri of urban streams is enhanced, and native aquatic life is thriving	The focus of this assessment is considered equivalent to that of the urban waterways so the same scores have been used.	2	3	2	4	5	3	3	4	4	5	5
			Avg Total	2	3	2	4	5	3	3	4	4	5	5
Waters Plan - Wastewater Chapter	*A regional resource consent for wastewater discharge is lodged by June 2022*	*Wastewater has a lesser impact on the health and mauri of the Manawatū River.*	The focus of this assessment is considered equivalent to that of the urban waterways so the same scores have been used.	2	3	2	4	5	3	3	4	4	5	5
	The wastewater network has the capacity to function without failure in significant rainfall events	*Rangitāne o Manawatū have opportunities for early involvement in all wastewater projects and initiatives.*	Rangitāne o Manawatū have been working with Council in a partnership from the outset of the BPO process. Therefore, this is not assessed on the basis that all options have been developed with a similar level of engagement resulting in there being no ability to differentiate between the options.	-	-	-	-	-	-	-	-	-	-	-

Relevant Plan	Measures of Success	What does Council want to Achieve?	Options Assessment	1	2	3	4	5	6	7	8	9	10	11
		Council understands impact of flows and loads from large trade waste discharges	Investigation on existing and future flows and loads from Tradewaste customers has occurred through the project and impacts all options equally. This is not assessed on the basis that there is no ability to differentiate between the options for this criterion.	-	-	-	-	-	-	-	-	-	-	-
		Council's renewal planning and investment in wastewater infrastructure is based on a better understanding of the asset condition.	This is not assessed on the basis that there is no ability to differentiate between the options for this criterion.	-	-	-	-	-	-	-	-	-	-	-
		Stormwater infiltration and inflow into the wastewater network is reduced.	This is not assessed on the basis that there is no ability to differentiate between the options for this criterion.	-	-	-	-	-	-	-	-	-	-	-
		Wastewater infrastructure is provided to support urban growth.	All options account for 'medium' growth until 2051 (35-year consent duration). After 2051 the growth rate of 0.8/annum has been adopted until 2073. This assessment considers the ability of the option to meet requirements under a high growth rate assumption. i.e. design capacity reached before 35 years requiring additional capacity to be provided. Options 4 and 5 have scored 1 on the basis that the already large land parcels will need to be expanded, resulting in further operational complexity. Option 1 will require a step change in treatment levels and/or the purchase of land not currently allowed for. Options 8,9, 10 and 11 have lower constraints with respect to the receiving environment although there are constraints in respect of infrastructure capacity.	2	3	3	1	1	3	3	4	4	4	4
		Wastewater infrastructure has improved resilience to natural disasters and mechanical failures.	Assessment considers the resilience of the specific infrastructure, the spatial extent of the infrastructure (location and lengths of pipeline) and land areas as well as the complexity of operation and its vulnerability to natural events. Option 1 and 2 has scored 4 on the basis the treatment plant and infrastructure are located at a single site, close to Palmerston North and on the basis that the WWTP will be designed with significant redundancy. Options that include coastal land and/or an ocean outfall (i.e. significant infrastructure at a distance from Palmerston North) are scored lower on the basis of their vulnerability to natural disasters and remote mechanical failure.	4	4	3	3	2	3	3	2	2	2	2
			Avg Total	2.7	3.3	2.7	2.7	2.7	3.0	3.0	3.3	3.3	3.7	3.7
Climate Change Plan	*Decrease in Council's total organisational emissions*	*Reduce Council's organisational greenhouse gas emissions.*	Options including carbon sequestration from trees on coastal land/soils score higher on the basis that they contribute meaningfully to reducing Council's organisational greenhouse gas emissions. Options 3 to 11 (inclusive) will continue to utilise aerated lagoons, and	4	3	2	2	5	2	2	5	5	3	1

Relevant Plan	Measures of Success	What does Council want to Achieve?	Options Assessment	1	2	3	4	5	6	7	8	9	10	11
			so will continue to have higher emissions compared to options 1 and 2 which use alternative treatment processes with lower emissions.											
	Decrease in citywide emissions	*City-wide reduction of CO_2e emissions of 30% by 2031*[3]	Assessed as equivalent to the greenhouse gas emissions sub-criteria so scored similarly.	4	3	2	2	5	2	2	5	5	3	1
			Avg Total	4	3	2	2	5	2	2	5	5	3	1
Resource Recovery Plan	*Decrease in per capita volume of waste sent to landfill*	*The amount of waste that is sent to landfill is minimised (the goal of the WMMP).*	Sludge and biosolids currently composted using green waste and applied as a capping material to the closed landfill site. This is not a long-term option, and the option of applying treated biosolids to land is the preferred future state. The assessment has been based on the total volume of biosolids generated by each option on the basis that the larger the biosolids volumes, the more challenging will be implementing a beneficial re-use strategy for biosolids which avoids disposal to landfill. The score has also considered the extent to which the option concentrates contaminants which may impact on the ability to re-use the biosolids i.e. as a soil amendment. Option1 and 2 score lower on both sludge volume and contaminant concentration as a result.	2	2	3	4	4	4	3	4	3	4	4
	Increase in the proportion of waste diverted from landfill (target 48% by 2025)	*The community considers, and where appropriate implements, new initiatives, and innovative ways to assist in reducing, reusing and recycling wastes.*	The Council is considering a range of interventions (education, incentives and regulations) as a means to achieving adoption of more sustainable water use and waste disposal practices in the home, in order to reduce water use and wastewater flows and loads. As this will apply equally across all options there is considered to be no ability to differentiate between the options so this has not been assessed.	-	-	-	-	-	-	-	-	-	-	-
			Avg Total	2	2	3	4	4	4	3	4	3	4	4
Manawatū River Plan	*Increase in the public use of the river environment*	*Council understands the contribution the Manawatū River makes to the City as its key cultural, environmental and recreation resource.*	Council has developed an understanding of the contribution the Manawatū River makes to the City. This is recognised through the Project Objectives as well as by the importance given to environmental and cultural values assessments within the Project's options development and assessment process. On the basis that this is equivalent for all options this criterion has not been assessed.	-	-	-	-	-	-	-	-	-	-	-
	Increase in native planting and observed biodiversity improvements in suitable locations in the river environment	*Rangitāne o Manawatū is involved in all aspects of planning and delivery of Manawatū River projects and services.*	Rangitāne o Manawatū have been working with Council in a partnership from the outset of the BPO process. As this applies equally across all options there is considered to be no ability to differentiate between the options so this has not been assessed.	-	-	-	-	-	-	-	-	-	-	-

[3] Refer to Goal 4 of Eco-City Strategy Report.

Relevant Plan	Measures of Success	What does Council want to Achieve?	Options Assessment	1	2	3	4	5	6	7	8	9	10	11
		There is increased use of the river environment by the public for active and passive recreation.	Recreational water quality standards can be met for all options including those with a river discharge. There are however differences between options in respect of the levels of achievement of the standards. The options also have impacts on recreation through their influence on public perception. Those options which effectively eliminate discharges to the river are accorded the highest score. For options which discharge to the river the score is a balance of the level of treatment provided and the extent to which the discharge is removed from the river. Option 2 score higher than option 1 on the basis that option 2 removes discharge during the summer low flow period despite both providing very high treatment levels.	3	4	2	5	5	3	3	3	3	5	5
			Avg Total	3	4	2	5	5	3	3	3	3	5	5
			TOTAL (out of 30)	**14**	**16**	**12**	**17**	**21**	**15**	**14**	**19**	**18**	**20**	**18**
			TOTAL Average Score	**3**	**3**	**2**	**3**	**4**	**3**	**3**	**4**	**4**	**4**	**4**

6 Recommendation

6.1 Weighting

A key objective for the Eco-City Strategy is the goal of meeting a 30% reduction in carbon emissions by 2031. On this basis, a carbon analysis was completed to determine how each option contributed to meeting this goal. In summary, the options do not contribute significantly to reducing carbon emissions on the basis that wastewater emissions comprise around 1% of the total emissions for the city. The wastewater BPO option is however a major contributor to Council's carbon emissions. On this basis, it is recommended that the score for alignment with the climate change plan is given greater weighting than scores describing alignment with the other plans. The recommended weightings are as follows:

Table 5 Technical Recommendation of weighting within Eco-City Strategy Plans

Plan	Weighting
Environmental Sustainability Plan	15%
Waters	15%
Climate Change	40%
Resource Recovery	15%
Manawatū River	15%

6.2 Recommended Options

The recommended scoring uses a scale of 1 to 5 to compare how well options align with the Eco-City Strategy Plans (refer Table 2). Each of the options aligns with each of the Plans to varying degrees. None of the options are considered fatally flawed. Technical advisors and Iwi have been involved in the assessment of all options against the Eco-City Strategy to develop the scores.

Overall, those options with the largest land areas which provide for forestry have achieved a higher ranking based on the significant carbon emissions reductions compared to options with long pipelines and land irrigation areas on the fluvial soils.

Table 6 below shows the ranked order of options based on the assessment of 9 sub-attributes across the 5 plans considered within the Eco-City Strategy.

Table 6 Options ranking against Eco-City Strategy Measures

Option Description		Treatment Level	Total Score (out of 30)	Average (total)	Ranking
1	R2 (b)	4	14	3	5
2	R2 (b) (75% DWF land): 760 ha.	4	16	3	6
3	Dual R+L (b) (75% DWF to land): 870 ha.	2	12	2	11
4	L+R(a): 3760 ha	1	17	3	7
5	L+R(b): 2570 ha.	3	21	4	1
6	L+R(d-1) 80 m3/s trigger: 2000 ha.	2	15	3	9
7	L+R(d-2) 62 m3/s trigger: 1640 ha.	2	14	3	10
8	L+R(e-1) 80 m3/s trigger: 3640 ha.	2	19	4	2
9	L+R(e-2) 62 m3/s trigger: 3010 ha.	2	18	4	3
10	O+L: 1470 ha	1	20	4	4
11	O no land	1	18	4	8

It is recommended that all options are considered in conjunction with the wider assessment approach before being recommended for assessment through the BPO Criteria. This will be determined in the BPO Recommendation Report.

Appendix 1: Carbon Footprint Assessment

PALMERSTON NORTH CITY COUNCIL
NATURE CALLS
Te whakamaho tika i a tātou wai

PALMERSTON NORTH WASTEWATER BEST PRACTICABLE OPTION (BPO) REVIEW

Draft Carbon Footprint Assessment

JULY 2021

PALMERSTON NORTH CITY COUNCIL

Prepared for Palmerston North City Council by:

Stantec

QUALITY STATEMENT

Project Details

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Reviewed by:	Peter Brown	12/05/2021
Approved & Issued by:	Roger Hulme	14/05/2021

Revision Schedule

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
1	14/5/21	Draft for Client Review	Andrew Slaney	Andrew Wong	Peter Brown	Roger Hulme
2	27/5/21	Update for carbon sequestration	Andrew Slaney	Andrew Wong	Jim Bradley	Melaina Voss
3	30/7/21	Update following updated summaries and Peer Review comments	Andrew Slaney	Michael Tan	Jim Bradley	Melaina Voss

Executive Summary

A high-level assessment of the carbon footprints of the shortlisted PNCC BPO wastewater treatment and discharge options was undertaken to compare the relative global warming impact of the options and to assess the compatibility of the options with the goal of a 30% reduction in CO_2-e emissions by 2031 contained in Palmerston North's Eco City Strategy 2021-31.

The carbon assessment included both embodied (construction) and operational carbon emissions over a 50-year period. The total emissions (embodied + operational) are expressed as tonnes of CO_2 equivalent (CO_2-e). CO_2-e includes methane and nitrous oxide emissions converted to the equivalent mass of CO_2 in terms of global warming potential.

The estimated 50-year carbon emissions are presented in Table 1-1 and Figure 1-1 overleaf, from lowest to highest. The net change relative to the current WWTP emissions are also shown, with those options with a net reduction highlighted.

Annual operational carbon emissions ranged from 2,000 – 8,000 tonnes CO_2-e per annum (not including reduction due to carbon sequestration in trees). This amounts to around 1% of the estimated total annual carbon emissions from Palmerston North (500,000 tonnes CO_2-e p.a.).

The three coastal land options have the lowest carbon footprint due to the carbon sequestered in the forestry plantation trees, which significantly offsets the operational carbon emissions from wastewater treatment and discharge.

The ocean outfall option (O) has the highest carbon footprint of the shortlisted options due to:

- High embedded carbon (long pipeline)
- Methane emissions (from the aerated facultative lagoons)

Aside from the coastal land options, the only other options that meet the 30% reduction in CO_2-e emissions by 2031 are the two local river discharge options (R(2) and R(2)b). These options have the lowest embodied carbon as well as low operational emissions (due to removing the aerated facultative lagoons).

Table 1-1: PNCC Wastewater BPO 50-Year Carbon Emissions

Option	TL	Embodied Carbon	Average Operational Carbon Emissions	Average Annual Sequestered Carbon	50-Year Carbon Emissions	Net Change from Current Emissions
		t CO_2-e	t CO_2-e p.a.	t CO_2-e p.a.	t CO_2-e	%
L + R (b)	3	68,700	2,340	(22,500)	-299,000	-173%
L + R (e-1)	2	67,600	8,530	(31,900)	-189,000	-146%
L + R (e-2)	2	66,300	8,470	(26,400)	-73,000	-118%
R2 (b) 2	4	7,000	2,400	-	129,000	-69%
R2 (b)	4	3,500	2,500	-	131,000	-68%
O + L	1	66,500	8,210	(12,900)	206,000	-50%
L + R (d-2)	2	21,600	8,400	-	450,000	10%
L + R (d-1)	2	22,000	8,450	-	453,000	11%
Dual R + L (b)	2	37,000	8,240	-	457,000	12%
L + R (a)	1	24,400	8,800	-	473,000	15%
O	1	63,600	8,140	-	479,000	17%

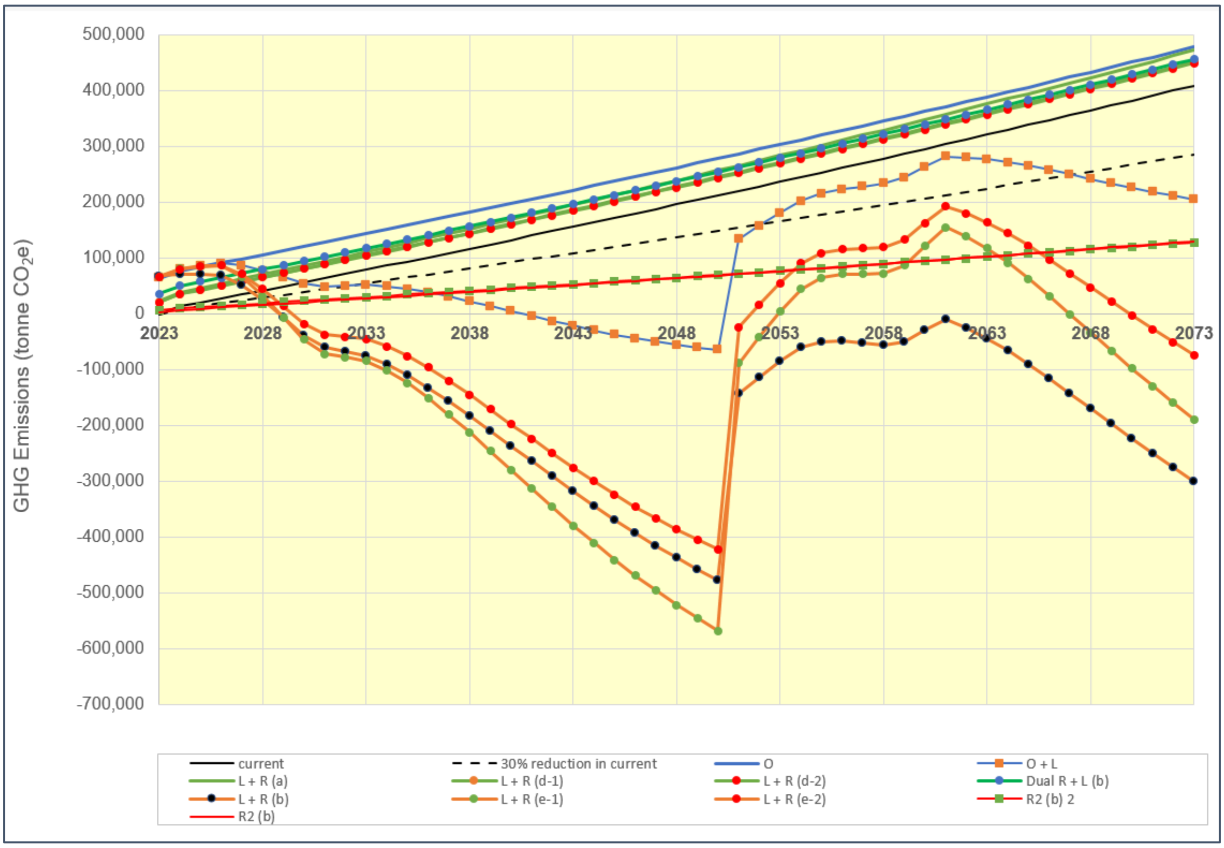

Figure 1-1: PNCC Wastewater BPO 50-Year Carbon Emissions

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1 Introduction

1.1 Background

Palmerston North City Council (PNCC) are currently reviewing options for the city's wastewater treatment and discharge, in preparation for the Palmerston North wastewater treatment plant (WWTP) resource consent application. The aim of the review is to identify a Best Practicable Option (BPO) for the treatment and discharge of treated wastewater to be taken forward for resource consent application.

The BPO review has identified a shortlist of 11 options which are currently being presented to stakeholders for consultation and feedback (Stantec, February 2021b).

An important criterion in the BPO assessment is compatibility with Palmerston North's 2021-31 (Draft) Eco City Strategy. This Eco City Strategy was developed to achieve the goal of an "eco city" which is for Palmerston North to decrease carbon emissions and reduce its ecological footprint (PNCC, 2021). The strategy contains a target reduction in carbon dioxide equivalent (CO_2-e) emissions of 30% by 2031.

1.2 Purpose of this Report

The purpose of this report is to undertake a high level comparison of the carbon footprints of the shortlisted wastewater treatment and discharge options. This will allow:

- Comparison of the carbon footprints of the shortlisted options.
- Comparison of the carbon footprints of the shortlisted options against the current WWTP
- Assess the compatibility of the shortlisted options with the goal of a 30 % reduction in CO_2-e emissions for the city.

Note:

Due to the early stage of this project (BPO assessment), there is insufficient design definition to undertake a detailed carbon inventory for the options, and the hence the objective of this report is to assess the ranking of the options in terms of carbon footprint, as well as gain an idea of the main emissions contributors and a rough estimate of the magnitude of emissions from the schemes.

2 Shortlisted Options

The shortlisted options along with the receiving environments are presented in Table 2-1 and in Figure 2-1. For descriptions and details of the treatment levels and discharge options, refer to Stantec (February 2021) and Stantec (August 2021).

Table 2-1: PNCC Wastewater BPO Shortlisted Options and Receiving Environments (Percent of Annual Volume)

Option	Treatment Level	Primary Environment	Secondary Environment	High Wet Weather Flows
O	1	Ocean 90%	n/a	Tōtara Rd 10%
O+L	1	Ocean 71%	Land (Coastal) 19%	Tōtara Rd 10%
L+R (a)	1	Land (Inland) 90%	n/a	Tōtara Rd 10%
L+R (d-1)	2	Land (Inland) 53%	River Tōtara Rd 47%	n/a
L+R (d-2)	2	River Tōtara Rd 57%	Land (Inland) 43%	n/a
Dual R+L (b)	2	River Tōtara Rd / Opiki 86%	Land (Inland) 14%	n/a
L+R (b)	3	Land (coastal) 90%	n/a	Tōtara Rd 10%
L+R (e-1)	2	Land (coastal) 53%	River Tōtara Rd 47%	n/a
L+R (e-2)	2	River Tōtara Rd 57%	Land (coastal) 43%	n/a
R2 (b) 2	4	River (Tōtara Rd) 86%	Land (Inland) 14%	n/a
R2 (b)	4	River (Tōtara Rd) 100%	n/a	n/a

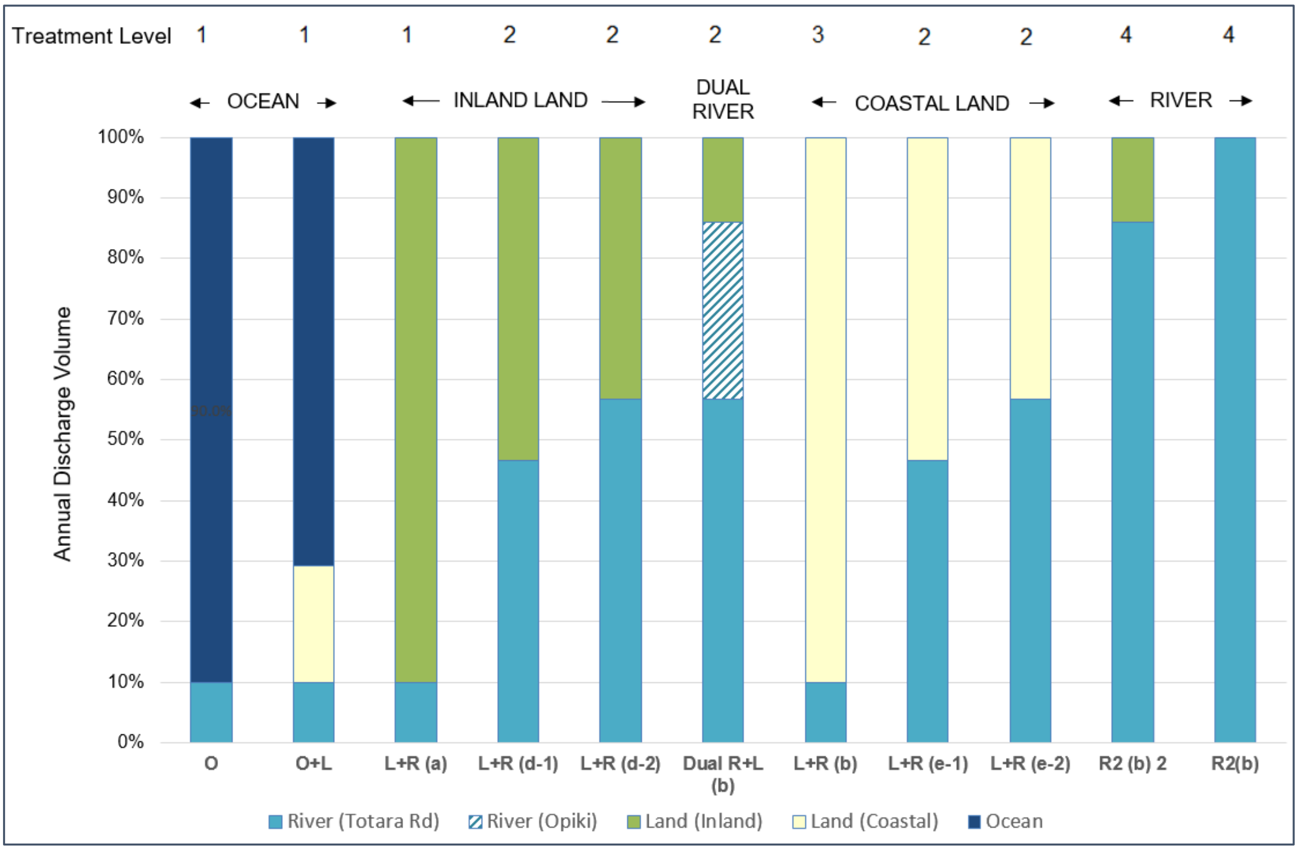


Figure 2-1: PNCC Wastewater BPO Shortlisted Options and Receiving Environments (Percent of Annual Volume)

3 Embodied Carbon

3.1 Major Capital Works Items

As the project is at the initial concept stage, the level of project definition does not allow for a detailed embodied carbon inventory of each option. Therefore, only the major civil works elements were included in the embodied carbon assessment as these were assumed to comprise the bulk of the embodied carbon. These are discussed below.

Treatment

The BPO review identified four treatment levels to meet the requirements of the shortlisted receiving environments for the treated wastewater. All four treatment levels require upgrade works to the existing WWTP, for either population growth, asset renewal or increased treatment.

The major treatment capital works items for the treatment levels are presented in Table 3-1. For a more detailed description of the treatment requirements, refer to the Shortlist Treatment Addendum (Stantec, February 2021).

Table 3-1: PNCC Wastewater BPO Major Treatment Capital Works Items

Treatment Levels 1 & 2	Treatment Level 3	Treatment Level 4
• Grit removal tank • Primary sedimentation tanks • Secondary clarifier	• Grit removal tank • Primary sedimentation tanks • Activated sludge bioreactors • Secondary clarifier • Secondary sludge facilities	• Grit removal tank • Primary sedimentation tanks • Activated sludge bioreactors • Membrane bioreactors • Secondary sludge facilities

Discharge

The BPO review identified five environments for the treated wastewater:

- Manawatū River (at the WWTP Tōtara Rd site)
- Manawatū River (below Oroua River confluence at Opiki)
- Land (inland fluvial/loam soils)
- Land (coastal sandy soils)
- Ocean (in the South Taranaki Bight)

The major capital works items associated with the discharge options are presented in Table 3-2. For a more detailed description of the discharge requirements, refer to the Shortlisted Options Summary Report (Stantec, August 2021).

Table 3-2: PNCC Wastewater BPO Major Discharge Capital Works Items

River at Tōtara Rd	River at Opiki	Inland or Coastal Land	Ocean
• Constructed wetland	• Transfer pipe and pump station • Constructed wetland	• Transfer pipe and pump stations • Irrigation storage lagoon • Irrigation infrastructure	• Transfer pipe and pump stations • Ocean outfall

Exclusions

Due to the high-level nature of this assessment, only the major reinforced concrete water retaining structure embodied carbon emissions were calculated. This forms only part of the total embodied carbon of the WWTP upgrade works, other items include:

- Access platforms and structures
- Buildings
- Pipework, pumps and other mechanical equipment
- Earthworks

To account for total WWTP embedded carbon, a factor was applied to the reinforced concrete tank embodied carbon estimates on the basis that roughly, the total amount of mechanical, electrical and ancillary works should be proportional to the major water retaining structures which form the main civil aspects of the WWTP upgrades. The following factors were applied to the reinforced concrete tank embodied carbon estimates, based on a published embodied carbon inventory for a water recovery park in the UK (Georgiou *et al*, 2019):

Treatment levels 1 & 2: 50%

Treatment level 3: 150%

Treatment level 4: 150%.

3.2 Capital Works Items Sizing

Concept sizing of the major capital works elements for each option is provided in Table 3-3.

Table 3-3: PNCC Wastewater BPO: Capital Works Sizing

Option	TL	Reinforced Concrete Volume	Wetland Volume	Transfer Pipe OD	Transfer Pipe Length	Irrigation Lagoon Volume	Irrigation Area
		m³	m³	mm	km	m³	Ha
O	1	1,240	40,000	1,332	38.0	n/a	n/a
O+L	1	1,240	40,000	1,332	38.0	10,000	1,130
L+R (a)	1	1,240	40,000	1,332	11.0	200,000	2,890
L+R (d-1)	2	1,240	40,000	1,332	11.0	90,000	1,540
L+R (d-2)	2	1,240	40,000	1,332	11.0	90,000	1,260
Dual R+L (b)	2	1,240	80,000	1,332* 1,332*	14.0 7.0	30,000	 670
L+R (b)	3	3,400	40,000	1,332	36.0	160,000	1,975
L+R (e-1)	2	1,240	40,000	1,332	36.0	60,000	2,800
L+R (e-2)	2	1,240	40,000	1,332	36.0	50,000	2,315
R2 (b) 2	4	2,000	180,000	630	11.0	40,000	585
R2 (b)	4	**2,000**	180,000	n/a	n/a	n/a	

* Dual R + L option has two pipes: The longer pipe is to the river discharge at Opiki; the shorter pipe is to land discharge

3.3 Embodied Carbon Emission Factors

Carbon emission factors for materials and construction activities are available from a variety of sources. In New Zealand, the Ministry for the Environment has published a useful summary (MfE, 2020). Other sources of emissions factors are published by the Transport Authorities Greenhouse Group Australia and New Zealand (TAGG, 2013) and the Infrastructure Sustainability Council of Australia (ISCA, 2020).

Note: Emissions from transport of materials to site are ignored in this assessment as they are assumed to be minor and would not affect the comparative assessment significantly. The embodied carbon emissions factors used in the assessment are presented in Table 3-4.

Table 3-4: PNCC Wastewater BPO: Embodied Carbon Emission Factors

Component	Unit	Embodied Carbon $kgCO_2$-e/unit	Comment / Reference
Concrete	m^3	337	40 MPa concrete - MfE (2020) Table 71
Reinforcing steel	kg	1.23	ISCA (2020)
Reinforced concrete at 200 kg/m^3 steel	m^3	583	From the above two values
Galvanised steel pipe (material only)	kg	2.46	ISCA (2020)
GRP pipe (material only)	kg	8.02	ISCA (2020)
PE pipe (material only)	kg	2.54	ISCA (2020)
Diesel	litre	2.70	MfE (2020) Table 4
Aggregate for pipe laying	m^3	3.14	ISCA (2020)
Earthworks (at 1.2 litres diesel / m^3)	m^3	3.24	TAGG (2013) Table 5-6

For the transfer pipes, embodied carbon emissions from earthworks needed to install the pipes were included. The earthworks required were calculated using the dimensions in Figure 3-1.

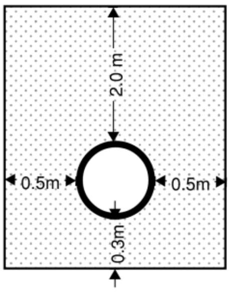


Figure 3-1: Transfer Pipe Trench Dimensions for Earthworks Volume Calculation

The embodied carbon of the transfer and irrigation pipes are presented in .

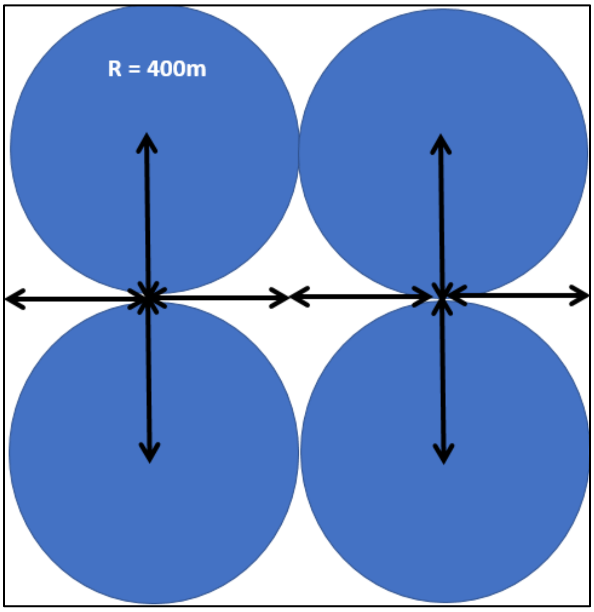
Table 3-5: PNCC Wastewater BPO: Transfer Pipe Embodied Carbon per Metre Installed

Outside Diameter	Inside Diameter	Material	Class	Pipe Mass	Earthworks Volume	Embodied Carbon ($kgCO_2$-e/m)		
mm	Mm			kg/m	m^3/m	Plastic	Earthworks + Aggregate	Total
1332	1287	GRP	PN16	195	16.9	1,564	77.7	1,642
1229	1189	GRP	PN16	167	15.7	1,339	72.2	1,412
900	765	PE100	SDR 13.6	176	12.2	447	55.9	1,467
630	528	PE100	SDR 13.6	110	10.3	178	43.8	222
315	285	PE100	SDR 21	14	1.7	36	5.4	41
50	45	PE100	SDR 21	0.37	n/a	0.94	0	0.94

For irrigation areas, the following assumptions were made for the purposes of embodied carbon estimates (note these are for the purposes of embodied carbon estimate only. No preliminary design has been undertaken on irrigation infrastructure at this stage).

Table 3-6: PNCC Wastewater BPO: Embodied Carbon Irrigation Assumptions

Component	Unit	Value	Reference
Centre Pivot Irrigation (inland land)			
Centre pivot radius (inland land)	m	400	Estimate, large areas require large pivots
Area covered per pivot	Ha	50	
Fraction of area covered by pivots	%	79	
Weight of steel per centre pivot	tonnes	19.5	At 48.6 kg per metre (Jacobs, 2006)
Weight of concrete per centre pivot	tonnes	7.2	Jacobs, 2006
Length of distribution main per centre pivot	m	800	2 x radius; See Figure 3-2
Distribution main diameter	mm	300	
Solid Set Irrigation (coastal land)			
Distribution main spacing	m	250	
Lateral spacing	m	25	
Distribution main diameter	mm	300	
Lateral diameter	mm	50	



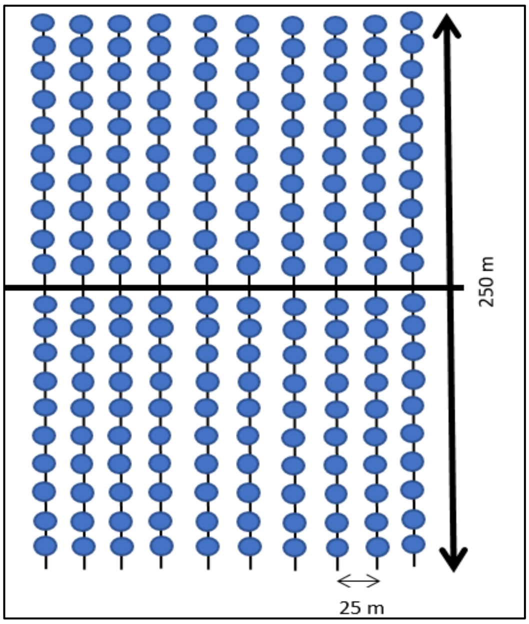


Figure 3-2: Centre Pivot and Solid Set Irrigation Layout Assumptions: Centre Pivot (L) and Solid Set (R)

Concept sizing of the major irrigation works elements for each option is provided in Table 3-7.

Table 3-7: PNCC Wastewater BPO: Irrigation Sizing for Purposes of Embodied Carbon Assessment

Option	Irrigation Location	Irrigation Area	Irrigation System	No. of Centre Pivots	Distribution Main Length	Lateral Length
		Ha			km	km
O+L	Coastal	1,130	SS	n/a	45	452
L+R (a)	Inland	2,890	CP	46	36	n/a
L+R (d-1)	Inland	1,540	CP	24	20	n/a
L+R (d-2)	Inland	1,260	CP	20	16	n/a
Dual R+L (b)	Inland	670	CP	10	8.0	n/a
L+R (b)*	Coastal	1,975	SS	n/a	79	790
L+R (e-1)	Coastal	2,800	SS	n/a	112	1,120
L+R (e-2)	Coastal	2,315	SS	n/a	93	926
R2 (b) 2	Inland	585	CP	9	7.2	n/a

* Coastal land discharge option based on treatment level 3 to achieve lower TN and lower land area. Alternative of larger land area and treatment level 1 available but not assessed.

3.4 Embodied (Construction) Carbon Estimates

The embodied carbon estimates for the shortlisted options are presented in Table 3-8 from lowest to highest.

Table 3-8: PNCC Wastewater BPO: Embodied Carbon Summary

Option	Embodied Carbon (tonnes CO_2e)						
	WWTP Concrete	WWTP Other	Wetland	Transfer Pipe	Storage Lagoon	Irrigation System	Total
R2 (b)	1,170	1,760	590	0	0	0	**3,520**
R2 (b) 2	1,170	1,760	590	2,500	130	890	**7,040**
L + R (d-2)	730	370	130	18,100	300	1,980	**21,610**
L + R (d-1)	730	370	130	18,100	300	2,370	**22,000**
L + R (a)	730	370	130	18,100	650	4,450	**24,430**
Dual R + L (b)	730	370	260	34,500	100	990	**36,950**
O	730	370	130	62,400	0	0	**63,630**
L + R (e-2)	730	370	130	59,100	170	5,830	**66,330**
O + L	730	370	130	62,400	40	2,850	**66,520**
L + R (e-1)	730	370	130	59,100	200	7,050	**67,580**
L + R (b)	1,990	2,990	130	59,100	520	4,980	69,710

* Coastal land discharge option based on treatment level 3 to achieve lower TN and lower land area. Alternative of larger land area and treatment level 1 available but not assessed.

As shown in Table 3-8, options involving land discharge or ocean outfall have the highest embodied carbon due to the long transfer pipe distances and large irrigation areas which require large masses of plastic for buried pipework as well as steel for the centre pivot irrigators.

As a result, the options that maintain the existing discharge location (R2 (b) and R2 (b)2) have the lowest embodied carbon.

4 Operational Carbon

4.1 Emissions Included

The following emissions were included in the operational carbon assessment:

- Methane emissions from the existing aerated facultative lagoons (where retained)
- Nitrous oxide emissions from new biological nitrogen removal (BNR) tanks
- Nitrous oxide emissions from nitrogen applied to land (in treated wastewater)
- Nitrous oxide emissions from nitrogen discharged to surface water (in treated wastewater)
- Carbon emission component of grid electricity consumption
- Carbon emissions from grid natural gas consumption
- Carbon emissions associated with aluminium sulphate consumption (for phosphorus removal)

4.2 Emissions Excluded

The following operational carbon emissions were excluded from the assessment as they were assumed to be insignificant and / or would be common across all options. (As stated previously, the current level of project definition does not allow a detailed emissions inventory of each option).

- Methane emissions from primary clarifiers and sludge handling facilities
- Diesel for transporting screenings, grit and biosolids to landfill
- Methane emissions from landfilled biosolids
- Carbon credits for heat and/or electricity generated from biogas cogeneration engines

4.3 Energy and Chemical Consumption

The energy and chemical consumption of the shortlisted options per unit volume is presented in Table 4-1.

Table 4-1: PNCC Wastewater BPO Energy and Chemical Consumption Summary

Option	WWTP Electricity	Transfer Pumping Electricity	Grid Gas	Alum Consumption
	kWh/ML	kWh/ML	kWh/ML	kg/ML
O	301	230	14	0.0
O+L	301	230	14	0.0
L+R (a)	301	129	14	0.0
L+R (d-1)	301	76	14	12.6
L+R (d-2)	301	62	14	21.5
Dual R+L (b)	301	85	14	38.7
L+R (b)	406	223	14	0.0
L+R (e-1)	301	132	14	12.6
L+R (e-2)	301	107	14	21.5
R2 (b) 2	611	40	14	52.9
R2 (b)	611	0	14	72.1

4.4 Emission Factors

Methane Emissions

Methane emissions from the existing aerated facultative lagoons are thought to be the major source of greenhouse gas emissions from the existing WWTP. The lagoons are designed to store and digest sludge in their base; this process generates methane which is released into the atmosphere.

It should be noted that a significant fraction (at least 50%) of the influent solids are captured in the primary clarifiers and digested in the anaerobic digesters, where the methane generated is either used to generate heat and electricity or is flared (and therefore does not contribute to the carbon footprint of the plant as the IPCC Guidelines exclude CO_2 generated from biogenic sources in WWTP assessments).

In the absence of site measurements there is a high level of uncertainty in the amount of methane emitted from wastewater treatment ponds. The Intergovernmental Panel for Climate Change (IPCC) Guidelines methodology uses a methane correction factor (MCF) which is the ratio of actual methane generated to the theoretical maximum capacity of the waste.

MCF values for ponds found in the literature are presented in Table 4-2.

Table 4-2: Facultative Ponds Methane Correction Factors

Source	Average	Range
IPCC (2019) Ch. 6 Table 6.3	0.20 (default value)	0.0 - 0.3
WSAA (2009) (aerated lagoon)	0.10	0.03 – 0.20
Paredes et al (2015) (includes anaerobic ponds)	0.72	

For the purposes of this study, the IPCC default MCF value has been selected.

The derivation of the aerated facultative lagoons methane emission factor is presented in Table 4-3.

Table 4-3: PNCC Wastewater BPO: Aerated Facultative Lagoon Methane Emission Factor Basis

Component	Unit	Value	Reference
Maximum methane generation	kg CH_4/kg COD	0.250	IPCC (2019) Ch. 6 Table 6.2
Methane correction factor		0.20	IPCC (2019) Ch. 6 Table 6.3
Methane emission factor	kg CH_4/kg COD	0.050	Generation x correction factor
Influent COD particulate fraction		0.60	Estimate - typical value
Particulate COD removal in primary clarifiers		50%	Estimate - typical value
Fraction of influent COD remaining in primary effluent		70%	From above parameters
Methane emission factor (influent COD basis)	kg CH_4/kg COD_{in}	0.035	From above parameters
Average influent COD concentration	mg/L	547	Stantec (2018) Table 6-1
Methane emission factor (volume basis)	kg CH_4/ML	19.1	
Methane global warming potential	x CO_2	25	MfE (2020) Table 1
Methane emission factor	**kgCO_2-e / ML**	**479**	

Nitrous Oxide Emissions

Nitrous oxide (N_2O) has a global warming potential approximately 300 times higher than carbon dioxide and can be a significant source of greenhouse gas emissions from wastewater treatment plants. N_2O is generated as a by-product of nitrification, or as an intermediate product of denitrification.

There are many factors affecting N_2O emissions from wastewater treatment plants, such as the temperature and dissolved oxygen concentration of the wastewater, and other operational conditions. The IPCC Guidelines use a nitrous oxide emission factor (kg N_2O per kg N) to estimate nitrous oxide from wastewater treatment processes. Due to the number of factors affecting N_2O emissions there is a wide range of emission factor values reported in the literature. For example, the IPCC Guidelines have a default emission factor value of 0.016 for “aerobic treatment plants” with a reported range of 0.00016 – 0.045 (IPCC, 2019 Ch. 6).

A recent Australian review of nitrous oxide emission factors for wastewater treatment plants recommended lower emission factors than the IPCC default, and inversely proportional to the degree of nitrogen removal (de Haas and Ye, 2021). A graph of measured emission factors versus total nitrogen (TN) removal is shown in Figure 4-1.

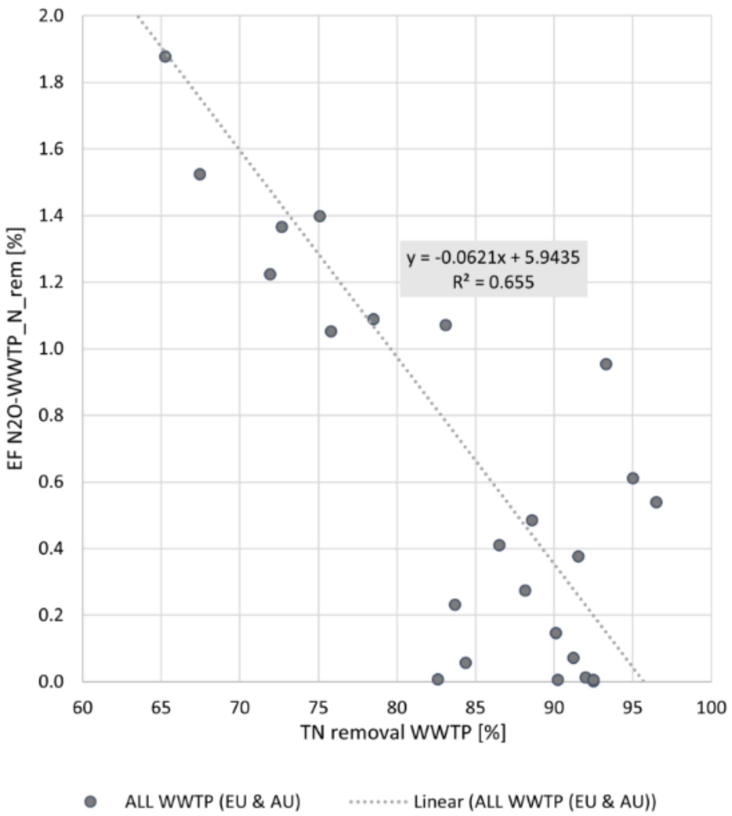


Figure 4-1: Average WWTP N_2O emission factors with respect to TN removal (de Hass & Ye 2021)

For the purposes of this study, a TN removal of 90% is assumed. An emission factor of 0.31 % per % removal is recommended by de Haas and Ye (2021). This equates to an emission factor of 0.28% on the basis of influent TN which is less than a fifth of the current IPCC default value (1.6%).

N_2O emissions can also occur from wastewater discharged into the environment (either into water or onto land). The IPCC Guidelines contain N_2O emissions factors for wastewater discharges to aquatic environments as well as to land (which are covered under the Managed Soils chapter).

The selected emissions factors are presented in Table 4-4.

Table 4-4: Nitrous Oxide Emission Factors

Source	Units	Value
BNR plant emissions (de Haas and Ye, 2021)	kg N_2O-N / kg Nin	0.28%
Freshwater, estuarine, and marine discharge (IPCC 2019)	kg N_2O-N / kg N	0.50%
Discharge to soil (from fertilisers, organic amendments and crop residues) (IPCC 2019)	kg N_2O-N / kg N	1.0%

The derivation of the nitrous oxide emission factors are presented in Table 4-5.

Table 4-5: PNCC Wastewater BPO: Nitrous Oxide Emission Factors

Component	Unit	Value	Reference
Activated sludge N_2O-N emission factor	kg N_2O-N / kg Nin	0.28%	de Haas and Ye (2021)
Average influent TN concentration	mg/L	43	Stantec (2018) Table 6-1
Activated sludge N_2O emission factor (volume basis)	kg/ML	0.19	
N_2O global warming potential	x CO_2	298	MfE (2020) Table 1
Activated sludge N_2O emission factor (volume basis)	**kgCO_2-e / ML**	**56**	
Treated wastewater N concentration – TL 1 & 2	mg/L	35	
Treated wastewater N concentration – TL 3	mg/L	10	
Treated wastewater N concentration – TL 4	mg/L	4	
Treated wastewater N_2O emission factors (volume basis)			
		River / Ocean	Land
Treatment Levels 1 & 2	kgCO_2-e / ML	82	164
Treatment Level 3	kgCO_2-e / ML	23	47
Treatment Level 4	kgCO_2-e / ML	9.4	19

Other Emissions

Other emissions included in the operational carbon assessment are electricity, natural gas and aluminium sulphate (alum). Emissions factors for these are presented in Table 4-6.

Table 4-6: PNCC Wastewater BPO: Operational Carbon Emission Factors

Component	Unit	Value	Reference
Grid Electricity	$kgCO_2$-e / kWh	0.1097	MfE (2020) Table 9 & Table 11
Natural Gas (from grid)	$kgCO_2$-e / kWh	0.2070	MfE (2020) Table 3 & Table 6
Aluminium sulphate	$kgCO_2$-e / kg	0.718	ISCA (2020)

4.5 Operational Carbon Estimates

The operational carbon emission estimates (volumetric basis) for the shortlisted options are presented in Table 4-7 from lowest to highest.

Table 4-7: PNCC Wastewater BPO: Embodied Carbon Summary (Volumetric Basis)

Option	Treatment Level	Operational Carbon (kg CO_2e / ML)					
		CH_4 Emissions	N_2O Emissions	Grid Electricity	Grid Gas	Alum Dosing	Total
L + R (b)	3	0	100	71	14	0	**185**
R2 (b) 2	4	0	67	72	14	38	**190**
R2 (b)	4	0	65	67	14	52	**198**
Current	1	479	82	30	14	33	**637**
O	1	479	82	71	14	0	**645**
O + L	1	479	98	60	14	0	**651**
Dual R + L (b)	2	479	94	39	14	28	**653**
L + R (d-2)	2	479	117	41	14	15	**666**
L + R (d-1)	2	479	126	43	14	9	**670**
L + R (e-2)	2	479	117	46	14	15	**671**
L + R (e-1)	2	479	126	49	14	9	**676**
L + R (a)	1	479	156	49	14	0	**697**

As shown in Table 4-7, options which include treatment levels 3 and 4 have lower calculated operational carbon emissions. This is due to the replacement of the aerated facultative lagoons with an activated sludge process (with activated sludge, all solids are captured within the process rather than a portion being anaerobically digested in the bottom of open lagoons).

As discussed earlier, the calculated CH_4 and N_2O emission factors have a high uncertainty as demonstrated by the wide range of values reported in the literature.

5 Carbon Sequestration

5.1 Methodology

Forestry

As part of the BPO project, consultants PDP in undertaking the land application assessment, determined that *pinus radiata* was the preferred crop for the coastal land options. Therefore, for the shortlisted options that include a coastal land discharge element, it is assumed that the land will be planted in *pinus radiata*. If the land was not already planted in trees (i.e., the plantation is developed specifically for the land treatment system) it is appropriate that the carbon sequestered by the pine trees is included in the carbon footprint assessment. For land already in pine plantation, then there is no change due to the land application system and no sequestration credit should apply.

The carbon sequestered by pine trees was calculated using the methodology described in the Ministry for Primary Industries Carbon Look-up Tables for Forestry in the Emissions Trading Scheme (MPI, 2017). Under the ETS methodology, when the trees are harvested, most of the sequestered carbon is released back into the atmosphere, with the residual carbon left over decaying over a 10-year period at the same time as the new trees grow. This results in a cyclical “saw tooth” pattern of sequestered carbon over time.

The assumptions used in the carbon footprint assessment are presented in Table 5-1.

Table 5-1: PNCC Wastewater BPO: Forestry Carbon Sequestration Assumptions

Component	Unit	Value	Reference / Comment
Fraction of land already planted in pine trees	%	60%	Estimate
Species planted		Pinus radiata	Common species in the region
Age of trees at harvest	years	28	Default value for ETS (MPI, 2017)

Note: It could be argued that operational emissions should take priority over sequestration credits, ie it should not be possible for PNCC to “plant away” carbon emissions from the treatment and discharge scheme as surrounding land use may change to forestry in future meaning no net change due to the scheme. However for the purposes of this assessment, sequestration credits have been included to show the relative impact of forestry sequestration compared to operational emissions of the schemes.

Pasture

For the shortlisted options that include an inland land discharge element, it is assumed that the land will be planted in some form of pasture with the material harvested under a cut and carry system (e.g. silage, bailage, hay). Cut and carry pasture does not have any carbon emissions (above the nitrous oxide emissions due to the treated wastewater, described in Section 4.4). Dairy farms have GHG emissions of between 3 – 19 tonnes CO_2e/ha/y, and sheep and beef farms 0.4 – 6.5 tonnes CO_2e/ha/y (AgFirst, 2019). Therefore, it could be argued that if land that is currently grazed is included in the land treatment system (i.e. converted into cut and carry) there is a net reduction in emissions from that land. However harvested material will be fed to livestock elsewhere so that much then depends on the off-site effects, e.g. farm management, etc. Therefore no carbon credit is applied to the cut and carry land treatment schemes. If inland land discharge options were planted in forestry, sequestration would apply however inland forestry plantations are not included in the shortlisted options considered so far.

6 Life Cycle Carbon Emissions

6.1 10-Year Cumulative Emissions Graph

The calculated 10-year cumulative embedded plus operational carbon emissions for the shortlisted options are presented in Figure 6-1. The dashed black line represents PNCC's target of 30% reduction in carbon emissions, relative to the current operation, by 2031 as set out in the Eco-City Strategy 2021 (shown by the dashed vertical red line).

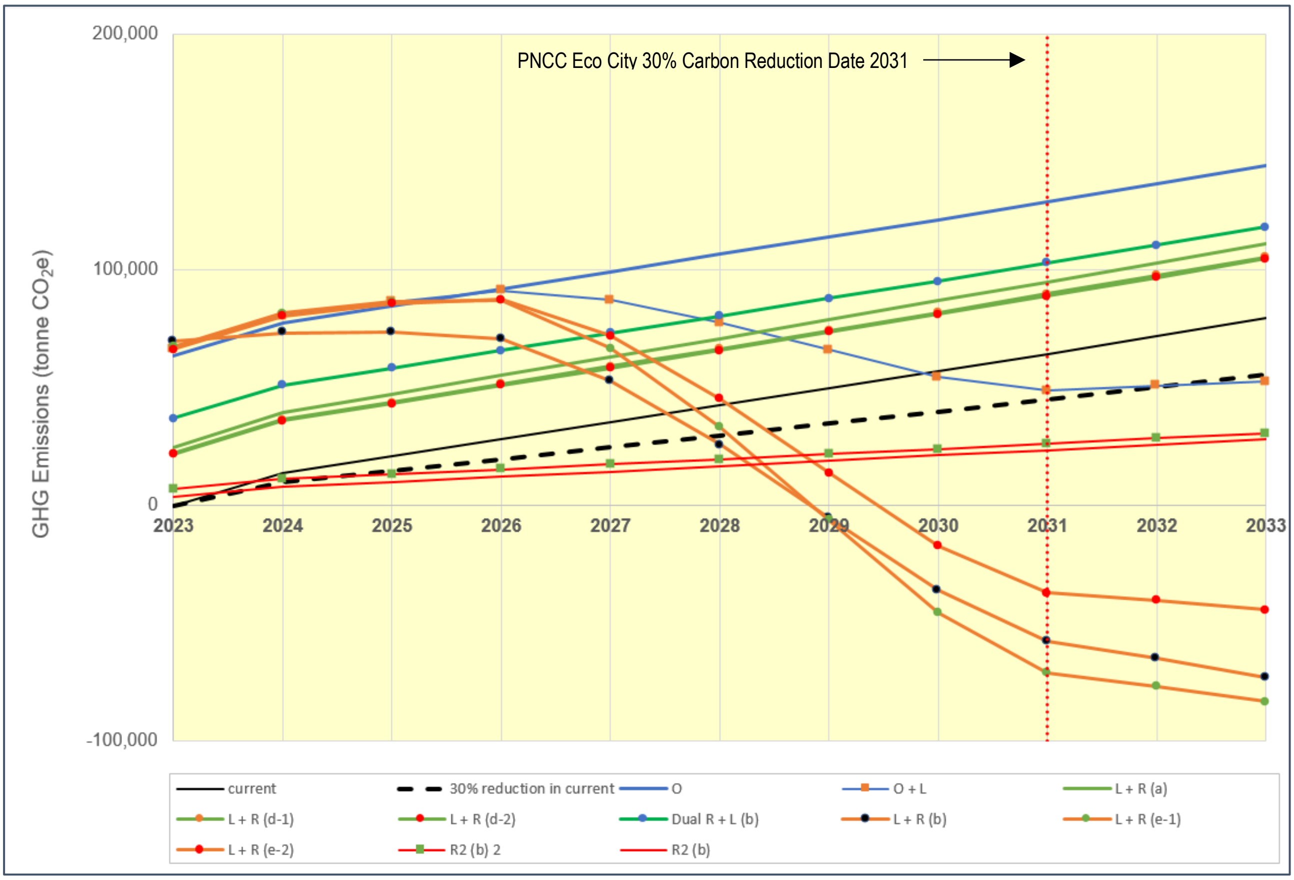


Figure 6-1: PNCC Wastewater BPO 10 Year Cumulative Carbon Emissions

The starting values (year 2023) represent the embodied carbon emissions. For the options not involving forestry the cumulative emissions increase over time.

For the options involving forestry plantations (coastal land discharge), the cumulative emissions reduce with time due to the carbon sequestered in the trees being larger than the operational carbon emissions. As mentioned previously it could be argued that sequestration credits do not apply as surrounding land use may change over time to forestry (ie no net change due to the scheme). However for the purposes of this assessment, sequestration credits have been included to show the relative impact of forestry sequestration compared to operational emissions of the schemes.

Of the non-forestry options, the local river discharge options (R2(b) and R2(b)2) are the only options that will provide a reduction in carbon emissions relative to the current operation. This is due to the removal of the facultative pond methane emissions as well as having the lowest embodied carbon.

6.2 50-Year Cumulative Emissions Graph

The calculated 50-year cumulative embedded plus operational carbon emissions for the shortlisted options are presented in Figure 6-2Figure 6-1. The dashed black line represents PNCC's target of 30% reduction in carbon emissions.

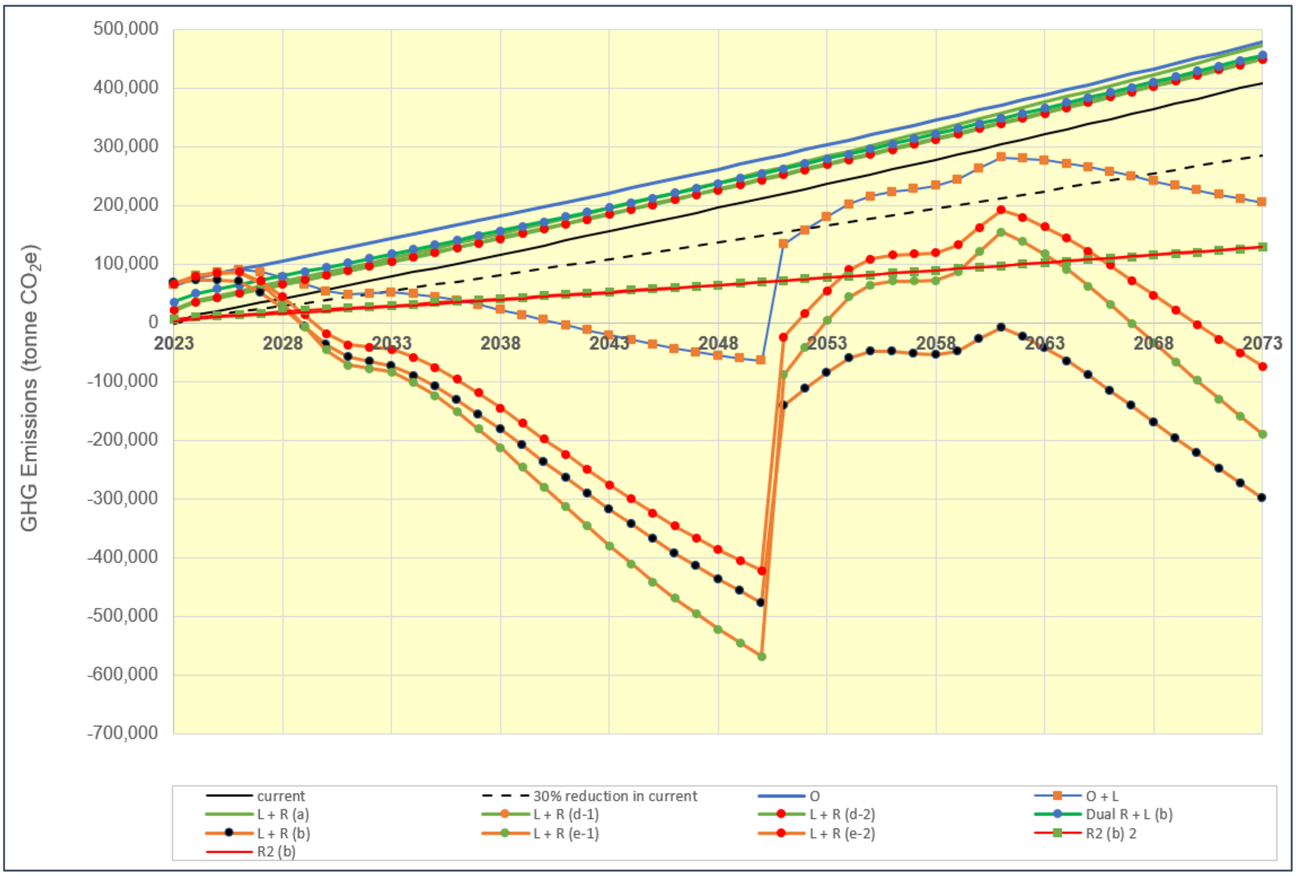


Figure 6-2: PNCC Wastewater BPO 50 Year Cumulative Carbon Emissions

The forestry options show a saw-tooth pattern due to the tree growth and harvesting cycle. After the trees are harvested after 28 years (2051), there is an increase due to the released carbon from the harvested trees. The cumulative carbon starts to decrease again once all of the residual carbon from the harvested trees has decayed (in 2061). The options where most of the wastewater is discharged to forestry land all have a negative cumulative carbon emission after 50 years.

The estimated 50-year carbon emissions are presented in Table 6-1, from lowest to highest. The net change relative to the current WWTP emissions are also shown, with those options with a net reduction highlighted.

Table 6-1: PNCC Wastewater BPO: 50-Year Carbon Emission Summary

Option	TL	Embodied Carbon	Average Operational Carbon Emissions	Average Annual Sequestered Carbon	50-Year Carbon Emissions	Net Change from Current Emissions
		t CO_2-e	t CO_2-e p.a.	t CO_2-e p.a.	t CO_2-e	%
L + R (b)	3	68,700	2,340	(22,500)	-299,000	-173%
L + R (e-1)	2	67,600	8,530	(31,900)	-189,000	-146%
L + R (e-2)	2	66,300	8,470	(26,400)	-73,000	-118%
R2 (b) 2	4	7,000	2,400	-	129,000	-69%
R2 (b)	4	3,500	2,500	-	131,000	-68%
O + L	1	66,500	8,210	(12,900)	206,000	-50%
L + R (d-2)	2	21,600	8,400	-	450,000	10%
L + R (d-1)	2	22,000	8,450	-	453,000	11%
Dual R + L (b)	2	37,000	8,240	-	457,000	12%
L + R (a)	1	24,400	8,800	-	473,000	15%
O	1	63,600	8,140	-	479,000	17%

The average annual operational carbon emissions range from 2,000 – 8,000 tonnes CO_2-e per annum depending on the option. For context, the estimated total annual carbon emissions from Palmerston North are approximately 500,000 tonnes CO_2-e per annum (Aecom, 2018).

For the options that involve forestry discharge, the annual sequestered carbon exceeds the operational carbon emissions, hence the overall net reduction in carbon emissions.

The ocean outfall option (O) has the highest carbon footprint due to:

- High embedded carbon (long pipeline)
- High operational carbon emissions (from the aerated facultative lagoons)

If the treatment process for option O was changed to an activated sludge process, the annual operational carbon emissions would reduce to around 5,000 tonnes CO_2-e per annum and the 50-year total would reduce to 312,000 tonnes CO_2-e which represents a reduction of around 24% relative to the current operation (improving its carbon ranking to 7th)

7 Conclusions

The following conclusions can be made from Figure 6-1 and the preceding sections:

- The three coastal land options have the lowest carbon footprint due to the carbon sequestered in the forestry land, which is larger than the operational carbon emissions from wastewater treatment and discharge. These options have a net accumulation of carbon.
- Apart from the options that include forestry sequestration, local river discharge options with high level of treatment (R2(b) and R2(b) 2) have the lowest carbon footprint. They have the lowest embodied carbon footprint as well as low operational carbon emissions due to the capture and combustion of methane within the treatment process.
- The ocean outfall option O (blue line in Figure 6-1) has the highest carbon footprint, driven by the embodied carbon of the long transfer pipe, coupled with the methane emissions from the aerated facultative lagoons.
- The inland land options (green lines) have the second highest carbon footprint, due to the transfer pipe, irrigation pipework, methane emissions from the aerated facultative lagoons and no sequestration.

8 References

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