Akaroa Wastewater Proposals

I have been coming to Takamatua for 45 years as a holiday maker and have lived here permanently since 2012. We moved here as a lifestyle choice to enjoy the beautiful unspoiled environment here on Banks Peninsula. We contributed financially to the water supply scheme that served Takamatua adequately for many years and bought, installed and maintain our own wastewater treatment system.

The inner bays communities have been facing uncertainty and cost in preparing multiple submissions over the last 4 years and face further anxiety as the process continues.

1. The first priority should be to eliminate the inflow and infiltration into the wastewater system as a result of broken or incorrectly connected pipes. This would reduce the requirements of the treatment scheme to 30% of that currently being proposed. It is impossible to understand why this is not being done as a "fence at the top of the cliff" rather than an "ambulance at the bottom of the cliff" approach.
2. The second priority should be to address the increasingly common water shortages faced by Akaroa by re-using as much of the wastewater as possible installing, at best, a treatment plant capable of producing potable water, or at the very least, a purple pipe system reticulated to Akaroa residents for garden watering and vehicle and boat cleaning. The demand for these uses is highest in the summer when the population of Akaroa increases significantly and when the water supply is at its lowest.
3. None of the options provided in the current consultation document require Akaroa residents who produce the waste to take any responsibility for its disposal. Takamatua and Robinson's Bay residents take full responsibility for their waste disposal by providing and maintaining underground systems on their own properties at their own expense.
   Wastewater systems are available for smaller properties and many of them could be provided for the estimated cost of any of the options.

Option 1

Harbour Outfall

Akaroa Harbour is an extremely important environment and enjoyed by residents and visitors alike as a scenic icon, food basket, playground and tourist attraction. The treatment level proposed appears to meet most of the standards necessary for a harbour outfall. Levels of nitrogen and phosphorus could be further reduced with suitable treatment. This option does not involve reuse of any wastewater.

Options 2-4

The intention to plant native trees to provide somewhere to distribute the wastewater is creating a beneficial reuse of wastewater rather than meeting a need that currently exists. It is an artificial "reuse" and has not been proven elsewhere. Native trees that are watered at the proposed levels will be shallow rooted and difficult to establish. Heavy watering, including during rainfall, will result in a build up of heavy metals and pharmaceuticals on land , streams and harbour mudflats.

Option 2 - Robinson's Bay/Takamatua Irrigation of native trees.

This option affects the most people who have absolutely nothing to do with the production of the wastewater. Storage ponds and irrigated areas are adjacent to residential houses in both Robinson's Bay and Takamatua and will undoubtedly affect their views, property values and livelihoods. There is also unnecessary risk associated with extreme weather events that can only be estimated. There will inevitably be considerable disruption to all communities during any construction periods and during operation of pumps. We have been told that if further land is needed it will be compulsorily taken and this adds to anxiety.

Local communities are not able to connect to the system.

The size of storage and irrigation areas could be greatly reduced should inflow and infiltration be eliminated.

Options 3 and 4 – Gough's Bay and Pompey's Pillar

Either of these options affect far fewer people at lower risk but do not address the basic issue of water shortage in Akaroa.

Conclusion

Provision of a treatment plant that has unnecessary capacity is a waste of ratepayers' money. The state of the waste pipework in Akaroa is indicative of a lack of infrastructure maintenance that has occurred for many years. It is crucial that this is fixed before or alongside the provision of a new wastewater treatment scheme.

The Local Government Act requires a "sustainable development approach and taking into account the social, economic, environmental and cultural wellbeing of communities now and in the future." They "must consider the views and preferences of people likely to be affected by, or with an interest in, the decision to be made." Council staff have made it clear that this has intentionally not been done at the design stage but is the responsibility of the Hearings Panel and Council. I sincerely hope this will happen and a decision that will be made that enables future generations to enjoy this area as much as I have.

Akaroa Wastewater Scheme Submission

We strongly oppose options 1-5.

My family have owned land on the Takamatua headland since 1952. My father farmed the land and subdivided parts of the North facing lower spurs and Lushingtons Bay for holiday homes. During this period, I spent a lot of time helping with work on the farm and have a good knowledge of this land and the problems associated with it. Most of the farm was sold in 1980. The area of Kingfisher Point was retained by the family and was developed more recently . We are currently building a bach at [redacted].

I have experience in agriculture, land development and contracting in this area and elsewhere.

We currently have a small block on the Port Hills. This block shares similar topography to the Takamatua land i.e.

- North to North Westerly aspect
- A mix of moderate slopes above steeper lower slopes
- A large actively regressing gulley system
- Deep loess-colluvium clays with active tunnel gulley systems

The Takamatua headland area proposed for irrigation has eight actively regressing gulley systems. These are immediately below or entering into the designated irrigation areas.

Numerous case studies have been carried out on these erosion prone, poorly structured, loess and loess-colluvium soils. The Bell and Trangmar 1987 study examines the association between soil type and land instability in fine grained loessial and volcanic soils on the Port Hills and Banks Peninsula. This study is often referred to in reports and is referred to in information associated with the Akaroa Treated Wastewater Disposal Options including the full Tonkin & Taylor geotechnical report and the pdp hydrogeological report.

Much of the information contained in the Bell and Trangmar report directly backs up my experiences and observations with this land over my lifetime.

Some points include:

- Tunnel gullies are most prevalent on North- North West exposed headlands (dry aspects)
- Constant exposure to seasonal wetting and drying
- Tunnel gullies occur on slopes 3-35 degrees
- Cracking in Summer due to shrinkage and low inter-granual cohesion
- Rapid slaking and dispersion when wetted
- Susceptibility to scouring by flowing water

In other words the soil cracks in the Summer, when it rains water goes into the cracks where it quickly starts dissolving the loess, forming small underground tunnels running downhill above the hard clay pan. These small invisible tunnels increase in size overtime and eventually fail (ie the ground above collapses into them). This sometimes leads to water build up and slips. Other times

the water finds a new path under the clay pan leading to new bigger and deeper tunnels which can lead to major slope failures.

These tunnels exist both under the proposed irrigation sites, and under the steeper slopes between the proposed sites and all of the houses below.

Any irrigation either by K line (spray to pasture or crop) or dripper lines to trees will put all of our houses and the residents within, at an increased risk of a massive slope failure.

According to Bell & Trangmar 1987 - the most common triggering mechanisms for large slope failures are a function of intensity, magnitude and duration of rainstorms and the antecedent moisture conditions within the regolith. (antecedent – meaning preceding thing or circumstance)

eg. a week's drizzle, a broken pipe or a month's controlled irrigation, followed by a heavy rain event could cause a massive slip onto our houses .

My point of quoting Bell & Trangmar here is that the heavy rain event alone probably wouldn't cause a large slope failure but a combination of any of the above and the heavy rain event is much more likely to.

In my opinion this increased risk is a good enough reason not to consider irrigation to the land above and around our homes. This increased risk is acknowledged in the Beca report on page IV option 2 under risks and opportunities and in the Ecan review on page 2 Rules 5.170 and 5.171 – Takamatua Peninsula is identified as a high soil erosion risk area.

Other factors that make irrigation of waste water to this land a dangerous and foolish option are as follows:

- The beautiful biodiversity of our region will be put at risk from spray drift and/or root infiltration from the wide array of contaminants that aren't picked up by the membrane filter and the chemical treatment. Even if in only micro amounts these could have a cumulative effect on the health of ourselves, our children and future generations. This can't be denied and must be considered.
- Contamination of potable water sources, there are many springs on the hills and in the valley which produce high quality clean drinking water.
- Contamination of all fruit and vegetables , nuts, grapes and honey.
- Contamination of livestock from grazing or eating contaminated fodder crops and hay.
- Farmers need to be wary. There is an increasing trend in this country and worldwide to trace food from farm to plate. Consumers increasingly want to know where their food comes from or where the animals have been grazing and what they have been eating.
- Organics is another consideration
- Rainfall after irrigation combined with surface scouring and leeching will wash contaminants from the higher irrigated land onto steeper slopes below where it will quickly enter the gulley systems and pollute the foreshore and the Takamatua Creek.
- A prospect of a 12,000m3 (12 million litre) pond full of waste water immediately above homes is a huge risk.

- Earthquakes are an all too real threat these days. A strike slip quake with high vertical acceleration similar to the very damaging one which occurred 22 February 2011 could throw the contents of the pond towards the homes located immediately below.
- Mosquitoes and odour are also concerns.
- Climate change is increasing the frequency of severe weather events.

Options 3, 4 & 5

All involve the pond or ponds in Block A as well as the coastal infiltration gallery. This discharge into the foreshore so close to our homes and beaches is an absurd idea. It is highly offensive to most people and is culturally offensive to Ngai Tahu. It also has a higher health risk than a deep harbour outflow. We have been advised by CCC staff that this coastal infiltration gallery is no longer an option.

Summary

Takamatua Peninsula has been correctly identified as a high soil erosion risk area. There is plenty of highly respected scientific research evidence supporting this.

My own observations over fifty years and as recently as last week confirm that it is indeed at risk of erosion. Any irrigation of wastewater to land in Takamatua poses an unacceptable risk to the lives and property of the residents living on the steep slopes below the proposed application sites.

It would be irresponsible of our council to consider this for any longer especially when a much safer option is available – the mid harbour outfall option 6 which was the initial choice made by the CCC.

Submission for Akaroa Treated Wastewater Disposal Options

From

Ken & Carol Reese

[redacted]

Christchurch 8022

[redacted]

Akaroa Wastewater Proposals

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Submission #33666

[redacted]

Akaroa & Takatamua

My name is Laurice Bradford I am a permanent resident of Akaroa, we also own a property at [redacted]Takatamua where we are hoping to build a new home there in the next 12 months, which will be our retirement home.

I support the treated wastewater being discharged into the Harbour only, my reasons for this is the cost of the scheme for the ratepayers but mainly it will have the least impact on the local community.

I believe the land options will have a massive visual impact on the surrounding landscape, and I am very concerned about the effect of sand flies and the odour that might occur. The plantings will be very close to the neighbouring boundaries which will shade those properties and that will have an impact on the wellbeing of those land owners.

I am also concerned that the land option at Takatamua and Robinson Bay will have an effect on the value of our property, and long term it might affect our ability to sell the property.

The Harbour option will have the less impact on the community, and all the residents needs should be taken into account.

Laurice Bradford

SUBMISSION:: Akaroa Treated Wastewater Options 23-August-2020

Submitter:: **Brent George**
[redacted] Cashmere, Christchurch 8022
[redacted]
[redacted]

I would like to speak to this submission.

Introduction::

I am a Registered Professional Surveyor and Licensed Cadastral Surveyor living in Christchurch. I have a family connection to the Pavitt Cottage in Robinsons Bay, and regularly visit the Bay, Akaroa, and other parts of Banks Peninsula. This submission stems from these personal factors, but also includes comments following a general review of the published documentation and various communications with the Pavitt Family Trust, the Friends of Banks Peninsula organisation, and the Protect Robinsons Bay group.

Submission Responses::

1. Of the two options – land or harbour discharge - I support the discharge to the harbour. *However, with the harbour discharge option presented, it does not address the cultural issues identified by Ngai Tahu.*

2a. I have deliberately not ranked any preference for the land based options presented.
This is a flawed question – there should at least be a "harbour outfall" option, and also a "none of the above" option.

2b. I strongly object to the Inner Bays option.
This option is flawed for many reasons (refer to the submission points detailed below.)

3. I support use treated wastewater to irrigate public parks (and also for public toilet flushing) in Akaroa.
This will provide one avenue for water re-use to the benefit of the community.

4. I would support Council exploring the feasibility of a "purple pipe" scheme for Akaroa.
This will assist with supporting the Council's stated objectives in its "Integrated Water Strategy" (2019) and other initiatives that a well-informed, future-thinking Council would seriously consider.

Submission Summary::

- **I oppose the option that uses the Inner Bays (Robinsons Bay, Hammond Point, Takamatua) to store and disperse treated wastewater from Akaroa. My primary reasons are:**
    - This solution would have a significant negative effect on the Pavitt Cottage and its environs which are part of an important archaeological landscape. *(Maxwell and Hubert Archaeological Assessment 2020)*;

- Disposal of wastewater to intensively planted native trees would be a first for New Zealand and the proposal is based on theoretical modelling and highly sensitive assumptions. *(Friends of Banks Peninsula Submission 2020)*;
- The social impact on the Pavitt descendants as owners and users of the Pavitt Cottage will be extremely detrimental. The development of a wastewater dam and ponds and irrigation planting adjacent to the site is very likely to trigger the demise of the Pavitt Cottage, as its financial viability is dependent on receipts from members and friends that use this special family taonga.
- I support the Friends of Banks Peninsula Submission. I endorse their suggestion for an alternative Reduce, Reuse and Recycle approach.

Submission Points::

These points support my submission. They are loosely grouped into general categories. They are not presented in any particular order or priority. These are provided to record my comments on the information presented that was – in my opinion – incomplete and/or misleading and/or overlooked.

Assessment: *"Have Your Say" document is biased*	The preferences listed within question 2 of the CCC "Have Your Say" document are biased and potentially misleading. • By eliminating the discharge to the harbour option, Council is effectively pre-determining a land-based option. • Further, if Council use the ranked options provided by submitters as part of their assessment in order to find the "preferred" option, then those submitters that reluctantly rank the best-of-the-worst options will inadvertently be signalling support for an option they may not consider the best.
LGA Assessment needs to be respected	The Local Government Act 2002 identifies the assessment criteria that Council should take into account when making its decision (s14.1.c). Specifically, the well-being of communities in terms of the social, economic, environmental, and cultural well-being of people and communities. Therefore Council must take in account the related aspects of these factors for all parts of the community. • As with the cultural sensitivities of Ngai Tahu, Council should also consider the cultural sensitivities of descendants of the early settlers to Banks Peninsula. • By overlooking the cultural well-being of the descendants of the early European settlers to Robinsons Bay (including Pavitt's), and constructing a wastewater dam and pond along with the threat of inundation and contamination, the Pavitt family's special connection to Robinsons Bay and the Cottage as a significant touchstone is irrevocably affected. • If the Inner Bays option is created – along with the dam site and ponds – the viability and future of the Cottage is threatened.
Working Party contribution	The Akaroa Treated Wastewater Reuse Options Working Party was established in order to assist with finding a mutually acceptable solution. • Their Joint Statement (June-2020) summarises their position.

	[Working Party 2020]. • It is telling that the Working Party could not recommend any of the options presented. • It is notable that the Working Party were disappointed with the final options presented. • This signals that the issue is complex, emotionally charged, and an important issue requiring a mutually acceptable solution.
Previous consultation still valid	Previous public consultation has been completed. • In 2017 a round of public consultation resulted in unanimous support for a non-potable re-use of treated wastewater in Akaroa along with another option – scoring 930/1000. • The Inner Bays option was ranked 5 out of 6 – scoring 230/1000. • Despite subsequent consultancy and analysis that has refined the 2017 options – this consultation appears to now be ignored. (Statement at Information Session – Christchurch 4-August-2020)
Information: *Images misleading*	The "artist impression" images used within the supporting information are misleading. • For example, on pg9 of the CCC "Have Your Say" document, the same Robinsons Bay image was used within the CH2M Beca Report [Beca (2020)] pg 65. Despite the same image being used, the size and shape of the pond is markedly different. • In addition, a simple analysis of the image in conjunction with the pond layout (Beca (2020) pg49) also concludes that the extent of the pond batters has not been taken into account with these mock-ups. • Further, to depict the visual impact from a point on Okains Bay Road some 1.5km away is also misleading. Any large structure will look small at that distance. ○ Why did Council not present multiple images of the pond structure from other (closer) vantage points? • To present these examples to the public in a consultation document could be construed to be deliberately misleading or disingenuous, as it would imply that the visual impact is insignificant.
Heritage: *Pavitt Family Trust letter of objection*	The Pavitt Family Trust provided a letter of objection [Pavitt Family Trust (2019] to Council dated 22-April-2019. This letter clearly articulated the collective views of the signatories, the Pavitt Family Trust Committee, and the ~300 Pavitt Descendants that are members of the "Friends of Pavitt Cottage". The main points within this letter were: • Significant concerns over the location of the proposed "Robinsons Bay Wetland Concept" (including the dam and pond storage site). • Confirmation that the dam presents a risk of loss of life and damage to property. • Identification that the structures and irrigation fields are located within an area of archaeological significance. • Notice that the irrigation field will potentially affect the Cottage's water supply source as well as other Robinsons Bay residential properties. • Acknowledgement that there will be negative visual, environmental,

	odour and amenity impact on the Valley – not only during construction but on-going.
Pavitt Family Trust commissioned archaeological assessment	The Pavitt Family Trust commissioned an archaeological assessment of the area including the Pavitt Cottage and the adjacent property. [Maxwell and Hubert (2020)]. • This assessment should have been completed by Council. • There is variable acknowledgement of this Report in the Council documents. It is noted within the Beca (2020) report (Appendix W) but not in other Council documents. • The assessment includes the wider area of the adjacent Lot 2 DP 82749 parcel where the historic Sawmill structures and landscape features existed (and can still be identified today). ○ Any planting of trees within this zone will obliterate these features. • The entire site of the Pavitt Cottage and adjoining Thacker property is a complex that deserves protection rather than key-hole archaeology before destructive earthworks or significant forest planting.

Pavitt Cottage is a Heritage Item (Christchurch District Plan)	The Christchurch District Plan identifies the Pavitt Cottage as a Significant Heritage Item (dwelling and setting) (Appendix 9.3.7.2 Schedule of Significant Historic Heritage)
	• This is noted within Beca (2020) pg 60.
	• The "standard" mitigating statements to address the impacts of the proposal on these adjacent Heritage features are purely subjective and meaningless. For example:
	  ○ The proposal will have "*minimal effects*" on the cottage (Beca (2020) pg61;
	  ○ Including a consent requirement to require archaeological approval before disturbance of an archaeological site does not protect the site or feature.
	• There are other Significant Heritage Items within the Robinsons Bay "affected area" (eg: School Masters House).

Construction:
Technical information misleading
	Beca (2020) (pp50-51) includes a summary of a "Dam Break Analysis". This was further summarised within the Community Briefing documents. The analysis was based on 15,000m³ volume released over 10minutes.
	• In order to conceptualise this quantity over time, the scenario is better explained to be:
	  ○ 15,000,000 litres released over 600secs = 25,000 litres per sec
	  ○ 25,000 litres is roughly the equivalent volume of a standard 4.5m diameter round "Para Pool"
	  ○ This presumes that the water is released at a constant flow – which will not be the case. It will start small and accelerate as the dam break progresses. Therefore, the peak flow will be much greater
	• Such a model would have many assumed factors, such as where the dam breaks; what flow path it follows; how it progresses; how much volume is in the dam; what other impediments are in the flow path etc. Such uncertainty should have been stated within the report and

	briefing documents in order to provide the public with a greater understanding of the complexity of such an event – along with a measure of the uncertainty of the effects.
	• The flood extents will therefore be extremely variable, and so the damage and impact would be variable. This should have been stated.
	• The liabilities related to such an event need to be identified and acknowledged.
	  o Will the Council be fully responsible for damages as the result of a Dam break?
	  o Will Council cover the increased insurance cost burden placed on private landowners whose properties are affected by a dam break event?
	  o Will Council acknowledge the extra burden of risk and insurance of affected landowners?

Detail information misleading	The Beca (2020) report (pg75) indicates that the domestic water supply source for 5 Sawmill Road (Pavitt Cottage) is not on the ECan list of registered bores and is consequently assumed to be "historic or not in use". This may be so but:
	• This well and the connection path are defined by an easement recorded on the record of title for this property. Therefore, the legal right still exists with Lot 1 DP 82749 and so cannot be ignored.
	• At any stage the owners of Lot 1 DP 82749 could seek to reinstate that well site.
	• All other wells and water supply sources downstream of the irrigation area could be affected by the treated wastewater irrigation.
	  o Can Council guarantee the Robinsons Bay residents drinking supply will not be affected?
	  o What safeguards will Council institute to prevent drinking water contamination?

Existing infiltration issues requires addressing first	It is acknowledged throughout the various documentation related to this issue that a significant amount of inflow and infiltration (I&I) is involved with the current wastewater infrastructure network. • It is critical that the current network of pipes are repaired/upgraded, and illegitimate inflow (eg: from roofwater downpipes) is removed in order to eliminate such infiltration.
Financial: *Extreme financial cost burden*	The costs of all options are significant ($45m to $76m). The cost of the consultation to date will also be significant ($10m+ estimated). The cost of professional consultancy and analysis will also be significant ($??m). • This is a direct burden on the Christchurch Ratepayers. • Have Christchurch ratepayers been sufficiently informed of the additional loading of this capital cost onto Council? • With a minimum potential cost of $45m, the cost per dwelling is some $45,000 (based on 2018 census dwelling figures rounded up to 1000). In the most expensive option this balloons to an equivalent $76,000 cost per dwelling. In reality, with cost escalations and including sunk costs to date, the value could be double. • Have these types of sums been adequately declared to Christchurch

	ratepayers?
Incomplete financial information	The Beca (2020) report (pg54) indicates that the amenity landscaping and planting costs have been excluded. • What are the likely costs? (they are likely to be significant)

Cultural:
Nagi Tahu requirements still not addressed
	The reasons provided by Ngai Tahu to stop the discharge of wastewater into the harbour are clearly understood.
	• Included within the Inner Bays options are safeguards to allow overflow of treated wastewater back into the harbour after certain events.
	  ○ How is this acceptable to Ngai Tahu – no matter how seemingly insignificant or rare (once every 5 years) it may be?
	  ○ What happens if such an overflow event happens more often?
	• Has there been consultation with Ngai Tahu about an alternative that involves passing treated wastewater through Papatuanuki before it enters the harbour?
	  ○ If not, why not?

Working Party:
Working Party Joint Statement
	I have read the Joint Statement of the Akaroa Treated Wastewater Reuse Options Working Party dated 25-June-2020. [Working Party 2020].
	• It is acknowledged within the Beca (2020) report (pg2) that the Working Party provided "invaluable input, guidance and feedback"
	• I am also aware of the inordinate amount of personal time and sacrifice that the community representatives applied to this group
	• I agree with and reiterate the Working Party's summary points being:
	  ○ High cost of an unproven system with little margin for error
	  ○ Design area is tightly constrained by suitable land
	  ○ Flooding risk for downstream houses
	  ○ Leaching of nutrients and contaminants into water bodies
	  ○ Negative impact on a significant archaeological site
	  ○ Wastewater will be released into Childrens Bay
	  ○ Sewage reticulation not being provided to the communities that are imposed with the Akaroa wastewater
	  ○ High value land is required for land based options

Other: *Other solutions explored?*	There will be other communities in other parts of the world with similar topography and population density that will have had a need to address wastewater disposal. • What other locations were investigated? • If none were – why not?
A future-proof solution?	It is noted that the "solution" has been designed to cope with wastewater quantities generated by population growth to the year 2052. This is 32 years from now (and probably some 25 years from any implementation of a system). • Is this sufficient allowance for future-proofing such an important development? • Is this development sufficient value-for-money in this time-frame? • It is noted that the existing system was implemented circa 1960 and

	so has had approximately 70 years life. Would there not be an expectation that a replacement system should have an equivalent life-span? • Is there an expectation that some future technology will render this "solution" partly or wholly redundant around 2052?

Thank you for the opportunity to provide a submission on this matter.

References:

Beca (2020): Akaroa Wastewater Summary of Disposal and Reuse Options - CH2M Beca Ltd dated 17-July-2020

CCC Community Briefing (2020): Akaroa Treated Wastewater Options – Robinsons Bay Community Briefing dated 13-July-2020

CCC Have Your Say (2020): Akaroa treated wastewater options (Submission Information Document)

Friends of Banks Peninsula (2020): Second Draft Full Submission Akaroa Treated Wastewater Options Consultation (2020) dated 21-August-2020

Local Government Act 2002

Maxwell and Hubert (2020): Archaeological Assessment of Lot 1, DP 82749, Robinsons Bay, Canterbury (Sunrise Archaeology) Report No.2020-3 dated May 2020 for Pavitt Family Trust

Pavitt Family Trust (2019): Akaroa Wastewater Treatment – Robinsons Bay Wetland Concept - Objection (Letter from the Trust to Bridget O'Brien (CCC) and Penny Carnaby (Working Party Chair) dated 2-April-2019

Working Party (2020): Joint Statement dated 25-June-2020

Submission to CCC re Akaroa Wastewater, August 2020 Sylvia McAslan [redacted]

I am opposed to the idea that it is ok to shift your shit into some else's backyard. This provides no incentive for sewage generating residents to pay attention or be conservative with their water use and subsequent sewage.

As in 2017, I support the beneficial re-use of Akaroa wastewater.

The proposed wetland provides additional storage and some treatment, this is not beneficial re-use. Neither are three new native bush areas, left alone most hillsides would revert to native bush without irrigation, as native bush is not drought prone.

I do not support the proposed land disposal options as they:

- Are extremely costly
- Export the sewage problem
- Not in an area with extensive flat land and versatile soils
- Negatively impact people far from where the sewage is generated
- Waste a potential resource.

At the Akaroa meeting and on the CCC website I was surprised the proposed land disposal options include continuing to irrigate during rainfall periods of up to 50mm. It is illegal for farmers to irrigate beyond field capacity (effectively waterlogged soil) as it is inefficient and it damages soils, invertebrates, micro-organisms, and causes nitrates and other contaminants to migrate. Irrigated trees are more likely to be shallow rooted, and on a slope the prospect of waterlogged soils moving downhill, even without an earthquake, is concerning.

I understand this is a wicked problem. Maybe a staged plan is the best way to achieve an efficient, economic, long term outcome suitable to everyone, while allowing for inevitable legislation changes. Potentially kliptanks for interim storage are less imposing and impermanent on a landscape.

- Part of the chosen option must include repairing or replacing pipes where necessary to prevent groundwater and stormwater infiltration
- The chosen option must include a non-potable (not for drinking) water reuse scheme (purple pipe scheme) with ultraviolet (UV) treatment as an additional level of treatment. To provide maximum re-usability for toilet flushing, garden watering, etc
- If possible, with a 'blue' (potable) pipe laid simultaneously to provide for the long-term recycling of highly treated wastewater into the potable water system. As anticipated will be possible and widespread in New Zealand in future as communities grapple with water shortages due to climate change
- Te Mana o te Wai obligations along with Taumata Arowai are likely to favour beneficial re-use
- The chosen option must be a long-term investment, for future generations, we do not want to be back at this expensive submission stage in 40 years
- This will be the newest wastewater treatment plant in NZ so it should be treated to a level higher than anywhere else, not "...among the highest anywhere in New Zealand."
- As a small community this is a good place to go hard and go early. Covid provides a clearer idea of priorities in life, and an understanding of the necessity to do things differently, for resilience, our future, our planet.
- Future opportunities – recycling to potable water, resilient water supply, showcase a contemporary approach to highly treated wastewater, demonstrated by a forward-looking Council.

Public awareness of careful use of freshwater should be associated with the subsequent sewage generated, never mind the 'ick' factor – own it. Loudly propose that all new builds in Akaroa must have composting toilets, with the compost used in community gardens. To be accompanied by a publicity campaign, 'Flush and walk away is NOT OK'. This may help focus peoples' attention and generate an awareness of personal responsibility.

In 30 years or so when I move into Akaroa it would be very satisfying to know I can have a productive garden to potter in, and that water is treated as the taonga it is. It would also be very satisfying to know that iwi, community, and Christchurch City Council had been able to work together to provide a forward looking, long term, economically, environmentally, and culturally sound solution for Akaroa's highly treated wastewater.

Akaroa Waster Water submission

Mark Wren

[redacted]

16/8/20

I am a resident in the Takamatua Valley and live here on a special block of land where my wife and I have a commercial walnut orchard and sheep flock. I have been a community member on the Akaroa Waste water Working party since Jan 2017 and lived here for 12 years.

The working party commenced with hope there would be the discovery of an exemplar solution to the treatment and discharge of the Akaroa sewage. After 3 ½ years work on the AWWWP not one single option was found which was even satisfactory.

The CCC consultation document on Akaroa waste water for the community to consider is severely biased and does not reflect the real community concerns which have been raised. All land-based options negatively impact surrounding communities and are risky. The extent of that impact is minimised in the consultation document but the opposite is the case for the harbour discharge.

Health concerns are raised as a disadvantage for those using the harbour recreationally but no recognition is given to the health risks of land-based alternatives. There is far more impact on the harbour from flood events causing silting, run-off and bird faecal contamination than the poorly operated current effluent treatment system in place. It is nonsense that a well operated modern treatment plant discharging into a strong tidal harbour is a risk. The cultural concerns of tangata whenua need to be balanced with science, top level treatment of waste water through reverse osmosis and the negative community impacts from land-based alternatives.

It is morally wrong for the Akaroa community to dump its waste into neighbouring communities, it is unwelcome and not wanted. There are no community advantages from the disruption, risk and dumping of the effluent. It takes up valuable and rare flat, fertile agricultural land. There is no plan developed or funding identified for the recreational and educational advantages touted for the Inner Bays options. It is a cynical glossing of the disposal method.

The Greenhouse gas inclusion as a point in favour for land based again is a gloss over to justify discontinuation of harbour discharge. By summarising GHG comparison over a 35 year period it gives no indication to whether this amount of emission is significant. To add perspective, the emissions offered to our globe by harbour discharge is the equivalent of the average emissions from 4-10 households. It is a trivial distraction compared to the other issues but given its own special place in the consultation document.

The CCC has demonstrated a lack of transparency and clear bias.

No Akaroa waste into communities through land-based discharge, continue putting it back into the harbour until a better solution can be found.

Regards

Mark Wren

Akaroa Waste Water.

In my view the harbour outfall is the most logical place at this stage to discharge the waste water. If the council actually does what it says and treats the water to a very high level then the body of water in the harbour and the amount of tidal flow will help dilute further the waster water discharge. This could be timed on the out going tide as well and given everything else that seeps into the harbour such as run off from land, boating and water activity pollution, the over population of Canadian geese and what comes out their rear end is far greater risk of contaminating the harbour than highly treated waste water from a controlled system.

This should be the first step in a system that treats the water to drinkable standards like many other places all over the globe has done. Each year Akaroa has restriction and in my view THIS is the BENEFICIAL re-use the council and Maori should be getting behind to make the township of Akaroa more resistant now and for the future. Water will be a precious resource, just look at what Auckland is facing right now.

The inner bay options are NOT a beneficial use because nobody in the valleys wants it. If the scheme goes ahead there are many down sides I see to this and there are a lot of families who will be affected and could possibly have to just live with it the negative affect of the system. These things included possible flooding due to break down of structure, normal flooding when we have a heavy rainfall downstream of where trees are watered as ground could be more saturated than normal because of the waste water watering.
Valuable land being taken to plant trees that would otherwise be used for families to have stock or crops on to support their livelihood and staying on the land which is where they have chosen to live and bring up children, or just loving be a beautiful pristine valley for their well-being, the huge structures and disruption and on going maintenance will destroy that tranquillity. Also because of the looming decision our land in the inner bays has decreased which is a very negative effect.

There are many concerns about the durability of these systems being imposed on our valleys and the consequences we will have to put up with when things go wrong, because what the council are proposing to do is all experimental and I find this offensive that we in the valley communities are being used as guinea pigs for disposing of another communities waste water.
Council have not addressed all the areas they say in their document of social, economic, environmental, cultural well being of the community you just have to attend they many meetings held over the years and what the people who have to wear these schemes say. What it does appear though is that one party is being considered over all the rest and there is politics behind it which is not for the good of most.

The responsible move for the council is to re-use the water and address the water shortage Akaroa has each year and there is an avenue for which this can happen and benefit all.
Printed in the Akaroa Mail (August 14th) was mention of a newly established three waters steering group which is part of Ministry of Internal Affairs that is working to literally nationalise the concepts of three waters (waste/drinking/storm water) so that communities benefit.
Most important if the council says is partly about money then the steering group will assist local councils establish world class systems and they have 71 MILLION to spend as they go. So that is a no-brainer get a world class system, address the storage of water in Akaroa and not impose it on other communities that are living off the land.

“We have had a holiday home in Robinson’s Bay for over 30 years and have always and continue to do so today enjoyed this semi residential environment and all the benefits that it offers.

For this reason, we now have difficulty in understanding why it could even be under consideration to put a wastewater system and a large storage pond in Robinsons Bay on this land that is blessed with such beautiful streams and a historic cottage.

We also question how can it be justified for our community to receive a wastewater system from Akaroa while we all still have to maintain a septic tank or alternative system at our own cost?

We believe the priority for the Council is ensuring the infrastructure and treatment quality are right before even contemplating the introduction of a long-term system, particularly in the inner harbour.”

Wendy & David Fleming

[redacted]

Robinsons Bay

Time should be utilised now to get the infrastructure right and the treatment quality right as a priority before the implementation of any long term system, particularly in the inner harbour., that may, in time, be a very regrettable and environmentally poor decision."

AKAROA WASTEWATER PLANNING SUBMISSION:

Further to years of discussion, consultation and numerous submissions on this matter,none of which appear to have been taken seriously into consideration,we once again submit to you the reasons and concerns over this proposed project,which will,if carried out, undoubtedly have an extremely detrimental effect on each of our four property titles,which are all in very close proximity to,and below, the proposed new sewage plant on Old Coach Road.

Although much information seems to have now been collated by the Council, the most recent being made available for public consultation, we as affected parties, were not consulted prior to this, in any way, as to the very serious situation we now find ourselves in, with our land being only approximately a sixtyeight meter distance at its nearest boundary, from the proposed raw sewage pond and wetland.The risk factor of potential damage to property during an unexpected adverse event where raw or partly processed sewage may be released through a stream on our property,is very concerning. Are we not trying throughout the country,to protect our natural waterways from pollution, or is there a special exemption for the Council on this issue?There appears to have been no foresight in this proposed possible, outcome, either to the possible risks to health by contamination,the damage to land, including current spring water sources,or wells, or the means to mitigate this possibility,apart from vaguely hoping that the outflow in the case of this devastating scenario, would be caught by, and flow down the main road, above us! The impact of heavy ground saturation, as we are fully aware in this geological area, may result in major slips of serious significance, with enormous damage to the property below, as clearly indicated by research maps provided by consultants to the Council. We cannot see that any consideration has been given to any compensation or insurance for affected property owners, if this predicted overflow was ever to occur.When considering these high risk factors it would be feasible to say that this proposal will have a very high impact on the lowering of our property values, and that of others close by, now,and in the future.

Having developed this land for nearly forty years, from a rough gorse ridden, and poorly fenced block, with no roading, to the ten cottages, two homesteads, on fully landscaped blocks it now comprises, owned by several individual owners,we are highly stressed and devastated,at the thought of the possible ruination of our huge investment, and work efforts, over these past years, which were completed, to provide a secure lifestyle in later life, for ourselves, and to continue being able to be enjoyed by our family, as an investment for the future. Also the value of our present building programme being undertaken, with resource consent currently in place, to build a new retirement and future holiday home on this property, would be greatly diminished, not only in monetary value, but in the detrimental impact on lifestyle conditions, such as undue noise, unpleasant odor, dust and insect infestation, which were never previously present on our property,or ever contemplated to ever occur, in this previously, and current idyllic living situation.The obvious disruption involving heavy traffic movement, with associated noise and dust during a lengthy building process will disrupt the quiet peaceful atmosphere previously enjoyed.Added to this will be the constant noise factor from associated pumps and machinery required to maintain the workings of this plant day and night.These intrusive factors cannot be completely overcome by any of the vague impractical suggested solutions so far, offered by the Council to mitigate these problems.

However the Council seems to be able to manipulate any obstacles in its pathway to achieving its own agenda, by changing or by bypassing its own rulings, on any matter,and paying little attention, or no obvious concern, for those who are most likely to be disadvantaged by their actions, or who stand in the way of their so called progress. Surely other better decisions on siting,away from close established places of residence, could have been reached at a much earlier stage of proceedings, given this saga has had a long history of dispute, mistakes, and indecision, which appears to continue, regardless of efforts of the local people to “Have their Say”

No one with normal,logical, reasoning could ever have imagined how in this area of great natural scenery and beauty, on the attractive entrance to a township, that it could ever be proposed to be used for the site of a sewerage works on this very visible prime site. The proposed wastewater outfall area consideration seems at present to be favouring,a choice of direction to appease the wishes, of a very small minority in a community, when it would be hoped a decision of this magnitude,and impact, would be made for the good and wellbeing of ALL members living in this society, especially all those living in very close proximity under the shadow of this proposed Council desecration of an area of great harbour views and natural beauty.

DR & DF Kingan

Submission regarding Akaroa waste water treatment S.W.Sinclair

Council Staff have produced a consultation document that is decidedly biased toward their recommendation that the Inner Bays option be preferred.

The most glaring example of this is the unbalanced treatment of the objections of affected communities. The cultural objections of Maori are listed as a disadvantage of the Harbour Outfall option. The environmental, visual and economic objections of the overwhelming majority of inner bay residents are nowhere mentioned – nor are risk of odour, risk of midge infestation, risk of dam burst and flooding. The only disadvantage listed for the Inner Bays option is cost!

The much more expensive Eastern Bays options (capital and running costs) should be discounted. I contend that the choice is essentially between the Inner Bays option and Harbour Outfall.

Harbour Outfall is the common-sense option and not just because it saves Christchurch taxpayers about $10 million. This can be demonstrated by refuting the listed disadvantages of Harbour Outfall in turn -

1. "No beneficial re-use of highly treated waste water unless a purple pipe scheme is included". Why is the possibility of purple pipe scheme not listed as an advantage? With the land-based systems the possibility for irrigation and stock water along the line of the pipe is listed as an advantage.
2. "Risk to public health albeit low…..". This is padding. It does not merit inclusion in a list of disadvantages of the harbour outfall option.
   The public seems to have stayed healthy for the last 60 years with a less high-tech treatment plant discharging its waste water only 100m from the shore. The harbour outfall proposal is for "highly treated" water to be discharged 1200m from the shore.
   There has been risk when there has been emergency overflow at times of high rainfall. The new system admits the same risk, and is the same for all four options.
3. "Conflicts with the goal of carbon neutrality." Again, padding. There's no reason why the Council can't offset emissions by undertaking a native planting scheme unrelated to waste water irrigation, on land already owned by the Council - not productive farmland - using some of the millions of dollars saved by adopting the Harbour Outfall option.
4. "It undermines the relationship of tangata whenua and their culture….". Anyone can appreciate that raw sewage released into a harbour used for food gathering would be highly offensive. Centuries ago when that prohibition would have been incorporated into Maori culture it made perfect sense and still does. But that is not what is being proposed here.
   Just as tangata whenua in the 21st century accept the other innumerable benefits of modern technology, there ought to be acknowledgement that, while the proposed treatment plant does not produce water that is potable, it is vastly purified in comparison to raw sewage and, immediately upon ocean discharge, is vastly diluted. In the context of providing for a much larger population than in former times, at

some point scientific knowledge has to overcome a cultural sensitivity that is not rational. It's rather analogous to the irrational claims made for homeopathy.

5. "The NZ Coastal Policy Statement…….aim to avoid the discharge of treated human waste…..unless there has been adequate consideration of alternative methods". The topography and soil types of Banks Peninsula make discharge to land particularly problematical and is a special case compared with, say, the Rolleston waste water treatment plant which discharges to well-draining soil and does not require storage ponds. The Environment Court sent the Council back to consider the option of discharge to land and this they have done – exhaustively and expensively (how expensively we are not told) - and no satisfactory land-based solution has been identified. Council should return to the environment court, armed with all their data and again request consent for Harbour Outfall.

I appreciate that we are asked to make submissions only on the outflow options but there are further comments I would like to make regarding the already consented sites of the pumping station and treatment plant:

While these sites are technically convenient for the land-based options it is illogical to position them in a residential area. Would Christchurch residents accept such a plant in Hagley Park?

A covered pond of raw sewerage and an open pond of treated waste water at the top of Old Coach Road are planned. Despite assurances from Council Staff, I have no confidence that these will be midge and odour free. Further, it's hard to imagine that visits to the pumping station and treatment plant by vehicle(s) to cart away filtered solids will not be accompanied by a release of odour down town.

Should there be an emergency overflow this will go into the Grehan Stream and/or Children's Bay stream at a place in the harbour where I expect there is relatively sluggish water movement. Imagine a raw sewage discharge at low tide….

Visual impact. Where else are buildings and ponds such as these sited at the beautiful main entrance to a town? Would Christchurch residents accept such a plant across Memorial Avenue from Russley golf course?

There needs to be a rethink about the siting of these facilities.

If/when the Harbour Outfall option is consented it does not make sense for sewage from a town halfway down a long harbour to be piped toward the blunt end of the harbour and processed in a residential area. It could be pumped to a treatment plant on land closer to the harbour mouth well away from habitation. Ideally, as suggested in a recent letter to the Akaroa Mail, the waste water would be held in a pond and emptied into the middle of the harbour only on the ebb tide.

Akaroa Wastewater Submission Pompey's Pillar

This submission is on behalf of two generations of the John's family who currently own and farm the land known as Pompeys Pillar situated on the tip of the Northern side of Otanerito Bay. Separated by 4km of road the family also own and farm land at Paua Bay.

This submission is in strong opposition that Akaroa's wastewater be applied to 48 ha of the land supported by the planting of native trees at Pompeys Pillar

The Block of land extends further SE than nearby bays meaning it is extremely open to the vagaries of the dry climate and in particular harsh winds from the southerly and north easterly directions.

Views of the property can be seen easily from all sides.?

This option has many negative features:

1. The idea that the Waste Water be transported 13 kms to a height of over 600m to the farm
2. Environmental impact and climate change
3. The farms location within and relation to the Banks Peninsula Wild Side
4. Farm production
5. Family and Community

Waste Water Transportation

. Transportation of waste water 13kms longest of all options

. The need to be pumped to height of over 600m

. Dangers of structural damage occurring in cases of natural disasters leading to further problems

. Road disruptions and associated problems during pipe insulation

. Annual Extreme high maintenance costs

. The above five points are the reasons this option is the most expensive.

Environmental Impacts and Climate Change

Ongoing Climate change will produce more extreme weather occurrences. Due to the 48 ha proposed for the planted trees being totally exposed these extremes especially wind and salt are a major problem.
A very recent weather event showed an example of what will be experienced in the future. 150mm of rain occurred in only a few hours. This caused a huge run off into our normally near dry gullies.

What ensured was raging torrents destroying all before them. With trees under such extreme conditions leaching would occur into those gullies taking waste water with it.

The farms location within in the Banks Peninsula Wild Side

The 48 ha of trees in the projected option are situated in the heart of the designated part of Banks Peninsula named the Wildside.
Two of the privately funded Wildside objectives are:
a) To maintain natural landscapes of the area
b) To maintain a natural environment

The potential plantings go against this. Walkers on the Bank Peninsula track and visitors to the nearby Hinewai Reserve will easily view the unnatural manicured landscapes.
The headlands natural environment of grassland and low growing tussocks will be replaced by manicured windswept bush seen as artificial and out of place even if it is perfectly done as is represented by the councils artists impression

Farm Production

The proposed 48 ha irrigated to trees is situated in the heart of the property. The farm amenities wool shed yards and other facilities are here, as are smaller productive paddocks that lead into these facilities.
This area has recently been developed for increased production and as insurance against climate change with increased stock water storage supply.
This 48ha even though windswept is the driving force for productivity and is financially critical to the success of the total farm It also contains ashes of the 4th generation who farmed the property.

Family and Community

The Johns Family farm contains both land at Pompeys Pillar but also the Home block at the nearby Paua Bay.

The valley at Paua Bay contains substantial covenanted areas of native bush in perpetuity in conjunction with the Banks Peninsula Conservation Trust.

In 2008 the family entered the Ballance Farm Awards and won the Habitat section for their work in conservation.

Rural Isolated areas such as these are in need of young people who will live, learn to care and cherish the area. For example in 1990 fourteen children met the school bus on the ocean side of the Long Bay Road. This year there are only four. Two are from our family

Pompeys Pillar is a parcel of land the family and its ancestors have farmed for six generations spanning over one hundred years. During that time the generations have created a culture that succeeding generations have been and continue to be extremely proud of. All six generations have played an active part in the community.

We believe putting waste water on Pompeys Pillar will destroy this ongoing legacy of the area.

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Akaroa treated wastewater options:

Submission: Penny Carnaby, [redacted]

Thank you for the opportunity to comment on the Akaroa treated wastewater options. I write this submission as an individual and not as the independent chair of the Akaroa Treated Wastewater Reuse Options Working Party (AWWRWP) which completed its deliberations when it presented a Joint Statement to CCC at the end of June 2020. I have been a resident of Banks Peninsula for over 30 years. I have a deep love of Bank Peninsula and the special nature of the landscape and biodiversity which surrounds us. While I appreciate that finding a sustainable wastewater solution for Akaroa has been a long, protracted and controversial process, I am confident that the options presented by CCC are all technically feasible. Whatever option is eventually progressed, there will need to be a real commitment to work closely with affected communities to ensure their concerns are listened to and mitigated.

1. A difficult problem to solve

Finding a wastewater solution for Akaroa has been a complex problem to solve. Over the last 11 years CCC has worked with interested parties and local communities to find a suitable option which is supported by all community and stakeholder groups. During my time chairing the Working Party there were many potential suggested options which were explored and dismissed for one practical reason or another. Two of the more promising potential options, deep bore drilling and Managed Aquifer Recharge (MAR), were both found to be unsuitable. The geology and steep terrain of the Akaroa area has meant that many of the suggested options were found to be unfeasible. MAR was not supported by CCC because of the potential risk of contamination of the drinking water supply in Akaroa. The learning from Havelock North made the potential risk to public health too great and therefore it was unacceptable as an option.

The four options presented are, in my view, the only technically feasible options that could be realistically considered.

2.There are some givens, which everyone agrees to.

While there is much disagreement about wastewater options there are some agreed to interventions which must be progressed as a priority regardless of the option chosen.

- The first step for CCC needs to be to ensure that the existing horizontal infrastructure is mended and secure. Stormwater pipes must not leak into the wastewater system necessitating larger water storage solutions. It simply doesn't make sense.
- The AWWRWP focussed on the beneficial reuse of wastewater particularly in the Akaroa harbour basin where there is a shortage of water for these purposes The most useful example of reuse is to install a "purple pipe system" from the wastewater network back to users in the Akaroa harbour basin. The purple pipe system could be provide water for irrigation for local rural use, for irrigation of public spaces such as parks/ cricket grounds and for toilets in Akaroa and, in the future, residential reuse of treated water for gardens and toilets.

3. The options considered

3.1 Options not supported by this submission

Pompeys Pillar Irrigation scheme

This option is problematic on several grounds:

- This is a culturally sensitive landscape for Ngai Tahu parties particularly the Kokorarata runanga
- This property has been farmed by Johns family for several generations. Locating the wastewater solution at Pompeys Pillar would have a devastating impact on the Johns family, and there are better options to consider.
- The proposed native plantings proposed would in all likelyhood fail. It is a harsh, exposed landscape and the proposed native tree plantings are unlikely to be successful.

The Harbour Outfall scheme

While this is on paper the cheapest option and therefore likely to be supported by several submissions, this option, and any variation of the proposal, eg to extend the pipe to discharge to the ocean, is my least favoured option

- Mixing of waters is culturally offensive to Maori and it therefore violates beliefs and concepts which are unacceptable on any grounds
- Proceeding with this option would be a breach of the CCC's Treaty commitment.
- If CCC proceeded with any option which is deemed culturally offensive by Nga Tahu parties, it would undoubtably be appealed. Based on recent environmental court decisions (e.g. Taranaki), the CCC would undoubtedly loose the appeal and we would be no further ahead.
- This option also presents unacceptable ecological and environmental impacts

3.2 Options supported

Both the supported options in this submission are strongly opposed by local communities in Robinsons Bay/ Takamatua and Goughs Bay. Because of this understandable concern it is recommended that CCC work with the local community to mitigate and address the perceived and actual concerns expressed.

Inner Bays Irrigation scheme

The Inner Bays Irrigation scheme option is strongly opposed by the Robinsons Bay Takamatua communities.

If this is the preferred option then it will be essential that CCC works with the community to reduce the actual and perceived impact of this option.

Steps will need to be taken to:

- Ensure that Pavitt Cottage and the surrounding area reflects and celebrates the European sawmilling alongside the Maori history of the area. There is an opportunity here to reclaim the history of the area from both perspectives.
- Work with the community to address concerns about the scale and proximity of the storage ponds to residential properties.

- Address all concerns of the community relating to flooding and dam break potential
- Make every effort to include beneficial reuse of wastewater through purple pipes and other options.
- Set up a community Steering Group to ensure that community concerns are both listened to and, where possible, addressed.
- Use the wetland area proposed above Childrens Bay as an educational opportunity so that the community can better understand Maori perspectives relating to the mixing of waters and the need to the cleanse water before it reaches the ocean.

Goughs Bay Irrigation scheme

The Goughs Bay Irrigation scheme is strongly opposed by the Goughs/Hickory Bay Community

If this is the option selected then it will be essential that CCC works with the local community to mitigate the perceived and actual concerns expressed.

Steps will need to be taken to:

- Preserve and enhance the ecological and conservation aspirations of the Wildside concept.
- Ensure that the risks of pumping water over the hill alongside a gravel road prone to erosion are considered and mitigated.
- Provide several ponds for firefighting at or near Hinewai Reserve.

Conclusion

I would like to present my submission in person

Nga mihi nui

Penny Carnaby

[redacted]

[redacted]

Possible Ideas

After a warm welcome on to Ōnuku Marae we gained some appreciation of the Rūnanga views regarding the wastewater problem.

My sister and I thought the following idea may go some way to spiritually cleanse the treated wastewater before its journey to the deep water outflow.

It involves a sprayed concrete half pipe meandering its way down the paddock opposite the proposed Waste Water Treatment Plant. This half pipe would be lined with locally sourced rocks, stones, pebbles and coarse sands. It would be wider and slower in places and narrower and faster in other places. Slowed right down in a settling pond where it could then pass slowly over earth with flaxes, rushes and puha before returning to the halfpipe where it would pass over a series of native timbers and rock waterfalls to invigorate it before flowing into a collection chamber then continuing down to Childrens Bay in the underground pipe to the deep harbour outflow.

Important Features

- Ngāi Tahu would need to oversee the design and construction and selection of locally sourced plants and materials.
- Overall length approx. 200m.
- Completely self contained no risk to groundwater or surrounding land.
- No use of plastic in any way.
- Must flow down Akaroa side of hill.
- The wastewater belongs to them and Akaroa residents need to take ownership of the problem and deal with it in a way that isn't detrimental to neighbouring communities.

This is only intended as a catalyst for discussion in hope of reaching a point where Ngāi Tahu no longer finds a deep mid harbour outfall so culturally offensive.

Harbour Pipeline

Hopefully an economic way of lengthening the pipeline can be found.

There is no suitable land anywhere around the inner harbour.

Discharge to the ocean remains the only viable option.

Submitter #33873

Do you have any other comments?

The deep harbour with it's large opening to the massive Pacific Ocean with tidal flows and strong ocean currents will quickly dilute the well treated wastewater by a factor of millions. The mid-harbour outfall option makes the most sense economically with very low running costs and eliminates all the problems and risks associated with spraying or trickling this treated effluent in such close proximity to our homes, gardens and fresh water sources. Another fact to consider is that any sample of sea water already contains minute traces of wastewater from other ocean outfalls both near and far. The new high tech plant and a deep mid-harbour outfall will be a vast improvement on the current situation without the risk of degrading, devaluing and detracting from the unique beauty of Akaroa and it's neighbouring small settlements. Any hint of effluent pollution either physical or sensory will threaten the attractiveness of Akaroa for both residents and tourists alike.

Supporting information

Attach any supporting documents (if applicable).
Note: When uploading multiple files please multi select and upload all at once.

The combined file size must not be larger than 10MB.

Choose Files | No file chosen

Department of Conservation
Te Papa Atawhai

DOCDM-6395453

19 August 2020

Christchurch City Council
PO Box 123
CHRISTCHURCH
Attention: Tara King

Dear Tara,

Akaroa Treated Wastewater Discharge Options Consultation

Thank you for the opportunity to comment on the Akaroa treated wastewater options advertised on the 20th July 2020.

It is important to note that Policy 23 (2)(b) of the New Zealand Coastal Policy Statement 2010 sets a stringent test for allowing discharge of treated human sewage to the coastal marine area under the Resource Management Act. While the Council's current process to identify and assess options for the wastewater discharge will likely satisfy the requirement of Policy 23, to consider alternatives to discharge direct to coastal waters, given the information provided regarding the effects on cultural values it seems unlikely that discharge to the harbour is a realistic option in the future.

We consider that continued discharge to the harbour to be at odds with efforts to maintain and improve marine biodiversity in this area. Akaroa harbour is an important habitat for Hectors dolphin, and this combined with the Akaroa marine reserve are a valued feature to visitors to the area and the local community alike.

We have a preference for land-based options for the discharge of treated wastewater over the option for a modified discharge to Akaroa Harbour. We support Ngai Tahu in its statements regarding a discharge to the harbour being incompatible with the cultural values of the harbour and coastal waters generally.

Regarding options for discharge to land, we note the sensible requirements for buffers for the discharge from surface water. We also note that there are positive outcomes from the discharge to land proposals with creation of native plantings which have some habitat potential for indigenous species. We also see that the discharge to land options create some encouragement for the Council to address or reduce the volume of wastewater needing to be treated and discharged, by identifying and reducing stormwater incursions into the wastewater network. It is expected that enough capacity is built into any new discharge to land option to ensure it accounts for potential future growth, to ensure that there is longevity in the design reducing the need to look for other options again the future.

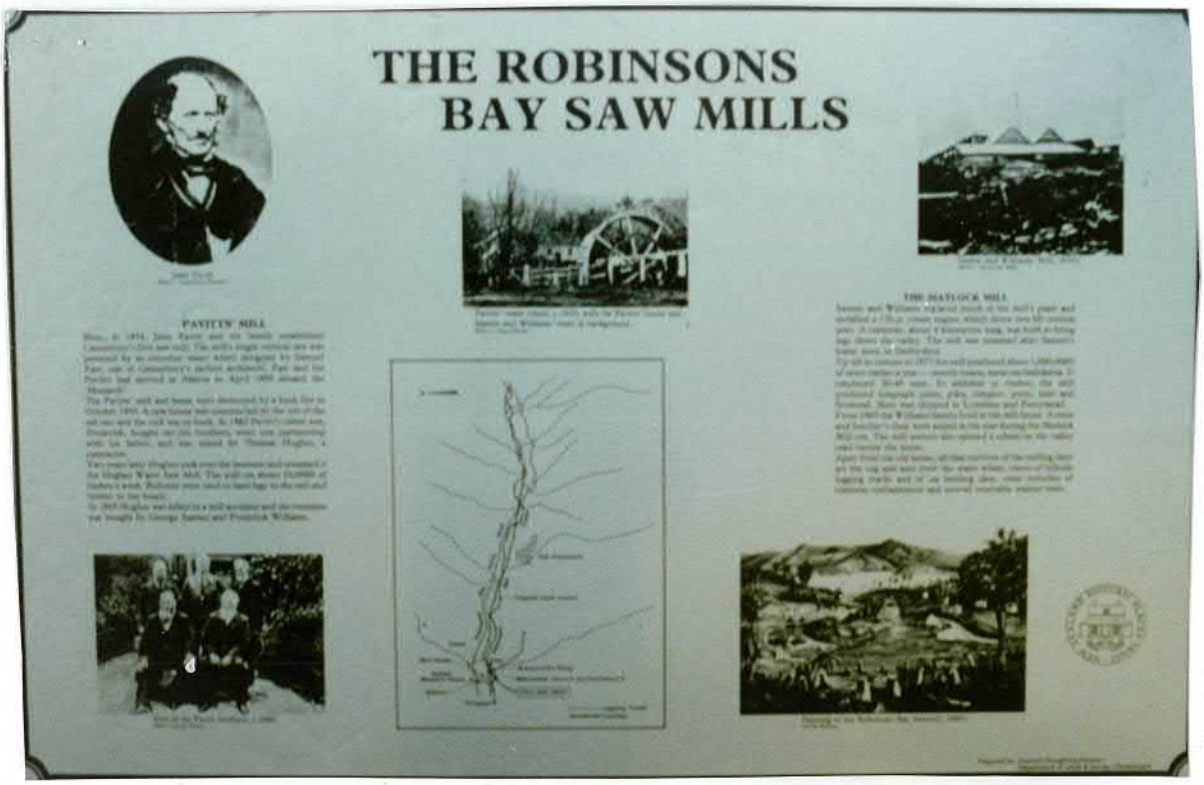
We note that linked to the land-based discharge options is the potential need for occasional emergency overflows to the marine environment at the new pump station site. If this is a possibility this may be acceptable in exceptional circumstances, only if the wastewater is treated to a high standard prior to this point in the system.

If you have any further questions on this matter, please contact Rachel Brown on 027 541 7691 or rabrown@doc.govt.nz.

Yours sincerely

Andy Thompson
Operations Manager
Maahanui District
For Director-General of Conservation

Submission #33892



Submission
#33920

Akaroa Wastewater Treatment Submission

We are permanent residents in the Takamatua Valley, about 1km from the main road. We have been living here for 15 years. We used to grow protea, lecuadendron and lucaspermum for the flower market. We have also grown organic vegetables for the Akaroa Farmers Market. We are now retired and grow all our fresh vegetables and fruit. We love living in Takamatua – it is quiet, there is a great community here and we aren't in Akaroa (though only 3km away, it is out of sight and sound).

We would like to see the council make the solution to Akaroa's wastewater treatment scheme a shining, innovative example for the world. The solutions presented are ways to dispose of the wastewater which we oppose. We would like to see it reused in Akaroa, where it is needed.

We suggest:

An education campaign in Akaroa to reduce the amount and type of effluent going into the system. We are even in favour of water usage charges.

Repair/replace the broken pipe network. We feel that the most important first step, along with an Akaroa education campaign, for the council to take is to fix ALL of the infiltration in the sewage pipes. The fact the new wastewater system is being designed without intending to first fix the pipes that are allowing 60-70% extra water into the wastewater stream is actually ludicrous and a waste of money.

And while the broken pipes are being replaced, put in purple pipe for re-use inside and outside the home to make it easier for homeowners to use in the future. In the 2017 round of submissions the purple pipe system was the most favoured by the public – reusing the water in Akaroa.

Treat the water to the highest potable standard so that all forms of reuse are possible (including managed aquifer recharge, stream replenishment, non-potable re-use inside and outside the home and, eventually, potable re-use). Water is going to become scarcer in future. In this way it will be able to be reused where it is needed – in Akaroa.

Figure out the best re-use option for ALL parties: Ngāi Tahu as well as communities in Akaroa, Takamatua, Robinsons Bay, Goughs Bay and Pompeys Pillar. Harbour outfall is not culturally appropriate for Ngāi Tahu, Inner Harbour Irrigation is not culturally appropriate to all the people who live in the bays being considered, Goughs Bay irrigation is not culturally appropriate to the people who live in Goughs Bay and Pompeys Pillar irrigation is not culturally appropriate for the owners of Pompeys Pillar.

Build a treatment plant with the goal of water re-use, not disposal. The land disposal options are all getting rid of the water while it will be needed in Akaroa in the future (there was a total outdoor watering ban in Akaroa and Takamatua last summer). If any of the land based solutions suggested are created, they are unlikely to be changed in future when the water will be needed in Akaroa instead of irrigating trees that don't need irrigation in other bays.

Not only having the water where it isn't needed, the impact on the local communities is way too high. People have been stressed for the last 4 years with the proposed ideas to put large ponds and irrigation to

the land near their homes. Robinsons Bay has 2 property owners in favour of the scheme there, one who doesn't even live in Robinsons Bay; the rest of the community do not want it. The same with Takamatua, Goughs Bay and Pompeys Pillar.

Replace the sewage pipe network and in the meantime figure out a better long term solution that meets the Council's Integrated Water Strategy. Make the Akaroa Wastewater scheme one the whole community can be proud of.

Regards,
Page Lawson
Stuart Jeffrey

Yes, I would like to be heard.

Akaroa Treated Wastewater Options

WE WISH TO BE HEARD

IN SUPPORT OF OUR SUBMISSION

Submission from:
AVERIL, KEVIN, NEST, EVELYNE AND PATRICK PARTHONNAUD
Email: [redacted]

Us and our love for our livelihood

The 5 of us live in Robinsons bay [redacted]

We moved here just over 5 years ago just a few days before our daughter's first birthday. We wanted more space for her and her cousins, which we look after, to safely run around as the house we were renting in Akaroa had no garden and no fencing from a busy road.

We found our dream home here in Robinsons bay an old farm house with some land that we could have a big vegetable garden and fruit trees and raise a few animals.

Our parents from France, Evelyne and Patrick live with us 6 months of the year and help look after all the kids in our team at Pohatu penguins. Our house ends up being kid central, there are 6 kids and this is their second home most days after school and every day during school holidays as we all work 7 days a week over summer.

We love to go on nature walks and enjoy the tranquil quiet space of Robinsons bay. The kids can spend an hour playing in a puddle on the side of the road and counting pukekos, foraging for black berries, water cress, walnuts and apples in the bay is just part of our normal routine here now. It's our little slice of paradise and we teach these kids all about trying to live regeneratively and try to practise this ourselves.

The house that we found is old and repairs were needed, we have invested a lot of time and energy to make it our home.

The socking news

Then a year after we bought our dream home we heard the city council was looking into spray irrigation only 5 metres from our bottom section where we have set up all our vegetable garden, glass house, fruit trees, chickens and kids treehouse.

That was a shocking news and we were very worried about spray drift and the treatment quality. I'm glad the community stood up and have pushed against this to end up where we are as so many things have changed and been learnt about since then. Like faulty water flow metres and the potential for purple pipes with drinkable water quality.

The thing that we are very against for the proposed scheme here is the huge storage dam above Pavitt cottage. It is a beautiful house and we enjoy looking at it from our garden and can't imagine a big ugly structure right above it.

We worry about all the earthworks involved taking a year, would the roads be busy and blocked? Will it smell, will it fill up with Canada geese poop and dead goslings and hedgehogs which can't climb out and become a contaminated cess pool, will it breed sand-flies, will the pond breed mosquitos.

There are so many what ifs. But the biggest "What if?" is, if it floods here, if it breaks with a natural disaster, the scenario on the risk assessment document looks like it floods our garage with all our tools, our work vehicle parking place, our glass house, our chicken coop, our vegetable gardens and newly planted fruit trees, our friends caravan, our wood storage.

Would the city council pay for all this to be fixed if that happened? Our garage has been maintained over the 90 something years it's been there and our neighbours said back in the day there was no consent for out buildings like that so it wouldn't be covered by insurance if something happened. That would be disaster for us as we use it so much and could never afford to replace it.

We also see our neighbours below us would potentially be flooded in their beautiful historic house and then further down the road our other neighbours near the creek could lose everything as well. There's so much risk involved in putting this in the middle of a community so close to houses.

New technologies and caring for the future

The world is changing extremely fast, new technologies are out there, and people are starting to question sustainability and how to live a more low impact life on our environment.

Auckland is facing a water shortage and are thinking about purple pipes. The laws will change soon or we can make them change now and be the first.

Akaroa will have water shortages in the future, maybe even this summer we haven't had rain for 6 weeks now and it's been winter, what is summer going to bring? Drought. The farming community is already stressed about the coming season.

Where will Akaroa's water supply continue to come from? What happens if Takamatua's water runs dry? Will you keep bringing an army truck from Christchurch to fill up Duvauchelle's water supply? It would completely blow up if council tried to take water from somewhere else and not tried the sustainable solution when they had the chance to and when everyone was asking about it.

If you build all this infrastructure out here in Robinsons bay and then realise you need to fix a water shortage problem then it will be all for nothing just a waste of time and money. We need to be thinking about the next generation now and even this generation.

We need to fix the pipes and reclaim the water for use. It needs to be treated to a drinkable standard so we can drink it and use it. In California people pay now for purple pipe water they are so short. Japan drinks it, London drinks it, Singapore drinks it, parts of China drink it. Why can't we? And if people don't want to drink it, provide a fountain/refill station in town with the treated creek water. The water tastes already so bad, highly chlorinated, I don't think it could get worse maybe with the extra filtration it would taste better than what it is now.

Community involvement and want

We understand and acknowledge that the Akaroa wastewater scheme is a hard topic with no easy solution. We understand that this has been happening for over 10 years now and that the Council went to consultation on different occasions, the last time being in 2017.

It was very clear though then that the community favoured some more sustainable solutions but we are very surprised to see that the options proposed are very similar to the one presented 3 years ago with some very minor changes.

Many community members have spent hours and hours working with the council and engineers to develop cheaper and more sustainable solutions. Hours that have saved the council disastrous outcomes such as the faulty flow meter.

All of this time, effort and pressure making our lives more stressful will not have any compensation other than the satisfaction to have help developed a more resilient and sustainable future for Akaroa if the council listen to what the people want.

4 well-beings

We understand that it is a complicated scheme due to the landscape of the area with no simple solution involving many parties.

However, we are not in favoured of any of the options as we feel that none of them are meeting the 4 well-beings: Social, economic, environmental, cultural.

- **Social**:
  High impacts on receiving local communities now and in the future with ongoing potential for odour, midges, Canada geese, destruction of heritage site.
- **Economic**:
  All of them are very costly taking funds directly away from more sustainable solutions.
  Decrease in property value.
  Limit any business development now and in the future for receiving communities and Akaroa.
- **Environmental:**
  Risk to local environment from intensity of irrigation, nutrient load and proximity to streams draining to mudflats.
  No ambition in tackling the issue at its source: preserving water and avoiding infiltration in broken pipe system (20% is simply not ambitious enough from the council staff and acceptable)
- **Cultural:**
  Although Maori values are taken into consideration, none of the receiving communities cultural values are. Families and couples and have chosen to move to other inner bays in order to live more in harmony with their surroundings.

Where we stand

<u>We do not believe:</u>

- That it is the time to start digging the roads of Akaroa once more but if so, it would have to be done at times of low visitorship with a sustainable reasoning behind the action such as working toward the purple pipe network.
- Although we understand that a consent has already been approved for a new treatment plant at the entrance of Akaroa. A 7 meters tall building that will need to be open once or so a month to carry solids away to Christchurch isn't an attractive building for the area and does not fit in the historic look of the village and so we urge the Council to revisit this part of the scheme. Especially when the building is 3 time the size it needs to be due to I&I
- We do not support any of the land based options

<u>We believe in:</u>

- A sustainable solution that will be beneficial to the community and make Akaroa a leading example in New Zealand which would put

it on the map and bring economic value to the region.
New Zealand is a fantastic country being nuclear free and marketing itself as a Green and environmentally friendly country caring for its unique wildlife. Countless projects are happening everyday around New Zealand but it is time that further steps are being taken to protect one of Nature's most precious resource: water.

- That the issue of the I&I (infiltration and Inflow) should be addressed and that a more ambitious level of fixing 20% of the broken pipes should be taken and be the first item on the council list.
- That treating the water to drinkable standard and reusing it through a purple pipe system is the way forward.
- We feel that the council is wasting time and money investigating any land disposal options.
- We support Friends of Banks Peninsula submission and implementing action steps.

The Robinsons bay crew enjoying one of our many walks.

Just behind is where the Dam site is proposed.

GOUGHS BAY FARMS LTD SUBMISSION

To:

Tara King, Engagement Team
Akaroa Wastewater Project
Christchurch City Council
PO Box 73016
Christchurch 8154
E-mail: tara.king@ccc.govt.nz

Submission on: Proposed Akaroa Treated Wastewater Options

Date: 23 August 2020

Contact: **John & Carol Masefield**
Goughs Bay Farms Ltd
[redacted]
Akaroa 7542

Phone [redacted]
Email [redacted]

SUBMISSION ON CHRISTCHURCH CITY COUNCIL'S AKAROA TREATED WASTEWATER OPTIONS

Introduction

We are John, Carol, George and Emma Masefield, owners and operators of Goughs Bay Farms Ltd, and we are writing to oppose the proposal to build an irrigation scheme at Goughs Bay.

We farm Sheep & Beef on 425ha in Goughs Bay in conjuction with our son and Family. We consider ourselves caretakers of the land for future generations.

The Masefields have owned and farmed land in Goughs Bay for 152 years. With 6 generations occupying the bay.

Summary points on our submission

We oppose the proposal to install a wastewater treatment plant at Goughs Bay, based on the following primary concerns:

- The lack of proper consultation with potentially affected landowners before the proposal was announced
- The adverse effect the proposal will have on existing significant indigenous vegetation on the *Wildside*
- The adverse effect the proposal will have on existing infrastructure, including our roads, pipes and ponds
- The impracticality of planting on the proposed location, and
- The negative impact on our farm.

We would support the Inner Harbour proposal because it is the most practical option and well-considered option available. We lay out our reasons in detail below.

Procedural Fairness

The project for the disposal of Akaroa wastewater has run about 10 years, but the Goughs Bay version has only appeared within the last 6 months. A meeting between CCC staff and local residents was held in December 2019, but since then there has been no further consultation, even though the original project concept has been substantially changed.

In contrast, the local community was heavily involved in the ongoing process of Inner Harbour option. Yet, both options have been presented in a public consultation process as though they received equal levels of robust research and analysis and community involvement.

We consider the consultation process on the Goughs Bay option has, thus far, breached the rules of natural justice, and this point will come to haunt the CCC if any further steps are taken to progress with the Goughs Bay proposal.

Impact on *Wildside*

The proposed site for the Goughs Bay option will include a part of the *Wildside*, which extends over a group of bays to the east of the crater rim on Banks Peninsula. The *Wildside* is an area of significant indigenous vegetation, and has few introduced flora species, relatively few weeds, and high rates of endemism. Much of the *Wildside* is in areas of Outstanding Natural Landscape, Ecological Significance and protected in reserves or covenants in perpetuity.

The *Wildside* is a wonderful community project; it represents over 30 years of positive collaboration between passionate landowners, contributing government agencies and community groups. It is nationally recognised for its unique community-driven approach, and individual landowners have made costly and long-term conservation investments on their own land.

The significance of the *Wildside* should not be taken lightly.

We oppose the proposal to plant a native forest on 33 ha at the location identified on the planning map for several reasons:

- The *Wildside* is predisposed to natural regeneration, with a range of protected natural areas in its immediate vicinity providing rich seed sources. The exemplar of this is the Hinewai Reserve, which is internationally renowned for its hands-off natural regeneration. This is because the *Wildside* experiences high rainfall and native seed bank, low weed species and, in some areas, nitrogen-fixing gorse is used as a nursery crop.

  Natural regeneration from natural seed source is preferable ecologically to planted forest. To be successful, planting native forest is a high input job that needs regular visits to ensure weeds are controlled, plant guards are not damaged or blown away in storms, and that pests are under control. Sourcing enough seed source from the ecological area, the use of weed and pest guards, and getting the right plant mix to grow would be extremely costly.

- Planting on Goughs site would be an intensive undertaking, with regular site visits to maintain the plants. The Goughs site is exposed to all wind directions with the wind being especially frequent and harsh. The high winds would risk wind guards blowing out to sea, and becoming a marine pollutant, on a regular basis.

  Plant growth would be severely reduced on the Goughs site due to the harsh environment, with frequent cold winds accompanied by hail, sleet and snow at times. Plant growth will be considerably stunted compared to expectations based on the plant trials that have been carried out in Pipers Valley, and the speed of plant growth and water uptake needs to be studied in this particular environment before any sound conclusions can be drawn.

- The Goughs site is particularly vulnerable to high rainfall. The plants inhabit a moist environment with regular high rainfall events; they cannot be expected to absorb or hold as much wastewater as you would presume.

  Rainfall is highly changeable across the *Wildside* with flood events being experienced that are not forecast. It is not at all uncommon to have 100mm rainfall events happening within a few hours at higher altitudes. The *Wildside* is also much cloudier than the inner harbour, with sea fogs and easterly drizzle that can cause long term dampness underfoot and reduce the wastewater intake capability of plants in this environment.

New trials would need to be undertaken over many years to ensure that the plantings could withstand this environment, take up the wastewater at an appropriate rate, and that the appropriate planting area has been set aside.

We have planted native shelterbelts that have not grown well due to the extreme weather conditions on on these exposed parts. As is evident in many places along the *Wildside* coast, the native forest in the area is stunted and twisted due to the persistent wind.

The suggestion that the *Wildside* would be somehow enhanced by having a planted forest shows a fundamental lack of understanding of its inherent nature: it is the side of the peninsula that is a little wild and intractable, and it is busy doing its own thing as part of a dynamic, natural process.

There would be almost no recreational advantage of a planted forest in an inaccessible place such as Goughs because almost nobody would visit, especially when they can visit a natural and inspiring place such as Hinewai.

Existing Roading Infrastructure

The only current access to the proposed Goughs site is a grass track, and an adequate access road would have to be built. This proposed road will need to run through an identified Outstanding Natural Landscape (ONL) in the current District Plan.

Any access road would represent a significant adverse effect on the values of the ONL and on the immediate neighbours, who would be in sight and hearing of the road cutting through the ONL and the subsequent traffic on it. Both building the road, and ongoing traffic, would increase the noise levels in an area that is renowned for its silence.

The road would need to pass along the top of a Banks Peninsula Conversation Trust (BPCT) covenant, and it is likely that this would have an impact on the ecology of that covenant area.

There has been no consultation or planning on the type of road required for the access and pipeline, the creation and maintenance of the ponds, or for the visits that would be required to establish and then maintain the plantings. However, it is clear an all-weather road is needed. Thus, a formed road would be created through a ONL and through neighbouring land including a block that is in the process of becoming a QEII covenant. This would have a significant impact upon the neighbouring properties and on the significant natural environment of the *Wildside*.

While the wetland of Goughs Bay has been mapped as *Ecologically Significant*, there are many other sites of ecological significance within Goughs Bay. However, these areas are still undergoing the process of being surveyed and signed off by the landowners. The BPCT Goughs multi-covenant will fit these criteria, as will the Top Bush BPCT Covenant, both of which are alongside the proposed road.

The proposed road is in a high rockfall area, and in the Canterbury earthquakes of 2010 several large rockfalls happened along the BPCT covenant, breaking the fence in many places. One very large rock fell across the track and fence and had to be blasted out of the way after weeks of planning and involving a team of workmen. If such an event happened in the future the road access would be cut to the ponds and planting site.

The site access road is intended to be formed along the route of the existing legal road corridor, and therefore there will be public access. The terrain is such that this

may create significant safety risks when oncoming vehicles meet, exacerbated by the shear drop on the southern side.

The entire construction process, including the movement of heavy machinery and maintenance vehicles, would pose a considerable risk of introducing new weed species to the *Wildside*, an area that currently has very few agricultural or ecological weeds.

The proposed road will have relatively high usage by local standards, and with the nearby power lines and associated structures, would have a significant impact on the visual aesthetics of the Goughs Bay valley.

In comparison, the Inner Harbour and Pompey's Pillar options already have formed roads, and there are no additional obstacles regarding Outstanding Natural Landscapes, ecological significance, or rockfall issues.

Existing Infrastructure – Pipes and Ponds

A pipe to pump wastewater up and over the summit of Banks Peninsula will have to be engineered to a high standard, with considerable risks if the pipe or pumping system fails.

We believe that the only way to lay a pipeline along Hickory Bay Rd would be to close the road for extended periods, causing significant additional disruption to residents, essential farming services, and access for emergency vehicles.

As there would be no intermediate pump station, any small issue with the pump, such as a power cut, could reduce the effectiveness of the operation. Any significant issue could cause longer term delays and spill over of wastewater through Children's Bay more directly into the Harbour.

There will be climate change issues if you proposed to pump over the summit rim, given that the annual power cost is in excess of $100,000. Even though planting native forest can offset some of the climate issues, it is a far more sensible option to conserve that power when there are suitable disposal options closer to the source.

The budgeted cost to install the high-pressure pumping station and pipe along the Long Bay Road is a significant cost to the ratepayers; it is an unacceptable burden in the post-Covid economic environment.

Impact on our farm

The Goughs site is close to two intakes for household water: one is an easement to Hickory Bay, and the other is a house supply to our home and buildings in Goughs Bay, which is within approx 450m of the proposed plantings.

The proposed Goughs planting site has a natural spring in it which flows all year into our farmland, any leaching of trace contaminants, such as antibiotics into our farm, stock water or ground water, will cause significant loss of value of the livestock when it is sold due to us being Anti-Biotic free.

We do not believe that there has been any specific study on the impact the Goughs Bay proposal will have on the area’s soil type and the risk this scheme may leach downhill or into groundwater.

There appears to have been no study on where the material from excavating the pond sites will go. If it is moved offsite there will significant disruption and added cost. If it is used to fill in the Crown Island stream catchment this will threaten the steam’s

ecological values. Crown Island is home to numerous native birds, fish, seal colonies, penguins, indigenous plants and waterfalls. No study has been done to assess the adverse effects this proposed Goughs Bay scheme will have on these freshwater plants and fish. This is the area which they propose to discharge water to the sea in an event of an overflow through our land.

The wastewater scheme would have a significant impact upon the values of the blocks of land being proposed. This would have an impact upon the our land values as well. We would be seeking compensation for the loss of land value.

We support the Inner Harbour option

The Inner Harbour proposal has been well studied.

We believe you can establish and monitor the proposed plantings at the Inner harbour without the risk of wind damage to plants, and the plant guards being blown away and lost

The sites are easily accessible for routine visits by the park rangers and maintenance staff.

The Inner Harbour proposal would create recreational and ecological habitats that are not currently available in that area. These native forests would be favoured habitats for a wide range of bird species, especially due to the sheltered valley environments.

These restored natural habitats in the Inner Bays could be enjoyed by a wide range of people, both residents and visitors alike, all with easy access. In comparison, on the *Wildside* the access is difficult, the environment harsh and at times inhospitable with associated health and safety risks.

Holding ponds in Robinsons Bay could act as wetland bird habitat, especially if small islands were built within them, which would inhibit predators from being able to access bird nests and allow an abundance of bird species to flourish in the protected valley. This occurred in the Christchurch oxidation ponds, where the city saw an increase in its wetland bird species and the ponds being considered a "rare bird hot spot".

On the site of Goughs, there would be very little advantage of ponds to wetland bird species, due to the exposed environment is not conducive to bird breeding.

Conclusion

We agree that a wastewater treatment facility is essential for the long-term health and wellbeing of the Akaroa community. However, we do not believe the option to process treated wastewater should include the proposed irrigation scheme at Goughs Bay, for the reasons we set above.

The Goughs Bay proposal was not well-researched or well-developed. It may look feasible on paper, but it runs a high risk of failing, or of a cost blow-out. We suspect that nobody from the CCC, or their consultants, has ever experienced the Goughs site in the middle of winter. It is often a bleak, cold, and windswept site from every direction, even when there is no rain or sleet. To establish a native forest there, within any reasonable timeframe and without a huge effort, is unrealistic.

The consensus of our knowledge is that plant growth rates in the Goughs site would be severally stunted in these harsh conditions in comparition ot what could be

expected at the Inner Harbour locations. We believe the proposed planting area is inaccurate.

The size of the proposed storage ponds implies around two months capacity, provided they are empty at the start of a rain period. Experienced locals can recall that in some years the site has been continuously saturated for significantly longer periods. This implies either the need for either much larger ponds, or alternatively more robust proposals for emergency discharges from the wastewater plant.

The Goughs Bay proposal will need a significantly larger budget than that currently estimated, if there is any chance it will be at all successful as a disposal option for Akaroa wastewater.

The Inner Harbour option has been researched and designed in detail. There are no significant risks, but there are some significant and obvious benefits, which we would support.

John, Carol, George and Emma Masefield
Goughs Bay Farms

Akaroa Wastewater Scheme Submission 2020 – Craig Church

My comments relate to the Inner Bays Irrigation option.

The diagrams below show the family property at [redacted] Robinsons Bay Valley Road.

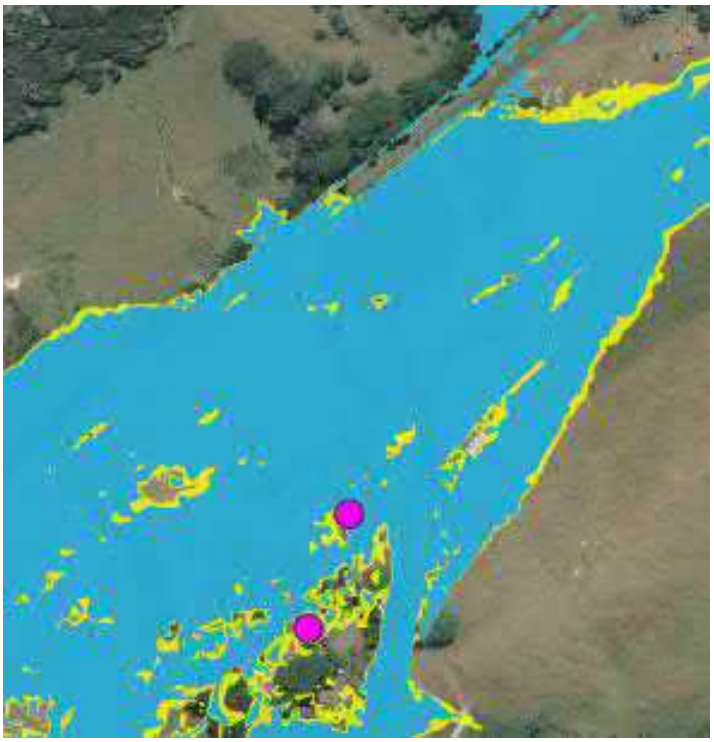


Figure 1

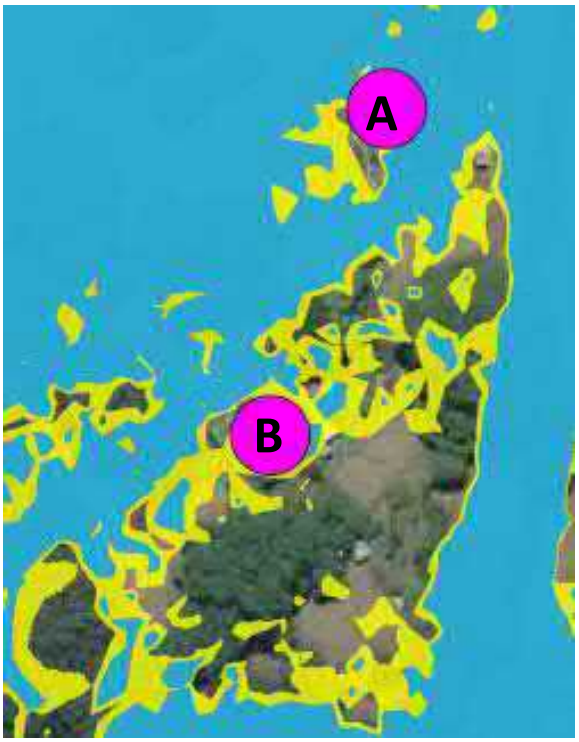


Figure 2

The map above is the 100 year 15,000m3 10 minute dam break analysis (BECA report), with the blue showing storm flooding over 50mm and the yellow showing the effect of a dam break resulting in flooding over 50mm. Figure 1 shows the property where we live – the boundary is pretty much where the blue is, showing nearly all of the property will be flooded in a 100 year storm.

My concern is shown in figure 2 – the one paddock where we always put our stock during a flood will now also have dam break water encroaching on it, compounding the flood effect and leaving even less room for our stock. Note that this is a very small area – the tree you can see in the middle of the clear area is just one large walnut tree. Water from the dam break will now go around the front of the main house (labelled 'A'), an area that has never flooded in the past 40 years, and where our hayshed is located. This shed is usually used for stock protection in severe weather but is shown to have water going through it from a dam burst. The 115 year old cottage (labelled 'B') has never been flooded, but will now have water all around it as the result of a dam break. CCC have offered no flood protection, say they will claim no liability if the property is flooded, and will offer no compensation for possible damage or loss of stock.

I have concerns that the dam break analysis does not consider any upstream slips, which have occurred in major ways in the past, or blockages in the waterway due to debris, when large amounts of logs and branches regularly wash downstream in flooding. To me this is just common sense to consider these scenarios, and yet a lot of these issues have been overlooked by Council. Who will rebuild our floodgates, fix our fences or pay for damages?

The creeks path often changes after major floods, affecting the water flow and depth, thus flooding can occur in places where it has never flooded before. Most times it is caused by sections of the banks slumping or by large

boulders building up in various points along the water way. This is something I keep a close eye on, with the creek being very close to the house. This variation does not seem to have been taken into consideration, nor its effect on the bridge at the bottom of the Valley that crosses State Highway 75.

I see that selling the property in the future would be an issue as no one will want to live downstream from a large wastewater storage dam or be associated with the stigma that goes with a sewerage scheme in the Valley.

Canadian geese are also a big problem in our Bay, and having a large pond that will sit reasonably empty in the warmer months will result in waterfowl stagnating the pond, attract midges and sandflies, and creating odour. The proposed nitrogen levels could result in leaching into the stream, and the effects of heavily watering native trees for the next 40 years is unknown.

This scheme is hugely oversized as the Council has not addressed the infiltration issue in Akaroas leaking pipe system. It also relies of expensive prime farm land instead of looking for marginal land to irrigate.

My family has been greatly impacted by this proposal over a long period of time and I ask the Council to remove the Inner Bays scheme as an option and look at a more modern way to deal with the issue that does not come with such a high human cost.

I see many issues with all of the land based options and do not support them. I support Harbour outfall, but only in conjunction with setting up long term re-use.

The water level of the stream rises dramatically during heavy rain.

Flooding causing major damage from debris build up by the main bridge on State Highway 75, Robinsons Bay.

Water pooling next to the historic Pavitt Cottage during heavy rain.

Damage to the above bridge caused by floodwaters undercutting the structure.

Clearly extra water is not required in our water catchment!

HERITAGE NEW ZEALAND
POUHERE TAONGA

20 August 2020

Christchurch City Council,
53 Hereford St,
Christchurch, 8013

Ref: 33005-094

Dear Sir/Madam

Consultation on a replacement Akaroa wastewater treatment plant scheme

Thank you for the opportunity to comment on the four options for this scheme. We appreciate the scheme's importance for the community and from our discussions with council staff, a lot of thought has been put into minimising the environmental impacts of the wastewater discharge which is supported.

We recognise that finding appropriate sites in Banks Peninsula is challenging given the constraints of the area and that, for a number of reasons land based disposal is preferable to discharging into the coastal marine area.

There is a rich history of archaeology, both Maori and European, throughout Banks Peninsula. Under the Heritage New Zealand Pouhere Taonga Act 2014, archaeological sites are defined as any place occupied prior to 1900 that may provide archaeological information on the history of New Zealand. An Archaeological Authority is required for any works that may modify or destroy an archaeological site.

Given the long history of occupation of Banks Peninsula, all of the options have the potential to impact on archaeology. The preference of Heritage New Zealand, in the first instance, is for whichever scheme has the least impact to any archaeology. Whichever option is chosen, we recommend that all proposed works are assessed by a consultant archaeologist, including the treatment plant and pipe alignments, as well as any storage ponds, dispersal fields, and planting. We appreciate the commitment for the pipeline routes for all options to closely follow the road reserve where possible as this will reduce the likelihood of disturbing previously undisturbed archaeology.

In particular, the Inner Bays Irrigation Scheme option, has a number of different components, including an area proposed for planting, irrigation and storage of the treated wastewater on Sawmill Road in Robinsons Bay. Despite being unable to access the site itself, , an initial archaeological assessment of this area indicated that this is an important archaeological landscape, containing the remains of industry associated with sawmilling from as early as 1855. Extant features identified in the assessment include the remains of 19th century dwellings, campsites, bridge foundations, a well, tramway, and the site of the mill itself. The assessment also identified that the landscape itself bears

modifications associated with sawmilling, including log furrows, a pond, water race, flume, and dam. The neighbouring historic Pavitt Cottage (scheduled in the district plan) is on a different parcel of land from the proposed development. The subject site would see a large amount of development including the large storage ponds, pipework, landscaping and planting.

Should the Inner Bays Irrigation Scheme proceed, Heritage New Zealand recommends avoidance of key archaeological features and mitigation of the impact to the archaeological values of the Robinsons Bay landscape. To inform these decisions around the avoidance of impact to archaeology, Heritage New Zealand recommends having the site and proposed works fully assessed by a consultant archaeologist. Based on current understanding of the proposal and landscape, this recommended avoidance and mitigation measures could include:

- Siting the storage ponds and associated earthworks within the lower terrace area so as to avoid impact to archaeology on the upper terrace area.
- Creating exclusion zones around key archaeological features and areas of occupation, as identified in the full archaeological assessment.
- Ongoing conservation of above-ground archaeological features, including site maintenance and low impact planting.
- Interpretation and opening of the site for the public, to promote connection with the history of Robinsons Bay, as appropriate.

The proposed setback of 25 meters from permanent waterways provides a mechanism to avoid impacting a number of the important archaeological remains of the landscape, increasing this setback to fully exclude other key features from disturbance would be supported. Public recreational use and education would be an excellent additional benefit to the scheme and would highlight and contribute to the preservation of the heritage values associated with the site.

Heritage New Zealand wishes to be heard in support of this submission.

Yours faithfully

Sheila Watson
Director Southern Region
Heritage New Zealand Pouhere Taonga

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Creative solution needed to a difficult problem

The Council staff and consultants who have been back to the drawing board after the Environment Court's request that disposal methods, other than the use of Akaroa Harbour, for Akaroa's treated wastewater be investigated have done a reasonable job. They have come up with possibly workable proposals for irrigating the water over land, with proposed planting of native species. If they are lucky the schemes might work – but little work has been done on the soils and subsoils, which are well-known to extremely liable to both tunnel-gully erosion and slipping. All three of the land-based schemes have severe environmental and landscape issues (and in the case of the inner harbour option very strong heritage issues) and they also rely on long lengths of buried piping, operating at quite high pressures. I have seen no study of the likelihood of the failure of the delivery pipelines, but if the failure of local roads (which have been constructed and maintained to be resilient) through washouts and slips is anything to go by, then one would expect a 10km pipeline to be compromised somewhere over its length about once a year.

The other area which makes me nervous about the schemes proposed is the lack of any serious sensitivity analysis in the calculations. They're the 'what if?' calculations. What would happen if treated water volumes could be reduced by half, or if the average rainfall doubled over the life of the project? And what happens to the long-term costs of the various options if, for example, the discount rate doubles?

For these reasons I do not support any of the options presented in the discussion document.

But that's not to say that there aren't any possible solutions for the disposal of Akaroa's treated wastewater. They just need to be a little more creative.

For example:

1) The way in which peak discharges currently coincide with high rainfall periods and high tides show that peak flows are largely driven by infiltration and inflow of one sort or another. If this could be eliminated not only would peak flows be a lot smaller, but so would overall volumes – leading to a substantial reduction in disposal needs, and the availability of a much wider range of disposal options. It is a ridiculous notion that the Council might in effect be collecting stormwater and groundwater in Akaroa, putting it through a high-class treatment system, and then pumping it over to Goughs Bay for disposal. A much better solution for that stormwater would be to let it flow naturally down the creeks and into the Harbour, and for the groundwater to follow natural pathways. In any scenario there are huge gains to be made by volume control. There are also tools available under the District Plan and the possibility of bylaws to require and deliver water conservation, and waste water reduction measures. Even simple things, like permitting, let alone requiring, the use of low-flush toilets would make a huge difference. At an earlier stage of the Akaroa wastewater process I suggested that a target of 2% of present volume per annum reduction of Harbour discharge be set, with severe penalties against the Council if that is not achieved. The result would be that in 50 years' time there would be no discharge into the Harbour. In the meantime there would be huge incentive to reduce volume. With a substantial flow reduction the difficulties of treatment and disposal would also diminish dramatically. If it were to take 10 years to

complete the construction and commissioning of a new system, by the time that is finished the volumes to be handled would be 20% less than at present. That'd make the job easier!

2) In the early days of European settlement in New Zealand the current notion of 'three waters' wasn't considered. There was a 'two water' system – with towns having a water supply, and drains. Later on the drains were split into stormwater and sewer systems, and the current 'three water' concept was born. But is that appropriate now? In practice water supplies have already been split (into potable and non-potable supplies). Should the sewer part of wastewater be split into 'bodily waste' water and 'grey water'? Actually the use of the term 'grey water' itself already implies that there is an underlying concept of a split. In effect, should the toilet water be separated off from the dishwater? In a town the size of Akaroa, and with its hills and gravity-driven system, this is actually quite feasible. It would be relatively straightforward to divert specifically toilet effluent through something like a 'STEP' system into new narrow-diameter, infiltration-resistant lines. This would give a controlled flow, and a volume of something between 5 and 50 cubic metres a day – which is within the range of being able to take it by tanker through to Christchurch for separate specialist treatment if it cannot be done locally. As I understand it Ngai Tahu has no great objection to a Harbour discharge of well-treated waste water which does not contain that specifically human waste. Cost? If it were $20,000 per connection, and the same again for the reticulation, then it might be in the range of $40 million – which with a treatment plant is quite comparable with the other schemes being proposed.
3) Discharge of treated wastewater to the sea hasn't been adequately considered. The Council's engineers have looked at the known cost of installing the new pipelines in Lyttelton Harbour, and said that the cost of a sea (beyond the Heads) discharge for Akaroa would be prohibitive. But they haven't seen that the circumstances at Akaroa are really quite different. The pipelines from Diamond Harbour or Governors Bay are required to handle peak flows of untreated sewage. In Akaroa the lines would only need to handle average flows, and of well-treated water. That means that both size and reliability factors required could be an order of magnitude lower. If one takes as a basis that the treated effluent could be pumped over the hills to the Eastern Bays, then pumping capacity for a total head of about 600 metres would be involved. If that figure is used with standard models for PE pipe capacity, then a 75mm diameter pipe would be capable of taking Akaroa's average flow to a distance of 12km – which is out beyond the Heads. Relay pumps would probably be needed, but the pipes would be parallel to harbour scouring currents, and away from anchorages and shipping channels. 75mm pipe comes in coils, can be joined and mended with screw fittings, and would have nothing like the buoyancy and anchoring needs of the sort of pipe used at Lyttelton, even if filled with warm fresh water. The technology is standard on dairy farms for cow shed effluent, and farmers pay around $20 per metre for the pipe.

Michael de Hamel

[redacted]

[redacted]

20 August 2020

Robinsons Bay and Takamatua concerns with disposal of Akaroa wastewater in our communities

The communities of Robinsons Bay and Takamatua have been extremely concerned for the past 4 years about the ongoing proposals to dispose of Akaroa's wastewater in our communities and near our homes and oppose the Inner Harbour Irrigation Scheme.

The Akaroa Wastewater Working Party was set up by the Community Board in response to our community concerns in 2017, but these concerns are not addressed by the Inner Bays option that continues to be included and is favoured by the Council staff.

The proposed Inner Bays scheme includes:

- Construction of a storage pond, 2ha in size (equivalent to four football fields) with capacity to hold 19 million litres of treated wastewater on a sloping site with a 4m high dam face adjacent to the main Robinsons Valley stream. It is in the centre of the Robinsons Bay valley community surrounded by houses on three sides, and immediately above the fragile and significant historic Pavitt Cottage.
- Three irrigation fields planted with native trees within 5m of neighbouring properties in upper Robinsons Bay, at Hammond Point and on the Takamatua flats.
- Construction of an artificial wetland on the land between State Highway 75 and Old Coach Road to enable discharge of wastewater to Childrens Bay when the storage pond at Robinsons Bay is full.

We oppose this scheme because it is a complex, high cost and untried system, placed in the centre of our communities with little margin for error, and does not provide resilience against future climate extremes.

This scheme places our environment, lives and properties at direct risk of adverse effects now and in the long term future for the following reasons:

1. High cost unproven system placed in the centre of communities with little margin for error
2. The design of the Inner Bays option is so tightly constrained by availability of suitable land that the minimum setback distances from houses, property boundaries and streams have been used increasing impacts of negative effects on communities
3. Risk of flooding from dam burst and stream bank slip for downstream houses
4. Risk of nutrients and other contaminants leaching to streams and draining to shallow mudflats impacting aquatic life due to irrigating close to streams, year round, and in wet weather
5. Negative impact on significant archaeological site, related heritage cottage and surrounding heritage landscape from storage pond and irrigation field in Robinsons Bay
6. Wastewater will be released into Childrens Bay at Akaroa
7. Sewage reticulation is not being provided to the receiving communities
8. High value land in the Inner Harbour required and any future expansion likely to require acquisition of even more high value private land.

We now explain these reasons in more detail:

1. **High cost unproven system placed in the centre of communities with little margin for error**
    - Irrigation of wastewater to planted native trees has never been tried before in New Zealand. This is an unproven and experimental system.
    - The setback distances used by the Council to select suitable sites for wastewater infrastructure are based on engineering concerns and do not take into account the social impacts on the neighbouring residents
2. **The design of the Inner Bays option is so tightly constrained by availability of suitable land that the minimum setback distances from houses, property boundaries and streams have been used**
    - Common adverse effects of storage ponds are odour, midges, mosquitoes, noise and visual effects
    - The risk of these effects impacting people is greatly increased by the placement of this infrastructure so close to houses
    - These risks are ongoing and likely to have a negative impact on the values of property in the immediate vicinity of the storage pond over the lifetime of the system, and the potential to devalue and hinder property sales for residents close to the irrigation fields in both Robinsons Bay and Takamatua.
    - Trees within 5m of property boundaries will shade neighbouring properties and affect views.
    - Residents of Robinsons Bay will be subjected to extreme disruption during the excavation of the storage pond and laying of pipes.
3. **Risk of flooding from dam burst and stream bank slip for downstream houses**
    - There are several houses downstream from the storage pond and irrigation field in Robinsons Bay
    - The storage pond will be constructed with the main Robinsons Valley stream below the northern dam face and is bounded by an ephemeral stream on the western side. The main stream appears to be closer than the minimum site selection parameter, which was intended to keep the dam out of the stream flood area.
    - Dam burst analysis presented in the Beca Report shows an increased risk of flooding if a dam burst occurs during a major storm with properties being inundated around houses, and in some cases under the floor boards, including the Pavitt cottage and the lower part of Robinsons Bay, also endangering stock.
    - The dam burst analysis does not take into account risks of debris blocking the stream where it passes under Sawmill road in a constricted space. The Beca report also identifies an elevated risk of stream bank slumps and slips which could lead to further flooding. Peninsula experience shows that flooding risks are heightened when debris constricts stream flow during storms leading to a build-up of water followed by a flash flood.
    - The irrigation field at Robinsons Bay includes some areas that have downslopes steeper than the 15^{o} site selection criteria advised by engineers, exacerbating the risks of slips. The irrigation field at Hammond Point is also sited above downslopes steeper than 15^{o}.
    - The irrigation field at Takamatua is on land that is close to sea level and already boggy in winter. The downstream settlement is flood-prone.
    - The wetland is sited above State Highway 75 and the Akaroa Cottages residential area. It involves substantial earthworks and a constructed face up to 10m high on the western side facing the State Highway. A comprehensive dam burst analysis has yet to be done, but Beca have identified risks.

4. **Risk of nutrients and other contaminants leaching to streams and draining to shallow mudflats impacting aquatic life due to irrigating close to streams, year round, and in wet weather**

   - Irrigation is to take place within 25m of the centre of continuous streams, and 10m from ephemeral streams (that run during times of rain only), again the minimum setback requirement.
   - The treated wastewater will contain high levels of nutrients, including nitrogen and phosphorous. It is not yet known what contaminants (eg, micro-plastics) will not be removed by the treatment process.
   - Irrigation of wastewater to planted native trees has never been tried before in New Zealand. A small tree trial has been running at Duvauchelle for several years, but the trees are not yet at maturity and no results have been released regarding their ability to absorb nitrogen. Nitrogen build-up in the soil has been problematic for other land based irrigation schemes such as Rotorua that discharge to mature pine forests.
   - The size of the native tree irrigation fields and irrigation rates are based on modelling assumptions. These assume that the eventual tree canopy will intercept sufficient rain water to enable irrigation throughout winter, only ceasing after 50mm of rain. Both Robinsons Bay and Takamatua valleys experience severe ponding and stream burst during this level of rain.
   - Irrigation during wet weather will increase run-off to the streams.
   - The streams at Robinsons Bay and Takamatua drain to shallow coastal mudflats. If nitrogen builds up due to run-off, or if the trees do not absorb the amount of nitrogen envisaged, there is a risk of pollution and odours.
   - The disposal of wastewater in an area that already receives adequate, and at times excessive rainfall, cannot be regarded as beneficial reuse.

5. **Negative impact on significant archaeological site, related heritage cottage and surrounding heritage landscape from storage pond and irrigation field in Robinsons Bay**

   - The storage pond and irrigation field in Robinsons Bay would be located on a registered archaeological site, significant to Banks Peninsula and to Canterbury as the place of the first sawmill in Canterbury with a large waterwheel harnessing the power of the Robinsons Valley stream. The site includes the mill site and associated ponds, tramways and ancillary buildings, and a now abandoned 19th century cottage. These matters are confirmed in a recently commission archaeological assessment that has yet to be acknowledge by the Council.
   - Adjacent to the Sawmill site is the Mill cottage, the oldest standing structure in the area. The cottage was subdivided from the main Sawmill site about 20 years ago when it was purchased by a member of the original Pavitt family who built the first mill, fully restored, and left in trust for the descendants of the early families to use and enjoy. It is now also rented as a holiday let to the public to assist with paying for its upkeep and maintenance.
   - The Mill cottage is focal point for the archaeological landscape that stretches up to the abandoned cottage and is hugely valued by the residents of Robinsons Bay as the starting point for the European history of the bay. The existing property boundaries in Robinsons Bay still reflect their original ownership by mill workers, and there are many extant heritage features in the Bay, including the Schoolmasters house, farm buildings and trees planted by early settlers.
   - The storage pond will now dominate that landscape as it is sited immediately above the Mill cottage and will be visible from Sawmill Road, Okains Bay Road and houses in the area.
   - Access to the site during construction and on an ongoing basis will be from Sawmill Road over the location of the Sawmill site. This is likely to be irreversibly damaged during the construction.

- Trees will be planted over the other archaeological features, completely obscuring the abandoned cottage and to the boundary of the Mill cottage, separating it from its heritage context.
- The owners, the Pavitt Cottage Trust, is extremely concerned that about loss of income during the construction period and ongoing loss due to the destruction of the archaeological landscape and the potential for odour, noise and other nuisance from the close proximity of the ponds.

6. Wastewater will be released into Childrens Bay at Akaroa

- The Inner Harbour option includes a constructed wetland at the top of Old Coach Rd for further purification of the treated wastewater, including restoring the mauri of the water to make it culturally acceptable to Ngāi Tahu prior to entering the harbour
- During normal conditions treated wastewater will trickle into it at the rate at which it evaporates. When the storage ponds in Robinsons Bay become full (anticipated during times of prolonged wet weather) water will flow through the wetland to the Childrens Bay creek and out into Childrens Bay. The wetland is intended to remove significant amounts of nutrients, particularly nitrogen, from the treated wastewater. In very large wet weather events (estimated at once every ten years), the wetland will overflow and the treated wastewater will flow directly to Childrens Bay without passing through the wetland.
- There is considerable uncertainty around whether the wetland will perform as intended; the study used to inform its design of a significantly different system (with continuous flow), and there are numerous examples around New Zealand of the failure or poor performance of constructed wetlands at wastewater disposal sites , including those at Whakarewarewa and Ashburton.
- If the wetland fails to perform as intended, there is a risk of pollution of the Childrens Bay mudflats.
- The wetland requires significant construction and visual alterations to a prominent site at the gateway to Akaroa

7. **Sewage reticulation is not being provided to the receiving communities**

- It is unfair to impose the risks and impacts of disposing of Akaroa's wastewater on another community when that community does not benefit from the scheme.
- There are many residences in Takamatua and Robinsons Bay that dispose of their own sewage via septic tanks, at their own expense. They are now being asked to also dispose of Akaroa's wastewater.

8. High value land in the Inner Harbour required and any future expansion likely to require acquisition of even more high value private land.

- The proposed disposal sites include rolling country on a north-facing farm in Upper Robinsons Bay, a coastal headland at Hammond Point, and the flat field alongside SH75 in Takamatua.
- Using these sites for wastewater precludes their use for other purposes, including farming, horticulture, housing and recreation.
- The use of high value land for irrigation fields is being promoted by Council as beneficial reuse of the treated wastewater because they will be planted with native trees. Resources would be better directed towards larger areas of lower cost marginal land enabling greater biodiversity and carbon benefits at less cost, and harnessing natural regeneration of indigenous vegetation. This occurs readily on Banks Peninsula and is preferable to planted forest, both ecologically and in terms of cost.

- These three sites are needed to provide the minimum land required to reduce the storage ponds to a feasible size. If the volume of wastewater becomes greater than planned for (due to settlement growth or extended reticulation), or if irrigation rates have to be adjusted, then more high-value land will be needed, further encroaching upon these communities.
- The site at Takamatua is also flagged by the Duvauchelle wastewater irrigation scheme for relocation of the Duvauchelle Show highlighting the scarcity of inner harbour land.

Signed by the following residents and landowners of Robinsons Bay and Takamatua:

Name	Community	Contact
Peter G Steel	Robinsons Bay	[redacted]
Karen Watson	Robinsons Bay	[redacted]
Susan Bruce	Takamatua	[redacted]
Ray Bruce	Takamatua	[redacted]
Elizabeth Foley	Robinsons Bay landowner	[redacted]
Garry and Tanya Moore	Robinsons Bay	[redacted]
Bryan and Nancy Tichborne	Trustees, Pavitt Family Trust	[redacted]
William and Joan Adair	Robinsons Bay	[redacted]
Mark and Anna Pitts	Robinsons Bay	[redacted]
G.D.Shanks & N.A Shanks	Takamatua	[redacted]
Doig and Andrea Smith	Robinsons Bay	[redacted]
John Thom	Ngaio Point, Robinsons Bay	[redacted]
Julie Wagner	Ngaio Point, Robinsons Bay	[redacted]
Paul and Pip McFarlane	Robinsons Bay	[redacted]
John Thacker	Takamatua/Robinsons Bay	[redacted]
Tim and Nadine Adair	Robinsons Bay	[redacted]
Brent Schulz and Christine Shearer	Takamatua	[redacted]
Kathleen Liberty	Robinsons Bay	[redacted]
Doug Neil	Robinsons Bay	[redacted]
Cynthia, Tony and Hannah Muir	Takamatua	[redacted]
Brendan and Marion Glover	Robinsons Bay	[redacted]
Eric Ryder and Judy Jeffrey	Robinsons Bay	[redacted]
David and Sue Thurston	Takamatua	[redacted]
Harry Thurston	Takamatua	[redacted]
Mary & Michael Browne	Trustees, Pavitt Family Trust	[redacted]
Helen Leach	Trustee, Pavitt Family Trust	[redacted]
James and Michelle Adair	Robinsons Bay	[redacted]
Mark & Denise Wren	Takamatua	[redacted]
Fiona Turner	Robinsons Bay	[redacted]
Craig & Leanne Hastie	Ngaio Point, Robinsons Bay	[redacted]
Kevin and Averil Parthonnaud	Robinsons Bay	[redacted]
Liz and Hayden Cleaver	Robinsons Bay	[redacted]
Graham & Lorraine Raxworthy	[redacted], Robinsons Bay	[redacted]
Jacqui & Brent George	Trustees ,Pavitt Family Trust	[redacted]
Andreas Lageder & Anabel Barino	Robinsons Bay	[redacted]
Chris and Annette Moore	Robinsons Bay	[redacted]
Ross and Julianne Blanks	[redacted], Robinsons Bay	[redacted]
Craig and Suzanne Church	Robinsons Bay	[redacted]
David & Christine Kelly	Robinsons Bay	[redacted]
Bill and Jaynie Abbott	Robinsons Bay	[redacted]
Richard and Pam Florance	Takamatua	[redacted]
Ross and Brigitte Shepherd	Robinsons Bay	[redacted]
Lyndsey Rhodes	Robinsons Bay	[redacted]

Lee and Marian Robinson	Robinsons Bay	[redacted]
Todd and Louisa Raxworthy	[redacted], Robinsons Bay	[redacted]
Chris and Tracey Pottinger	Robinsons Bay	[redacted]
John and Rosalyn Curry	Robinsons Bay	[redacted]
Michael and Barbara Harrington	Takamatua	[redacted]
Brian and Anne Eves	Robinsons Bay	[redacted]
Craig and Sarah Raxworthy	[redacted], Robinsons Bay	[redacted]
Dick and Shirley Fernyhough	Trustees ,Pavitt Family Trust	[redacted]
Sara Parks	Takamatua	[redacted]
Graeme Curry	Landowner, Robinsons Bay	[redacted]
Toby and Annabell Smith	Robinsons Bay	[redacted]
Suky Thompson	Robinsons Bay	[redacted]
Brent Martin	Robinsons Bay	[redacted]
Joyce and Murray Walker	Takamatua	[redacted]
Johannah & Michael Curwood	Trustees , Pavitt Family Trust	[redacted]
Dianne Carson	Robinsons Bay	[redacted]
Julian and Katrina Calcutt	Robinsons Bay	[redacted]
Elizabeth Lawson	Takamatua	[redacted]
Alistair and Nerolie Davidson	Robinsons Bay	[redacted]
Trevor and Gill Bedford	Takamatua	[redacted]
Peter and Stephanie Ganly	Takamatua	[redacted]
Stuart Jeffrey	Takamatua	[redacted]
Amanda & Callum Wilson	Trustees , Pavitt Family Trust	[redacted]
Andrew & Mandy Bax	Trustees , Pavitt Family Trust	[redacted]
Viola Kasikova	Robinsons Bay	[redacted]
Craig & Julie Swan	Takamatua	[redacted]
Richard and Sue Lovett	Robinsons Bay	[redacted]
Hugh Martin	Robinsons Bay	[redacted]
Pamela and Tony Fisher	Landowner, Robinsons Bay	[redacted]
Ken and Yvonne Marshall	Robinsons Bay	[redacted]
Garth and Robin Tiffen	Takamatua	[redacted]
Jamie Palmer	Robinsons Bay	[redacted]
Norman Bayne	Robinsons Bay	[redacted]
Neil and Rebecca Barnett	Takamatua	[redacted]
Tom and Lynne Brennan	Robinsons Bay and Takamatua	[redacted]
Gary & Ruth Fail	Takamatua	[redacted]
Monique Connell	Takamatua	[redacted]
Stephanie Connell	Takamatua	[redacted]
Prunella Downes	Takamatua	[redacted]
Maria Browne	Trustee, Pavitt Family Trust	[redacted]
Wayne Best	Robinsons Bay	[redacted]
Fran Anderson & Grant Robertson	Robinsons Bay	[redacted]
David & Claire Williams	Trustees , Pavitt Family Trust	[redacted]
Peter Zwart	Robinsons Bay	[redacted]
Anne Zwart	Robinsons Bay	[redacted]
Steve and Annette Lelievre	Takamatua	[redacted]
Steve Parker	Trustee, Pavitt Family Trust	[redacted]
Peter Roberts	Takamatua	[redacted]
Glenys Roberts	Takamatua	[redacted]
Pat Lyons and Wayne Sceats	Robinsons Bay	[redacted]
Robyn Walker	Lessee, Takamatua	[redacted]
Geoff Harris	Robinsons Bay	[redacted]
Laurice Bradford	Takamatua	[redacted]
Hannah and Paul LeLievre	Takamatua	[redacted]

Christine Aylesworth and Richard Evans	Takamatua	[redacted]
Benoit Navarron and Flore Mas	Ngaio Point	[redacted]
Janey & Roger Thomas	Trustees , Pavitt Family Trust	[redacted]
Ben Tichborne	Trustee, Pavitt Family Trust	[redacted]
Kevin and Heather Sibley	Takamatua	[redacted]
David and Wendy Flemming	Robinsons Bay	[redacted]
Janice and Rodney Innes	Tamakatua	[redacted]
Kim and Barbara Avery	Robinsons Bay	[redacted]
Anne and John Bowden	Takamatua	[redacted]
Noel & Sue Strez	Takamatua	[redacted]
Nancy Kennedy	Robinsons Bay	[redacted]
Tony & Pip Mason	Robinsons Bay	[redacted]
Tim and Jacquie Johnson	Takamatua	[redacted]
Geoff Beaver	Takamatua	[redacted]
Gavin and Sonia Shepherd	Robinsons Bay	[redacted]
Hugo Tichborne	Trustee, Pavitt Family Trust	[redacted]
Guy Tichborne	Trustee, Pavitt Family Trust	[redacted]
Niall Holland & Jan Whyte	Takamatua	[redacted]
Elizabeth and Brian Bain	Robinsons Bay	[redacted]
Mark Milligan	Takamatua	[redacted]
Murray and Linda Smith	Robinsons Bay	[redacted]
Graeme and Karen Bryant	Takamatua	[redacted]
Ken and Carol Reese	Takamatua	[redacted]
Carolyn Browne	Trustee, Pavitt Family Trust	[redacted]
Chris & Sharyn Reid	Takamatua	[redacted]
Simon Hadfield	Robinsons Bay	[redacted]
Darryl and Martine Swann	Takamatua	[redacted]
Amy and Amber Swann	Takamatua	[redacted]
Jill Lockett	Robinsons Bay	[redacted]
Richard and Lorraine Troughton	Takamatua	[redacted]
Mike and Rose Ryan	Robinsons Bay	[redacted]
Brett Lea	Takamatua	[redacted]
Kathrine and Hugh Fraser	Takamatua	[redacted]
Gordon Boxall	Ngaio Point	[redacted]
Evelyn and John Oliver	Robinsons Bay-Duvauchelle	[redacted]
Derek & Sue Marr	Takamatua	[redacted]
Jenny and Tony Hay	Takamatua	[redacted]
John Thomson and Joanna Hase	Robinsons Bay	[redacted]
Shaun Huddleston	Robinsons Bay	[redacted]
Frank and Maryline Shaw	Takamatua	[redacted]
Lizi Reese	Takamatua	[redacted]

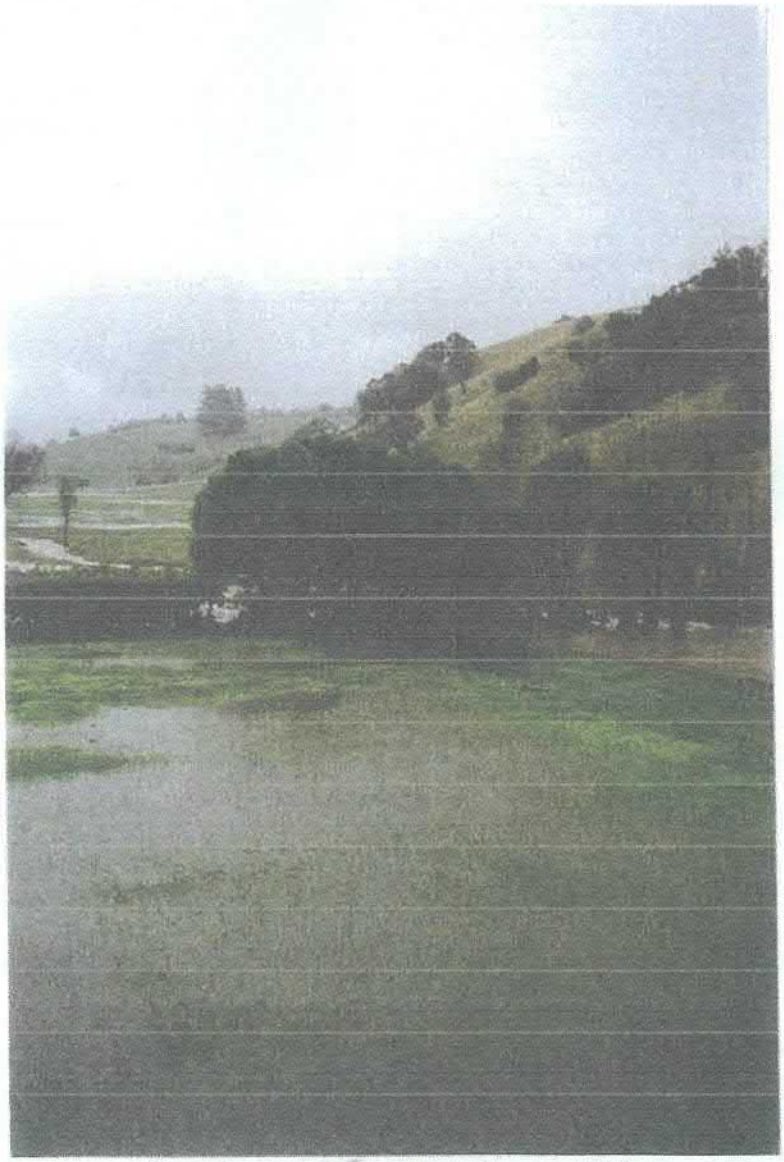
Total 225

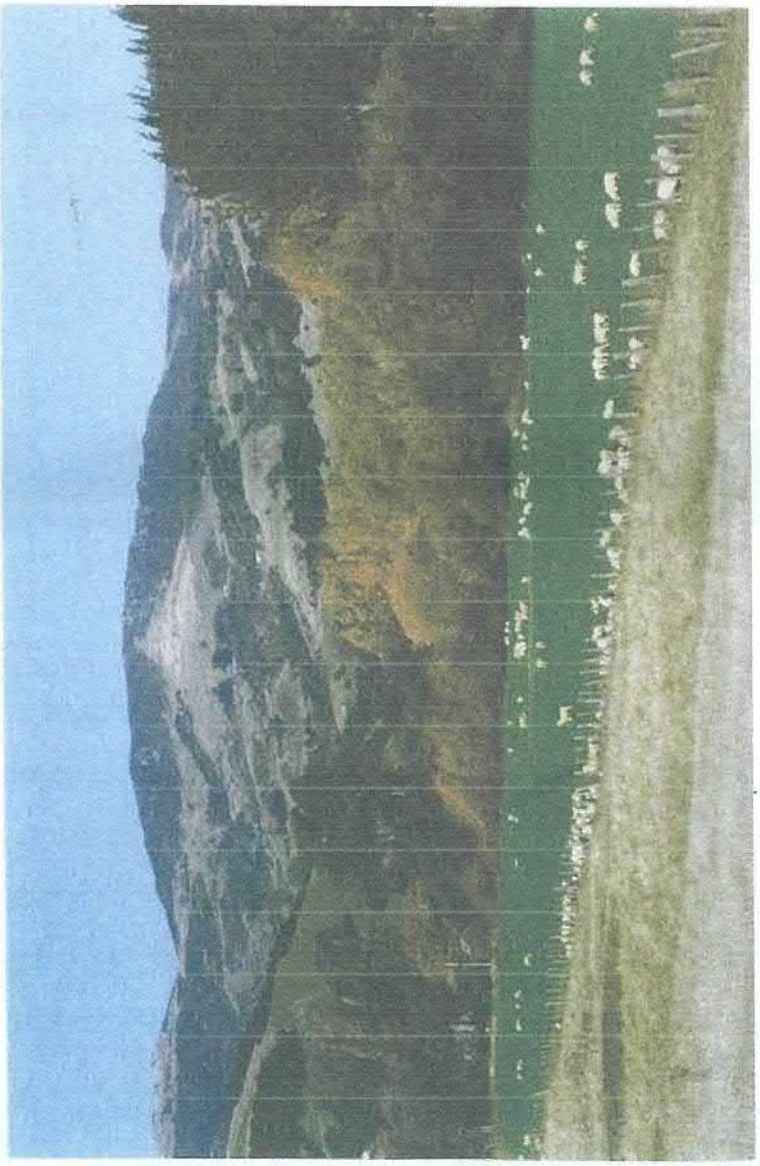
Extra names after date closed

Fi Smith and Tony Bird	Takamatua	[redacted]
Michael and Anne Schlumpf	Takamatua	[redacted]
Fiona Buchan-Ng	Takamatua	[redacted]

Beautiful Rural Vista from our property [redacted] Takamatua. Site of ~~Road~~ & irrigation & Trees.

View of proposed ~~road site~~ Irrigation from State Highway 75.

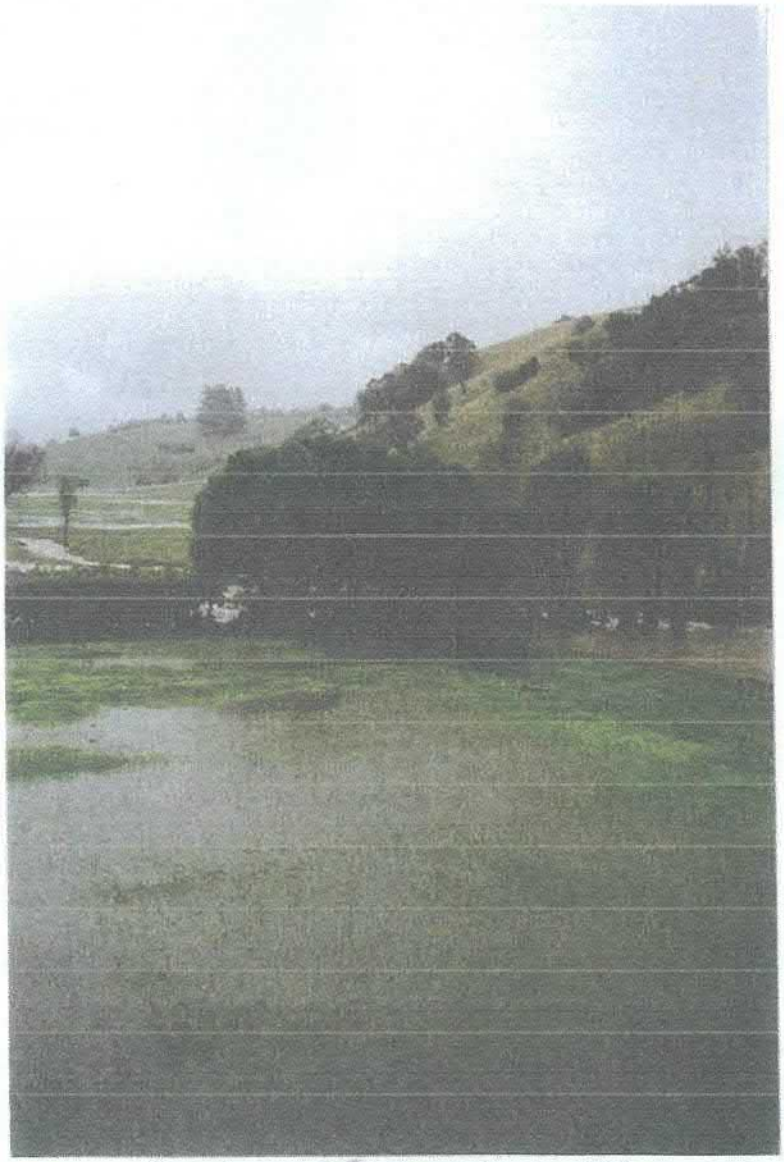


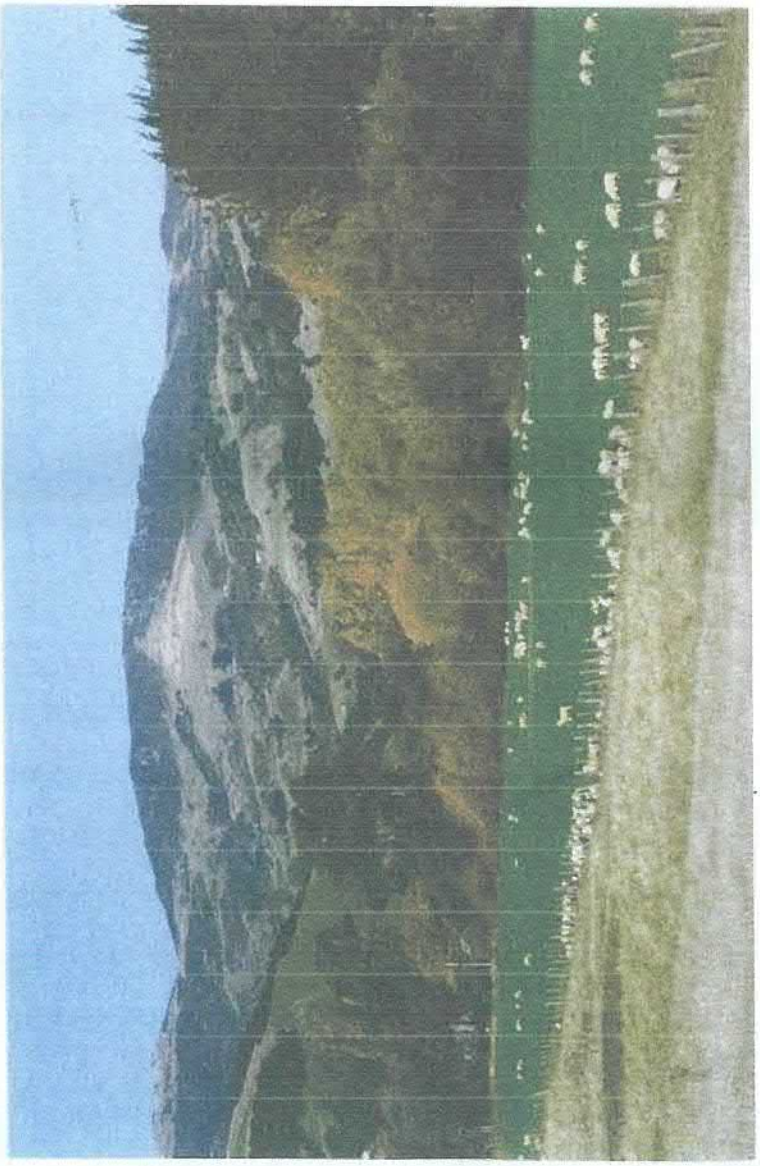


Many floods over the last 29yrs

Beautiful Rural Vista from our property [redacted] Takamatua. Site of ~~Road~~ & irrigration & Trees.

View of proposed ~~road~~ site / Inundation from State Highway 75.





Many floods over the last 29yrs
[illegible]

SUBMISSION FROM

Jeremy Moore
[redacted] Mount Pleasant
Christchurch

CCC's Akaroa Treated Wastewater Options Consultation 2020

I OBJECT to the Inner Bays Option for the following reasons;

- Close proximity of wastewater pond to our family home – only 100m.
- It is unfathomable how Council can recommend that the wastewater pond be located 100m from a home.

- Impact on property values in Robinsons Bay - stigma of living close to a wastewater pond
- Negative effect on the local environment - midges, odour, Canadian geese
- Lack of information about how the pipe can be safely constructed along State Highway 75. Serious health and safety concern on narrow windy and hilly road. Significant disruption to traffic for a long period of time.
- High cost to ratepayers for land based options disproportionate to Akaroa's population
- High risk and untested civil infrastructure option – very high chance of failure
- Negative effect on Robinsons Bay Extra Virgin Olive Oil Business and local accommodation providers including Heritage Listed Pavitt Cottage

Submission by John Curry

Proposed Akaroa Wastewater Scheme

Introduction

The harbour outfall option for the proposed Akaroa Wastewater Scheme appears to be the least favoured option of some because of the cultural objections of Ngai Tahu. According to Maori customs, human waste should be filtered through the land before entering water courses and the sea. Alternatives to the harbour outfall have been proposed primarly to address the concerns of Ngai Tahu. These alternatives are more expensive, and will have a greater social and environmental impact with higher risk of failure. These impacts are addressed in the Friends of Banks Peninsula submission.

The purpose of my submission is to discuss the cultural objection of Ngai Tahu to the Harbour Outfall option. I do not have any Maori heritage, but I am a local resident and descendant of early Banks Peninsula settlers.

Scientific basis of Maori cultural practice

First of all, I am of the opinion that the Maori cultural custom of human waste being filtered through land before entering waterways has a sound scientific basis in minimising/eliminating the risk of polluting waterways, and food taken from them. The buried human waste that would decompose over time was an effective waste treatment system based on the technology available at the time, and the relatively small population sizes.

Following European settlement, human waste/sewage from the township of Akaroa has been disposed into Akaroa harbour, oftentimes with minimal treatment in the earlier years, and sub-optimal treatment up to the present. And it has negatively impacted the quality of seawater in the harbour. For example, at times it has not been safe to eat shellfish taken from the harbour due to pollution. Understandably this would concern local Maori because of their cultural belief about human waste disposal, and on observing the environmental and health impacts on their traditional food gathering practices.

It is also understandable that Ngai Tahu would also want to see the present sewage/wastewater treatment plant located at Takapuneke be relocated because of the site's cultural and historical significance to local Maori. The proposed wastewater scheme allows for this, regardless of the various wastewater disposal options.

The proposed replacement of the outdated wastewater treatment station at Takapuneke with a new wastewater treatment station located above Akaroa at Pond Site 10 represents a major improvement. Solid waste materials from the town's sewage will be separated out before the remaining wastewater will being pumped up to the new treatment station. There it will be treated to a very high standard such that it will be suitable for non-potable reuse via a purple pipe system within Akaroa township, and for release into Akaroa Harbour via an outfall pipe. This is the basis of Option 1 which is the option that I most strongly support.

From a practical point of view, this is the most pragmatic option. Benefits include:

- It is the lowest cost option,
- The treated water released into the harbour is non-polluting so there will be no negative effects on the physical environment
- it allows for reusing the treated water within Akaroa township via a purple pipe system

- it ensures the recycled water is available for the township during the typically dry summer months
- it doesn't require large storage pond(s) – water can be released into the harbour or used for for recycling as per the need.
- It helps future-proof the water supply of Akaroa township anticipating population growth and the potential effects of climate change.

However, there remains the cultural objection of Ngai Tahu to treated wastewater being discharged into the harbour, regardless of the level of water purification. As acknowledged above, there is a practical, public health basis to the traditional Maori practice of filtering human waste through the soil before it enters waterways. The proposed treatment of Akaroa's sewage incorporating human waste will fulfil the spirit and intent of the Maori cultural practice by ensuring that no polluted water enters the local waterways. Waste solids will be separated out and processed in Christchurch, the waste water will be filtered to a high level, and also subjected to UV light to kill pathogens, and the treated water will be non-polluting. The end result is the same although achieved by different means. Allowing treated wastewater to flow through the wetlands associated with Pond Site 10 may go some way to addressing the cultural concerns of Ngai Tahu.

Adapting of cultural practices

Cultural practices adapt over time according to changing circumstances. Today we live in a bi-cultural society much changed from pre-European Aotearoa/New Zealand. It is not possible, or even desirable, for cultural practices in any society to remain unchanged and adhered to regardless of changing circumstances. An extreme example of this would be the practice of slavery which was acceptable in many cultures including both European and Maori up until the mid-nineteenth century. Changes in thinking about human rights over time led to slavery becoming culturally unacceptable in most societies that once practised it. I am not aware of anyone seriously advocating the reintroduction of slavery because it was the cultural practice of earlier generations.

We should not over-ride long-established cultural practices whenever convenient, but instead examine them in light of the intent and beliefs behind them. In some cases we can discard them out-of-hand when they are based on ignorance and superstition (e.g. the burning of 'witches' in pre-Enlightenment Christian Europe). In other cases we can see that there is logic and validity to a cultural practice, such as the burial of human waste as a public sanitation measure. The challenge is adhering to the cultural intent behind these practices in a way that reflects improvements in science and technology and societal thinking. In a bi-cultural society, this can be particularly challenging as evidenced by differing views about the disposal of treated wastewater from Akaroa township.

Another consideration is that in a bi-cultural or multi-cultural society, some level of pragmatic accommodation that takes into account competing beliefs and priorities is more likely to result in a successful and widely-accepted outcome. I am of the opinion that for Ngai Tahu the proposed harbour outfall represents a significant improvement on the current treatment of wastewater regardless of the other proposed options. The site of the treatment plant will be moved from Takapuneke, the spirit and intent of Maori cultural practice regarding human waste disposal will be met through modern sewage treatment technology, and there will be a vast improvement in the quality of the treated wastewater released into the harbour.

Furthermore, should a purple pipe scheme be implemented in Akaroa, a significant portion of the wastewater will be reused for garden watering, particularly during the dry summer months, thereby being filtered through the earth according to Maori cultural practice. The reuse of water in this way is likely to increase as Akaroa township grows, and if climate change results in a drier local climate.

Environment Aotearoa 2019

Summary

New Zealand's Environmental Reporting Series

Ministry for the Environment
Manatū Mō Te Taiao

Stats NZ
Tatauranga Aotearoa

Citation

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Cover photo: Ministry for the Environment

Contents

Aotearoa New Zealand

Our land and sea are unique and very special, having evolved so distinctly and separately from the rest of the world. From the time our ancestors first stepped onto its shores, the land of the long white cloud has provided nourishment, protection, and resources to its inhabitants. People have become part of the environment and shaped it, modifying the land to grow food, building houses, and establishing settlements, roads, and infrastructure.

The relationship and connection New Zealanders have with the environment goes well beyond the goods and services we receive from it, like food, fuel, and clean water. Our environment is where we stand, our tūrangawaewae – where we live, learn, work and earn a living, play, and socialise. It is our home and our identity, and the foundation of our national culture and tradition.

For Māori as tangata whenua – people *of* the land – that connection is indivisible from the health of Papatūānuku, the Earth Mother.

Te ao Māori (the Māori world view) has an important place in environmental reporting in New Zealand. It ensures the unique connection of tangata whenua is respected and brings a way of thinking that helps us all see ourselves as a part of, not apart from, the environment.

The changes we have made (and continue to make) to this rich landscape are having profound effects on our environment. Some parts of our environment are in good shape, others less so. How we go forward from here is up to us all.

About this summary report

This summary is an overview of *Environment Aotearoa 2019*, which is part of the Ministry for the Environment and Stats NZ's legislated environmental reporting programme. Every six months we produce a report focused on a different 'domain' – air, freshwater, marine, atmosphere and climate, and land. Every three years we produce a 'synthesis' report – bringing together the data and findings from across the domain reports to help us step inside and view our environment as a whole, in all its complexity.

Environment Aotearoa 2019 uses five themes to look into nine priority issues – those that matter most to the current state of our environment.

> **An 'issue' is a change in the state of the environment that is (partly) caused by human activities (pressures) and has consequences (impacts).**
>
> *Parliamentary Commissioner for the Environment*

While not suggesting any responses (which are out of scope under the report's governing legislation), *Environment Aotearoa 2019* provides evidence to enable an open and honest conversation about what we have, what we are at risk of losing, and where we can make changes.

For the full picture on the health of our environment and more detail on each issue, see ***Environment Aotearoa 2019***.

Throughout this summary report, you'll see references and links to various environmental indicators. These are metrics that help us assess the state of the environment. Each indicator that appears in *Environment Aotearoa 2019* has an accompanying web page and a dataset that is free to access.

A focus on what matters

Environment Aotearoa 2019 presents the most important issues that affect the health of our environment today.

Four criteria were established to help describe the sense of significance and urgency of the issue:

Spatial extent and scale – how much of New Zealand is affected by the issue?

Magnitude of change – is the issue increasing in scale and/or distribution, or accelerating?

Irreversibility and lasting effects of change – how hard is it to fix?

Scale of effect on culture, recreation, health, and economy – how much does it affect the things we value?

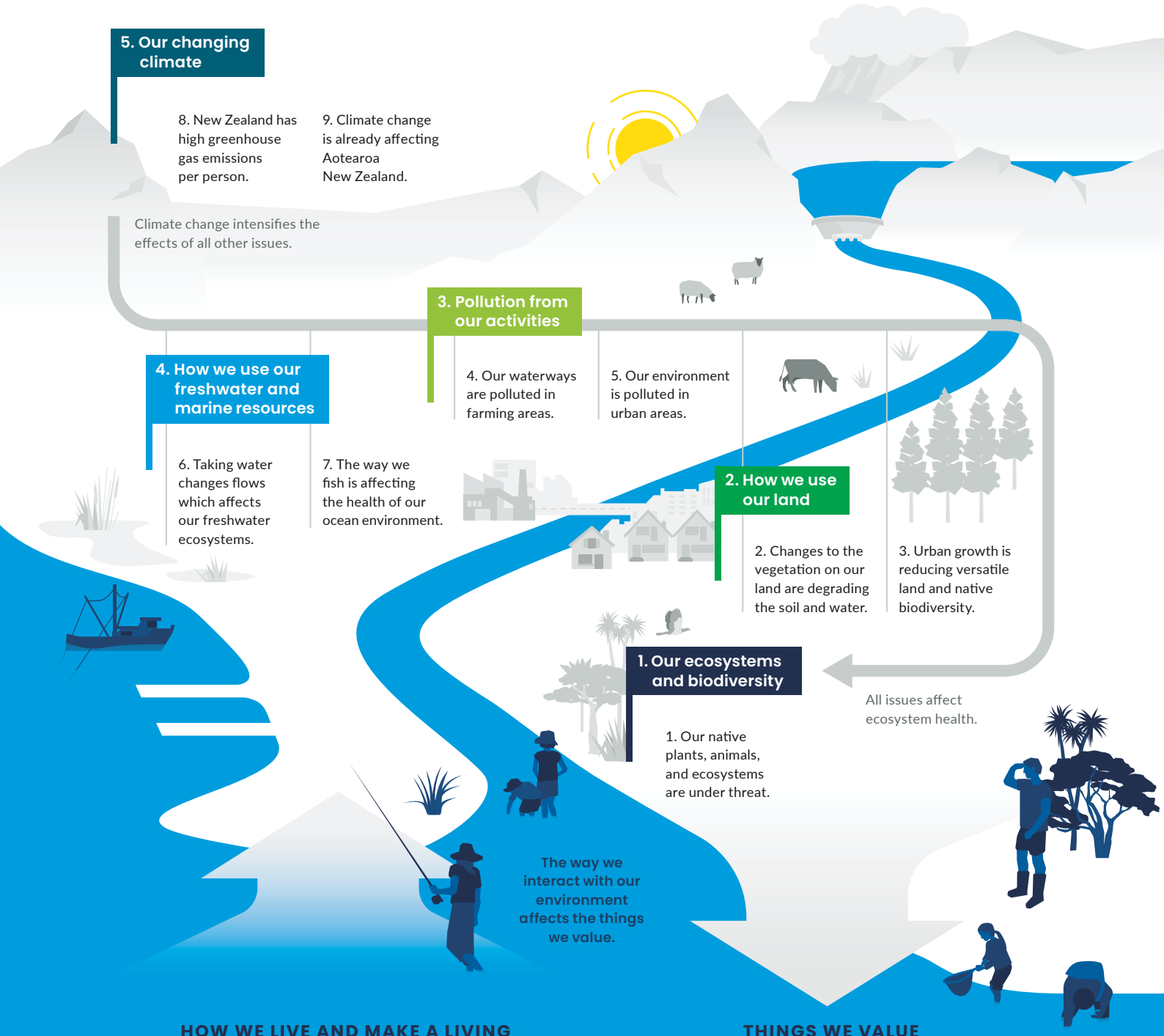
An independent panel of scientists verified the selection process to ensure the criteria were appropriately applied to the issues. The relevance of the nine issues to mātauranga Māori, kaitiakitanga, and other cultural values was also considered by Māori researchers and practitioners.

The priority issues presented here are not an exhaustive list of all the pressures our environment faces. Some have an impact on the environment but are not featured here as they do not rank as highly against the criteria as other issues. Mining for example, is not included because of its localised nature.

As an issue is defined as a change in the state of the environment, some environmental problems are not included such as plastic waste which is considered as a pressure.

Environment Aotearoa 2019 themes and issues

The themes and issues in this report show how the way we live and make a living affects our environment and the things we value.



HOW WE LIVE AND MAKE A LIVING

Forestry · Fishing · Farming · Transport · Energy · Waste disposal · Building & construction

THINGS WE VALUE

Health · Economy · Identity · Nature · Culture · Recreation · Stability

Photo credit: iStock

THEME 1

Our ecosystems and biodiversity

The biodiversity of Aotearoa New Zealand is essential to our culture, identity, and well-being. The whole variety of native plants, animals, microorganisms, and the ecosystems they create, is unique to New Zealand and irreplaceable.

Our native plants and animals are under pressure from all the issues identified in *Environment Aotearoa 2019*, including climate change, sedimentation, and urban development. When combined with the significant pressure from introduced species, this forms a set of 'compounding pressures' that can intensify the effects of individual pressures on animal and plant communities.

In this theme, we report on the state of our biodiversity, considering the loss and risk to species and ecosystems across land, freshwater, and marine environments.

ISSUE 1

Our native plants, animals, and ecosystems are under threat

Our unique native biodiversity is under significant pressure from introduced species, pollution, physical changes to our landscapes and coast, harvesting of wild species, and other factors. Almost 4,000 of our native species are currently threatened with or at risk of extinction.

What is happening?

The biodiversity of Aotearoa New Zealand is unique and vulnerable to changes we make to the environment. Many of the species found here are found nowhere else in the world.

Our biodiversity has declined significantly. At least 75 animal and plant species have become extinct since humans arrived in New Zealand. Marine, freshwater, and land ecosystems all have species at risk: 90 percent of seabirds, 76 percent of freshwater fish, 84 percent of reptiles, and 46 percent of vascular plants are currently threatened with or at risk of extinction.

The extinction risk has worsened for 86 species in the past 15 years. The conservation status has improved for 26 species in the past 10 years, but more than half require active management to stay that way. Kākāpō is one example.

For a small country, we have a very diverse range of unique ecosystems. Some are naturally rare (there were only a few even before people arrived, like volcanic dunes) and others are also uncommon internationally (like braided rivers). Many of our native ecosystems have been cleared or extensively altered, and this trend continues today.

Why is it like this?

People have changed the landscape and introduced new species. Farming and urban expansion have caused forests to be cleared and wetlands to be drained. In the process, habitats and species have been lost. Farming and urban expansion also create pollution, such as excess nutrients (like nitrogen) and sediment, which can degrade ecosystems and harm organisms. Taking water degrades our freshwater ecosystems (see Issue 6), while commercial fishing alters marine ecosystems and can accidentally kill threatened species (see Issue 7).

Introduced species threaten our native species through competition, predation, and diseases. Non-native plant species now outnumber natives here, and stoats, possums, and rats were present on more than 94 percent of New Zealand land in 2014.

New diseases also pose threats: myrtle rust, a disease that kills native plants like mānuka, pōhutukawa, and rātā, made it to our shores in 2017.

Climate change is already impacting some species by changing where they are found or creating conditions where invasive pests like wasps can live (see Issue 9).

What are the consequences?

Healthy ecosystems provide important functions that benefit us and our society. Native forests, for example, regulate the climate (by storing carbon), prevent erosion, and create nectar for honey production. Natural wetlands also provide important ecosystem services (benefits we receive from nature) such as purifying water by filtering out nutrients and sediments, regulating water flow during storms, and storing carbon as peat. Degraded habitats and a loss of species can make ecosystems less resilient to other changes and lead to further declines in biodiversity.

Degradation of our ecosystems and a loss of biodiversity can also impact our ability to connect with and use the environment. Native biodiversity provides mahinga kai (food provisioning) and materials for other purposes like raranga (weaving) and rongoā (medicinal uses). It also provides important indicators (like the timing and intensity of flowering) for kaitiaki, as well as being essential for maintaining and passing knowledge from one generation to another.

Losing biodiversity affects our sense of belonging and connection. We call ourselves 'Kiwis' and proudly use the silver fern (ponga) as a national symbol, so our identity suffers when we experience damaged or lost native species and ecosystems. Recreation opportunities and the connections we have to nature are also affected.

New and updated environmental indicators used in *Environment Aotearoa 2019:*

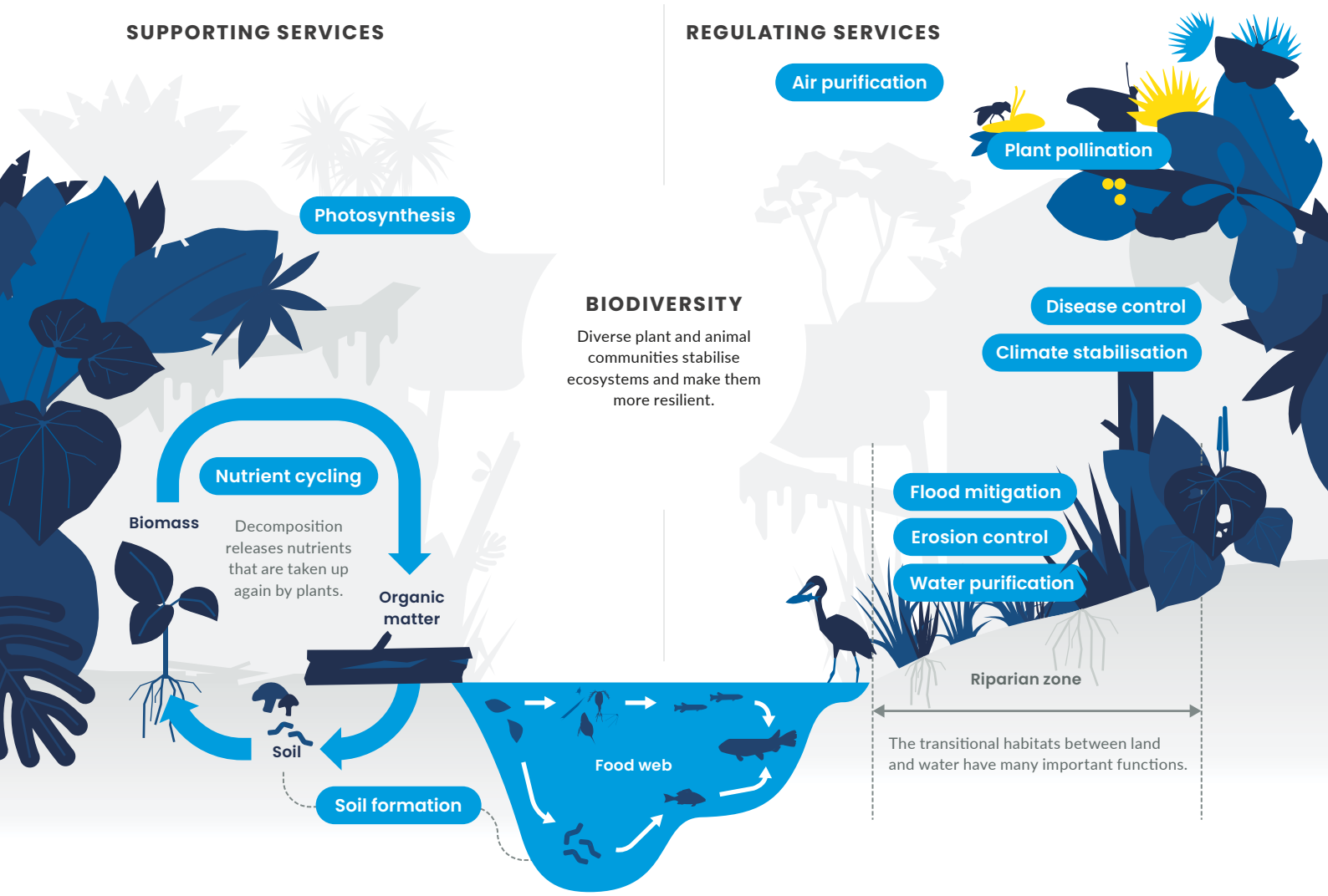
- Conservation status of indigenous freshwater species
- Conservation status of indigenous land species
- Conservation status of indigenous marine species
- Lake water quality
- River water quality: macroinvertebrate community index

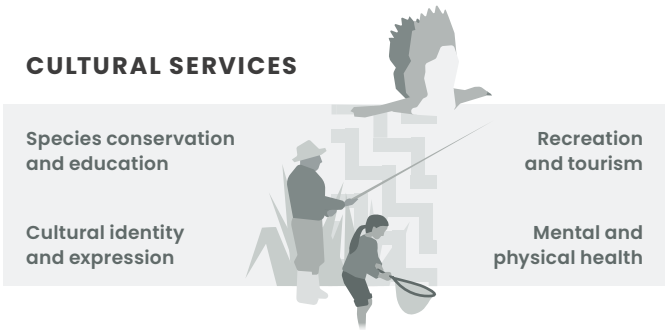
Existing environmental indicators used in *Environment Aotearoa 2019:*

- Active sand dune extent
- Cultural health index for freshwater bodies
- Freshwater pests
- Lake submerged plant index
- Land cover
- Land pests
- Marine non-indigenous species
- Predicted pre-human vegetation
- Rare ecosystems
- Wetland extent

Ecosystems

A healthy ecosystem provides many benefits (services) that are essential for native plants and animals as well as our own well-being.





CULTURAL SERVICES

Species conservation and education

Recreation and tourism

Cultural identity and expression

Mental and physical health

PROVISIONING SERVICES

Food

Water

Medicines

Wood and fibre

CULTURAL VALUE

A healthy ecosystem enables tangata whenua to connect with the environment and each other. It provides sustenance and materials for cultural practices and expressions like waiata, karakia, and wairua.

ECOSYSTEM HEALTH

Measuring the overall condition of our ecosystems is more than counting the number of different species. Ecosystems are complex and made of many interacting biological and physical components that can all be affected by environmental changes.

Photo credit: Photonewzeland

THEME 2

How we use our land

The changes we have made to our land have significantly altered the wider environment. This theme highlights two specific types of physical changes we humans have made to the world around us:

1. **What we have removed:** Cutting down native forests, draining wetlands, and clearing land for farming and development have accelerated our naturally high rates of soil loss. This has also degraded a range of ecosystem services provided by native vegetation.
2. **What we have built:** Human-made structures and hard surfaces affect the natural systems we rely on. There is a particular focus in this issue on the spread of urban areas over versatile land (which can be used for many purposes, including farming) and scarce high-class soils.

ISSUE 2

Changes to the vegetation on our land are degrading the soil and water

Logging native forests, draining wetlands, and clearing land have degraded a range of benefits provided by native vegetation, accelerated our naturally high rates of soil loss, and affected our waterways.

What is happening?

Since human arrival in New Zealand we've shaped our physical surroundings. Native vegetation has been extensively cleared so that the native forests that once covered about 80 percent of the country, now only cover a little over one quarter of New Zealand. Ten percent of New Zealand was once covered by wetlands – 90 percent of these original wetlands have now been drained.

In 2012, just over half of our land had a modified land cover like urban areas and non-native (exotic) vegetation. Exotic grassland (pasture) is now the largest single type of land cover and accounts for about 40 percent of our total land area. Exotic (plantation) forest covers about 8 percent of the country, concentrated in the central North Island.

The loss of native vegetation has continued in recent years, with more than 70,000 hectares lost between 1996 and 2012 through conversion to pasture, plantation forestry, and urban areas. Wetland areas have also continued to shrink, with at least 1,247 hectares lost between 2001 and 2016.

Why is it like this?

The conversion of native vegetation to pasture and plantation forestry has supported the way we live and provided our livelihoods. In 2016, agriculture contributed 4.2 percent of our gross domestic product (GDP) and employed more than 122,000 people, while forestry contributed over $1.7 billion to our economy and employed over 6,000 people. Our growing population also drives urban expansion.

What are the consequences?

When native forests, shrublands, and wetlands are lost, we lose the wide range of benefits (ecosystem services) they provide. These benefits include regulating the flow of water in rivers and streams, recreation, storing carbon, purifying water, and providing habitats for native species. The benefits we get from simply being in nature, though not measured or quantified, could also be lost.

Loss of native vegetation has accelerated New Zealand's naturally high rates of erosion and soil loss. A model of soil erosion shows that 44 percent of the soil that enters our rivers each year is likely to come from land covered in pasture. Once they are established, plantation forests retain soil in the same way as native forests, but harvesting by clear-felling exposes and disturbs the soil, which can then be vulnerable to erosion for up to six years after harvest.

The economic losses associated with soil erosion and landslides are estimated to be at least $250–300 million a year. Increased erosion and soil loss can also increase sediment in our rivers, lakes, and coastal environments. Too much sediment can smother freshwater and marine habitats, inhibit the growth of aquatic plants and animals, and increase the risk of flooding in towns and cities.

When ecosystems and biodiversity have been degraded, there is a corresponding effect on the extent, quality, and access to customary resources, like kaimoana.

Updated environmental indicator used in *Environment Aotearoa 2019:*

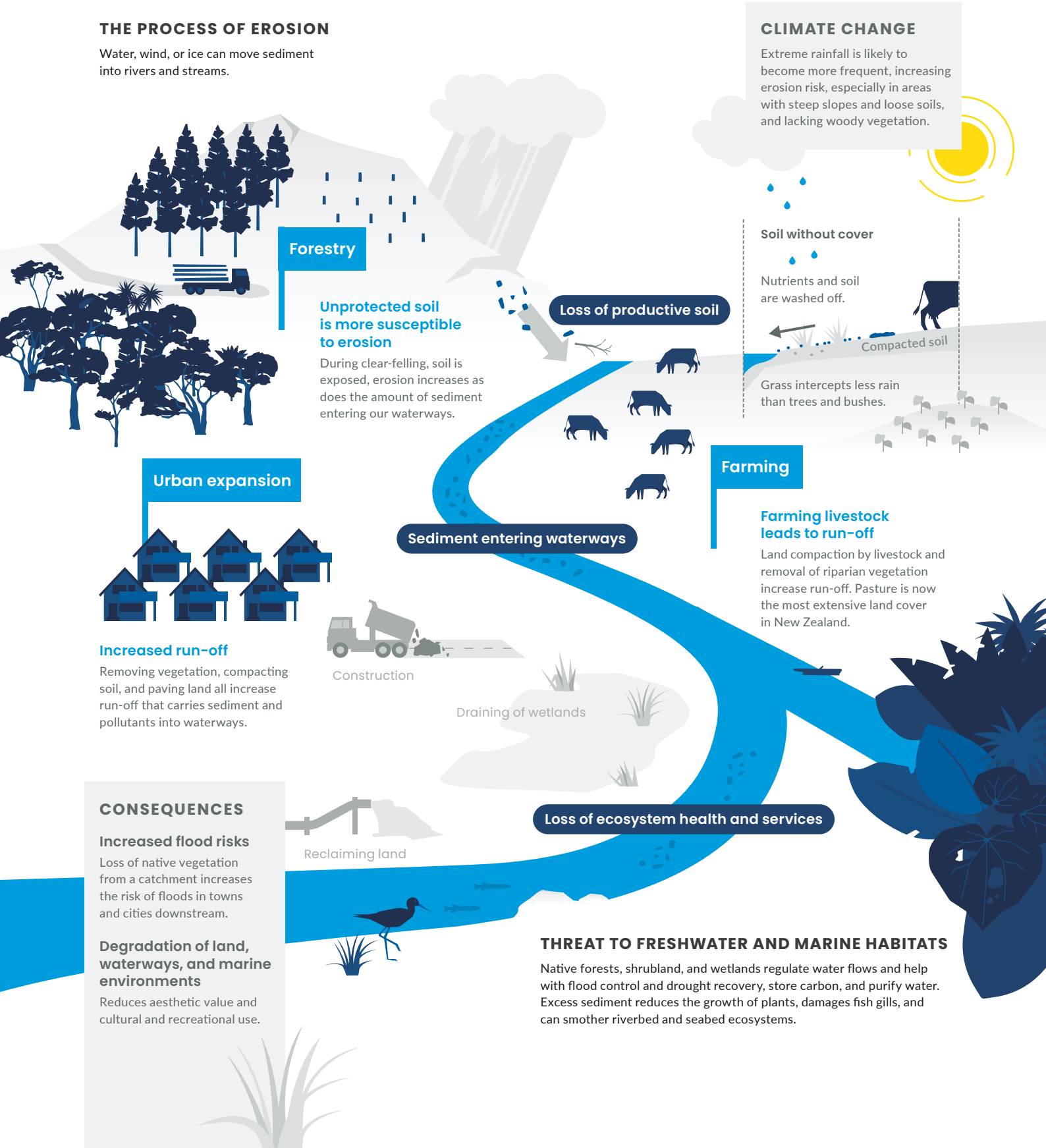
- Highly erodible land

Existing environmental indicators used in *Environment Aotearoa 2019:*

- Estimated long-term soil erosion
- Land cover
- Wetland extent

The changing way we use our land

Replacing native vegetation with exotic forest, grasslands, or urban areas can increase erosion and degrade land, freshwater, and marine environments.



ISSUE 3

Urban growth is reducing versatile land and native biodiversity

Growth of urban centres has led to land fragmentation and threatens the limited supply of versatile land near Auckland and other regional centres.

What is happening?

Most New Zealanders live in cities. According to 2018 population estimates, 86 percent of us live in urban areas. Urban areas make up a small proportion of our total land area, only about 0.85 percent (approximately 228,000 hectares) in 2012. Most urban centres have developed on our best land – often fertile floodplains near the coast – with native forests being cut down and wetlands drained (see Issue 2).

Our urban areas are spreading – the area of urban land increased by 10 percent between 1996 and 2012, especially around Auckland, Waikato, and Canterbury. Between 1990 and 2008, 29 percent of new urban areas were on 'versatile' land. This type of land often has the best, or 'high-class', soils and has many agricultural uses (like growing food), but represents just over 5 percent of New Zealand's land.

The fringes of our urban areas are increasingly being fragmented – broken into smaller land parcels – and sold as lifestyle blocks. The number of lifestyle blocks has increased sharply in recent decades, with an average of 5,800 new blocks a year since 1998. A 2013 study found that 35 percent of Auckland's versatile land was used as lifestyle blocks.

Why is it like this?

Urban expansion is mostly driven by population growth. Between 2008 and 2018 our population increased by 14.7 percent. Growth is expected to continue, with the highest rates in Tauranga, Auckland, and Hamilton, and lower rates in Wellington and Dunedin.

What are the consequences?

Our versatile land and high-class soils are gradually being lost to urban growth, making them unavailable for growing food.

The loss of versatile land is happening at the same time as our food production system is under pressure to increase production without increasing its effect on the environment. This loss can force growers onto more marginal land that is naturally less productive and requires more inputs, like fertiliser.

Urban growth changes the land cover dramatically – and often reduces native habitats and biodiversity. In New Zealand, native land cover accounts for less than 2 percent of land in urban centres and only 10 percent on the urban-rural boundary.

Also, many of the plants and animals people bring with them to cities can be harmful to native biodiversity. For example, cats can hunt native animals, and non-native plants in gardens and urban plantings can become problematic weeds if they spread to native areas.

Existing environmental indicator used in *Environment Aotearoa 2019:*

- Land cover

THEME 3

Pollution from our activities

Photo credit: Ministry for the Environment

Our environment is polluted when substances or kinds of energy (noise, light, heat) enter it and cause harm.

Some pollutants directly affect our health. Pathogens (disease-causing microorganisms like the bacteria *Campylobacter*) in drinking water can cause illness, and very fine particles in the air can cause lung and heart problems. Other pollutants pose threats to the health of plants, animals, and ecosystems, like plastic waste in the ocean or excess nutrients in our waterways.

Pollution also affects our connections to nature. Artificial light from towns and cities reduces our view of the night sky, and murky streams spoil our enjoyment of these environments.

Most pollution comes from human activities, such as industry, agriculture, power generation, home heating, and transport, but some comes from natural events like volcanic eruptions. Often pollution has a mix of sources. Waterways, for example, can contain disease-causing bacteria from human or animal faeces, nutrients from farm run-off and urban areas, and heavy metals from vehicle wear (copper from brake pads and zinc from tyres).

This theme focuses on two kinds of pollution – pollution of waterways from farming and pollution in urban areas.

ISSUE 4

Our waterways are polluted in farming areas

Waterways in farming areas are polluted by excess nutrients, pathogens, and sediment. This threatens our freshwater ecosystems and cultural values, and may make our water unsafe for drinking and recreation.

What is happening?

In farming areas, water pollution affects almost all rivers and many aquifers. Some lakes and estuaries may also be affected. Compared to catchments dominated by native vegetation, waterways in areas of pastoral farming have markedly higher levels of pollution by excess nutrients (like nitrogen), sediment, and pathogens.

Recent measurements show that water quality has been improving at some places, but worsening at others. It can be difficult to understand exactly what is causing the changes in water quality because water catchments can contain a mix of different types of farms and land uses, and the effects of natural variations in climate and the connections between rivers and groundwater are also poorly understood.

Why is it like this?

In less than 1,000 years New Zealand has changed from an unpopulated group of islands covered with dense forest, to an intensely farmed country. Setting up our farms involved clearing native vegetation and draining wetlands, which have dramatically affected how our soils and water function.

More recently there has been a significant shift from sheep and beef farming into dairy farming, most notably in Canterbury, Otago, and Southland. The national dairy herd increased by 70 percent between 1994 and 2017, while numbers of sheep and beef cattle declined. This shift is important because cattle excrete more nitrogen per animal than sheep (cows produce more urine and the urine has a higher nitrogen concentration).

We are also using our farmland more intensively now than a few decades ago. The number of cattle per hectare has increased in some parts of the country, a change that can make it more likely that pollutants will leach into waterways. The amount of nitrogen applied in fertiliser has also increased more than six-fold across the country since 1990.

What are the consequences?

Our ecosystems can be seriously impacted by water pollution. For 2013–17, 71 percent of river length in pastoral farming areas had modelled nitrogen levels that could affect the growth of sensitive aquatic species. Higher nutrient levels may also cause excess algal growth (or blooms), which degrades the ecosystems and can make waterways and coastal environments unfit for recreational and cultural uses.

Water pollution by pathogens from livestock dung also has risks to human health, including gastrointestinal illness. Computer models estimate that 82 percent of the river length in pastoral farming areas was not suitable for activities such as swimming, based on the predicted average *Campylobacter* infection risk during the period 2013–17.

Water pollution degrades cultural values such as mauri and wairua of waterways, and impacts the customary practices associated with mahinga kai and kaitiakitanga (guardianship). When waterways are polluted it can also affect the mana (prestige) associated with an iwi or hapū.

New and updated environmental indicators used in *Environment Aotearoa 2019:*

- Coastal and estuarine water quality
- Groundwater quality
- Lake water quality
- Livestock numbers
- Nitrate leaching from livestock
- Nitrogen and phosphorus in fertilisers
- River water quality: clarity and turbidity
- River water quality: *Escherichia coli*
- River water quality: macroinvertebrate community index
- River water quality: nitrogen
- River water quality: phosphorus

Existing environmental indicators used in *Environment Aotearoa 2019:*

- Agricultural and horticultural land use
- Cultural health index for freshwater bodies

Intensified farming

Recent intensification of farming has increased the risks of water pollution.

CHANGES TO OUR USE OF LAND IN THE PAST THREE DECADES

Less sheep, more cows

Cattle numbers have increased, especially dairy cattle. Cows produce more urine with a higher nitrogen concentration than sheep.

More animals per hectare

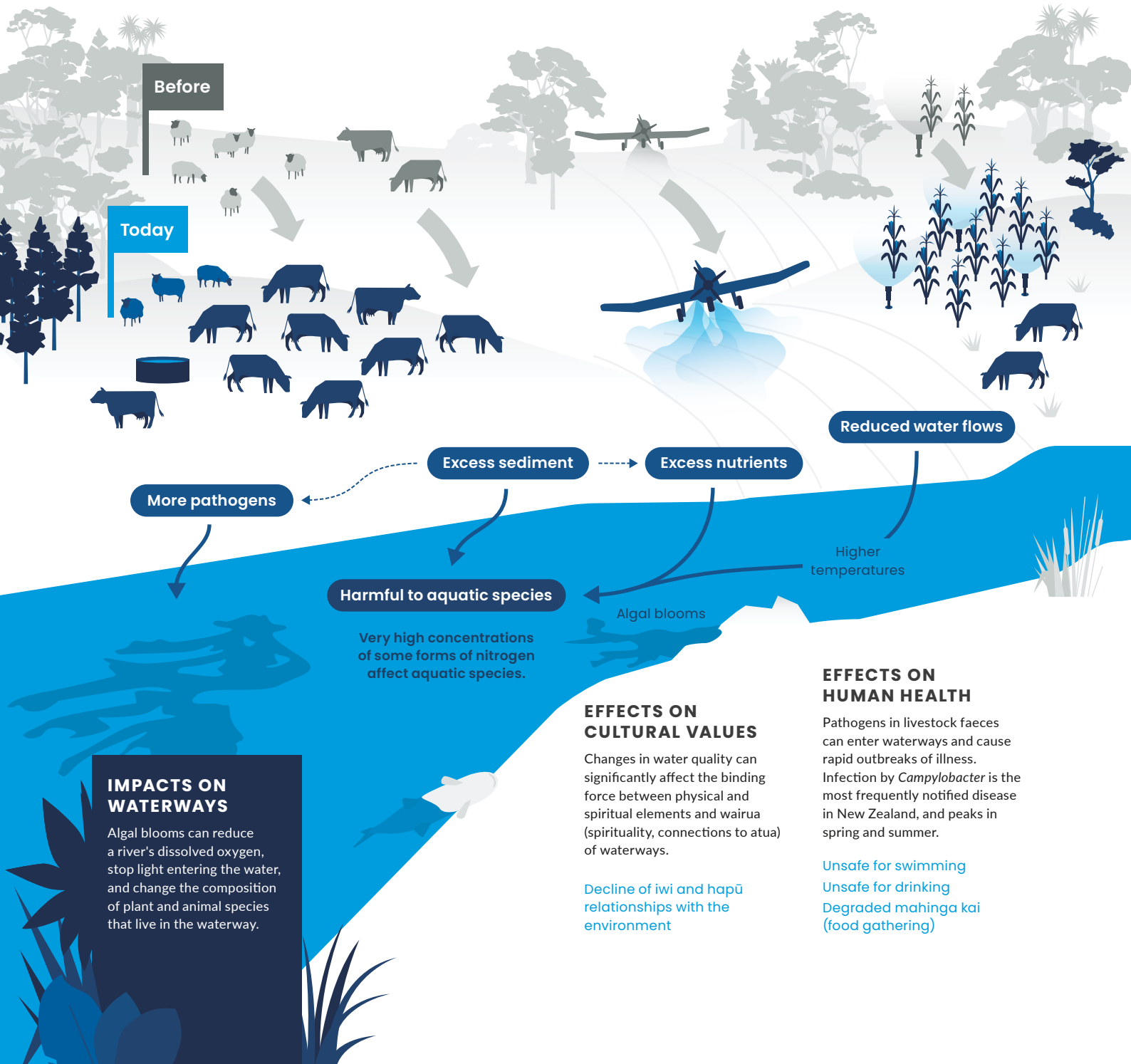
High stocking rates and vehicles driven on the land cause soil compaction, increasing the likelihood of polluting run-off into streams.

More fertiliser

The amount of nitrogen applied in fertiliser has increased. Fertilisers like nitrogen and phosphorus can pollute waterways.

More irrigated land

The amount of irrigated land has increased. Taking more water for irrigation reduces river flows and affects species and habitats.



IMPACTS ON WATERWAYS

Algal blooms can reduce a river's dissolved oxygen, stop light entering the water, and change the composition of plant and animal species that live in the waterway.

EFFECTS ON CULTURAL VALUES

Changes in water quality can significantly affect the binding force between physical and spiritual elements and wairua (spirituality, connections to atua) of waterways.

Decline of iwi and hapū relationships with the environment

EFFECTS ON HUMAN HEALTH

Pathogens in livestock faeces can enter waterways and cause rapid outbreaks of illness. Infection by *Campylobacter* is the most frequently notified disease in New Zealand, and peaks in spring and summer.

Unsafe for swimming

Unsafe for drinking

Degraded mahinga kai (food gathering)

ISSUE 5

Our environment is polluted in urban areas

Some of our cities and towns have polluted air, land, and water. This comes from home heating, vehicle use, industry, and disposal of waste, wastewater, and stormwater. Pollution affects ecosystems, health, and use of nature.

What is happening?

Many different pollutants are produced in urban centres where most (86 percent) New Zealanders live (see Issue 3). The pollutants vary in type and amount, from place to place, and over time.

Our air quality is good in most places and at most times of the year. However, levels of tiny particles in the air that are bad for our health can exceed air quality standards, especially in cooler months because of emissions from home heating.

Urban waterways contain many of the same pollutants found in farming areas – excess nutrients (such as nitrogen), sediment, and pathogens – but their levels are typically even higher in our cities and towns. Urban waterways can also contain other pollutants, like heavy metals.

Recent measurements show that urban pollution has lessened in many places. Air particulate matter (PM_{10}) levels decreased in 17 of 39 monitored areas in winter between 2007 and 2016. Where changes in water quality could be detected between 2008 and 2017, the majority of urban river water monitoring sites had improving trends for nutrients and sediment. The trends for *E. coli* were mixed, with some sites getting better and some getting worse.

Less information is available about other types of urban pollution. Monitoring networks do not yet cover all our cities and towns. Data is not available to assess trends in light pollution, noise pollution, odours, or pollution in urban soil, land, or coastal waters.

Why is it like this?

In urban areas, burning wood and coal for home heating in winter are the main sources of particulate matter in the air. Emissions from vehicles and industry also contribute to air pollution in some places. This includes particulate matter and carbon dioxide from cars, and nitrogen oxides and other gases from industries.

Pollutants enter urban waterways through the stormwater and wastewater networks. Stormwater is rainwater plus any pollutants it picks up on the land surface, like nutrients, pathogens, sediment, or heavy metals from the wear of road surfaces, tyres, and brake pads. Wastewater is the water that has been used in houses and businesses, which can contain nutrients, pathogens, and many chemicals used in industrial and domestic activities.

Urban pollution

Urban areas are sources of pollutants that affect ecosystems and our health. The type and amount can vary from place to place and over time.

SOURCES OF URBAN POLLUTION

Home heating

Burning wood and coal for home heating during cooler months is the main source of particulate matter in the air in our cities and towns. Burning treated timber is the primary source of arsenic in urban air.

Air particulate matter

Transport

Vehicle emissions contribute to poor air quality. Abrasion of road surfaces, tyres, and brake pads release small particles, including heavy metals into the environment. Petroleum spills and leaks contaminate land, soil, and water.

Air particulate matter
Gaseous pollutants
Heavy metals

Industry and manufacturing

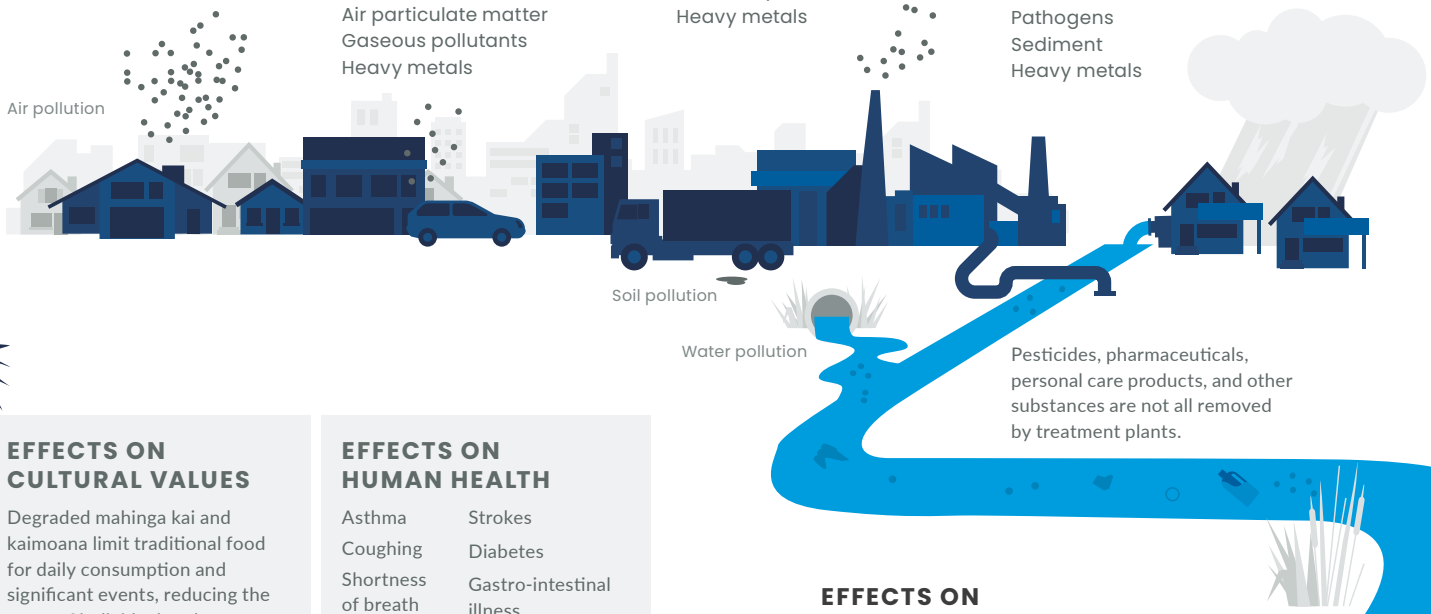
Pollutants from industry vary depending on the type of industry. Burning fuels for processes or electricity pollutes the air while storage or disposal of waste can contaminate soil and waterways.

Air particulate matter
Gaseous pollutants
Heavy metals

Wastewater and stormwater

Wastewater and stormwater enter urban streams through leaky pipes, illegal connections, and consented overflows during storms. Rainwater carries pollutants through the stormwater system into the waterways.

Nutrients
Pathogens
Sediment
Heavy metals



EFFECTS ON CULTURAL VALUES

Degraded mahinga kai and kaimoana limit traditional food for daily consumption and significant events, reducing the mana of individuals, whānau, and hapū, and their capacity to express hospitality.

EFFECTS ON HUMAN HEALTH

- Asthma
- Coughing
- Shortness of breath
- Strokes
- Diabetes
- Gastro-intestinal illness
- Premature death

EFFECTS ON AQUATIC ECOSYSTEMS

High concentrations of nitrate-nitrogen or ammonia can be toxic to aquatic species. Heavy metals can accumulate in food sources like fish and shellfish, making them unsafe to eat.

What are the consequences?

Air pollution can have health impacts including shortness of breath, asthma, heart attack, stroke, and even premature death.

Water pollution can affect both human and ecosystem health. Computer models estimate that 94 percent of the river length in urban areas is not suitable for activities such as swimming, based on the predicted average *Campylobacter* infection risk between 2013 and 2017.

The models also show that 94 percent of river length in urban areas has nitrogen levels that may affect the growth of sensitive aquatic species. The elevated levels of nutrients in urban streams also increase the likelihood of excessive algal growth.

Pollution in urban areas impacts the mauri of ecosystems and affects values like the condition of mahinga kai and kaimoana (traditional foods), recreation (swimming, waka ama), and oranga (health and well-being) of Māori.

Limited knowledge of the full range of pollutants, their extent, and their cumulative effects, makes it challenging to fully understand the impacts of urban pollution.

New and updated environmental indicators used *Environment Aotearoa 2019:*

- Coastal and estuarine water quality
- Heavy metal load in coastal and estuarine sediment
- River water quality: clarity and turbidity
- River water quality: *Escherichia coli*
- River water quality: nitrogen
- River water quality: phosphorus

Existing environmental indicators used in *Environment Aotearoa 2019:*

- Air pollutant emissions
- Artificial night sky brightness
- Carbon monoxide concentrations
- Ground-level ozone concentrations
- Health impacts of PM_{10}
- Land cover
- Nitrogen dioxide concentrations
- $PM_{2.5}$ concentrations
- PM_{10} concentrations
- Sulphur dioxide concentrations
- Urban stream water quality

THEME 4

How we use our freshwater and marine resources

Photo credit: Nature's Pic Images

Natural resources are essential for our modern way of life and we use them in an astounding number of ways. Some resources regenerate naturally but others, like fossil fuels, are not easily replaced. If we take too much from the environment, the use of a resource becomes unsustainable. This can affect natural systems and deny future generations the same opportunities and benefits from nature that we enjoy today.

This theme examines two activities where our use of a natural resource is affecting how the environment functions, and changing our relationship with it:

1. **Taking water from rivers, lakes, and aquifers:** Using water for agriculture, hydroelectric generation, and domestic purposes can have significant effects on our waterways. Here, we look at how taking water is affecting our waterways and our relationships with them.
2. **Fishing:** We fish for commercial gain, for food, recreation, and as part of our culture in te ao Māori. Fishing and gathering seafood are widespread in coastal areas and in our exclusive economic zone, and can have long-lasting effects.

ISSUE 6

Taking water changes flows which affects our freshwater ecosystems

Using freshwater for hydroelectric generation, irrigation, domestic, and other purposes changes the water flows in rivers and aquifers. This affects freshwater ecosystems and the ways we relate to and use our waterways.

What is happening?

The use of freshwater supports our economy and way of life. We rely on surface water and groundwater (taken from aquifers) for drinking, domestic, and industrial uses, and irrigation from these sources is vital for farming. Although New Zealand has plenty of fresh water, we are also heavy users. In 2014, New Zealand had the second highest volume of water take per person of OECD countries.

Consents (permits) to take water are managed by regional authorities, which allocate water for particular uses. Individual consents to take water have specified conditions, such as how much water can be taken, from where, at what rate, and at what times.

Nationally, aside from hydroelectricity (which generally doesn't consume water but does alter river flows), most of the consented water allocation was for irrigation (51 percent in the 2013/14 year). Household consumption made up 14 percent, and industrial use made up 13 percent. Taking water for irrigation happens nationwide but on a large scale mainly in Canterbury and Otago. About 100 hydropower sites nationwide provided 55–60 percent of our electricity in 2017, lessening our dependence on fossil fuels.

Why is it like this?

The demand for fresh water for irrigation has increased markedly. This has been driven by a near doubling of New Zealand's irrigated agricultural land area between 2002 and 2017, most notably in Canterbury. This reflects a nationwide shift from sheep and beef farming to dairy farming, and an increase in the number of animals per hectare in some parts of the country (see Issue 4).

What are the consequences?

The consequences of taking water are mainly related to changes in river flows. Low river flows reduce the habitat for freshwater fish and other species that provide food for other species and for people. Native fish such as the taonga whitebait species inanga and tuna (eels) are vulnerable because they need to move between the sea and fresh water during their lifecycle and dams and culverts can block these migration. Taking water can also reduce the flows and number of channels in braided rivers, which affects some threatened birds like wrybill and kakī.

With reduced or less variable flows, the temperature and the concentration of nutrients and pathogens in a waterway can also increase and make them more susceptible to algal blooms. These changes can degrade freshwater ecosystems and make waterways unfit for recreational and cultural uses.

Updated environmental indicator used in *Environment Aotearoa 2019:*

- Irrigated land

Existing environmental indicators used in *Environment Aotearoa 2019:*

- Consented freshwater takes
- Cultural health index for freshwater bodies
- Groundwater physical stocks
- Selected barriers to freshwater fish in Hawke's Bay

Effects of taking water

Taking water for irrigation, drinking, and hydroelectricity generation reduces the flow of water and its variability.

ISSUE 7

The way we fish is affecting the health of our ocean environment

Harvesting marine species affects the health of the marine environment and its social, cultural, and economic value to us. Fishing could change the relationship that future generations have with the sea and how they use its resources.

What is happening?

As befitting an island country, many New Zealanders have a strong connection to the sea. For many, that connection is through fishing – for employment, enjoyment, or cultural connections.

Commercial fishing and the pressures associated with it have reduced in the last decade, and most (97 percent) commercially caught fish come from stocks that are considered to be managed sustainably. In 2017 16 percent of routinely assessed stocks were overfished and 10 stocks are considered collapsed.

Animals that are caught unintentionally are called bycatch. Bycatch of protected species like Hector's and Māui dolphins, fur seals, sea lions, and seabirds has reduced, but still has a serious effect because many of these species are already threatened.

Trawling the sea floor with large nets or dredges to catch fish and species like scallops and oysters are the most destructive fishing methods and cause damage to the seabed. The area trawled and the number of tows have decreased over the past 15 to 20 years, but still cover a large area, and some areas have been trawled every year for the past 27 years. Between 1990 and 2016 trawling occurred over approximately 28 percent of the seabed where the water depth was less than 200 meters, and 40 percent where depth was 200–400 meters.

Why is it like this?

Fishing vessels are now larger and more powerful, and use wider trawls and longer lines than when trawling first started more than 100 years ago. A small number of boats today can have the same impact as a larger fleet would have had in previous decades.

Past activities, like hunting seals, are still having an effect on marine mammals, seabirds, and other species. Some species, particularly those with long lifespans or low fertility, recover slowly from disturbance.

Other environmental pressures interact with fishing to increase our impact on the marine environment. Excess sediment and nutrients from rivers, urban pollution including heavy metals, plastic pollution, introduced predators, loss of habitats, and a warming and acidifying ocean all combine to put pressure on the marine environment. When combined and acting simultaneously, these pressures may have more serious impacts that are complex and hard to predict.

What are the consequences?

Fishing affects the whole marine ecosystem. Fish stocks are managed individually and do not account for interactions between different stocks or the broader marine environment. Because we don't know the cumulative effects of fishing on the marine environment, it is unclear if the current levels of fishing are sustainable or where the tipping points are.

Removing fish also changes food chains, affecting species that depend on fish for food (like seabirds and marine mammals), or that are eaten by them.

Seabed trawling changes the physical structure of the seabed and we don't know how long it takes to fully recover.

Any accidental capture of a protected species is an issue. For example, the number of Māui dolphins caught has declined in recent years, but this is a critically endangered animal and in 2015/16 there are only an estimated 63 animals left.

Overfishing can lead to loss of livelihoods. For commercial fishers, depleted fish stocks could mean catching less or having to go out further to catch fish.

Overfishing removes opportunities to harvest kaimoana. The loss of biodiversity erodes the mauri of the marine environment and impacts key values such as ahikāroa, mana, manaakitanga (acts of giving and caring for), and whanaungatanga (community relationships and networks).

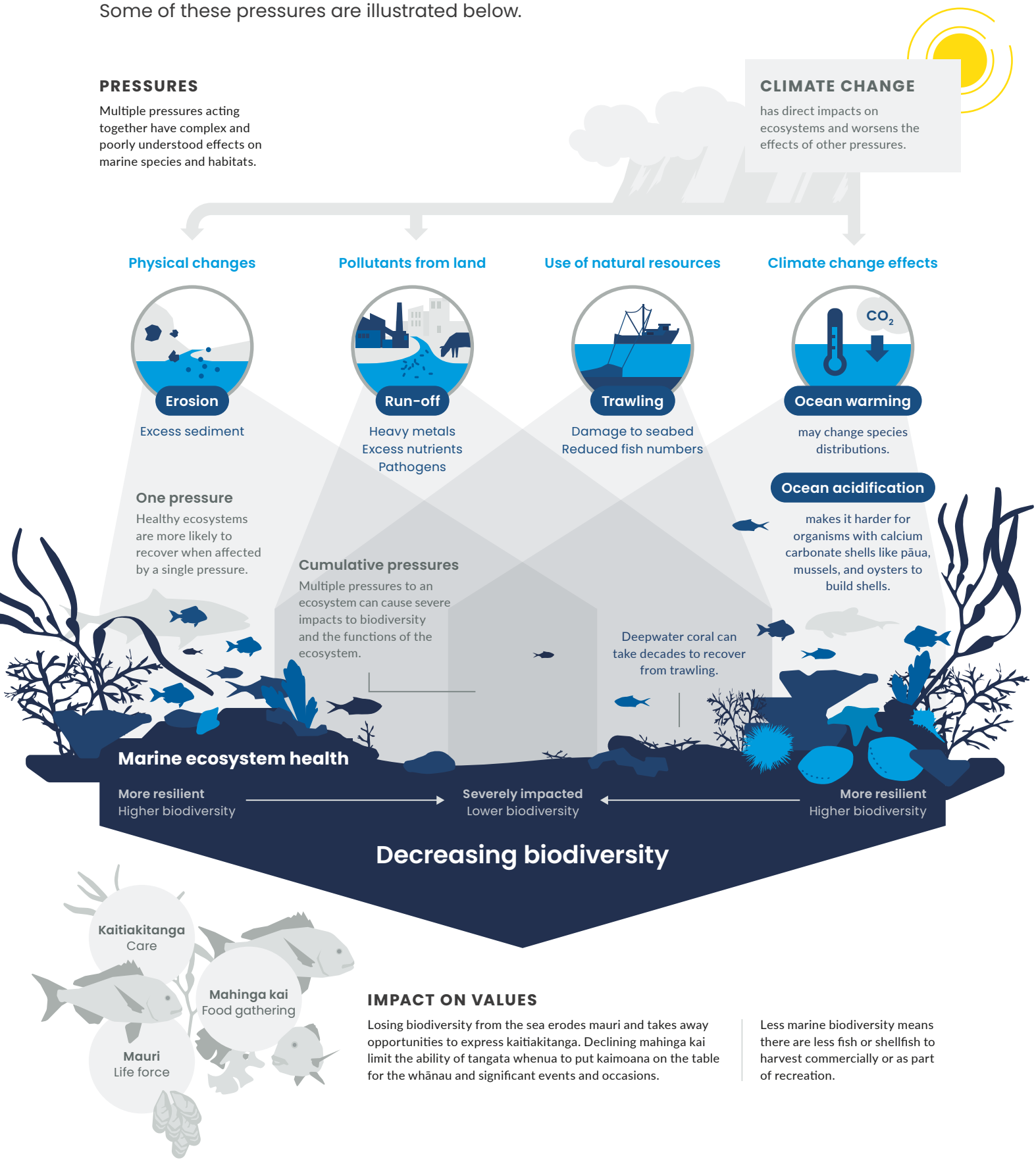
New Zealand's marine environment faces increasing pressures from activities besides fishing. This includes the effects of excess sediment and nutrients from rivers, plastic pollution, loss of habitats, and climate change. These multiple and simultaneous pressures may have far-reaching and hard-to-predict effects on marine species and habitats.

Existing environmental indicators used in *Environment Aotearoa 2019*:

- Bycatch of fish and invertebrates
- Bycatch of protected species: Hector's and Māui dolphins
- Bycatch of protected species: seabirds
- Bycatch of protected species: sea lion and fur seal
- State of fish stocks

Cumulative pressures on the marine environment

Life in the ocean is degraded when there are multiple pressures on the environment. Some of these pressures are illustrated below.



IMPACT ON VALUES

Losing biodiversity from the sea erodes mauri and takes away opportunities to express kaitiakitanga. Declining mahinga kai limit the ability of tangata whenua to put kaimoana on the table for the whānau and significant events and occasions.

Less marine biodiversity means there are less fish or shellfish to harvest commercially or as part of recreation.

THEME 5

Our changing climate

Photo credit: Alan Blacklock, NIWA

Greenhouse gas emissions are causing significant changes to Earth's oceans, atmosphere, and climate. We expect these changes to be very long-lasting – some will be irreversible.

We are already seeing changes in our climate and marine environment, and these are expected to become more severe. These changes reach across the length and breadth of Aotearoa New Zealand, with some regional differences. As an island nation with a large marine zone, long coastline, and an economy based mainly on primary production and international tourism, we are vulnerable to the impacts of climate change.

This theme looks at two climate change issues:

1. How our activities in New Zealand are contributing to global increases in greenhouse gases.
2. How changes in the climate are already affecting our environment, and how they will affect our lives now and into the future.

ISSUE 8

New Zealand has high greenhouse gas emissions per person

Our per-person rate of greenhouse gas emissions is one of the highest for an industrialised country. Most of our emissions in 2016 came from livestock and road transport.

What is happening?

Global greenhouse gas emissions have increased dramatically and are at a record high. As a consequence, global temperatures have already increased by about 1 degree Celsius above pre-industrial levels. Such rates of change far exceed any past natural rates of change.

New Zealand makes a small contribution to global emissions, but we have high emissions per person when compared internationally. In 2015, New Zealand emitted 17.5 tonnes of carbon dioxide equivalent greenhouse gases per person, which was higher than all but five of the 43 Annex I (industrialised) countries. Agriculture is responsible for nearly half of our gross greenhouse gas emissions, which reflects agriculture's economic importance, followed by road transport, which enables movement of goods and services on our roads.

Although our global contribution is small (0.17 percent of gross global greenhouse gas emissions in 2013), the contribution of small nations like New Zealand is important. Our gross greenhouse gas emissions have increased by 20 percent since 1990, but have been relatively steady in the past decade, despite increases in population and GDP. This means our emissions per person are lower now than 10 years ago. Similarly, our emissions per unit of gross domestic product since 1990 are 43 percent lower, but still high internationally – the fourth highest in the OECD in 2016.

Our larger cities tend to have high levels of black carbon (also known as soot), one of the most important contributors to global warming.

According to the International Panel on Climate Change, our emissions are reversible if we make that choice as a society. Even small reductions in greenhouse gas concentrations will reduce the changes that our grandchildren and their descendants will experience.

Why is it like this?

Our high emissions per person are partly due to the large proportion of methane and nitrous oxide from agriculture. These gases warm our atmosphere more strongly than carbon dioxide (CO_2), and increase our per-person CO_2-equivalent greenhouse gas emissions.

Road vehicles are our main source of CO_2 emissions. We have the highest rate of car ownership in the OECD, and our cars are old compared to other OECD countries. This raises per-person emissions because older cars tend to use more fuel for each kilometre travelled and emit more black carbon.

What are the consequences?

The rate of warming is unprecedented, and may be faster than some organisms and ecosystems can adapt to. The impacts of these changes are already being felt globally, for example ice sheets and Arctic sea ice are shrinking. Climate change is already affecting Aotearoa New Zealand (see Issue 9).

The issues described in the report are made worse in some way by climate change. Climate change will add another layer of stress on our ecosystems, making it harder for them to recover from other impacts like pollution or seabed trawling. In turn, this will decrease the benefits we get from nature and undermine our connection to the natural environment.

Our high rate of per-person emissions compared with other industrialised countries also carries a reputational risk because international trade and tourism are strongly linked to our environmental credentials.

Updated environmental indicator used in *Environment Aotearoa 2019:*

- New Zealand's greenhouse gas emissions

Existing environmental indicators used in *Environment Aotearoa 2019:*

- Black carbon concentrations
- Global greenhouse gas emissions

ISSUE 9

Climate change is already affecting Aotearoa New Zealand

Changes to our climate are already being felt in our land, freshwater, and marine environments. We can expect further wide-ranging consequences for our culture, economy, infrastructure, coasts, and native species.

What is happening?

New Zealand is already being affected by climate change and many significant changes in our climate are being seen across the country.

These include higher land and sea temperatures, sea-level rise (14–22 centimetres in the last century), ocean acidification, more sunshine, and melting glaciers (our glaciers have lost 25 percent of their ice in the past 40 years). Some locations are experiencing drier soils, altered precipitation patterns, fewer frost days, and more warm days. Extreme wind has decreased at some locations. Most places have seen no change in extreme rainfall since 1960, but studies indicate that because of climate change, some flood and drought events were worse than they would have been or had a higher likelihood of happening.

Many of the impacts of climate change are irreversible on a human timescale, and some impacts, like erosion from extreme rainfall or species extinction, cannot be reversed at all. Stopping further emissions will not return us to a normal climate because carbon dioxide remains in the atmosphere for centuries to millennia. As long as greenhouse gas concentrations remain elevated, the risk from extreme events like heat waves, droughts, and storms will be elevated.

Existing environmental indicators used in *Environment Aotearoa 2019*:

- Annual glacier ice volumes
- Coastal sea-level rise
- Extreme wind
- Frost and warm days
- National temperature time series
- Oceanic sea-surface temperature
- Ocean acidification
- Rainfall intensity
- Soil moisture and drought
- Sunshine hours

Why is it like this?

Carbon dioxide and other greenhouse gases are building up in the atmosphere and causing changes to the global climate.

New Zealand makes a small contribution to global emissions, but we have high emissions per person because of methane and nitrous oxide emissions from agriculture, our high rate of car ownership, and our aging vehicle fleet (see Issue 8).

What are the consequences?

The effects that are already being felt in New Zealand are expected to intensify in the coming decades. Although good information on the cumulative and cascading effects that climate change will have on our economic, social, and cultural well-being is still lacking, we can be sure that nearly all aspects of life in New Zealand will be affected.

Climate change will affect the things we value. Many culturally important sites such as early Māori and European archaeological sites, as well as marae and urupā (burial sites), are located in areas that are vulnerable to flooding or erosion. As sites are lost, so is the intergenerational connection to these places, along with the knowledge and understanding of those connections. Also, changing environmental conditions may cause some species to move to other areas, while others may be lost.

Climate change will affect where we live. Sea-level rise will put property at risk, and some places may become uninsurable. Flooding and heat waves could impact our infrastructure, including the transportation, communication, and power networks that our modern life relies on.

Climate change will affect how we live. It will affect what we grow and where, through warmer temperatures, changed precipitation patterns, more intense and frequent droughts, and intense rainfall, but also more growing days. A warming and acidifying ocean will affect the fish we catch and harvest, while more extreme fire conditions and pests could change the landscape and how we use it.

Impacts of climate change

Relatively small changes in our climate can have big effects on our ecosystems.

CHANGES ARE ALREADY AFFECTING NEW ZEALAND

Warming land

+ 1°C

Average temperature increase, 1909–2016

Warming sea

+ 0.7°C

Average sea-surface temperature increase around New Zealand, 1909–2009

Rising sea levels

+ 14–22 cm

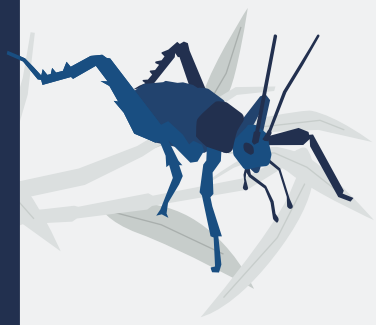
Varying sea-level rise around New Zealand, 1916–2016

Increasing ocean acidity

+ 7%

Increase in acidity off Otago coast, 1998–2016

Climate change affects our environment directly and intensifies the effects of other pressures.



Drought

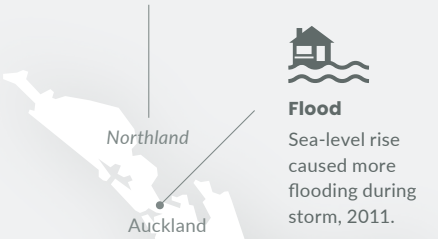
The 2012–13 drought was one of the most extreme in recent history and affected the entire North Island and the west coast of the South Island. Climate change made it more likely to happen.

Shifting seasons

Hapū and whānau-based fishers observe changes in the seasons, which affect harvest times.

Changing distribution

Warmer temperatures played a role in shifting the range of two wētā species in Taranaki.



Flood

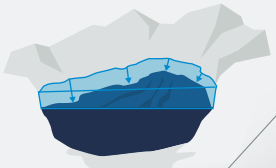
Sea-level rise caused more flooding during storm, 2011.

Flood

Flooding from the highest high tide, 2016.

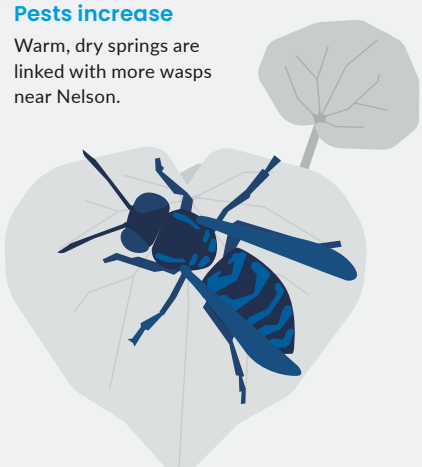
Melting glaciers

Glaciers in Southern Alps decreased 25% in ice volume, 1977–2016.



Pests increase

Warm, dry springs are linked with more wasps near Nelson.



Warming seas

Increasing sea-surface temperatures were a factor in the reduced survival of yellow-eyed penguin.

Note: Data for this illustration is from Mattern et al (2017) and this report.

Photo credit: photonewzealand

Understanding our environment

Our environment is complex and multi-dimensional, and changes in the environment can have multiple causes and happen at different rates. The time it takes for the effects of a change to show can also be significant, which makes establishing a cause harder.

Each place is also distinct because of the environmental conditions and the people who live there – what they do, how they make a living, what they value, and what they want to achieve. All of these are important and have effects on the health of their local environment.

Good progress has been made on understanding particular aspects of our environment but many significant gaps in our knowledge remain. These are highlighted throughout *Environment Aotearoa 2019* and include how the environment functions as a whole system, the cumulative impacts of multiple pressures, regional variations, and where tipping points (when change becomes irreversible) may exist. More work is needed to address these challenges.

Environmental data and knowledge currently come from many sources, including scientific data, computer models, monitoring data, cultural monitoring systems, and citizen science. Finding good ways to draw on all of these sources will provide the richest picture of our environment.

Collecting and analysing data, and exploring scientific knowledge, take time and money. Taking opportunities to align our efforts across the knowledge and reporting system would enable New Zealand to be better equipped to understand the effect our actions are having on the environment, as well as deciding what our response to that understanding should be.

Wildside Wastewater Proposal's – Goughs and Pompey's Pillar

This document presents the concerns and opinions of the undersigned local community on the Wildside and in particular those in Goughs and Hickory Bays who will be affected by the proposal to create a wastewater disposal system on the adjacent headland.

This document was written by Marie Haley, conservation ecologist, landowner and operator of The Seventh Generation tours.

The Wildside

- The proposed area is part of the Wildside, which extends over the group of bays to the east of the crater rim on Banks Peninsula. The Wildside is an area of nationally recognised biodiversity values, and has few introduced flora species, relatively few weeds, and high rates of endemism. Much of the Wildside is in areas of Outstanding Natural Landscape, Ecological Significance and protected in reserves or covenants in perpetuity.
- The Wildside is a community project that does not belong to any one agency or group. It is a collaboration over more than thirty years of passionate hard-working landowners and contributing government agencies and groups. It has been nationally recognised due to its unique community driven aspect, and that individually landowners have made costly and long-term investments into conservation outcomes on their own land.
- This speaks volumes for the rugged, remote, ingenious and very unique community that may not see each other for years at a time but each contribute to a better and more beautiful environment. The significance of the Wildside should not be taken lightly.

Tree Planting Proposal – Goughs Headland

The proposal to plant a native forest on 33 Ha at the location identified on the planning map raises a number of concerns:

- The Wildside is predisposed to natural regeneration with a range of protected natural areas in the immediate vicinity providing rich seed source. The exemplar of this is Hinewai Reserve which is internationally renowned for its hands-off natural regeneration, this is possible particularly on the Wildside due to the high rainfall, high native seed bank, low weed species and in some areas by using nitrogen fixing gorse as a nursery crop.
- Natural regeneration from natural seed source is preferable ecologically to planted forest for a number of reasons, these are quite practical issues; the cost, the sourcing of enough seed source from the ecological area, the use of weed and pest guards, and getting the right plant mix to grow in the particular environment. To be successful, planting native forest is a high input job that needs regular visits to ensure weeds are controlled, plant guards are not damaged or blown away in storms, and that pests are under control.
- Thus, planting on either the Goughs/Hickory or Pompeys Pillar headlands would be an intensive undertaking, with regular site visits to maintain the plants. The high wind environment would be a risk for wind guards blowing out to sea to simply become a marine pollutant.
- Plant growth would be severely reduced on the Goughs or Pompeys headlands due to the harsh environment, with frequent cold winds accompanied by hail, sleet and snow at times. Plant growth will be considerably stunted compared to expectations based on the plant trials that have been carried out in Pipers Valley, and the speed of plant growth and water

uptake needs to be studied in this particular environment before any sound conclusions can be drawn.

- The suitability of this site for wastewater disposal will be especially influenced by the high rainfall that occurs on the Goughs headland. The plants will be in an already moist environment with regular high rainfall events, and cannot be expected to be able to absorb or hold as much wastewater as would be possible on a more favourable sites.
- New trials would need to be undertaken over many years to ensure that the plantings could withstand this environment, take up the wastewater at an appropriate rate, and that the appropriate planting area has been set aside.
- The Goughs site is exposed to all wind directions with the North-East wind being especially frequent and harsh. Pompeys is also exposed to most winds and with especial exposure to the Southerly winds. There are almost no days without wind on either site.
- Adjacent landowners have planted native shelterbelts that have not grown well due to the extreme weather conditions on these exposed headlands, as is evident in many places along the Wildside coast, the native forest in the area is stunted and twisted due to the persistent wind.
- Rainfall is highly changeable across the Wildside with flood events being experienced that are not forecast. It is not at all uncommon to have 100mm rainfall events happening within a few hours at higher altitudes. The Wildside is also much cloudier than the inner harbour, with sea fogs and easterly drizzle that can cause long term dampness underfoot and reduce the growing conditions and wastewater uptake capability of plants in this environment.
- The suggestion that the Wildside would be somehow enhanced by having a planted forest appear shows a fundamental lack of understanding. The Wildside is just that – it is the side of the peninsula that is a little wild and uncontrolled, and it is busy doing its own thing as part of a totally natural process.
- There would be almost no recreational advantage of a planted forest in an inaccessible place such as Goughs headland because almost nobody would visit, especially when they can visit a natural and inspiring place such as Hinewai.

Observations regarding the Inner Harbour proposal

- The Inner Harbour proposal has been well studied and there is a high degree of certainty that the plantings will perform as indicated by the Pipers Valley trial, which had a similar aspect and environment to the proposed Inner Harbour sites.
- It will be achievable at the Inner harbour sites to establish and monitor the proposed plantings, without the risk of wind damage to plants, and the plant guards being blown away and lost. The sites are easily accessible for routine visits by the park rangers and maintenance staff.
- The Inner Harbour proposal would create recreational and ecological habitats that are not currently available in that area. These native forests would be favoured habitats for a wide range of bird species, especially due to the sheltered valley environments.
- These restored natural habitats in the Inner Bays could be enjoyed by a wide range of people, both residents and visitors alike, all with easy access. In comparison, on the Wildside the access is difficult, the environment harsh and at times inhospitable with associated health and safety risks.
- Holding ponds in Robinsons Bay could act as wetland bird habitat, especially if at least some areas were arranged with small islands were built within them, which would inhibit

predators from being able to access bird nests and therefore allow an abundance of bird species to flourish in the protected valley. This occurred in the Christchurch oxidation ponds resulting in Christchurch increasing its wetland bird species and the ponds being considered a "rare bird hot spot"[1].

- The original wetland habitats in the Akaroa Inner Harbour are now highly degraded and incorporating wetland habitats into the wastewater solution would be a real source of opportunity. New species of bird would most likely visit the ponds and could then also take advantage of the extensive foreshore of the inner harbour bays. In contrast, on the headlands of Goughs or Pompey's there would be very little advantage of ponds to wetland bird species, due to the exposed environment not being conductive to bird breeding. If plantings and mitigation were managed well there could be a substantial beautification of the Robinsons Bay foreshore for bird watching.
- In the Inner Harbour there would be a public advantage to establishing a fund for intensive pest control, to allow the planted native habitat to flourish. The public good that emanates from having native animal species in peoples' backyards, and the spill over effect into the wider community, is likely to increase the public acceptance of the waste-water ponds and plantings.
- In comparison, there is no such advantage on the Wildside where there is already extensive pest control, and people live too far away from the proposed sites to benefit from or to become involved in pest control. The environment is also too harsh to allow for the same levels of enjoyment by the public that can occur at Inner Harbour sites.

Infrastructure concerns - Roading

- The only current access to the proposed Goughs site is a grass track, and an adequate access road would have to be formed. This proposed road is mapped as going through an Outstanding Natural Landscape (ONL). This would have a significant impact on the Outstanding Natural Landscape and on the immediate neighbours who would be in sight and hearing of the road cutting through the ONL and the subsequent traffic on it. Both building the road, and ongoing traffic, would increase the noise levels in an environment that is of significant natural quiet.
- The road would need to pass along the top of a BPCT covenant, and it is likely that this would have an impact on the ecology of that covenant area.
- There has been no consultation or planning on the type of road required for the access and pipeline, the creation and maintenance of the ponds, or for the regular visits that would be required to establish and then maintain the plantings. However, it is clear that this would have to be an all-weather formed road. Thus, a formed road would be created through a ONL and through neighbouring land including a block that is in the process of becoming a QEII covenant. This would have a significant impact upon the neighbouring properties and on the significant natural environment of the Wildside.
- While the wetland of Goughs Bay has been mapped as being of Ecological Significance and is thought to be the best wetland in the Peninsula's outer bays, there are many other sites of ecological significance within the Goughs and Hickory Bays, but these are not yet mapped as

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- [1] For reference contact Andrew Crossland CCC, and (http://www.birdsofchristchurch.co.nz/top-5-birding-areas/

they have not been through the process of being surveyed and signed off by the landowners. The BPCT Goughs Multi covenant will fit these criteria, as will the Top Bush BPCT Covenant, both of which are alongside the proposed road.

- The proposed road is in a high rockfall area, and in the Canterbury earthquakes of 2010 several large rockfalls happened along the BPCT covenant, breaking the fence in many places. One very large rock fell across the track and fence and had to be blasted out of the way after weeks of planning and involving a team of people. If such an event happened in the future the road access would be cut to the ponds and planting site.
- The site access road is intended to be formed along the route of the existing legal road corridor, and therefore there will be public access. The terrain is such that this may create significant safety risks when oncoming vehicles meet, exacerbated by the share drop on the southern side.
- The entire construction process, including the movement of heavy machinery and maintenance vehicles, would pose a considerable risk of introducing new weed species to the Wildside, an area that currently has very few agricultural or ecological weeds.
- The grass track that exists would need to be widened to be suitable for heavy machinery, and to include suitable passing areas. This would create issues with rockfalls, and risk potential cost blowout if areas of hard rock are encountered. The road forming process would be an ecological threat to the rare and endemic plant and animal life, as well as having a negative impact upon the covenant that is adjacent to the road corridor. It would of course also impact upon the Outstanding Natural Landscape and sites of Ecological Significance which are yet to be designated.
- The proposed road will have relatively high usage by local standards, and with the nearby power lines and associated structures, would have a significant impact on the visual asthetics of the Goughs Bay valley. In particular it would impact upon the land values in Goughs Bay, and most significantly affect 235 Goughs Rd, the Haley Hussain residence, and Vicky and Burt Turner on Hickory Bay Road. There would be a need to mitigate the land value impact through compensation to the landowners.
- We believe that the only way to lay a pipeline along Hickory Bay Rd would be to close the road for extended periods, causing significant additional disruption to residents, essential farming services, and access for emergency vehicles.
- In comparison, the Inner Harbour and Pompey's Pillar options already have formed roads, and there are no additional obstacles regarding Outstanding Natural Landscapes, ecological significance, or rockfall issues.

Infrastructure concerns - Pipes and Ponds

- A pipe to pump wastewater up and over the summit of Banks Peninsula will have to be engineered to a high standard, with considerable risks if the pipe or pumping system fails.
- As there would be no intermediate pump station any small issue with the pump such as a power cut could reduce the effectiveness of the operation, any significant issue could cause longer term delays and spill over of wastewater through Children's Bay more directly into the Harbour. This issue would not be likely to Robinsons Bay as the wastewater does not need pumping and can be gravity feed to the site.
- There are climate change issues arising from the proposed pumping over the summit rim, given that the annual power cost is in excess of $100,000. Even though planting native forest (at even more expense) can offset some of the climate issues, it would be a far more

sensible option for that power not to have been used, and in effect wasted, in the first place when there are acceptable disposal options closer to the source.

- The budgeted cost of approximately $8 million dollars to install the high pressure pumping station and pipe along the Long Bay Road, is a significant cost to the ratepayers that would be an unacceptable burden in the post-Covid economic environment.
- There appears to have been no study on where the material from excavating the pond sites will go. If it is moved offsite there will significant disruption and added cost. If it is used as fill in the area of the Crown Island stream catchment this will threaten the local ecology.

Farming impacts

- The Goughs Headland site is directly upstream of two intakes for household water, one an easement to Hickory Bay and the other the house supply to the bottom house in Goughs.
- The proposed Goughs planting site is directly upstream of farmland. Any leaching of trace contaminants such as antibiotics into the neighbouring farm, stock water or ground water, will be likely to cause the loss of value of the livestock when sold. We do not believe that there has been any specific study in this environment and soil type, regarding leaching downhill or into groundwater.
- Both the Goughs and Pompeys sites are at present good clear productive farmland. In both situations it would cause a significant loss to the landowners if all or part of their farms were taken by any compulsory process for the wastewater project, and in both locations the landowner is unwilling to sell. In Goughs Bay a forced sale would also likely mean the eviction of the land manager and family from their house and disruption to their children at the local school.
- The wastewater scheme would have a significant impact upon the values of the blocks of land being proposed. This would have an impact upon the neighbouring land values as well. We would seek compensation as a community for the loss of land value.
- Although post-Covid we are yet unsure of the future of tourism it is likely that planting at Pompeys, if not managed well, and the access road at Goughs, could have an impact upon the potential tourism value on the Wildside. Much of the additional income from farming operations have come from on-farm tourism based upon the wild remote and ‘untouched’ aspects of this unique community and environment.

Issues of fairness and consultation

The project for the disposal of Akaroa wastewater has been ongoing for about 10 years, but the Goughs Bay version has only appeared within the last 6 months. A meeting between CCC personnel and local residents was held in December 2019, but since then there has been no further consultation even though the project concept has been fundamentally changed.

In contrast, the Inner Harbour option has been well researched, and representatives of the local community have been heavily involved in the process from the beginning.

It seems that both options are about to be presented in a public consultation process as they are valid alternatives and have had equal levels of applied research and community involvement. This could not be further from the truth. It is obvious that this is a fundamentally unfair process lacking in natural justice.

In Summary

The Goughs Bay proposal is not a well-researched or practical option. Rather it is an idea that looks like it might be feasible on paper, but which runs a high risk of failing, or of a cost blow-out, when the idea impacts with the realities of this site.

The Wildside in winter is often a bleak, cold, and windswept, even when there is no rain or sleet. To suggest that it is realistic to establish a planted native forest there, within any reasonable timeframe and without a huge effort, shows outstanding optimism that will ultimately be shown to be misplaced.

Local knowledge indicates that plant growth rates in the Goughs headland can be less than half what could be expected at the Inner Harbour locations and we believe that the proposed planting area has not been trialled appropriately.

The size of the proposed storage ponds implies around two months capacity, provided they are empty at the start of a rain period. Experienced locals can recall that in some years the site has been continuously saturated for significantly longer periods. This implies either the need for either much larger ponds, or alternatively more robust proposals for emergency discharges from the wastewater plant.

Taken together, the above points suggest that the Goughs Bay proposal will need a significantly larger budget than that currently estimated and the likelihood of a budget blowout is significant.

In contrast to the poorly researched Goughs Bay proposal, the Inner Harbour option has been researched and designed in detail. There are few significant risks, while there are some potential benefits, if well managed.

We believe that there are many similar points raised about the Goughs headland that also apply to the Pompey's Pillar headland, particularly the issues around planting on an exposed headland, being within the special Wildside conservation area and pumping wastewater over the crater rim. We do not support either proposal.

Signed by the following residents and landowners of Goughs, Hickory and the Wildside:

Marie Haley and Asif Hussain, Goughs Bay, [redacted]

John and Carol Masefield, Goughs Bay, [redacted]

Hugh Wilson, Hinewai Reserve, Otanerito, [redacted]

Akaroa Water Treatment and Re-use Scheme 22 August 2020

Submitted by Andrew Ashby and Bronwyn Hayward

Bronwyn Hayward is a Professor of Political Science at UC and a coordinating-author of the Intergovernmental Panel on Climate Change Report for 2021, leading the chapter on planning for cities and their infrastructure in a changing climate. Andrew Ashby is a senior manager at Hamilton Jet. We have a small property on Takamatua [redacted] which they have owned for 14 years.

Bronwyn has also followed the water case with UC students of environmental policy and planning for 5 years and her own PhD had originally considered how to consult the public about difficult planning cases one of which waste water treatment/pipeline debate for Christchurch in 2000.

We recommend the following:

1) Adopting the Inner bays scheme with the following caveats:
2) Call this project a "water treatment and reuse scheme" rather than a "waste"-water scheme. Today, cities and towns around the world, from small to large, are face increasing water shortages and growing demands for water in a changing climate. We can no longer think of water as something to be "wasted" but a precious resource and taonga.
3) Reducing storm and ground water infiltration should be a bold, explicit and measurable public project, with transparent public reporting, to reduce the water volume at source.
4) Commit to lead the nation with the water reuse scheme. Plan for much more than the relatively easy 4% target of reuse in the immediate term and instead set a bold target of at least 30% reuse within 5 years in gardens and toilets.
5) Lobby Government to prioritise the legislation, regulation and standards required to also allow full water recycling in towns and cities. Undoubtedly however a national health and cultural / Treaty discussion will be required first.
6) Ensure all Akaroa communities have recycled water in residential properties and toilets within 10 years or as soon as technology and funds permit, for potable water.
7) Respect the cultural values of Tangata Whenua, and recognise the insensitivities of the past, particularly the location of waste facilities on historically tapu land, by ceasing to discharge treated water to the harbour as soon as possible when developing the new scheme.
8) We recommend that a scheme for local employment is created for the planting and maintenance of the native trees.
9) We recommend that planting is softened to create a natural contour with the hills, for example bush running down gullies to the shoreline where possible and raised board walks where appropriate for recreation in new wetland areas.

In closing we'd like to thank council staff, and local residents, and representative group, and community board members, and Ōnuku Marae communities for taking the time over many years to work carefully through the competing issues considering risks including nitrogen and virus intrusion, possible water logging and cultural impact.

SUBMISSION FROM

Chris & Annette Moore
[redacted]
[redacted] **Robinsons Bay, Akaroa 7581.**
Ph. [redacted] **M.** [redacted]

In response to CCC's Akaroa Treated Wastewater Options Consultation 2020

Introduction

- We have been living at [redacted], Robinsons Bay, for 15 years

- During this time we established a highly successful Bed & Breakfast operation, hosting several thousand guests from around the world

- We have also built a very successful olive oil business under the brand Robinsons Bay Extra Virgin Olive Oil. We produce from our olive grove in Sawmill Road arguably New Zealand's best olive oil as evidenced by our success in The New Zealand Olive Oil Awards where we have been judged to be "New Zealand's Best" in 4 of the last 8 years and in 2017, we won Gold at the prestigious New York Olive Oil Awards where over 900 entries from 27 countries competed. Our Robinsons Bay Olive Oils have become recognised throughout New Zealand for outstanding quality.

- We have invested our life savings into this wonderful property in a beautiful part of the world where we live and work. We are now in our early 70's and have become fearful for our future in terms of the Inner Bays Option creating significantly reduced property values but perhaps more importantly our ability to actually sell our property because of the stigma attached to having Akaroa's wastewater in a large dam, approx 100 metres from our family home.

The Options

We reject all options proposed by Council staff as they do not support a resilient future focused solution. The options take no account of either Climate Change or Akaroa's water shortages and all options are hugely costly for Christchurch Ratepayers. We strongly support a Reduce, Reuse and Recycle approach.

Background to this decision

- All the irrigation options proposed are disposal options aimed at getting rid of the water. The Inner Bays Option for the disposal of wastewater to intensively planted native trees will be a first for New Zealand....**do Councillors really want to support such a high risk and high cost option**

- The Inner Bays Option is a high risk option because of the unknowns and nowhere in New Zealand has it been done successfully. We do not want our Council and the Residents of Robinsons Bay and Takamatua to be part of such a large experiment that will have potentially catastrophic results and wide ranging ramifications for our Community and our City. This is underpinned by the opinion from Canterbury's Andrew Dakers (Technical Expert Wastewater) who has stated "I know of no other similar year-round large scale wastewater land application system in NZ on similar soils and topography that has been operating successfully for a substantive period at design load".

- The Inner Bays Option uses a significant archaeological and historical site in Robinsons Bay for the proposed massive dam. The Dam would be built on the site of Canterbury's first sawmill and next to the beautiful and historic Pavitt Cottage. **We must preserve our history and cultural values**

- Leaking pipes in Akaroa mean total wastewater is over 60% storm water and groundwater infiltration. We say replace this old and broken pipe network with high tech pipes that eliminate most of the current problems.....

- The proposed system is 3 times bigger than it needs to be if the pipes are replaced..... **Replace the pipes and resize the complete wastewater system required for Akaroa**

- The increasing impact of climate change and scarcity of water in Akaroa has not been taken into account in any of the options. **We say treat the wastewater to a potable/drinking water standard so that it becomes an asset for the Akaroa Community.**

- The costs of the various options for the Akaroa Wastewater system have dramatically increased since 2017.....up to 250%. We are deeply concerned at the overall cost of up to$75 million and the impact on the Christchurch City Council and it's Ratepayers. It seems to us that this massive cost for some 800 connections makes it the most expensive wastewater system in New Zealand and for The Inner Bays Option, a system that is designed to be a disposal mechanism and an experiment that has not been successfully used in NZ before.....we would be surprised if Councillors would be happy to support such a proposal knowing that it has no background of success.

- Central Government has already signalled that it will be setting up a National Water Ministry that will take over responsibility of all New Zealand Local Body's 3 waters. Central Government need to be involved now so that correct decisions are made on water quality, sustainability and resilience.

<u>Impact of the Inner Bays Option on our lives</u>

- Very close proximity of wastewater pond to our home – only 100m
- midges, odour, Canadian geese
- property value, ability to sell
- impact on our health
- no mention of compensation to residents for loss of property value etc

<u>Friends of Banks Peninsula Submission</u>

We strongly endorse the Friends of Banks Peninsula Submission and see it as a practical and cost effective way forward while also addressing climate change, resilience and sustainability.

Akaroa Treated Wastewater Options

Submission from Simon Trotter and Roz Rickerby,
[redacted] Robinsons Bay

We reject the following options:

- Inner Harbour Irrigation Scheme
- Gough Bay Irrigation Scheme
- Pompeys Pillar Irrigation Scheme
- Harbour Outfall Scheme

We reject these options for the following reasons:

1. Climate change

1.1 Akaroa has traditionally been short of water in the summer. Climate change will exacerbate and increase water shortage.

1.2 All the options proposed are discharging wastewater on land or inner harbour. The Council needs to take a long-term vision that Akaroa's wastewater needs to be reused. This is an opportunity for Council and residents to have a holistic approach to water.

1.3 A long-term view for water would propose filtration through wetlands and/or other processes whereby water can be re-used as grey water or put into the stream, or filtrated to the harbour at a quality that is acceptable.

1.4 New Zealand's legislative framework is changing rapidly to put a focus on future resilience as the impacts of climate change become better understood. We still have time to re-think Council's approach and use this opportunity to having a long-term sustainable solution for future generations.

1.5 We encourage the Council to design an integrated solution that facilitates re-use of the water in Akaroa, eventually recycling it back to the potable supply. The submission by Friends of Banks Peninsula proposes a reuse-recycle scheme. Other professionals support this solution. We therefore encourage Council to consider this alternative scheme.

1.6 We encourage Council to adhere to it's Integrated Water Strategy, by designing and investing in a Three Waters solution built for the future, and align to the National Coastal Policy Statement which has a strong focus on climate change and integration.

2.Resilance

2.2 The options proposed by Council do not build or encourage a resilient community. An integrated approach to water and wastewater in Akaroa is required. Council needs to demonstrate leadership on ways and means to build and encourage resilience by using water resources wisely, and sustainably within the infrastructure.

2.3 None of the options Council proposes reduce the wastewater volume. The consultation document states there are high levels of stormwater or ground infiltration into the

wastewater system (up to 60%). We urge Council to fix the pipes in Akaroa first and build a wastewater scheme that is more appropriate for 850 households. Akaroa residents should be encouraged to have their connections to the system upgraded.

2.4 Robinsons Bay residents are not connected to the Councils water or wastewater systems. The Inner harbour option does not provide any beneficial use to us as residents. However, the Inner Harbour scheme creates new risks to the environment, our property, waterways and community. The positive outcomes of wetland are overstated and untested.

3. Risk

3.1 Disposal of wastewater to intensively irrigate planted native trees would be a first for New Zealand. Land and storage volume requirements are based on theoretical modelling that is highly sensitive to assumptions, particularly around the ability to irrigate throughout the winter.

Should any of these assumptions prove incorrect then the storage and land irrigation areas will be too small – resulting in the need for system expansion or release of wastewater, along with nutrients and other potential contaminants, to streams and harbour. The anticipated level of nutrient leaching for the Inner Bays option could be as high as that of a dairy farm.

3.2 The Inner harbour option means water will leave the treatment site without testing and maintaining of any compliance standards because no outflow buffer is incorporated into the system. This leaves storage ponds and the irrigation fields at risk of receiving contaminated water.

3.3 The Inner Bays option would require consent as a non-complying activity, due to its reliance on some level of discharge to a water body. It carries the highest economic, social and environmental risks due to the complexity of the system proposed compounded by the proximity to populated areas and downstream infrastructure.

3.4 Many millions of rate-payer dollars are being spent on building a wastewater system that is extremely expensive per connection, but leaves Akaroa with its sewer network of broken pipes, increasingly vulnerable to climate change effects, raw sewage overflows, and with worsening water shortages.

3.4 Hammond Point Irrigation area has potential for erosion and landslides. Although a buffer zone is planned, the risk of erosion needs further investigation, and mitigation measures identified. The soil type in this are is loess. Loess is windborne sediment being an accumulation of clay, sand and silt. It's loosely cemented and highly porous, and very susceptible to tunnelling, and landslips. The landform around Robinsons Bay, and around Hammond Point shows this naturally occurring. With additional irrigation there is risk for further landslips. Hammond point irrigation scheme is too close to residential properties. We urge Council to carry out a thorough consultative investigation of these risks.

4. We support the re-use- purple pipe scheme, and reduce, re use and recycle approach proposed by the Friends of Banks Peninsula.

These are our reasons:

4.1. Climate change. We urge Council to take an integrated approach to water and a long-term view for sustainable use of water for Akaroa.

4.2 Build and encourage community resilience for the use of water within the Akaroa community.

4.3 Reduce risk. The risks mentioned previously on the Inner Harbour option are too many for the Council to mitigate, including further mitigation associated with a non-complying activity. The mitigation strategy or costs have not been thoroughly investigated, or added to the true cost of this option and operational costs. We therefore recommend the alternative option to reduce-reuse, recycle approach be put on the table.

Akaroa Wastewater Scheme Submission 2020 – Suzanne Church

I oppose all of the proposals in their current form. They do not meet the social, economic, environmental and cultural needs of the community and provide little long term benefit, sustainability or climate proofing.

Why design and build a wastewater scheme to process large volumes of ground water and storm water?

It is my opinion that all of the land based schemes proposed are **fundamentally flawed**, due to the whole design concept being based around a system that contains 61% inflow and infiltration – **not wastewater at all**. This has resulted in proposals for far larger storage dams and irrigation areas than would be required if the I&I issue was addressed completely, or at least corrected on a far larger scale than is currently proposed.

To design large scale schemes that threaten to encroach on the properties and lifestyles of rural communities seems fundamentally wrong, and also avoidable if the I&I was addressed - with a new smaller and more robust proposal then formulated based around a far less quantity.

This is nothing more than a $60 million band aid which fails to address the severity of the I&I issue, which will obviously worsen as time goes by. I understand that old pipe systems and infrastructure are an issue many Councils face, but the reality is the issues will not go away of their own accord.

I also wonder what contamination is being caused by untreated sewerage seeping back out from the broken pipe networks into the surrounding environment. If wastewater if leaking out of the broken pipe network then how can CCC accurately measure the amount of water that is actually in the system to design the scheme around?

There appears to be no real beneficial use of the water for the land based options as they all require prime farm land to be planted in native bush that does not even require heavy watering in the first place. It is purely a way to dispose of the wastewater and the cost and risks far outweigh any supposed benefit.

The quality of the treated wastewater is stated to be among the best in New Zealand. Although bacterial removal appears to be at a high level, nitrogen removal is poor and nitrogen leaching results for native trees are missing from the latest BECA report. It makes nitrogen comparisons with high-intensity dairy farming; only the very worst farms on Banks Peninsula have this rate.

Harbour outfall, in its current proposed form, fails to address cultural concerns or make use of the water in a beneficial way. It provides no solution to the seasonal water shortages faced by the Akaroa community. Should a Harbour discharge be chosen as the final option the Council still need to address the I&I issue first to reduce the volume, look for a solution to the cultural issue and work to reduce the discharge level over time as re-use standards are put into place - working towards an eventual plan for total reuse and keeping the harbour outfall operating only for emergencies.

Due to seasonal water restrictions in Akaroa the community has long asked for reuse and investigations into a purple pipe network began in 2017. The idea was offered as a proposed option in the 2017 consultation, but unfortunately it was not until 2020 that Beca eventually stated in a report that there were in fact no national standards in place for a re-use scheme. It seems very misleading that this important fact was omitted for so long. With the potable water crisis that some regions are already facing long term re-use needs to be taken seriously as a way forward in the future. There are many new technologies being developed and with the new 3 Waters approach being introduced at Central Government level I urge the Council to look for a broader and more sustainable solution and not spend a huge amount of ratepayer money rushing into a scheme that will not solve the problems facing the Akaroa community.

As a resident of Robinsons Bay I will comment on the Inner Bays Irrigation Scheme.

I see this as nothing more than a disposal field, using expensive prime Inner Harbour land. It is high cost, has little benefit and is not in any way climate change resilient. It places a large storage dam in the middle of our community, on a heritage listed property, next to a heritage listed cottage, with the risk of a dam break flooding properties both nearby and downstream. The dam will be 2ha in size with a security fence and a road around the top. Thick native bush will be planted as close as 5m from residents' boundaries, and over many of the historic features on the heritage listed site and changing the whole vista of the area. These plantings will be heavily watered for lifetime of the scheme – around 40 years, and watering will often continue in wet weather. There are many homes within a very close proximity to this scheme and the wellbeing of our community has already been hugely impacted over the last four years, with this threat leaving many residents feeling very uncertain about the future. Some residents have been unable to sell their properties due to the stigma attached to the proposal, and devaluation of properties is a genuine concern. There is no ability to expand this scheme without purchasing yet another parcel of land, and not factoring expansion into the proposal fails to consider the future effects of climate change and the more severe storm events that may occur because of this.

Many aspects of this proposal seem unjust or inconsistent:

- The proposal is so tight for space that the 100m setback from storage pond to houses has been taken from the water's edge, not the edge of the pond structure itself to make it fit the buffer criteria! If the measurement was taken from the edge of the pond structure it would be less than 100m from homes.
- No assurances of compensation have been offered to residents whose properties, homes and stock may be affected by a possible dam break.
- No dam break analysis has been carried out on the actual size of the proposed 19,000m3 storage dam – only a 15,000m3 analysis was done.
- No flood protection has been offered for the Pavitt Cottage or downstream properties.
- CCC have indicated that if they have undersized the scheme they would consider compulsory purchasing more inner harbour land.
- It seems unfair that the wastewater is being placed in Valleys where residents have to pay for their own private septic tanks to be emptied and maintained. We will then be asked to pay for the Akaroa scheme with our rates. Council financial management staff have stated that the scheme will in fact be funded from borrowing and this cost will be met from the general rate charged to all properties - residential, commercial and rural – even those of us who receive no sewerage services!
- CCC staff has stated that the Inner Bays option would take 8 years to be fully up and running. This is not stated anywhere in the consultation document.
- There is clear bias with the consultation process - The Inner Bays option was clearly stated as CCC's favoured option and far more technical work was carried out on this proposal than the other two land based options.
- The consultation document lists five disadvantages for harbour outfall, one stated as low risk, but only lists one disadvantage for the Inner Harbour Irrigation scheme, failing to address all of the many concerns about the scheme stated in the Working Party Joint Statement.
- To move the treatment plant from Takapūneke because it is an offence to cultural and heritage values and then place it on another heritage site that will hugely impact the culture and heritage of that area seems unjust.
- With regards to the heritage listed Pavitt Cottage CCC state "There is no risk to the cottage or its setting." How is this so when there will be up to a year of noisy, heavy construction work taking place not more than 100 meters from the cottage, the cottage will lose its income during this period,

thick tree plantings will be 5m from the property boundary and the Beca dam break analysis shows the possibility of water through the floorboards of the Cottage. The Beca report also states that measures may need to be taken to 'mitigate' midges and odour from the storage dam.

- The Pavitt Cottage Trust has had to fund their own archaeological assessment of the heritage area as CCC would not do so. The report states: *"Any ground-disturbing work in this area is likely to uncover remnants of the old mill, flume, tramway, blacksmith's workshop, and other outbuildings. Earth-moving projects that would modify this landscape will also compromise what remains of the engineering footprint of the water-driven mill operation, including the spillway, dam, and ponds. These features are readily visible on the ground, and in aerial and satellite photographs."*
- The Thacker land is failed to be listed in the consultation document as a heritage listed site.
- The 'artist's impression' in the consultation document fails to show the large built up bund, the road around the top of the storage dam, the security fence or the utility building housing the pump station.
- The dam burst analysis does not take into account the risk of debris blocking the stream where it passes under Sawmill road in a constricted space.
- The Council assure us that there will be no midges, but Beca acknowledges that storage ponds have the potential to support insects such as midges. "Midge and mosquito nuisance is identified as a risk to be mitigated by fluctuating level, high treatment and screening with trees."
- Robinsons Bay residents have been verbally offered purple pipe for watering their gardens by Council staff but Akaroa residents are not allowed it.
- The consultation document states as an advantage that wastewater would be gravity fed to Robinsons Bay, but fails to mention it would still need to be pumped up the plantings when it gets there, thus a pump is still required.
- Ngāi Tahu have worked on the design of a wetland scheme to enable a one in five year discharge of treated wastewater in severe weather events into Childrens Bay, with this process addressing the cultural concerns that come with such a release. This will enable the reduction of the overall storage capacity, but still leaves Robinsons Bay with a massive storage dam. Why has the Council not engaged further with Ngāi Tahu to ensure a more regular release is made possible, thus reducing the storage capacity and associated risks even more? This appears to have been negotiated for the Duvauchelle wastewater proposal, with regular winter releases, via a wetland, into the Pawsons Stream now being factored is as a possible part of the design. (Beca July 17 2020, Appendix D)

This proposal had taken a huge personal toll on our family. Since 2016 we have been threatened with huge storage ponds on the flat paddock in front of our family property, wastewater irrigation on part of our 7 acre land (part of that area including some of our walnut trees which are harvested commercially), wastewater irrigation on the boundary on three sides of the property, spray irrigation, dripper irrigation, and now the latest plan places a large storage dam on a hillside upstream and on the edge of a creek, with our downstream property having that same creek very close to our back doorstep. The stress of not being able to plan for the future, not sure if the property is sellable, the threat of property devaluation due to the stigma attached to the scheme, along with the risks associated with living downstream from the dam has hugely impacted the wellbeing of our household, compounded by the process being drawn out over such a long period of time.

As the unofficial 'communications' person for our Valley I receive a large amount of feedback from concerned residents. It has been a huge task collecting information and trying to get the message across to the Council that the community is feeling very threatened by the impacts of this proposal. It was unfortunate that the Council did not take this into consideration and that the many risks and concerns we face were not reflected at all in the public consultation document.

We must not overlook the human cost of this project – this is not a purely environmental issue. CCC should be challenged to pursuing and commit to re-use long term - as an example of sustainability and to lead the way to bring about change nationwide.

I support the long term re-use proposal stated in the Friends of Banks Peninsula submission.

Above: August 2019 - Runoff occurring after only 42mm of rain on already wet ground – the Council will keep irrigating until the rain gauge hits 50mm.

Akaroa Ratepayers and Residents Association Inc

To: Christchurch City Council
PO Box 73016
Christchurch 8154

Date: 22 August 2020

Attn: Tara King, Engagement Advisor

SUBMISSION REGARDING AKAROA WASTEWATER PROJECT

The Akaroa Ratepayers and Residents Association is an Incorporated Society that has been established to promote the interest and wellbeing of the community in the Akaroa area. This submission is made on behalf of the members of this organisation, and we believe this also represents the general interests of the wider community.

This submission has been prepared by Harry Stronach, the President of the Society.

We wish to be heard in support of this submission.

Executive Summary

The Environment Court decision of 2014 required to CCC to fully explore land based disposal options for the disposal of treated wastewater. They now have been explored, at length, and the CCC is clearly in a position to present a well-researched and convincing case to say that there are no viable land based disposal options.

All of the options that have been researched are unacceptable in various ways, either prohibitively expensive, unrealistic, high risk, or imposing unacceptable penalties and disruption to local communities.

In the period since 2014, there has also been accelerating interest towards re-use and recycling, and the technology that is able to make this possible has been progressing in parallel. At the same time awareness of climate change has increased, and the summer water shortages in Akaroa provide local proof of that. There is an obvious solution staring out - treat the wastewater to a standard where it can be used to mitigate the water shortage.

The fact that CCC staff support the Inner Bays disposal option indicates that they are unconcerned about the impact of project costs on ratepayers invoices, and that they weigh Ngai Tahu cultural objections (which are not related to any scientific evidence) as being more important than the well-being of local communities. Claims by CCC that the disposal of wastewater by irrigating a planting indigenous forest is a “beneficial re-use” is a stretch of both imagination and fact. Planted native forests are not “indigenous”, and there are no examples where the benefits outweigh the costs.

We encourage the council to move to a more strategic position, where the objectives are:

- Genuine consideration for the well-being of local communities
- Full re-use and recycling of wastewater to contribute to the water supply
- Science based, evidence driven outcomes

Within the Akaroa community, over 97% of ratepayers and residents support full re-use and recycling. Until that happens, they support the discharge to sea of highly treated wastewater.

They do not support disrupting local communities, imposing unfriendly projects with huge footprints on the inner harbour, engaging in nutty schemes, risking cost blow-outs, or pandering to mysticism.

Existing Potable Water Supply

The supply of fresh water in Akaroa has been problematic for years, and the restrictions on water use over this last summer, where the township effectively ran out of water, are yet more proof that the supply situation is inadequate. The situation is unacceptable, and we do not believe that CCC has any viable plan in place to improve the capacity of the water supply.

Increasing Population

Inherent in the Wastewater Project is the planning for population growth which is based on a CCC growth model, which indicates population growth of less than 15% over the next 30 year period. That may be fair enough if we are referencing trends in the recent past and population growth tied house building, given the way that the footprint of township is constrained. But has anybody noticed that changes are happening due to technology improvements and events such as Covid19 pandemics?

The fact is, that 60% of Akaroa residences have been typically unoccupied in recent years, one of the highest rates in the country. In coming years it is likely that many holiday homes in Akaroa will transition to being permanently occupied, either by their current owners using them as a base for a revised work-life style, or after being sold to incoming permanent residents (at ever increasing prices, of course). More people are now able to value lifestyle over inner-city location, and technology has enabling alternative options. More people now can, and will, work from home in Akaroa.

Our estimate is that the permanent population of Akaroa may double to 1200 or so, in less than 10 years, but without actually increasing the footprint of the town. In that scenario the empty house proportion would still be around 20%, which is still higher than most small towns in New Zealand.

Some aspects of this level of population growth could be very good for the town, but they will be fatal for wastewater project as currently planned.

Recycling and Reuse are the Future

Humanity is steadily moving to a more sustainable future, some sectors more reluctantly than others. CCC is a little slow on the uptake in this area, but we are pleased to signs of change coming from central government which will permeate down in due course.

The Ratepayers and Residents of Akaroa hope that the township will become a case-study in how recycling and re-use of water resources can be demonstrated in practical operation, so that this experience can be applied across the entire catchment area.

Wastewater Disposal Options as Presented by CCC
The CCC have presented 4 possible options for wastewater disposal, and our comments are as follows:

Inner Bays Option
This option is promoted by Council staff, and while it is well researched and is technically feasible, there are some major problems.

The scheme imposes an unacceptably large footprint on the inner bays area, and is excessively disruptive to the local communities involved. There are some significant issues related to historic and cultural values. The scheme has no capacity for growth, and on that factor alone should be discarded.

Goughs Bay Option
Council staff describe this option as "technically challenging", which are code words for "warning – cost blow-out imminent". There is no comparable example anywhere in NZ of a pipeline operating at this length and pressure, through such difficult topography.

Local residents who are familiar with the site, describe the idea as nutty. It will simply not be possible to establish a native forest on this exposed and elevated site that achieves growth and water take-up at anywhere near the required levels to dispose of the predicted wastewater volumes.

This option has not been properly researched - the engineering design has not been done, there have been no trials of native plantings at this locality, and there are no relevant meteorological records.

The local community have been ignored, with the only attempt at consultation being a preliminary meeting in Nov 2019 when an earlier version of the current scheme was presented in draft format.

Pompeys Pillar Option
Same issues as the Goughs Bay Option, only worse. More expensive, and more disruptive to the local community.

Harbour Outfall
The CCC option is for a discharge point in the middle of the harbour, and while clearly acceptable in term of science and engineering (and favoured by our membership) we also understand that this is not considerable acceptable by all parties.

But, it is a matter of choosing the "least worst" option, so we believe that the harbour discharge should be improved, as discussed late in this submission, until it is a clear winner and achieves broader acceptance. It is unfortunate that CCC technical staff have been distracted by land based options over the last 6 years, when that effort could have been applied to refining a sea discharge option.

Strategic Approach
We believe that CCC has been misguided in expending significant resources over the last 6 years in researching land based disposal options, when the effort could have been better applied into a parallel strategy focussed on:

- Track A - Work towards the full re-use and recycling of treated wastewater
- Track B - Work towards an ocean outfall for treated wastewater

Re-use and Recycling
The current proposal is to treat the wastewater to the "highest standard possible" and the "highest standard in New Zealand". So far so good, the end product will be completely clear and odourless and, in broad terms, of better quality than the water that runs into the harbour every day from the various streams in the catchment.

It would not be a huge step to go one level higher, and treat the water to a potable standard, where it could be either directly added to the water supply, or indirectly via a Managed Aquifer Recharge (MAR) system. We understand that there will be other submissions which will present these options in more detail.

The CCC proposed "Purple Pipes" system, where treated wastewater is made available for grass/garden watering and such, is supported by almost all residents. We understand that the official view currently restricts this proposal, because of perceived risks of improper cross-connections to potable water supplies. We hope that the officials concerned "grow up" and stop putting road-blocks in the way of communities that wish to develop and act responsibly.

Sea Discharge
The CCC proposed mid-harbour discharge option for highly treated wastewater meets all reasonable engineering and scientific standards, and passes the "common-sense" test, so why is it still being debated? We suggest that is because of a poor understanding of the future level of treatment, poor community understanding of science in general, and widespread distrust in the ability of CCC to operate the system to a reliable standard given past events.

All those points can, and should be, addressed by CCC. Within this submission we wish to discuss improvements to the proposed option, that will also address what are referred to as "cultural concerns". The proposed mid-harbour option is good, but it can be improved on.

The down-harbour option
Extend the discharge pipework around 5 km down the harbour, to a point where it is south of "Nine fathom point" and in the outer harbour. At this location it is pretty much beyond civilization, and facing the open ocean with greater water depths and far higher levels of tidal mixing. Combine this with a regime of discharge only on an outgoing tide, and it is hard to see how any reasonable party could mount a considered objection. This option is at least 10 times better, in terms of acceptance from all sectors of the community, than the current proposal.

The ocean outfall
Extend the discharge pipework a further 4 km until it is beyond the outer harbour, and beyond the heads of Akaroa harbour, and in the ocean. CCC claim that they looked at this option in the historical past and that the cost was excessive, however there has been no level of detail provided and engineering experience and common-sense suggest that this option will now be viable, given the issues and costs associated with all other options.

The multi-stage strategy
We are in a difficult economic environment, and neither the ratepayers nor the other financial options available to CCC are in the mood for any excessive or ill-considered expenditure. However it is fortunate that the sea discharge option lends itself to a multi stage approach, as funding allows and as technology progresses.

- Stage 1 - Mid harbour diffuser, as currently presented by CCC
- Stage 2 – Extend the pipework 5 km south, and relocate the diffuser in the outer harbour
- Stage 3 – Extend the pipework a further 4 km, so that the discharge point is beyond the heads of the Akaroa harbour

The total harbour strategy
If a properly engineered and managed sea discharge is arranged as discussed above, then it would be a logical and feasible step to connect the other harbour communities to the same pipeline system.

The Wainui area could be connected at a mid-harbour point near where the currently proposed outfall would be located.

The Duvauchelle area could be connected via a pipeline down the harbour to the same location.

Basic Principles
The CCC documents point out that this is a tricky decision – so here is some guidance on how to go about it:

- Choose the lowest cost, least impact, disposal option for the intermediate term

- Develop options for full re-use and recycling, including treatment to potable standard and storage options such as MAR.

- Develop plans for a staged approach for a sea discharge option as an alternative, that will conclude with an ocean discharge point

- Keep staged sea discharge (preferably ocean) as an option but aim to reduce this to zero as re-use and recycling become mainstream

Other Submissions
We share with other local organisations a common vision for the future of Akaroa and the surrounding area. We have read and reviewed the submission made on this subject by the Akaroa Civic Trust, and the Friends of Banks Peninsula, and in general we support the observations, comments, and suggestions that have been made in those submissions.

Submission by

Harry Stronach

(President, Akaroa Ratepayers and Residents Association Inc)

AKAROA
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Have Your Say - Akaroa treated wastewater options
Attn: Tara King, Engagement Team
Christchurch City Council
PO Box 73016, Christchurch 8154

August 22, 2020
Name: Akaroa Civic Trust
Role: Rosie Davidson, Secretary; Victoria Andrews, Deputy Chair
Address: [redacted], Akaroa, 7542
Email: Rosie Davidson: [redacted]
Victoria Andrews: [redacted]

- The Akaroa Civic Trust wishes to be heard in support of this submission.

Introduction

The Akaroa Civic Trust is a volunteer organisation that has worked since 1969 to preserve the town's historic character and the surrounding countryside's rural amenity and cultural landscapes.

In the 1960s the Akaroa County Council built the Akaroa sewage treatment works on a small area of land next to Takapuneke in Red House Bay. The Council later added a rubbish dump near Onuku Road in 1979.

In 1999 the Civic Trust recognised the need to protect Takapuneke, a historic site located adjacent the Britomart Memorial, from residential development. At the time, the land was owned by Banks Peninsula District Council (BPDC). In 2008 the Council formed a working party to investigate the wastewater consent to discharge water which was due to expire in 2013. The Council recognised that the existing plant was culturally offensive to Ngai Tahu. Working closely with George Tikao and Onuku Runanga, the Civic Trust supported greater recognition of the overall area as a significant bicultural landscape.

The BPDC was abolished in 2006 at which point Christchurch City Council assumed responsibility for the administration of Banks Peninsula. A determining factor with regard to the abolition was the need to upgrade the water infrastructure based on a population of 7,500 ratepayers.

The Takapuneke Historic Reserve was created in 2010 and was predicated on the closure of the treatment plant. The event was marked by three days of commemorations. However, in 2020 the matter of the appropriate disposal of Akaroa's wastewater treatment has yet to be resolved.

The Civic Trust's submission is based on the following information and documents

1. Environment Canterbury (ECan) became the first council in New Zealand to declare a climate emergency.
2. Following ECan's lead, the Christchurch City Council declared a Climate Change and Ecological Emergency in May 2019. The Council voted to recognise the urgency of

the environmental situation and ensure the council puts climate considerations at the heart of its thinking.

3. **The Banks Peninsula Community Board Plan 2020-2022** states that its priority is for the Peninsula's environmental sustainability and biodiversity is maintained and enhanced. The following are excerpts taken from The Plan via the BPCB agenda dated 20 July 2020.

   (page 124) Why this matters:
   It is important to play our part in contributing to carbon neutrality and mitigating climate change to ensure our environment is protected for future generations. We are committed to balancing tourism with environmental sustainability so that we have healthy harbours and lakes and thriving biodiversity.

   Response to the council's declared Climate and Ecological Emergency: Taking the current Climate and Ecological Emergency into account in all decision making and planning for our area.

   (Page 126) Why this matters:
   Our beautiful, dramatic landscapes are a much-loved place for locals, both those living on Banks Peninsula and in Christchurch. Our scenic beaches and bays are also a top destination for visitors from the region.

   Appropriate maintenance and development of infrastructure, including greenspace, wastewater networks, marine structures and land drainage, are vital for sustainable tourism as well as the environmental, economic, cultural and social health of our settlements. In addition, appropriate transport, power and communication networks are key for keeping our many isolated communities connected and safe.

   What the board will do:
   Advocate for wastewater treatment systems that minimise environmental damage and respect cultural and community values.

   Approve and implement the Akaroa, Duvauchelle and Wainui wastewater projects.

   (page 130)
   The cultural, environmental and built heritage of Banks Peninsula is valued and enhanced
   Why this matters:
   The unique character of each of our communities creates a sense of place that forms part of our identity. Of particular importance are our scenic landscapes, tangata whenua's taonga, local stories and historic buildings. It is important to look after this heritage so we can continue to pass on our shared identity to future generations.
   What the board will do:
   Support the preservation of our heritage, including buildings, structures, features, historic cemeteries and cultural heritage.

4. Christchurch City Council, Our Heritage, Our Taonga, Heritage Strategy 2019-2029
The main points are as follows.

The introduction written by the Deputy Mayor states: Our heritage, our taonga defines us. It is who we are, where we have come from and it guides what we will become. It contributes to our own personal sense of belonging and identity and anchors us to our communities and our city. Heritage connects us: to this place, to each other, to the past and to those who will follow us. Our heritage is precious and valuable. It has social, cultural, educational, recreational and commercial benefits. It contributes to our cultural wellbeing and brings visitors to the district. We are guardians of our taonga, charged with caring for these treasures and passing them on to our children.

Heritage Strategy: Executive summary
This strategy recognises that the Council has a leadership role in facilitating a collaborative approach with its partners and communities, ensuring a broad range of our built and natural, tangible and intangible heritage is recognised, protected and celebrated.

This strategy is based on the following principles:
• Accessibility – this strategy includes people of all ages and abilities through a range of accessible options.
• Respect for all cultures – this strategy includes and respects all people in the district, their heritage and culture.
• Heritage Conservation Principles – The Council will implement this strategy in alignment with best practice conservation management of heritage places and the safeguarding of intangible heritage.
- Heritage conservation principles and processes in the ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010 (ICOMOS New Zealand Charter 2010)
(Appendix C).
- The Nara Document on Authenticity 1994; Historic Gardens (The Florence Charter) 1982; The ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites 2008, Convention for the Safeguarding of Intangible Heritage 2003; Quebec Declaration on the Preservation of the Spirit of Place 2008.

Our Heritage, Our Taonga is tangible and intangible, built and natural, and comprises places, objects, stories, memories and traditions.
Our Journey, Our Stories
We have all journeyed here, and brought our own stories, traditions, objects and memories. In this place we and those before us have shaped the land, left our mark and created new memories, stories and traditions to be passed on to future generations.

Our Heritage, Our Taonga is visible – and includes tangible, physical evidence such as buildings, public spaces, places of worship, monuments, archaeology, objects, artefacts, colours in the landscape, urupā and graveyards, sports grounds, artworks, literature, documents (physical and digitised) and infrastructure.

…**and not so visible** – it may be intangible, or it may be hidden. It includes knowledge, stories, waiata, sounds, oral histories, smells, trails, past landscape features and vegetation. It also includes past events and their associated sites and the people and groups connected with them; hidden archaeology, wāhi tapu, wāhi taonga, ingoa wāhi, music, kapa haka, dance and language.

Tangible and intangible aspects usually co-exist in heritage places and items, and are interwoven.

Our Heritage, Our Taonga is varied in scale and type. It can be an individual building, place, garden or tree, or it may be an avenue of trees, a neighbourhood, street, area, view or a cultural landscape on a large scale.

Our Heritage, Our Taonga includes cultural landscapes.
Usually there are important connections between buildings, places and items and their settings, and this can extend to other nearby places and the wider landscapes in which they are located. Ngā Tūtohu Whenua is a heritage concept which conveys the interaction of people with their environment over time, and the connection between culture, nature and landscape and intangible and tangible values within particular areas. Most of our landscapes have cultural values as well as natural values, because of human

interaction with the land over time. Whakapapa is embedded within the natural environment and this relationship is reinforced through the naming of landscape forms, myth and legend.

Our Heritage, Our Taonga is valued for different reasons and is seen through different lenses by different groups within a community. This strategy acknowledges that we need to recognise all values and aims to improve understanding of different viewpoints as there may be multiple heritage values and stories all residing in one place.

What will the Council do to lead implementation of the strategy?
• The Council will ensure that internal plans, policies, strategies and regulations are in alignment with this strategy.

Our Submission

The Akaroa Civic Trust does not support the proposed inner bays irrigation scheme as it has been presented for the following reasons.

Banks Peninsula is identified, in its entirety, as an Outstanding Natural Landscape under the RPS and 'Landscape' being defined by the NZILA as "the cumulative expression of natural and cultural features, patterns and processes in a geographical area, including human perceptions and associations."

- The scheme will significantly alter long established cultural landscapes.
- The scheme does not recognise and is contrary to the purpose and intent of the Environment Canterbury's declared state of Climate Emergency, Christchurch City Council's Climate and Ecological Emergency, Our Heritage, Our Taonga 2019-2019 and the Banks Peninsula Community Board's Plan 2020-2022.
- Christchurch City Council has failed to recognise the importance of European settlement and farming heritage in the context of the rural amenity landscape which is an integral component of the inner harbour's wider cultural landscape.
- Christchurch City Council has not given due consideration to Appendix W, Pavitt Cottage archaeological assessment May 2020.
- The council has not given due consideration to European associations, spiritual and cultural values in relation to the affected land and areas of water.

The Submission Focuses on Robinson Bay and Valley

The stream and bay were first known by Maori as Kakakaiau. Robinsons Bay has largely been a working, pastoral landscape. Peninsula families have long and well established histories, cultural associations and relationships as well as having made their livelihoods working the land since their arrival in 1840-50s. Natural resources and the quality of the soil provided a sound basis for farming and timber milling for the early settlers.

Robinsons Bay has been a working, cultural landscape altered over time by traditional farming and sawmilling practices. The hills and valleys can be viewed in a manner similar to reading pages in a book for those who look closely at the landscape. (See Archaeological Assessment of Lot 1, DP82749, Robinson's Bay, Canterbury for the Pavitt Family Trust; Justin Maxwell and Jennifer Huebert, Sunrise Archaeology Report No. 20203, May 2020).

The rural landscape forms the setting and context for rich oral traditions and family histories.

The Sawmill Road location holds an invaluable range of early European history with visual evidence of how life was lived around the 1850s period. The valley contains a transformed, working landscape as pasture replaced trees. European settlers started small dairy farms, grew cocksfoot grass and grazed sheep. Banks Peninsula's first sawmill opened at this location in 1855.
Farming practices and organic production continue in Robinsons Valley to the present time.

Visual Effects

The assessment of visual effects contained in Appendix 5 does not take into consideration the following issues which could be deemed to be "fatal flaws".
The area is listed as a Rural Amenity Landscape.

- The area of the upper Robinsons Bay Irrigation Concept is of historic importance. It is unique in the rural setting which is located in proximity to Akaroa
- View shafts and the visibility of the proposed activity are not restricted to Okains Bay Road as shown in the consultation document
- No consideration has been given to the visual impact of the proposal on residents in the area as well as visitors
- The new irrigation areas and associated storage ponds require extensive tree planting and landscaping that will alter to a significant degree the amenity of the existing cultural landscape and may alter and/or destroy important archaeological material and sites
- Due to the location of the proposal it is not possible to "blend" the new activity with existing open pastural, working landscape by the extensive planting of new trees

As stated in Appendix 5 there are no existing or established ponds in close proximity. Therefore the ponds will be a "new activity" as well as a visual feature in the landscape.

The proposed earthwork and the creation of a large holding pond will alter and/or destroy a significant heritage site as well as a living, cultural landscape.

The proposed work would possibly include the following requirements

- a massive holding pond for of treated wastewater
- extensive irrigation fields
- a high embankment and dam with a 4m high bund adjacent to the Pavitt cottage
- safety fencing
- extensive tree planting
- formed public walking tracks that will likely be wheel chair accessible
- working access to the site
- visitor car parking
- pump equipment and building
- possible lighting

The proposed mitigation of tree planting to shield the new, massive 19,000m3 holding pond lined with plastic, divided in the centre with a bund, will significantly impact and alter the existing visual qualities and rural amenity of the working landscape as well as potentially damaging an archaeological site. However, the actual berm area of the large holding pond will likely not include trees as a visual shield since roots may cause damage to the structure. Therefore the new pond will be visible from numerous viewpoints especially during the long, dry summer months and winter when trees have few leaves.

The visual assessment, Appendix 5, is superficial with regard to the amenity and heritage values of the existing rural landscape. The assessment appears to have been written from the viewpoint of urban professionals who might not be familiar with the values of rural communities and the traditions of Banks Peninsula. The assessment refers to "Heritage Items as mainly built features" and does not include areas or landscapes. This statement in itself is contrary to the Christchurch City Council's Our Heritage, *Our Taonga Heritage Strategy 2019-2029* as follows.

- **Our Heritage, Our Taonga is tangible and intangible, built and natural and comprises places, objects, stories, memories and traditions.**

- **Our Heritage, Our Taonga is visible** – and includes tangible, physical evidence such as buildings, public spaces, places of worship, monuments, archaeology, objects, artefacts, colours in the landscape, urupā and graveyards, sports grounds, artworks, literature, documents (physical and digitised) and infrastructure.
- …**and not so visible** – it may be intangible, or it may be hidden. It includes knowledge, stories, waiata, sounds, oral histories, smells, trails, past landscape features and vegetation. It also includes past events and their associated sites and the people and groups connected with them; hidden archaeology, wāhi tapu, wāhi taonga, ingoa wāhi, music, kapa haka, dance and language.
- Tangible and intangible aspects usually co-exist in heritage places and items, and are interwoven.
- **Our Heritage, Our Taonga is culturally diverse**, reflecting
- all the cultures of our communities, and includes places of worship, traditions, customs, folklore, language, festivals, food and clothing. Welcoming visitors and new residents is part of our heritage.
- **Our Heritage, Our Taonga is varied in scale and type**. It can be an individual building, place, garden or tree, or it may be an avenue of trees, a neighbourhood, street, area, view or a cultural landscape on a large scale. It ranges from grand masonry public buildings, to humble timber cottages or fragments of a lost building. Our heritage places reflect the broad ranges of themes of the development of the district, including settlement, transport, industry, politics, entertainment, commerce, recreation, business and the arts. Our heritage is contained within our built and natural environment.
- We know these lands and these lands know us. We are in every blade of grass.
- **Our Heritage, Our Taonga includes cultural landscapes**.
- Usually there are important connections between buildings, places and items and their settings, and this can extend to other nearby places and the wider landscapes in which they are located. Ngā Tūtohu Whenua is a heritage concept which conveys the interaction of people with their environment over time, and the connection between culture, nature and landscape and intangible and tangible values within particular areas. Most of our landscapes have cultural values as well as natural values, because of human interaction with the land over time. Whakapapa is embedded within the natural environment and this relationship is reinforced through the naming of landscape forms, myth and legend.
- **Our Heritage, Our Taonga includes built heritage** which represents different styles, materials, designers and eras, and the people, uses and stories associated with them. Our built heritage reflects a variety of traditional English and other international influences and is also unique to this place. The extent of remaining colonial buildings in Akaroa makes it a highly intact township. Original uses for buildings have in some cases continued to the present day, creating a long tradition. Our built heritage also reflects our different cultures, provides us with landmarks and contributes to our distinctive neighbourhoods.

Furthermore the Council has failed to recognise the importance of cultural tourism. Visitors as well as residents walk, hike, cycle and move slowly through the landscape absorbing features that cannot be seen by individuals travelling past in a speeding car or tour buses full of cruise passengers heading into Christchurch for the day.

Photo: Robinsons Bay School Reserve, Robinsons Bay Valley Road, promoting a 20 minute walk and passive recreation. Signage: courtesy Christchurch City Council.

Robinsons Bay and the valley contain a rich and varied collection of heritage features, rural amenity and farming traditions that form an important cultural landscape in a modified, working setting of cottages, farm structures and houses.

View of the historic Pavitt cottage mill house c. 1855-1861 located to the far right as seen from Tizzards Road. The red arrow shows the approximate location of the holding ponds.

Numerous archaeological sites are located in the general area including the site of the original sawmill and flour mill, farm buildings, mill dam, waterwheel, spillway, flume and bridge foundation.

The following is an excerpt from Archaeological assessment of Robinsons Bay for the Pavitt Family Trust May 2020.

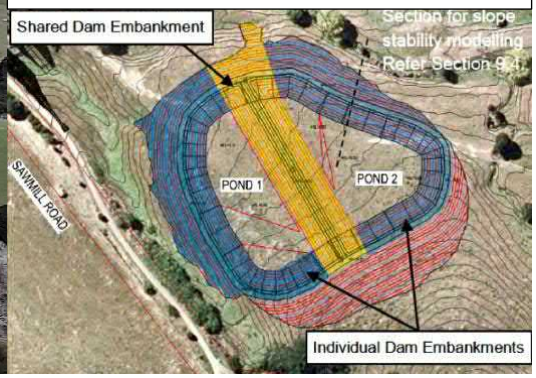
7.6 Robinsons Bay archaeological landscape

The mill cottage is but a small part of the larger cultural and archaeological landscape of Robinsons Bay. While the exact location of the Pavitt/Hughes/Saxton sawmill is not certain, the evidence suggests that it was not far from the present-day location of the mill cottage. At its peak, upwards of 30 people were working at the mill (Jacobson 1914:291) and they (and probably their families) were living in the bay. The sprawling footprint of a Banks Peninsula sawmill such as this in the mid-19th century heyday would have been considerable (see Figure 7-20 and Figure 7-23). Artworks that illustrate the valley in the 1870s suggest numerous structures existed; many of these buildings would have been poorly built and not lasted long after they were abandoned.

Numerous vestiges of the 19th century European landscape do however remain, including components of the sawmilling infrastructure, trees planted by the early settlers, and a number of other historic structures. In addition to the schoolmaster's house there are easily visible, but unrecorded, structures such as the small derelict 19th century cottage on Lot 2, DP 82749, which is next to the mill cottage. Thanks to limited development over the last 170 years, this lot has retained much of its 19th century character as well as above-ground vestiges of the early industries in the bay.

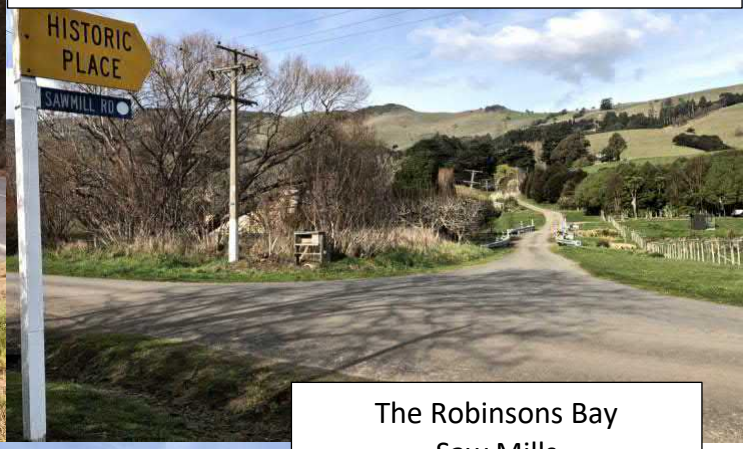
Further investigation is likely to uncover additional examples of the 19th century European land use throughout the valley. During this assessment, a number of new sites were recorded throughout the valley: the remnants of bridge foundation (Figure 7-49), cocksfooter's camps (Figure 7-43 to Figure 7-46), the remains of what may be 19th century structures (Figure 7-47, Figure 7-48), and a well (Figure 7-50). Further research will be necessary to determine whether they all relate to 19th century activities. There are, for example, 19th century camp sites beside the creeks further up the valley in less accessible areas; these small camps are notable by low stone walls or what were once chimneys, and the presence of 19th century bottle glass and metal artifacts.

Further images relating to the proposed location and scale of the Thacker dam and 2 ponds located in proximity to Sawmill Road and the Pavitt House



Heritage New Zealand, formerly Historic Places Trust, installed three sign posts directing visitors specifically to Sawmill Road to view the location of the first working sawmill on Banks Peninsula. The area is of historic significance as recognised by Heritage New Zealand.

Left photo, signage on Highway 75.
Photos below, signage from Robinsons Bay Road pointing to Sawmill Road and the historic site.
(NZHPT/Heritage New Zealand)



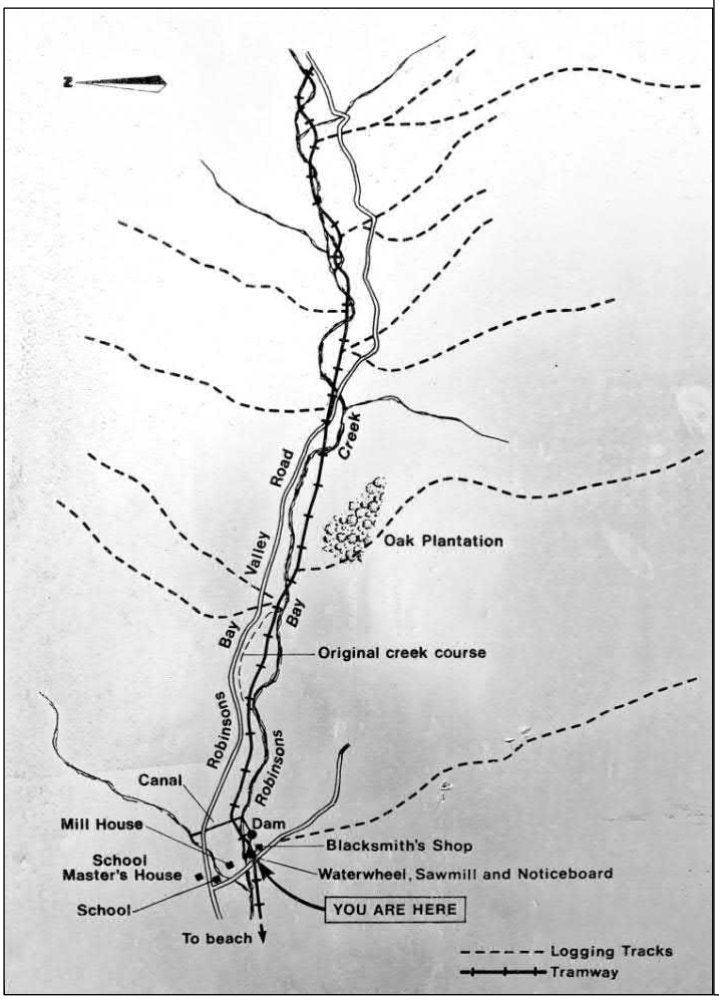
The Robinsons Bay Saw Mills

In 1987 Historic Places Trust erected an interpretative panel next to the waterwheel axle which had been placed on a platform near the mill cottage along Sawmill Road.

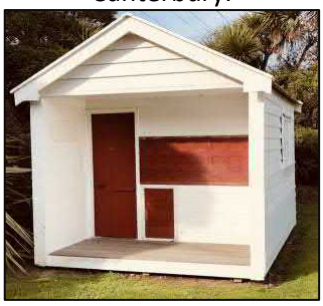
The panel was prepared by Department of Lands and Survey Christchurch.

Sawmill Road, August 13, 2020

- The red arrow to the left shows the location of the Pavitt cottage.
- The blue oval is the general location of the two wastewater ponds.
- The red arrow to the right shows the location of the Heritage New Zealand interpretative panel.



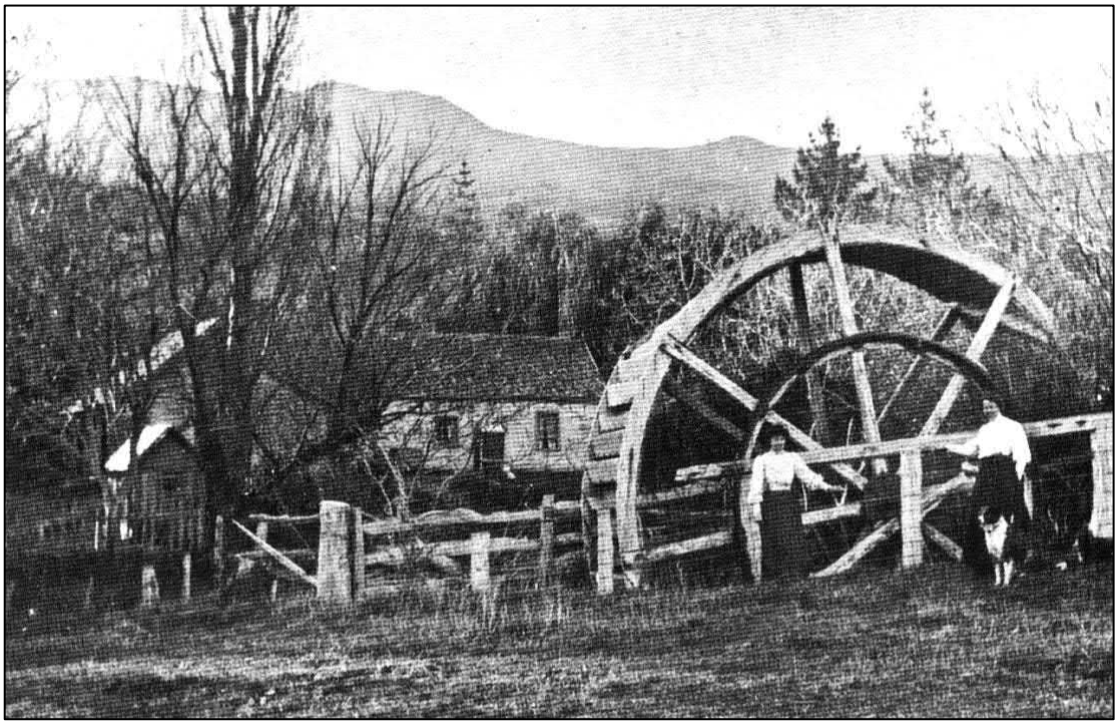
The map is taken from the Historic Places Trust panel. It shows the degree of activity as John Pavitt and his family established Canterbury's first saw mill which was designed by Samuel Farr, one of the regions earliest architects. They had arrived at Akaroa in 1850 aboard the 'Monarch'.
The present cottage replaced one that burned in bush fire in 1856.
The mill cut about 10,000 ft of timber a week and bullocks were used to haul logs to the mill and timber to the beach at Robinsons Bay.
The mill employed 30-40 men. A butcher's shop, store and school were located nearby.
The first post office opened in 1863. The photo below shows the 1912 post office which was the smallest in Canterbury.



Robinsons Bay Sawmill and Cottage is a copy of the original painting, artist and date unknown.
Gift of Sal MacPherson, a Williams family descendent, to the Pavitt Family Trust, Aug 2020.

The painting depicts the site in the 1870s. The house, waterwheel, blacksmith's shop, school and workers cottages and related details are all visible in the landscape.

Robinsons Bay Steam Mill operated 1865-1877 when all the accessible timber was cut out.
The flume and waterwheel were used for emergencies, the blacksmith shop is to the right.
Photos: Orville Williams. Source: Cradle of Canterbury



Farr's water wheel which powered the mill until 1865. The photographs shows the 1856 Pavitt home in the background. During the Matlock Mill era a shop was added. Sarah and Maggie Hayward are standing by the wheel. Photo: Marie Rhodes. Source: Cradle of Canterbury

The above photograph shows the same fence line and location of the 1987 Historic Places Trust interpretative panel that was installed to illustrate the historic importance of the overall site in relation to Canterbury's early settler history.

"After Orville William's death in 1986, Murray Thacker purchased the farm adjacent to the Pavitt Cottage. He planned to preserve all the historic aspects of the old mill site. Robinsons Bay has changed very little with the years. Few communities have such a range of pioneer cottages, dairies, cheese rooms, stables and outhouses in such original condition."
Source: Banks Peninsula, Cradle of Canterbury by Gordon Ogilvie, 2007 published by Phillips and King Publishers.

Murray Thacker died in 2017. Murray never had the opportunity of realising his dream of preserving the heritage of Robinsons Bay for this and future generations.

The following information is contained in ARCHAEOLOGICAL ASSESSMENT OF LOT 1, DP 82749, ROBINSONS BAY, CANTERBURY FOR THE PAVITT FAMILY TRUST, JUSTIN MAXWELL AND JENNIFER HUEBERT SUNRISE ARCHAEOLOGY REPORT NO. 2020-3, MAY 2020. Image below, page 4 Lots 1 & 2. Lot 2 below is the location of the proposed double pond and tree planting.

9 Assessment of Effects on Archaeological Features

At the present time, there is no planned work that would affect the mill cottage or old mill site. The following assessment recounts what effects development would have on these archaeological features.

The cottage is an important historic building, already recorded as Archaeological Site N36/155. It should be preserved and protected from further modifications that would compromise its unique character. It is highly likely that archaeological materials will be encountered below the surface in Lot 1, DP 82749. These could include historic rubbish pits, latrines, remnants of structures that are no longer standing, and materials related to the use of the cottage, schoolhouse, and nearby sawmill.

The sawmill site, recorded through this assessment as Archaeological Site N36/260, is an expansive historical landscape that borders Lot 1, DP 82749, and spans Lot 2, DP 82749 and other neighbouring lots. Any ground-disturbing work in this area is likely to uncover remnants of the old mill, flume, tramway, blacksmith's workshop, and other outbuildings. Earth-moving projects that would modify this landscape will also compromise what remains of the engineering footprint of the water-driven mill operation, including the spillway, dam, and ponds. These features are readily visible on the ground, and in aerial and satellite photographs.

In addition, the planting of native species on Lot 2 would significantly alter the existing environmental diversity of an important cultural landscape. Exotics, including oaks, walnuts, macrocarpas and fruit trees, are an important heritage element in this cultural landscape. Members of the public are currently able to view remnants of early 19th century European culture and lifestyle in association with the historic Pavitt Cottage and mill site. It would be inappropriate to introduce the extensive planting of native species in the context of early colonial settlement as well as being contrary to the Christchurch City Council's **Banks Peninsula contextual historical overview and thematic framework** by Louise Beaumont, Matthew Carter and John Wilson, June 2014.

The planting of native species may be a Council policy. However, it this particular context and setting it is not appropriate.

In Conclusion

The Akaroa Civic Trust has concerns regarding the visual impact of the new treatment plant, Pond Site 10 and the wetland area located in the vicinity of Old Coach Road as well as the already consented pumping station that will be built behind Akaroa Mini Golf on the recreation ground parking next to the designated two night freedom camping area.

Appendix A, figure 5.2 includes information relating to cruise ship passenger numbers and tourism. It concludes that Akaroa has a modelled population of **2,418** between the months of October and April. However, double and triple ship days bring more passengers than the graph illustrates. The population figure shown is likely to be low when the volume of cruise passengers and holiday home owners, as well as casual visitors, are factored into the equation over the peak holiday season between December 26-January 19.

Information contained in the Have Your Say Akaroa treated wastewater options pamphlet fails to recognise the importance of maintaining and enhancing the historic character, existing rural amenity, heritage landscapes and the need to retain, reuse and recycle treated wastewater for use by the town of Akaroa.

Wastewater should be treated to the highest possible standards, reused and recycled as required. Scientific research advises that the east coast of the South Island will continue to become drier as the climate continues to change. Drought conditions may become common over the dry summer months. Leaking pipes and a general lack of maintenance also need to be investigated and remedied by the Council.

In our view, the Council needs to reconsider the wastewater treatment system and bring it into line with its 2019 Integrated Water Strategy which includes providing people, communities and future generations with access to safe and sufficient water resources through international best practice. The proposal as presented is contrary to Council policies and objectives and it is inconsistent with the intent and purpose of the Banks Peninsula Community Board Plan 2020-2922.

- The Akaroa Civic Trust urges the Council to reconsider “concepts” that are presented in the Have Your Say consultation booklet. Neither the land based or harbour outfall are acceptable as long term options for future generations.

- The proposal should be updated to the highest possible standard to meet the needs of the community as well as visitors well into the future.

- Building strong community resources will assist in the protection of the historic character and amenity of not only Akaroa but the surrounding countryside for future generations.

- The Akaroa Civic Trust supports the submission of the Friends of Banks Peninsula

Christchurch City Council - Akaroa Treated Wastewater options 2020

Suky Thompson, Personal Submission
[redacted] **Robinsons Bay, RD1 Akaroa 7581**
[redacted]

I have lived in Robinsons Bay for 30 years and developed a strong connection to the land, the people who worked it before me, and the community who live here now. We are bound by a shared sense of history and appreciation for this environment. There is a love of this place and a commitment to it that runs deep.

Representing Robinsons Bay on the Akaroa Wastewater Working Party has taken much of my personal time over the past four years. I have gained a thorough understanding of the Inner Bays proposal and the impacts of the Inner Bays proposal on the Robinsons Bay community, and of the community views as I have held many meetings with the community to gauge this as their representative.

The Council is putting our people and environment, heritage, values and properties at risk with its proposal to store and irrigate Akaroa's wastewater next to our homes. The closer people are, the more at risk they are of adverse effects and the more they will suffer over the year of excavation to dig the storage pond. Downstream neighbours will live with an ongoing heightened flood risk. All of us will see this storage pond every time we drive through or walk in our once beautiful valley. Odour, noise, midges will be problems than can pop up any time. Our heritage will be trampled on, destroyed and planted over. Possibly people will drift away, taking a hit on their property values. The system may need to creep out and expand if it proves short of room or we could just be left with an environmental mess if this experimental system fails.

This is a genuine worry. The Akaroa wastewater system has been poorly managed for years as evidenced by the faulty flow meter debacle. A resource consent and two consultations have been based on the wrong data, and now, even when the correct flows are known and most of it is infiltration, the proposal is still based on collecting up Akaroa's stormwater and then digging a hole in Robinsons Bay to put it in.

The problem is the same team has been working on this for years, and they are wedded to the current heavily engineering focussed solution. This is a social problem to solve and the Council needs to put a forward thinking multi-disciplinary team on the job so it can change direction.

Water is a precious resource – but only when it is clean and under control, wanted and needed. Water that is contaminated, out of control or when there is too much is a threat.

The community has been consistent in its demand that the water is treated to a potable standard because that is what changes it from a contaminated waste product to a precious resource. If it is in a potable state then it will be wanted and in times when there is too much of it (such as winter), people will trust that it be let go on its natural course to the sea.

Nobody has been found willing to take the Council's treated wastewater in its current form because it is not up to that potable standard. The Council has refused to acknowledge or accept the risks associated with it. Hence communities are up in arms, farmers have walked away, the DHB has put the kibosh on much purple pipe use, and the Council itself on Managed Aquifer Recharge. The Council has earmarked the land in the Inner Harbour by finding owners looking to sell anyway, not because anyone wanted the water.

Hence the Council has been stuck in the disposal paradigm – it must get rid of water no-one wants and on the smallest piece of land it can, given that the harbour appears out of bounds.

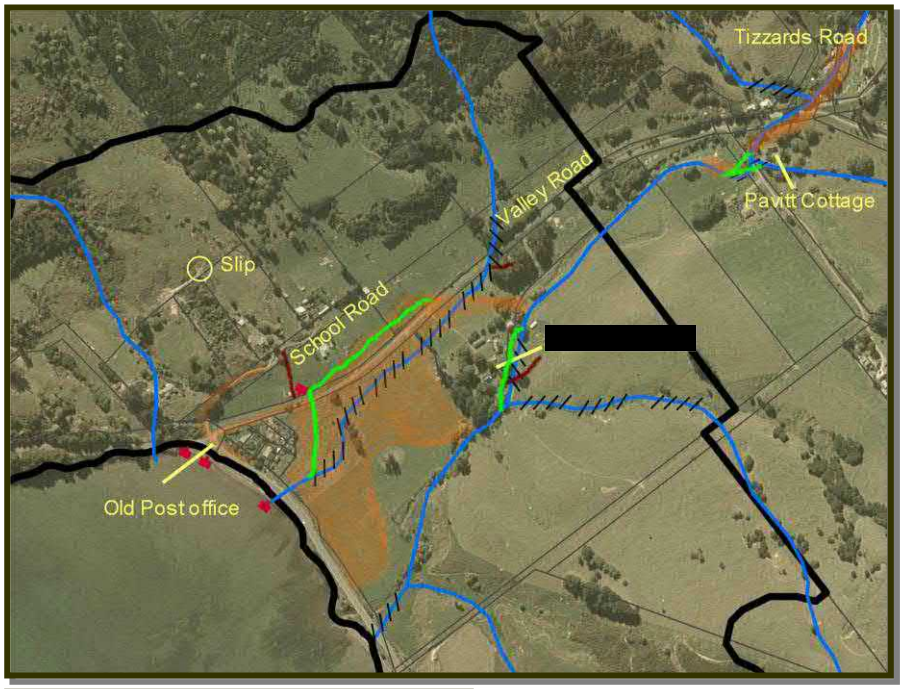
The team of engineers have been unable to cope with the social issues that result and have ignored them. The upshot is a solution that solves one cultural offense by creating another.

I wholly support the Friends of Banks Peninsula submission. It gives the Council a path forward to a practical, feasible, affordable and consentable solution and has huge support from the community. I am confident that the Council will get there if it appoints a new multi-disciplinary team, in tune with the fast moving legislation and technology, who can understand the social as well as the engineering concerns and opportunities, and work with government initiatives that are seeking to build nationwide three waters resilience. I wish to be heard in support of my submission.

Appendix – Flooding Concerns,

In 2008 I was engaged by Christchurch City Council to research historical flooding in the area as part of the Akaroa Harbour Settlements Study. The report *"Historical Flooding Research and Mapping Project, 8 February 2008"* revealed how vulnerable the Inner Harbour settlements are to flooding. Some the worst floods have been caused when debris washed down by swollen streams gets trapped at a constriction point such as a bridge, and water then backs up causing a flash flood when it eventually releases. I am concerned that if a blockage occurs at the Sawmill Road bridge below the dam, water could back up right under the dam face on the Thacker land exacerbating the risk of dam failure and with potentially catastrophic and life-threatening consequences for the historic Pavitt Cottage sited immediately below t and only meters from an already eroding stream bank.

Figure 1 Robinsons Bay flooding pattern 1994. Extracted from Akaroa Harbour Settlement Study Areas Historical Flooding Research and Mapping Project report 2008.Orange areas show flooding experienced.



Robinsons Valley Stream behind Dianne Carson's house during 1994 floods. Stream has overflowed normal banks, and broken out here, but returned to its bed by the time this picture was taken.

Figure 2 Flooding at Pavitt cottage April 2017

As the site of the first powered sawmill on Banks Peninsula, Pavitt cottage is of great historical importance to Canterbury. Its historical significance has been long recognised locally, with the site registered by the Historic Places Trust and documented in the book "The Old Water Wheel", by Jessie Mould. The cottage was purchased by Pavitt descendant John Fernyhough, fully restored and left in trust for use by the extended family in 2002. It has since been used for community events as well as family occupancy and is seen as the hub of the community. It is greatly valued by Robinsons Bay residents.

The areas shown flooded behind the cottage were formerly part of the mill workings. The former mill site sits above a confluence of streams in Robinsons Bay and is likely to be at elevated risk of flooding if soil moisture levels in the Thacker land above are maintained at a high level due to a wastewater irrigation disposal field or from steam bank slips.

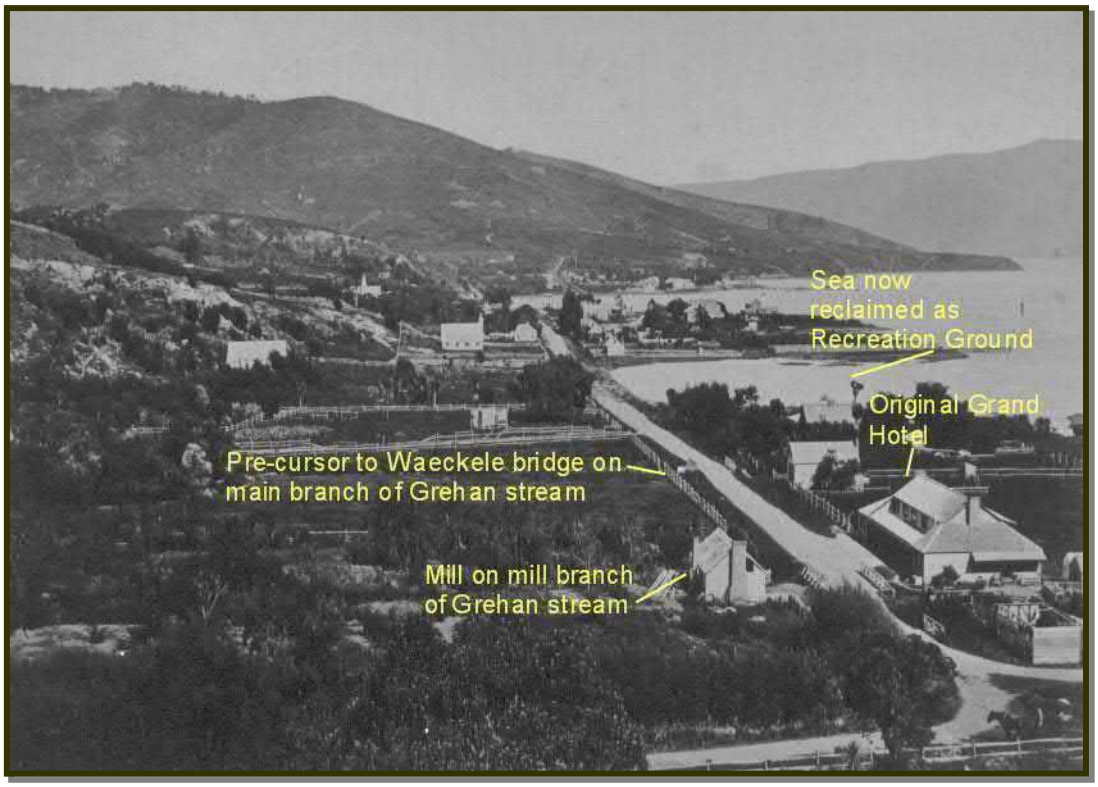
View from behind the cottage on the Thacker land showing runoff experienced in Cyclone Debbie, during the 2017 consultation. Before Cyclone Debbie the land had a soil moisture deficit. The rainfall experienced (based on Akaroa data) was 192.6mm. This level of rainfall has been experienced at least 13 times since 1934, so this could probably be classed as approximately a 1 in 10 year event based on the previous climate.

It is likely to occur more frequently and heavily with the increased cyclones expected under climate modelling.

I am also extremely concerned about the proposal to build the Terminal Pump Station in Akaroa at the car park near the boat store. This is reclaimed land and a former dump site. This is an area that persistently experiences flooding in Akaroa. The image below shows what the land look like before any reclamation took place.

The map in the Friends of Banks Peninsula submission showing Annual Flood levels expected by 2050 shows that the sea will be reclaiming this area back by then.

Figure 3 Akaroa circa 1867 showing the sea occupying the area now reclaimed as the Recreation Ground



Photograph from Akaroa Museum collection catalogue number 1103

Akaroa Recreation Ground January 2002

Groundwater Replenishment

Submitter #34114

With **Fresh Water Thinking**, we are diversifying our water sources and focussing on those that are not climate dependent.

Groundwater replenishment is where treated wastewater is further treated so it's good enough to drink, and then it is recharged into our groundwater supplies.

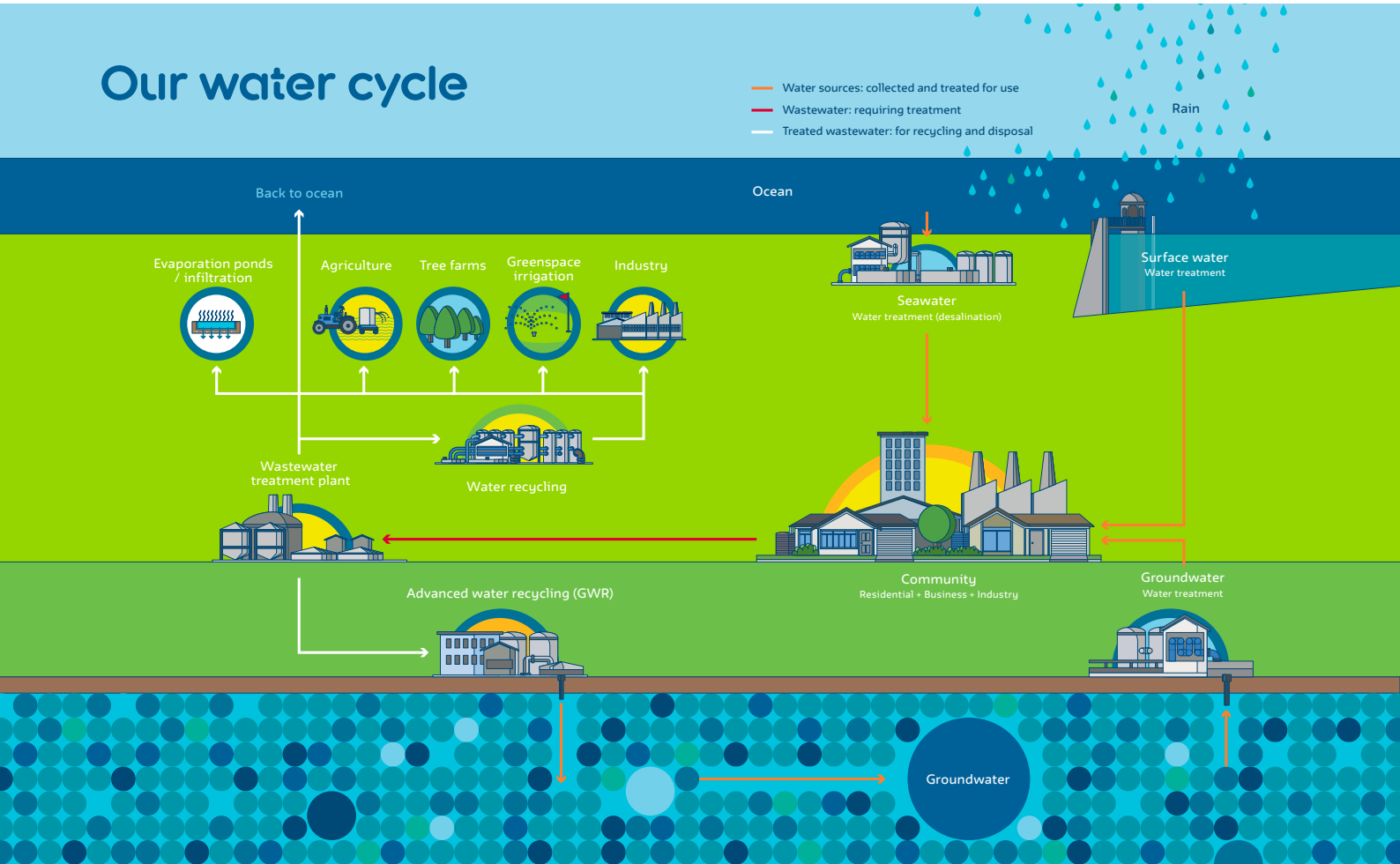
The water is then stored or 'banked' in the ground and taken out later for further treatment and supplied to a drinking water system.

This is just one of the many solutions that will help us become more climate resilient and secure our water supply for generations to come.

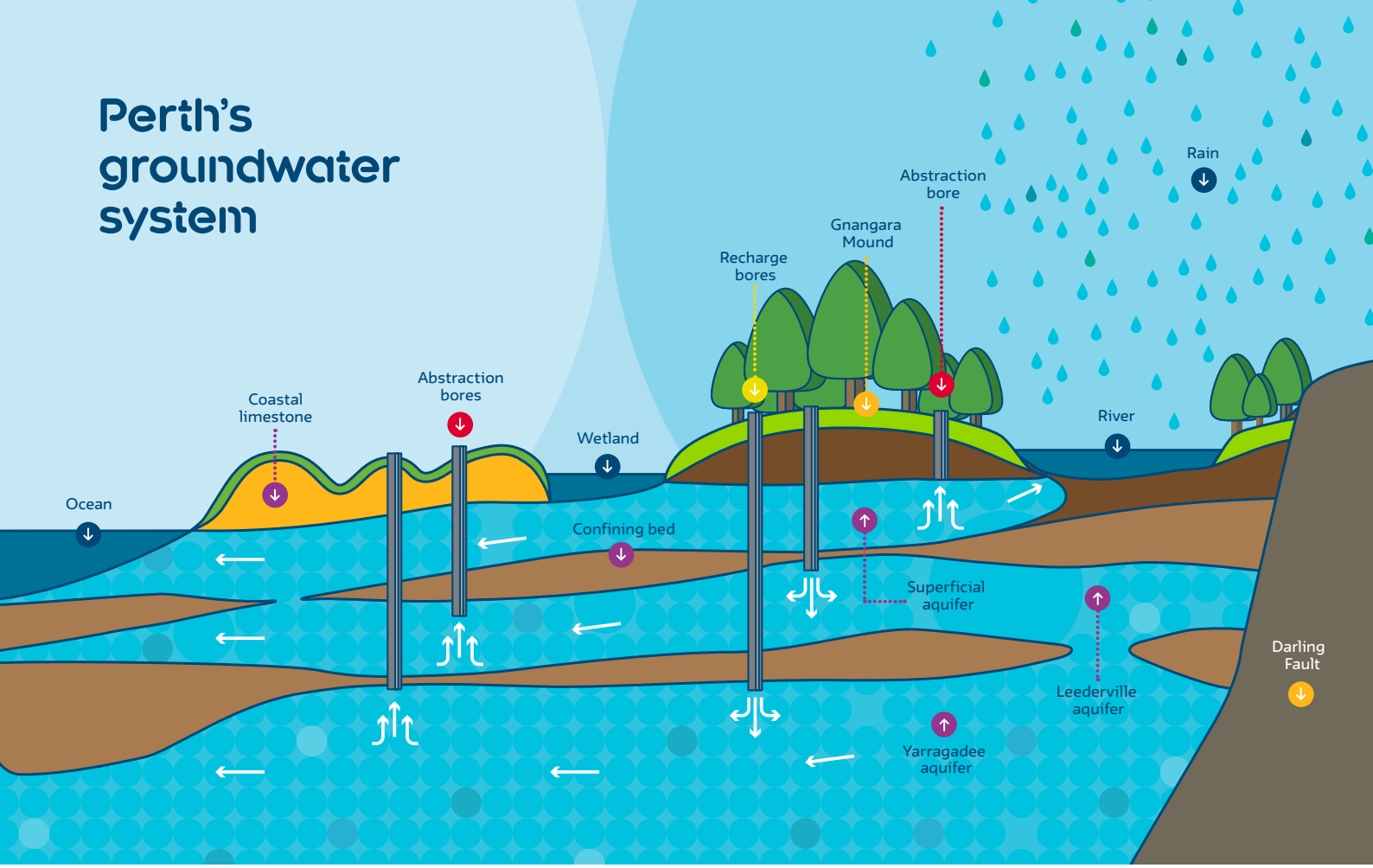
You can do your bit too, by reducing your water use. Together, we can expand our fresh water thinking.

By **2060** groundwater replenishment could make up to **20%** of Perth's yearly drinking water supply

Our water cycle



Perth's groundwater system



Perth's groundwater system

Perth has a vast groundwater system. It currently provides about 40% of the drinking water supply for about 2 million people.

Groundwater is mostly rain that has trickled down from the surface through rocks and soils into aquifers.

Our aquifers aren't the underground rivers and lakes you might imagine. They're actually made up of sand, sandstone and limestone, which allow water to move between the particles.

Perth's aquifers

Superficial aquifer

- Is located close to the surface
- Often appear as wetlands or lakes
- Is the main groundwater source for home garden bores, and bores used for schools, parks and playing fields
- Includes the Gnangara Mound

Leederville aquifer

- Sits below the Superficial aquifer
- Is generally separated by dense layers of materials, such as clay and shale, that minimise water movement between aquifers
- Connects with the surface in some areas

Yarragadee aquifer

- Is generally separated from the upper aquifers by dense layers of materials, such as clay and shale, that minimise water movement between aquifers
- Provides a stable supply of water, even in dry years, because of its vast storage capacity
- Has limited connection to the surface environment
- Extends from Geraldton in the north to Albany in the south

Australia's first full-scale Groundwater Replenishment Scheme is located in Perth's northern suburbs, in Craigie, Western Australia.

The water we recharge through the scheme gives us the opportunity to take out equivalent groundwater, adding to Perth's drinking water supply.

The scheme has the capacity to recycle around 28 billion litres of water per year. That's enough to supply up to 100,000 households.

Benefits of groundwater replenishment

- Doesn't rely on rainfall
- Sustainable water source
- Has the potential to recycle large volumes of water naturally
- Enables equivalent groundwater to be taken out while reducing impacts to the environment or other water users

Using recycled water to replenish groundwater has been successful in other parts of the world such as Orange County California, USA, since the 1970s.

Water recycling schemes are also used to supplement drinking water supplies in Singapore and in Windhoek, Namibia.

28
billion litres each year

That's enough to supply up to
100,000
households

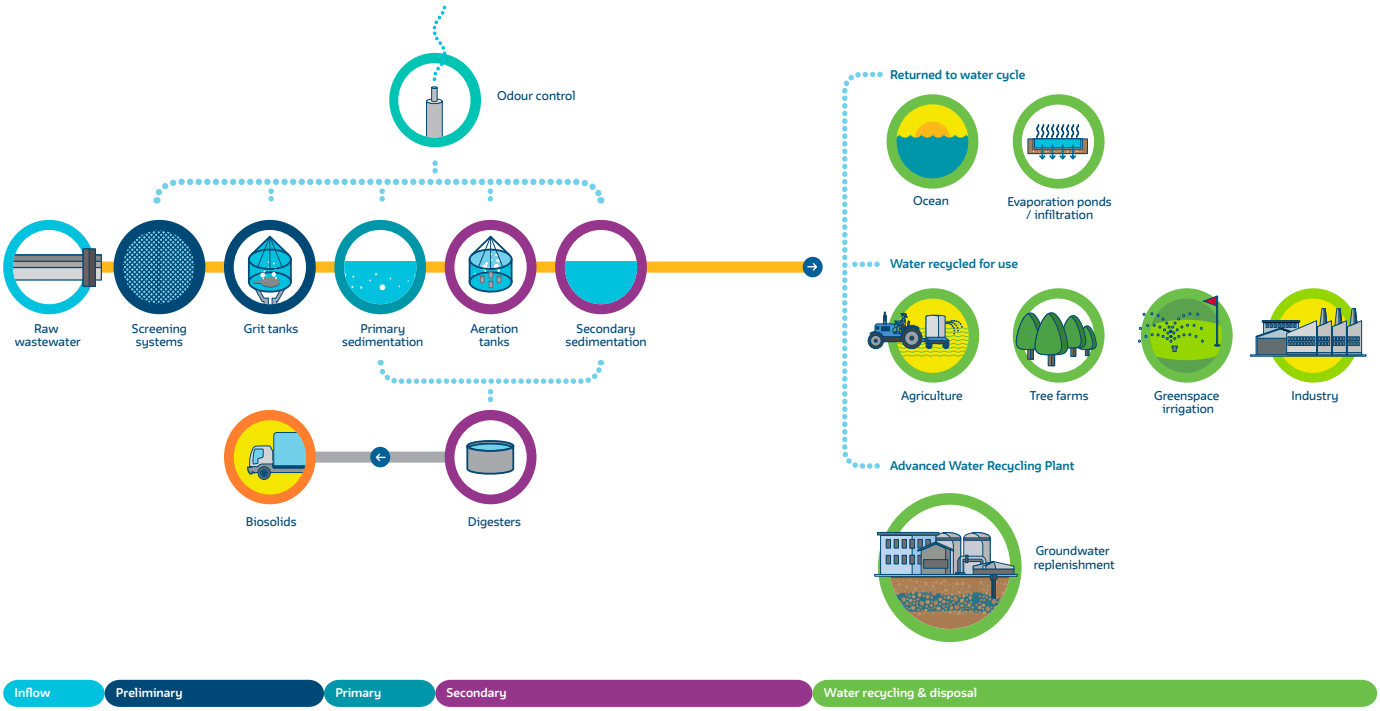
Wastewater: how is it treated?

Wastewater from the community (households, businesses, industry) flows by gravity or is pumped through a network of pipes until it reaches a wastewater treatment plant.

The five main Perth wastewater treatment plants are Beenyup (located in Craigie), Subiaco, Woodman Point, Alkimos and East Rockingham.

Wastewater is 99.97% water.
It mostly comes from household uses such as showers, baths and washing machines.

Wastewater treatment process



The collection, treatment and disposal of wastewater are integral parts of the water cycle.

- Recycled water can be used for industry, greenspace irrigation, agriculture and tree farms.
- The bi-product of this process can be made into biosolids for certain horticultural and agricultural uses.
- Groundwater replenishment and other water recycling schemes will reduce the amount of treated wastewater released to the environment.

Our goal is to recycle

30%

of wastewater by 2030

And

60%

by 2060

How is water treated for groundwater replenishment?

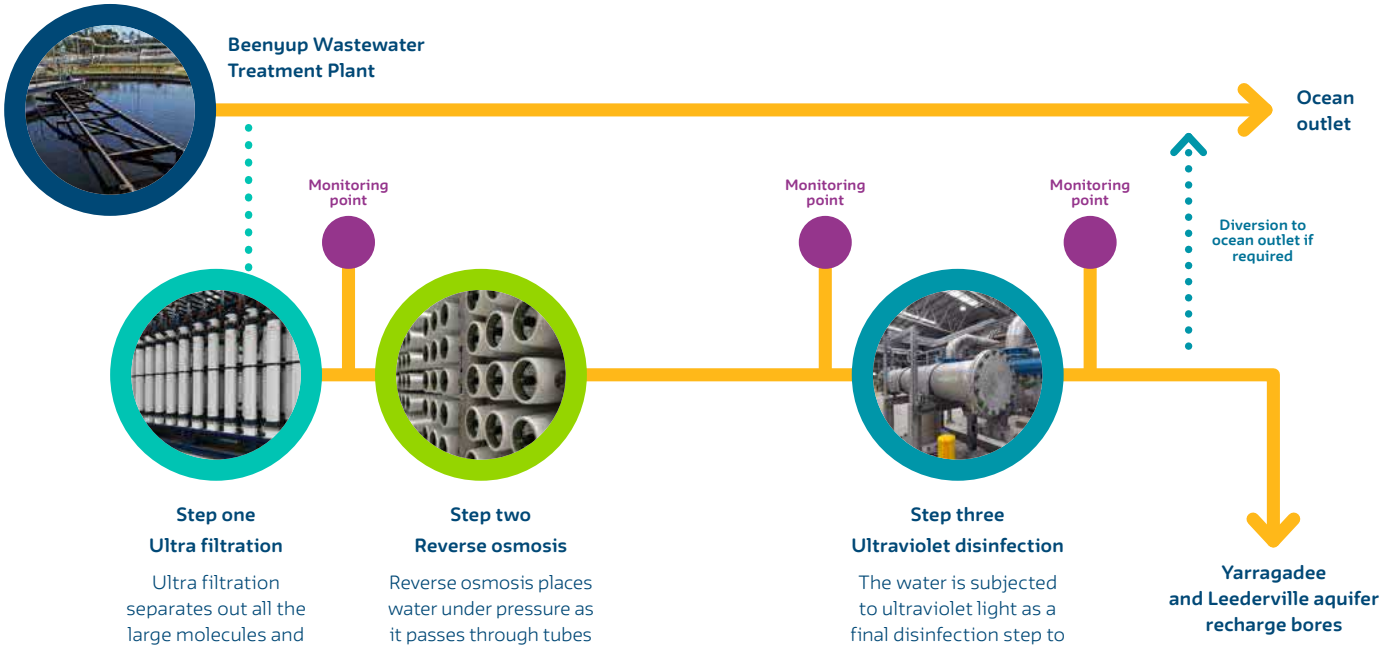
Before entering the Advanced Water Recycling Plant, the wastewater has already undergone rigorous treatment at a wastewater treatment plant, including the removal of most chemicals and micro-organisms such as bacteria, nutrients, detergents and heavy metals.

It then undergoes further treatment to remove any trace levels of micro-organisms and chemicals so that it meets drinking water standards.

Throughout the treatment process, the water is continuously monitored to ensure strict water quality guidelines are met.

After this process, the recycled water is now of drinking water quality. It's then recharged into an aquifer where it mixes with the existing groundwater. This recharge amount is less than 0.1% of their total storage, so it's only a drop in the aquifer. Over time, we won't be able to tell the difference between the recycled water and existing groundwater.

Advanced water treatment process



The success of the Groundwater Replenishment Trial, which ran from 2010–12, proved it can safely be used to boost our drinking water supplies.

During the trial, treated wastewater from the Beenyup Wastewater Treatment Plant in Craigie was transferred to the nearby Advanced Water Recycling Plant to undergo further treatment. The recycled water was recharged into the Leederville aquifer to depths of between 120 to 220 metres.

It was the first trial of its kind to be conducted in Australia, on this scale.

We have the systems, processes and regulations to ensure groundwater replenishment does not put public health or the environment at risk.

The systems include water quality checkpoints to ensure each stage of the plant works at optimum levels.

- If the water is not treated to a safe level when it reaches a checkpoint, the treatment process shuts down and water is diverted to the ocean outlet.
- Groundwater monitoring tells us if there are any changes to the groundwater environment.
- The Department of Health has set very strict water quality guidelines that the recycled water must meet at the point of recharge and in the aquifers.
- Information about these water quality guidelines can be found on our website.
- Independent laboratories test water quality samples to ensure they meet the guidelines.
- The recycled water must meet drinking water standards before it's added to groundwater, giving the highest level of protection for our water supplies and the environment.

Key facts and figures

1. The Groundwater Replenishment Trial ran for three years, from 2010 to 2012.
2. The trial plant continued to operate until September 2014. From the start of the trial until closure in 2014, the plant recharged nearly four billion litres of recycled water into groundwater supplies.
3. More than 11,000 community members toured the trial's Advanced Water Recycling Plant and Visitor Centre.
4. During the trial plant's operation from 2010 to 2014, more than 85,000 water quality samples were taken.
5. All of these samples met the stringent guidelines set by the regulators.
6. Water from the full-scale scheme will be recharged via both onsite and offsite recharge bores. This comprises both Leederville and Yarragadee bores, with the Leederville bores about 300 metres deep and the Yarragadee bores about one kilometre deep.
7. The Groundwater Replenishment Scheme will have the capacity to recharge some 28 billion litres of water into groundwater supplies each year.
8. By 2060, we could recycle 115 billion litres of water each year through groundwater replenishment from Perth's main wastewater treatment plants. If not recycled, this water would otherwise go out to the ocean.

Glossary

Abstraction bore

A bore used to pump groundwater from the aquifers to the earth's surface.

Aquifer

Soil, sand and rocks that are able to store and transmit useable quantities of groundwater.

Coastal limestone

Extends along the coastal strip of Perth made up of quartz sand, fine to medium grained shell fragments and clay.

Confining bed

A layer of rock, or sediments, that restricts the movement of water in and out of an aquifer.

Darling Fault

A fracture in the earth's surface running in a north–south direction that forms the eastern edge of Perth's largest source of groundwater, the Gnangara groundwater system.

Gnangara Mound

The common name for the Superficial aquifer in a large mound of sandy soil located north of Perth.

Groundwater

Water that is found below the earth's surface and is stored in the cracks and spaces in soil, sand and porous rocks.

Recharge bore

A bore used to pump recycled water into the aquifers below the earth's surface.

Surface water

Water that is collecting either on the ground, in a stream, river, lake, wetland, dam or ocean.

Wastewater

Water that has been used inside a home, business or industry that travels to a wastewater treatment plant.

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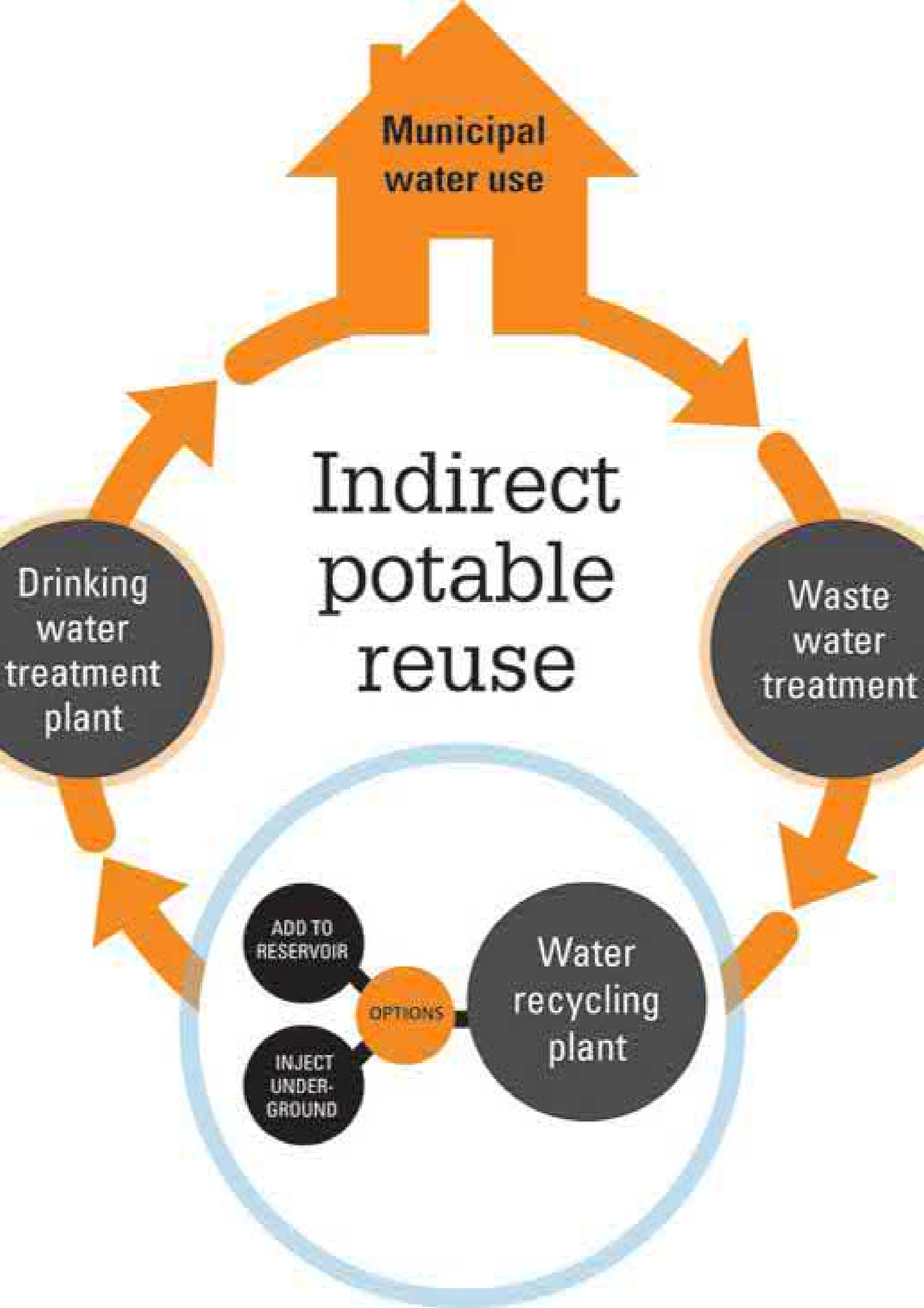
Municipal water use
Indirect potable reuse
Drinking water treatment plant
Waste water treatment
ADD TO RESERVOIR
OPTIONS
INJECT UNDER-GROUND
Water recycling plant

Christchurch City Council Akaroa Treated Wastewater Options Consultation (2020)

Submission of

FRIENDS of Banks Peninsula

WE WISH TO BE HEARD

IN SUPPORT OF OUR SUBMISSION

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Submission version V6-3 August 23, 2020

Executive Summary

Short form Submission

Full Submission

Bibliography

Endorsements

Tektus Consulting Engineers Memo

Harrisons Quantity Surveyors Letter

Executive Summary

Akaroa's wastewater network is being replaced at a time when the challenges of climate change are increasingly clear. Potable water supplies and storm and wastewater systems will be particularly at-risk in future. This will exacerbate Akaroa's current issues of chronic water shortages, and an old and leaking wastewater network that suffers from extreme infiltration and inflow of storm water.

Te Wai Ora o Tāne, the Council's Integrated Water Strategy recognizes these issues, but the wastewater disposal options proposed in this current round of consultation do not address them; rather, despite their very high cost, they leave the system even more vulnerable to climate change impacts.

Friends of Banks Peninsula therefore does not support any of the proposed options, and instead puts forward an integrated approach to reduce, reuse and recycle the treated wastewater in Akaroa, where water is most needed. We ask Council to reject their current proposals and instead adopt this approach to build sustainability and future resilience to climate change in this community.

A new wastewater system requires a very substantial investment of funds and must be safe, efficient and sustainable well into the future. It must be as risk free as possible because the need for **sewage treatment cannot be 'switched off' if a system fails.**

The sudden and on-going shock of the COVID-19 pandemic has further highlighted the need for resilience and fiscal prudence, but the costs of the Akaroa wastewater system have escalated substantially since it was last presented to the community. **The options are similar to those proposed in 2017 but their costs have increased by between 116% - 245%.** The volume of water is more than double that previously thought and it is now established that **over 60% of the wastewater flows are storm and ground water caused by extreme levels of infiltration** into Akaroa's broken and leaking sewer network. This peaks during times of heavy rain or prolonged wet weather when land-based options are unable to irrigate, driving the need for huge and expensive storage ponds. A raw sewage pond to smooth out these large peaks is also now required for **all** options, opposite the Treatment Plant near the town entrance.

It is a misuse of public funds for the Council to construct a costly new wastewater disposal system without fully fixing the pipes first. Failing to do so results in a system that is much bigger, more expensive and with greater negative impacts than necessary, while at the same time lacking capacity for future expansion. Having high levels of infiltration (especially in wet weather) has not been a major issue for the Council to date because the current discharge to the sea is not limited by volume. Moving to a land-based volume limited system without dealing with unlimited inflow is a recipe for disaster when we face increasingly intense storms and sea level rise. Future generations will be saddled with debt and a sub-standard wastewater and water system.

All the land-based options have high risks and constraints, are untested and their positive outcomes are overstated. Of these, the Inner Bays scheme is the worst. It has an unacceptable impact on existing communities, is the most land-constrained and has the highest potential for environmental impacts. Goughs Bay and Pompeys Pillar involve pumping over a high hill and have unwilling landowners. Harbour Outfall, as proposed by the Council, does not incorporate sufficient mitigation measures to meet the cultural needs of mana whenua. We consider all options to be unsustainable management to differing degrees, and have not chosen between harbour and land-based disposal, nor have we ranked the land-based options.

New Zealand's legislative framework is changing rapidly to put a focus on future resilience as the impacts of climate change become better understood. Hence, the Council needs to set aside yesterday's thinking and adopt an integrated long-term solution that provides resilience for future generations.

We present a "Reduce, Reuse and Recycle" integrated approach to guide the Council on this course.

Short-form submission

We present a summary of our arguments in this Short-form submission. Our Full submission follows and provides detailed information and professional advice in support of these arguments.

Christchurch City Council has a difficult problem that it needs to address - the disposal of Akaroa's wastewater. It has been searching for a solution since 2007 and this is the fifth time it has consulted on the issue.

Friends of Banks Peninsula is Akaroa's community environment society. It has been closely involved with the Akaroa wastewater issue since 2007. In its submission to the Council's wastewater consultation in 2017 the Society advocated a staged approach toward reusing the wastewater in Akaroa to address its chronic water shortages. **Reuse gained the most public support of all the options in the 2017 consultation**.

However, this consultation had to be abandoned because the solutions proposed were based on faulty flow meter data and were therefore significantly undersized.

In the three years since, while the search for alternative solutions has been underway, the need for re-use in Akaroa has become even more apparent. Last summer (2019/20) a total outdoor watering ban was abruptly introduced after stream levels dropped precipitously[1.] The public and government agencies are much more aware that climate change will increase the frequency and intensity of storms and droughts, as the impacts begin to be felt around the country. Scientific research has revised predictions for the worse. Akaroa is identified as a settlement that is likely to be water stressed in the future[2]. The Resource Management Act has been amended to require particular regard to the effects of climate change, the Council has developed its Integrated Water Strategy, the Canterbury Air Regional Plan is operative, and the government has announced Three Waters reform and funding.

The land based options now being proposed are substantially the same as those on offer three years ago, but with the added problem that there is now *more than double* the volume of wastewater to deal with, due to the massive levels of infiltration through leaking pipes – 61% in an average year, rising to 68% in the wettest years is due to stormwater inflow and groundwater infiltration. The cost of all options has risen dramatically because they have to deal with this extra water.

We share the disappointment expressed by the Akaroa Treated Wastewater Reuse Options Working Party Joint Statement, especially in relation to climate change and scarcity of water. Genuine reuse in Akaroa, where the water is most needed, is once again pushed down the list of priorities. Plans to fix the sewer pipes are conservative and substantially fail to deal with the problem.

The three land-based disposal systems presented are all flawed, and none more so than the Inner Bays Scheme favoured by the Council staff. While the Harbour Outfall solution is an improvement over the previous one as it now includes the core infrastructure for beneficial re-use, it still fails to address the cultural requirements and still disposes of the bulk of the water

Hence Friends of Banks Peninsula is once again asking the Council to design an integrated solution that facilitates re-use of the water in Akaroa, eventually recycling it back to the potable supply. In coming to this view we have kept abreast of developments via the Akaroa Wastewater Working Party, reviewed the technical documents, taken professional legal, engineering and quantity survey advice, and conducted community meetings. Our submission concludes with a suggested Reduce, Reuse, Recycle solution path that reflects the wishes of community, and would be affordable and consentable.

[1] https://newsline.ccc.govt.nz/news/story/council-closely-watching-water-levels-in-banks-peninsula

[2] CCC Infrastructure Strategy 2018-2048 pp52,100

Consideration of issues common to the Land-based options in the consultation document

We find that all of the land based options presented by the Council are flawed.

- **All the irrigation options proposed are disposal options**, aimed at getting rid of the water. Native trees have been selected to absorb the water, rather than pasture based options, because they enable winter irrigation and therefore reduce storage requirements. Nevertheless, they all require major earthworks and construction of large storage ponds to facilitate the disposal of the water on the *minimum* feasible areas of land. They are portrayed as biodiversity and climate friendly options, but a genuine biodiversity and carbon sequestration goal would seek to **maximise the area of native trees** and minimise destructive and carbon emitting construction. The area would be as large as possible, rather than minimum feasible as in this case.
- **Disposal of wastewater to intensively planted native trees would be a first for New Zealand.** The land and storage requirements are based on theoretical modelling that is highly sensitive to assumptions, particularly around the ability to irrigate throughout the winter. Assumptions used to determine the area of land for disposal and size of storage include:
    - soil absorption rate,
    - canopy intercept rate,
    - the ability to irrigate during wet weather (up to the point where 50mm has fallen in a single day) without exacerbating the risk of slips or harming the trees,
    - nitrogen uptake by trees, and,
    - weather patterns based on historical data rather than future predictions.
- **Should any of these assumptions prove incorrect then the storage and land irrigation areas will be too small** – resulting in the need for system expansion or release of wastewater to streams along with nutrients and other potential contaminants. The anticipated level of nutrient leaching for the Inner Bays option could be as high as that of a dairy farm.
- **Population growth parameters are minimal.** Disposal capacity does not allow for both modest growth in Akaroa and any future sewerage reticulation for Takamatua.
- **The water is directed away from where it is most needed - the Akaroa catchment** from which it emanates. Re-use of the wastewater in Akaroa would be a major step toward resolving Akaroa's water shortages.
- **Water would leave the treatment site without testing for compliance** because no outflow buffer is incorporated into the system. This leaves storage ponds and the irrigation fields at risk of receiving contaminated water.
- **Scarce, high value agricultural land would be taken out of production.**

Consideration of issues specific to each of the individual Land-based options

Inner Bays option

The Inner Bays option would require consent as a non-complying activity, due to its reliance on some level of discharge to a water body. **It carries the highest economic, social and environmental risks due to the complexity of the system proposed compounded by the proximity to populated areas and downstream infrastructure.**

The Inner Bays solution is not practical because it:

- Relies on the Council managing to purchase several private properties – one of which is potentially earmarked for another public purpose.

- Critically relies on achieving at least a 20% reduction of inflow and infiltration (I&I) up-front, without making this a budget priority (the budget is capped).
- Relies the most heavily on modelling assumptions around the wetland function, tree canopy intercept rates, storm frequencies and nitrogen uptake. There is little scope for error because the expansion capacity is very limited and the catchments drain to shallow inner harbour mudflats. Further private properties will need to be purchased if the system is undersized.
- Has high social impact because wastewater infrastructure of large storage ponds and irrigation is in close proximity to communities and residences. This exposes many people to risks such as odour, midges, loss of amenity, dam failure, disruption during construction and loss of property value.
- Uses a significant archaeological site in a historically sensitive area as its principal area for storage and disposal.
- Creates the greatest cumulative impacts on the Inner Harbour communities, and adds more sites to the already large inner harbour footprint of the new Akaroa Wastewater Treatment plant and terminal pump station. The new proposed Duvauchelle scheme will further add to this.

Goughs Bay option

Goughs Bay would be a discretionary consent and would require pumping the wastewater over the crater rim to an outer headland area.

The Goughs Bay scheme is somewhat more practical than the Inner Bays, but carries different risks:

- A longer pipe run is required and the water would be pumped over a 600m hill, exacerbating risk of pump failure, and this must be installed along narrow rural roads affecting local residents during construction.
- The system has raised environmental concerns from local residents committed to the Wildside concept of the area as a natural biodiversity hub who do not support the introduction of planted forest.
- The landowner who was at one stage a willing participant has become alienated by the process and withdrawn his support.
- The neighbouring farm owner also has concerns about impacts on his antibiotic-free status being compromised by any leachate from the irrigation area close to his boundary.
- The ability to successfully establish irrigated native trees is unknown, given the altitude and exposed nature of the site.

However, the scheme does also have some merits:

- Unlike the Inner Bays proposal, the scheme would be barely visible and is much further from any houses and streams.
- It has room for expansion should it turn out to be undersized. Based on the land purchase costs, we presume the Council plans to purchase and retain the bulk of the farm for future expansion
- Pumping to the crater rim opens the potential to include high-level fire ponds, which would be of general benefit to Akaroa and to the rural environment and biodiversity.

Pompeys Pillar option

Pompeys Pillar would also be a discretionary consent and would require pumping the wastewater over the crater rim to an outer headland area. While it is similar to the Goughs Bay option in these respects, it is less practical and acceptable because:

- The ability to successfully establish irrigated native trees is unknown, but likely to be even more difficult given the exposed nature of this coastal headland.

- The proposal to exclude the Outstanding Natural Landscape zone creates an unnatural visual effect on the headland.
- **The land has been farmed by the same family for over 7 generations and is currently in transition to the next generation. The land identified for wastewater is the heart of the farm and it is financially critical to the success of the farm. To remove it would impose a severe social injustice upon the family and their longstanding intergenerational relationship with their land.**

Consideration of issues specific to the Harbour Outfall option

Harbour Outfall as proposed by Council would be a non-complying option because it involves a direct discharge to Akaroa Harbour without first making land contact, and would only be consentable in this form if there are no other acceptable alternatives. **Friends of Banks Peninsula does not support this option in its current form because there will still be residual disposal, and the continued use of a harbour outfall as proposed does not incorporate mitigation measures to meet Ngāi Tahu's cultural needs.**

However, it is otherwise a practical option and from an environment, economic and social perspective has the least impacts of the options proposed:

- It presents the lowest risk because it uses proven technology and is the simplest to operate. It provides the greatest degree of certainty and resilience as it is not inherently limited in the volume of water it can process, and is entirely gravity fed. It will require the least energy and has the lowest operating cost.
- The disposal of the treated wastewater to the centre of the harbour would mean its rapid dispersal. The outfall would be much further away from the shore than the current one, negating impacts of nitrogen or nutrient build up.
- There is no need to acquire private land, no large treated wastewater storage ponds required, no risks from irrigation failure and no visual effects. The enhanced level of treatment minimises any environmental and health impacts.
- The Harbour Outfall is the cheapest of the options both to construct and to operate.
- In terms of sustainability, while the outfall itself is a disposal option, the option directs the water through Akaroa where it is most needed, rather than constructing infrastructure elsewhere. The pipe would be run through the town, **providing the core infrastructure for a purple pipe re-use system in Akaroa**, and meaning this option can be easily expanded in future to include non-potable re-use. **This is markedly different from the scheme for which consent was declined in 2015** and is now based on the Friends of Banks Peninsula submission to the 2017 consultation.
- The first stage of purple pipe re-use can come on stream at the low extra cost of $270,000 (as opposed to $3.7 million for the land based options).
- The addition of a purple pipe system means the water will be treated to higher standard than that proposed for the land based options and provides reassurance that water will meet the consented standard. The water will receive additional UV treatment and an outflow buffer pond is included at the treatment site enabling it to be tested before it is released.

If the Council decides to adopt a harbour outfall, we urge it to work with Ngāi Tahu to explore whether a constructed sub-surface wetland or some other form of land-contact could mitigate cultural concerns for the entire wastewater flow. **The long process of looking at alternatives has now suggested that there are ways to incorporate a treatment process that restores mauri prior to discharge to a water body**. A wetland with 2-3 days of contact is already incorporated into the Inner Bays option and supported by the Ngai Tahu parties, and is essential to the feasibility of the Inner Bays option. A wetland discharging every winter is now also proposed for the Duvauchelle scheme.[3] If wetlands are considered able to restore mauri of the water in this way, then serious consideration should be given to making use of them to treat all

[3] Beca Report July 2020 Appendix D, p2

flows, particularly where this facilitates reuse, or in conjunction with a staged solution. Our legal advice is that an option involving some form of harbour outfall or discharge is potentially consentable provided sufficient mitigation measures are incorporated into the design.

Consideration of Costs

Cost is an important factor when considering the practicality of the options.

In our view the **consultation document has been disingenuous in its presentation of the option costs**. The options proposed are for the disposal of the treated wastewater, but the costs presented include the construction of the new Wastewater Treatment Plant, terminal pump station and pipe network that have already been consented. These are a constant across the options and account for approximately $30 million of the total cost of each. Operating costs of the treatment plant and the disposal options have also been bundled together. Taking out these common costs, the relative differences between the proposed disposal options are:

Table 1 Costs of the disposal component of each option

Option	Capital cost	Operating cost p.a.
Harbour outfall	$18 million	$0
Inner Bays	$27 million	$40,000
Goughs Bay	$35 million	$177,000
Pompeys Pillar	$40 million	$177,000

- **We are concerned about the validity of these costs after a re-costing exercise was carried out by the Council in March 2020.** The result was the cost of the consented Treatment Plant and ancillary works increased by $6 million, the **cost of the Inner Bays disposal reduced by $10 million** and the **cost of the Harbour Outfall increased by $8 million**. These are substantial differences compared to the most recent figures produced by Beca and result from large changes to overheads and contingencies, markedly increased costs of pipelines, reduction in planting costs and various other additions and omissions.
- **We strongly urge these costs are independently reviewed by a Quantity Surveyor**, before the Council makes any decision. Quantity Surveyor Stewart Harrison, who has been supplied with the costing details, and asked to provide comment for this submission is of the view that: ***"On first review, it appears Council are simply attempting to increase costs for their least preferred option, the harbour outfall, whilst reducing costs for their preferred option, the Inner Bays."***[4]
- Notwithstanding these concerns, based on these costings, all the options come at an extremely high cost per connection. Akaroa has around 830 connections and the total cost is $57,000 - $68,000 per connection.
- A new wastewater system must be safe, efficient and serve the community well into the future. In considering practicality and weighing costs the Council must consider the ongoing operational costs and the risk of future costs if the system does not perform as designed, or if greater capacity is needed. **Council should also take into account the additional funds that will still be needed to improve Akaroa's water supply and to fix the sewer pipe network.**
- On the basis of the costs presented it is clear that the land-based options presented are all significantly more expensive than the Harbour Outfall option. This represents a significant sunk cost toward directing water away from Akaroa rather than facilitating re-use.

[4] Harrison Quantity Surveyors 2020

Summary of our views on the options presented

FOBP does not support the options as currently presented, but make the following observations should the Council take the view that it *must* select one of these options:

- **Harbour Outfall** should be modified with some form of land contact to restore mauri to water, such as a constructed sub-surface wetland. Given the large cost difference between this and the land-based options, it would still be the lowest-cost option with the least environmental and social impacts. The costs (particularly contingency and design overheads) should be reviewed as there may be considerable further savings.
- **Goughs Bay** should be reworked in collaboration with the landowner, neighbouring community and Wildside stakeholders to find an acceptable solution that maximises benefit and minimises disruption during construction. An acceptable solution could be either pasture-based, in a manner that is beneficial to the previously-willing landowner (such as CCC accepting they must carry some of the risk associated with regulation compliance and marketing of products from stock grazed on wastewater), or, preferably, a genuine reforestation project that maximises environmental benefits while minimising impacts on the operation of the farm. While Goughs Bay is a higher cost option it does contain space for expansion on the farm, and the opportunity to construct high-altitude fire ponds would bring general community benefits as Banks Peninsula faces a drier future with an elevated fire risk.
- **Pompeys Pillar** would only be acceptable if it could be designed in a way that was acceptable to the farm owners and their neighbours, and therefore avoided the need for compulsory purchase. Otherwise, it is a totally unacceptable option because of the social injustice to the owners.
- **Inner Bays is totally unacceptable** because it has a huge footprint within communities and across valuable inner harbour land, involves placing wastewater infrastructure close to many homes with significant ongoing impacts, has no room for expansion without even further incursion on these communities. It puts the shallow coastal bays of the inner harbour at risk of environmental degradation. We oppose this option.

However, in our view none of the options provide sustainable and integrated management. It would be a misuse of scarce Council funds to spend many millions of dollars building a wastewater system that is extremely expensive per connection, but leaves Akaroa with its sewer network of broken pipes, increasingly vulnerable to climate change effects, raw sewage overflows, and with worsening water shortages.

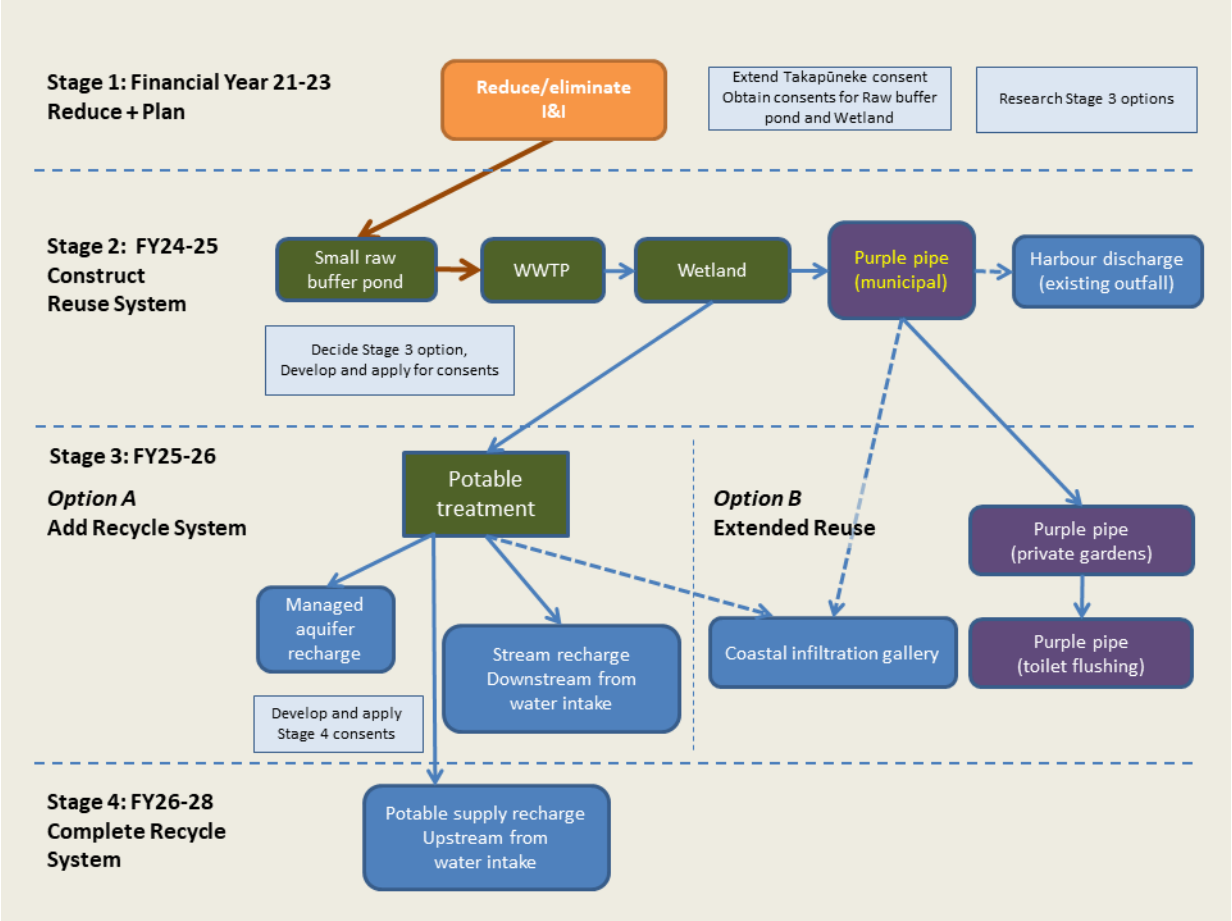
We strongly urge the Council to stop and rethink its path forward. It needs to set aside the current options and instead adopt a new integrated solution, focussed on reducing the wastewater volume, re-using treated wastewater where it is needed and wanted and recycling pure water back to the Akaroa catchment. We believe a solution can be found that is acceptable to the whole community, addresses Akaroa's issues and creates resilience for future generations.

Our proposed Integrated Akaroa Wastewater solution: Reduce, Reuse and Recycle

In September 2019 the Council adopted Te Wai Ora o Tāne, its Integrated Water Strategy. This recognises that water is a taonga, fundamental to the life of our communities. It is an overarching strategy that sets a vision and framework to manage water resources in an integrated way over the next 100 years. It sets goals and objectives for infrastructure efficiency and resilience through integrated three waters (water supply, wastewater and surface water) management and a proactive risk-based approach. This includes ensuring the sustainability of water supplies and wastewater systems, understanding and adapting to climate change and sea-level rise and reducing wastewater overflows and infiltration.

We suggest that the Council now develops a staged solution for the Akaroa wastewater problem implementing the goals of Te Wai Ora o Tāne. We see it being implemented as follows:

Figure 1 Integrated Akaroa Wastewater concept based on a Reduce, Reuse and Recycle philosophy



We envisage the integrated solution being introduced in 4 stages, completing in 2028. This matches the timeframe for the Council's proposed land-based options which require the Takapūneke outfall to continue until 2028 so as to allow the native tree areas to establish sufficiently prior to full irrigation.

Stage 1. Council invests in maximum reduction of stormwater inflow and groundwater infiltration (I&I). Consents are obtained for the additional new components of the wastewater system and to retain the Takapūneke plant and existing harbour outfall until Stage 3. Research is done on Stage 3 options.

Stage 2. The new WWTP (wastewater treatment plant) is constructed at Old Coach Road along with a much smaller raw buffer pond, larger wetland and purple pipe system along Akaroa's main street. The old Takapūneke plant closes at this stage. The disposal still connects through to the existing harbour discharge pipe as an interim solution to disposing of unused water. The wetland assists to restore the mauri of the water. **No additional sunk cost is invested in a new harbour outfall.** A decision is made on which Stage 3 option to pursue and appropriate consents are obtained.

Stage 3. **Harbour outfall ceases** either through the development of recycling or extended re-use.

Option A –Under our preferred option, the treatment process is upgraded to produce potable water. This opens opportunities for safe managed aquifer recharge (MAR) stream recharge (below the water take) or disposal of potable water to the harbour via coastal infiltration.

Option B – If potable recycling is not selected, then the purple pipe network is extended throughout more of Akaroa, and harbour discharge is replaced by coastal infiltration.

Stage 4. If Option A has been selected, then once NZ government standards permit, the potable water is recycled back to the drinking supply via stream discharge above the intake.

We give more detail on our proposed solution in Chapter 12 of our full submission.

Conclusion

Council could elect to borrow to invest in one of the consultation options, leaving the issues of leaking pipes, climate resilience and water shortages unresolved and a high level of debt for future repayment.

Alternatively the Council can move on from yesterday's thinking and follow Te Wai Ora o Tāne, its own Integrated Water Strategy, by designing and investing in a Three Waters solution built for the future and in conjunction with new government initiatives.

We urge the Council to take the latter course and develop a genuine beneficial re-use and water recycling system through treatment to a potable standard so that the water becomes an asset for the benefit of the whole community and the environment. The time to make that decision is now when major capital investment is planned for the Akaroa wastewater system.

Long-form submission

The remainder of this document presents the full submission of Friends of Banks Peninsula and provides supporting evidence for the Executive Summary and Short-form submission. Advice from our technical experts is referenced and given in full in the appendices.

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Chapter 1 Introduction

The Friends of Banks Peninsula Inc. (FOBP) has been Akaroa's Community Environment Society since 1990. It works to protect and enhance the environmental heritage of Banks Peninsula. Our involvement with the Akaroa wastewater issue goes back more than 20 years and we have been closely monitoring and following developments since the previous consultation in 2017 and regularly meeting with our community. Our submission is based on a thorough understanding of the options and how the Council has progressed these over the years, what the community wants its wastewater system to deliver and the legislative framework.

We are part of a community with a strong conservation ethic and desire to respect culture and heritage.

This submission first sets out:

- the background of the work to date on the Akaroa wastewater;
- the elements, constraints and impacts of the new wastewater treatment plant that will be common to all the options; and,
- the elements in common across all the land options.

It then presents:

- detailed consideration of each of the options proposed,
- comparison of the costs; and,
- comparison of the carbon and climate impacts.

This is followed by a summary of our view of each of the options taking into account the four well-beings of the Local Government Act, and the circumstances under which the harbour outfall would be appropriate and consentable.

We then consider whether the options meet the criteria of sustainable management, and as we find this wanting, we outline our preferred solution –a future focussed vision aimed at solving the problems with all three of Akaroa's waters and creating a holistic and more resilient future that is not envisioned by any of the options currently proposed.

1.1 Background

The first Akaroa Waste Water Working Party was convened in 2007 and was tasked with the issues of finding a new location that would remove the treatment plant from the culturally sensitive site at Takapuneke where it has been since the 1960s, ending discharge to the harbour and avoiding wastewater infrastructure south of Akaroa near the Ōnuku marae settlement. It concluded that, while there was potential to locate the wastewater treatment plant at northern end of Akaroa, it would be more pragmatic and much cheaper to move it slightly further south. It also concluded that it was not possible to avoid a harbour discharge altogether, because irrigation to land was not feasible in winter.

This work fed into the first Council consultation exercise in 2010. In 2014 the council developed a resource consent application to relocate the treatment plant to the north end of Akaroa, despite the additional expense, but to dispose of the treated water to the harbour as land options were not considered feasible. Consent was granted for the treatment plant to be situated at the top of Old Coach Road and for a primary filtration and pumping station (needed to push the wastewater up the hill) in the town itself, on reclaimed land behind the Akaroa recreation ground. However, the harbour outfall was declined on the grounds that it would have a significant adverse effect on the

environment from the perspective of tangata whenua and that the Council had not adequately considered alternatives.

In 2016 the Council consulted again with disposal options based on the Takamatua headland opposite the new treatment site and some additional sites in Takamatua valley. This consultation exercise was terminated after submitters' concerns that the Takamatua headland was not geotechnically suitable for irrigation to trees were substantiated. The other options involving some form of land treatment in combination with coastal discharges were also discounted as they were generally unpopular with the public and thought not to meet the cultural concerns.

Later in 2016 Council announced new proposals to irrigate wastewater in flat settled areas of Takamatua and Robinsons Bay valleys, and including large storage ponds to hold the winter surplus. At this point residents turned to Friends of Banks Peninsula for assistance feeling that any solution needed to be driven by an environmentally based organisation. Friends of Banks Peninsula worked with these residents to produce the *"Community Strategy toward an Acceptable solution to the disposal of Akaroa Wastewater"* and presented it to the Community Board. The Board responded by setting up an Akaroa Wastewater Working Party once again. Friends of Banks Peninsula was not given representation on this Working Party, but has been kept informed by the Robinsons Bay community representatives as matters have progressed.

1.2 Reuse widely supported in 2017 consultation

The next round of consultation in 2017 featured options substantially similar to those presented now. These were not well received by community with a strong voice from Friends of Banks Peninsula (supported by 300 people) and many individual submissions asking for the water to be re-used in Akaroa with the remainder to go out into the harbour initially, but eventually all re-used in Akaroa. Re-use was by far the most popular choice of all the submitters, followed by harbour discharge.[5]

1.3 Incorrect flow readings: Akaroa has an I&I problem

This consultation also terminated – after it was found that the options had been designed based on faulty wastewater volume data and were substantially undersized.

1.3.1 Faulty flow metre detected in 2010

Council had been advised of the faulty flow meter in in 2010 by their consultants Harrison Grierson who noted in a Technical Memorandum attached to their report that *"Based on the recent influent flow data provided by CCC, the daily wastewater flow in Akaroa ranges between 50 and 2500m³/day. It is understood that the flowmeter is faulty and the readings likely to be inaccurate. CCC is working with the flowmeter supplier to re-calibrate the flowmeter. However, for the purposes of this study, it has been decided to disregard the flow measurements and consider typical New Zealand per capita wastewater generation rates".*[6]

The Council has never given an indication that a flow meter fault had been detected in 2010 or whether this fault had been fixed. Instead the design flows used for the 2015 consent application, and the consultation exercises in 2016 and 2017 were based on flow data going back to 1972. It seems likely therefore that, despite being advised on the fault in 2010, it was never dealt with and the Council staff overlooked it.

It is disturbing that this fault was not rectified at the time or picked up by any of the staff or consultants working on the project given the patterns shown by the data were so obviously in error. Indeed, FOBP flagged in their "Community Strategy toward an Acceptable solution to the disposal of Akaroa Wastewater" delivered to the Council in January 2017 that "*infiltration could be as much as*

[5] Beca Report July 2020, p135

[6] Harrison Grierson 2010: Technical memorandum, starts page 57 (67 of 132), bottom of page 2

80% of the water flowing through the system. There is currently much less difference between winter and summer flows than the population alterations in Akaroa alone would cause."

Had this flow meter been fixed in 2010 there would have been many more years of reliable data available now. An enormous amount of work by Beca consultants, and the costs, both monetary and social, associated with a resource consent and two failed consultations based on faulty data could have been avoided.

1.3.2 Infiltration and inflow problem revealed by correct measurement

Wastewater flows measured since the meter was replaced now show that the volume is more than double the amount that the 2016 and 2017 consultation options were based on. The Akaroa wastewater network has a big problem with inflow and infiltration (I&I). Beca estimate that an average of 61% of all wastewater flows are either groundwater infiltration or rainfall-derived stormwater infiltration, rising to 68% in the wettest years.[7]

1.3.3 Akaroa infiltration levels are extreme

To put Akaroa's I&I problem into perspective, groundwater infiltration is considered to be excessive when it exceeds 20% of average *dry weather flows*[8]; in Akaroa the proportion in an average year is 52%. Rainwater incursion is considered excessive if peak wet weather flows are more than eight times the average dry weather flows; in Akaroa the peak rainfall inflows can be as high as 30 times the population-based flows[9].

1.3.4 Design and cost implications of I&I levels

This level of infiltration has enormous implications for the design of the wastewater disposal systems and the overall cost.

- The extraordinarily expensive land disposal systems proposed include storage and irrigation fields that are more than double the size of what would be required to deal with the actual sewage volumes.
- The treatment plant and new wastewater network mains must be larger to deal with the extra volume.
- The treatment plant volume-based running costs (electricity, disposal of sludge/screenings) are doubled.
- The system is highly susceptible to extreme weather events when large volumes of water enter the system through the leaking pipes and can overwhelm the network leading to raw sewage overflows. Also, it is during prolonged wet weather that wastewater can't be irrigated, so all of the extra water needs to be stored, leading to much larger storage dam requirements.
- A raw sewage buffer pond is needed at the plant, because it cannot process the inflow fast enough in these conditions for it to be buffered at the plant.
- Where infiltration occurs, sewage can also leak out and this may account for times when the Akaroa main beach is polluted.
- These problems are set to increase with climate change, with rainfall patterns shifting to storms of increased intensity and sea level rise affecting ground water levels.

[7] Beca Report July 2020, p8
[8] Water New Zealand I&I 2015, p13
[9] Calculated from BECA Report July 2020 Appendix B Model Results, p5: maximum flow / average population flow

- Unless the network is comprehensively repaired then there is a serious risk that any I&I reductions achieved now could be negated in the future

1.4 Developments since 2017

It has become increasingly apparent over the three years since the previous consultation, that the issues facing Akaroa in dealing with its three waters are as much about long term sustainability as cultural issues. However, the options developed have not moved forward in this respect. We attribute this to the pressures of the process to deal with cultural concerns about harbour disposal. The Council and community have been placed in a difficult position by the 2015 decision to approve a Treatment Plant but with nowhere to put the treated water it produces.

Staff effort has focussed on the Inner Bays irrigation option at the expense of wider investigation.

1.5 Long term sustainability issues

1.5.1 Climate change

The public and government agencies have developed a much greater awareness of climate change and an understanding that it will increase the frequency and intensity of both storms and droughts. The impacts are now beginning to be felt around the country as events such as the collapse of the Fox River landfill and chronic water shortages in Auckland and Northland graphically demonstrate. These impacts are predicted to intensify[10], and the Resource Management Act has now been amended to include climate change implications as a key consideration. The latest NZ climate change assessment lists the potable water supply as one of the top ten climate change risks, with a risk level of "extreme"[11]. Climate change projections for Banks Peninsula include reduced mean annual discharge from surface waters and mean annual low flow.

Tektus conclude that "climate change and future resilience is a considerable concern and requires due consideration in all future infrastructure planning", and note that low-lying infrastructure is at risk of inundation by rising sea level and groundwater levels[12].

1.5.2 Water shortages

Akaroa has been identified as a settlement that is likely to be water stressed in the future (Christchurch City Council 30 Year Infrastructure Strategy 2018–2048, page 52, 100) and the abrupt introduction of a total outdoor watering ban in the most recent 2019-20 summer underlines the severity of that threat.

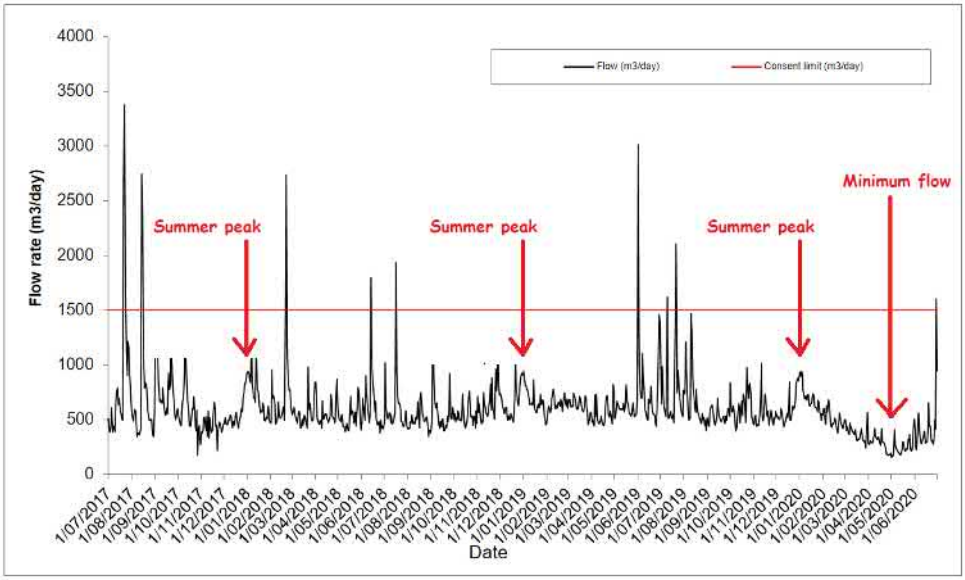
1.5.3 Leaking pipes

The Council has done some initial work to identify why the inflow and infiltration is happening. This has identified that it is a mix of storm water from private properties, leaking manholes and leaking pipes. However, the Council's plan to address these issues is unambitious, with a goal of achieving only a 20% reduction.

The potential benefits for the size of the wastewater treatment system from reducing the I&I were borne out earlier this year. Owing to the particularly dry summer and autumn, flow dropped significantly from January until the beginning of May. The minimum flow fell from around 500m3/day typically to under 160m^3/day, demonstrating the large proportion of flow that is normally groundwater (up to 340m^3/day), and closely matching Beca's modelling of 328m^3/day. Once significant rainfall occurred, flows began to climb back towards previous levels, strongly suggesting the drop was attributable to the weather.

[10] Environment Aotearoa 2019, p99
[11] Climate change risk 2020, p5
[12] Tektus 2020 (2.3)

Figure 2 Flow pattern with groundwater drop



The spikes are infiltration during rainfall events. The summer sewage peaks are below 1000m^3 per day and broader. The difference between the base level prior to December 2019 and the minimum point at the end of April 2020 shows the level of ground water infiltration. The decline from December 2019 to April 2020 represents the 2020 summer drought and demonstrates how ground water levels dropped. The level picks up again when it started to rain in May.

As the minimum flow point on the graph above shows, eliminating inflow and infiltration and dealing only with the real sewage would more than halve the wastewater flows and therefore the size of the system needed to deal with them. It would remove the fundamental problem that the wastewater volumes are greatest at the time when water is least needed and most difficult to get rid of.

Even more importantly, it reduces the times when the pipe network is simply overwhelmed by storms and general leakages – both of which release raw sewage into the environment and streams, near where people live, recreate and gather food. This causes the greatest health and environmental risk and should be the highest priority to address.

1.5.4 Integrated Water Strategy

In September 2019 the Council adopted the "Te Wai Ora o Tāne /Integrated Water Strategy" (IWS). This recognises that water is a taonga, with significant cultural values and fundamental to the life of our communities. It is an overarching strategy that sets a vision and framework to guide decision making and manage water resources in an integrated way over the next 100 years. It sets goals and objectives for infrastructure efficiency and resilience through integrated three waters (water supply, wastewater and surface water) management and for a proactive risk-based approach. This includes ensuring the sustainability of water supplies and wastewater systems, understanding and adapting to climate change and sea-level rise and reducing wastewater overflows and infiltration.

The IWS (page 4) sets 4 goals:

- *Goal 1: The multiple uses of water are valued by all for the benefit of all. This includes increasing awareness and enhancing natural and cultural values;*
- *Goal 2: Water quality and ecosystems are protected and enhanced. This includes Improving water quality and enhancing the natural, cultural and ecological values of waterbodies and Reducing the effects of wastewater overflows – by network upgrades, targeting efforts to address overflows and reducing inflow and infiltration.*

- *Goal 3: The effects of flooding, climate change and sea level rise are understood, and the community is assisted to adapt to them. Understanding risks due to sea level rise and consequences resulting from climate change, and developing an adaptive response.*
- *Goal 4: Water is managed in a sustainable and integrated way in line with the principle of kaitiakitanga:*
    - *Managing assets across all of the Council's activities (such as roading, water supply, wastewater and stormwater operations, parks, etc.) in an integrated manner to maximise attributes such as place making, collaborative benefits, eco-system service harmonies which may not be realised when assets are developed in isolation for a single discipline.*
    - *Managing wastewater systems to meet community needs – including through reviewing and revising trade waste and biosolids management and developing long term solutions for Christchurch's future growth and for the disposal of treated wastewater from the Akaroa Harbour communities.*
    - *Managing water sources to meet reasonable demands by improving understanding of water sources and water use, implementing demand management projects and securing access to water supplies.*
    - *Infrastructure efficiency and resilience – by utilising a risk based approach, proactive monitoring, and the implementation of intelligent technology.*

These goals are followed by 11 Objectives, the most relevant in this case being:

- *Objective 2: Efficient and resilient infrastructure. Ensure efficient use of three waters infrastructure through a completely integrated management structure and ensure the resilience of entire networks (including natural waterbodies) to future environmental, social and/ or cultural changes and natural hazard risks over the long term through timely asset renewal and/or better alternative solutions.*
- *Objective 8: Sustainable wastewater systems. Manage the effects of the wastewater systems to meet community needs for environmental, social, cultural and economic sustainability over the long term*.

Guiding principles include:

- Kaitiakitanga – actively seeking to protect our water resources and improve their state for future generations
- Longevity – the strategy should not be time bound, but will be intergenerational, while also being aspirational yet pragmatic, affordable, 'real' and achievable.
- Efficiency – there is a need to rationalise the three existing water-related Council strategies, to respond in the short-term to the effects of the earthquakes and to maximise the cross-benefits when considering replacement or new assets.

The IWS identifies 11 key issues, including:

- 5.4 Wastewater overflows and effects on surface water
- 5.9 Long term availability of water for water supply
- 5.10 Long term sustainable wastewater treatment and disposal
- 5.11 Infrastructure efficiency and resilience

Of particular relevance is:

5.5 Treated wastewater discharges into Akaroa Harbour

Two wastewater treatment plants at Akaroa and Duvauchelle discharge treated wastewater into Akaroa Harbour. There is a dual issue for these discharges – the concern of the community and Ōnuku Rūnanga about ongoing discharges to the harbour (notwithstanding the wastewater is treated to reasonably high levels), and the issue for the Council of the feasibility, practicality and cost of land disposal or land contact of the treated wastewater.

Why is it a key issue?

Discharging treated wastewater to the harbour is offensive to members of the community. The discharge is particularly offensive to Ōnuku Rūnanga, whose preference is for the treated wastewater to be taken out of the harbour and irrigated onto land. The Council will be making a Local Government Act (LGA) decision on which reclaimed water disposal option to pursue.

It must take into account social, cultural and economic interests; the option must be efficient, effective and appropriate; and it must be consentable as sustainable management under the Resource Management Act (RMA). Discharge to water is not sustainable management under the RMA unless land-based options have been adequately investigated and reasonably discounted.

The IWS goes on to give detailed goals and objectives. Recurring themes are valuing and respecting water, enhancing ecological, cultural and natural values, **managing water in a sustainable and integrated way, efficiency and resilience, proactive risk-based approach, resilience and adaptation to climate change, reducing wastewater overflows and I&I**.

Objective 8 (Sustainable wastewater systems) identifies providing a long term solution to the treated wastewater discharges into Akaroa Harbour as an immediate challenge. This objective proposes **reducing wastewater at source including I&I and investigating potential reuse of treated wastewater**. It also describes the Duvauchelle wastewater treatment plant and its consent requirements.

FOBP welcomes this Integrated Water Strategy. It offers the sustainable and integrated management approach that our Society has been promoting for three decades. We suggest that the Akaroa wastewater project provides an ideal test for the IWS and would inform the proposed Implementation Plans. The Akaroa community is engaged and asking for this.

The Consultation document (page 6) states that all three land based options align well with the Integrated Water Strategy. Other than removing wastewater discharge from Akaroa Harbour (and not completely for the Inner Bays scheme), in our view the land based options ***do not*** appear to align at all well with the IWS and are in fact contrary to it. They do not provide integrated and sustainable management or resilience and adaptation to climate change. They are untried and risky and very costly. They do not address water supply problems or I&I and wastewater overflows or seek to maximise cross benefits.

We argue that the proposed options ignore the Integrated Water Strategy and do not give effect to its goals of efficiency and sustainability, proactive risk-based approach, resilience and adaptation to climate change, reducing wastewater overflows and I&I and supporting the wellbeing of current and future generations.

1.6 Why the process so far has failed to address these issues

The options presented in the current consultation are based on storm, ground and sewage water continuing to mix. The result, particularly for the land-based systems, is that they are more expensive, with higher impacts and risk than if they had to deal with the real sewage volume only. Our concern is that of the Commissioners' decision in 2015 – if the Council has a large sunk cost invested in the disposal of the mixed water, they are unlikely to dedicate further funds to the Akaroa

system in the future to deal with its broken pipe network, leaving it vulnerable to the effects of climate change and prone to failure.

We identify a number of reasons why this situation has got to this point:

- The Akaroa network has been allowed to run down over the years, due to age-related deterioration and earthquake damage.
- **Failure to address the faulty flow meter in 2010 when it was first identified means the various options designed since have been based on incorrect data,** and the problems compounded by then trying to retrofit the existing designs to accommodate the true, much greater, volume.
- The legislative paradigm within which the options have been developed has not been conducive to solutions dealing with three waters in an integrated manner, although this is now starting to change.
- New Zealand's unique cultural environment compounds the difficulty – but may also provide the answer through its more holistic approach.
- The Council and community have been placed in a difficult position by the 2015 decision to approve a Treatment Plant but with nowhere to put the treated water it produces.
- Council has been under pressure since to produce a solution with no discharge to water body, but on extremely difficult terrain.
- Hence, once staff had identified a geotechnically suitable piece of land in Robinsons Bay of reasonable size and with a willing seller, they pursued the option relentlessly, as has been evident to Working Party members. Most of the Working Party's time was devoted to considering the different manifestations of this option, including the size of the storage dam needed, addition of the wetland adjacent to the Treatment Plant and its provision for emergency discharge to the Harbour in order to bring down storage requirements, and, finally, the addition of three more land parcels for irrigation.
- The result is the complex Inner Bays option with its multiple sites and wetland. Far less effort has gone into developing the Outer Bays options, and opportunities with willing landowners and potentially receptive communities squandered. No effort has gone into holistic or staged approaches, or Working Party discussions with Ngāi Tahu examining what might make for culturally accepted practices.
- The skewed effort is evident in the resulting consultation document with far more pages dedicated to the Inner Bays option, the unbalanced assessment of the options and the clear statement of staff preference.

Chapter 2 New wastewater treatment plant

The consultation options all presume that the new treatment plant will be constructed at the Old Coach Road site as consented in 2015, at a time when a harbour outfall was proposed for the wastewater, the wastewater flow assumed was less than half the actual volume, and when untreated bypass flows during wet weather were proposed as acceptable by the Council engineers.

In order to assess the different disposal options, it is useful to have an overview of the new treatment plant components that are already consented, their impacts and how they constrain what is possible.

2.1 New WWTP system description

The Treatment Plant is being moved from its current site at Takapūneke at the south end of the town because it is on a culturally sensitive location.

The new plant and its associated components will have a significant and ongoing impact on Akaroa. These are placed over several sites at the entrance to and through the town, and pipes will need to be relaid.

Figure 3 Akaroa Wastewater Treatment Plant system

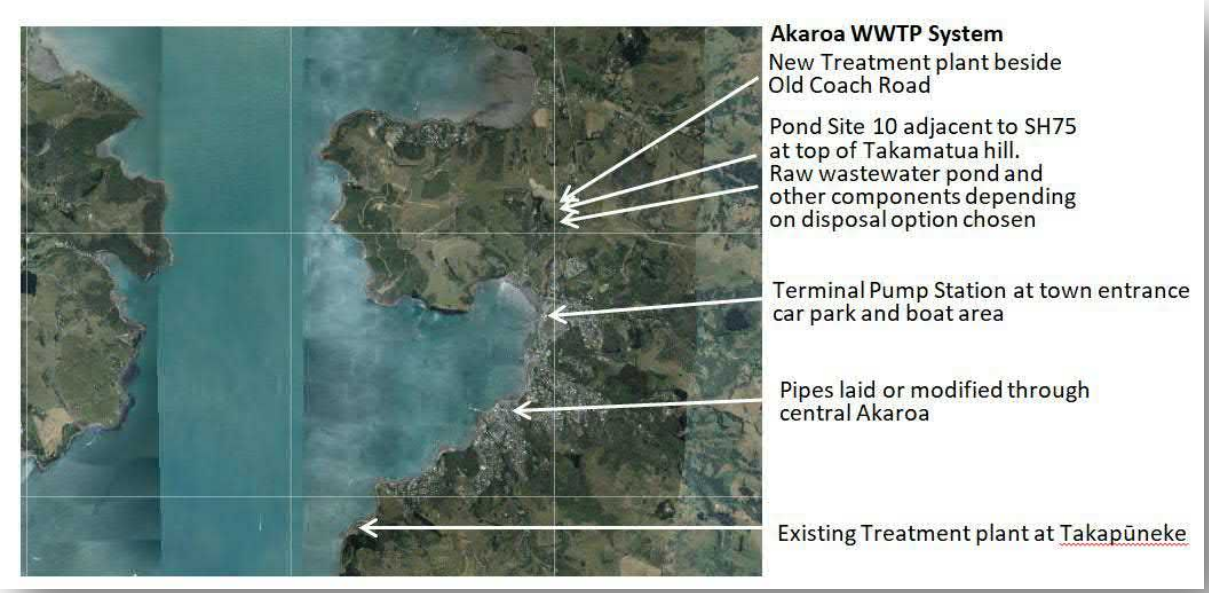


Figure 3 above shows the different components of the new wastewater treatment system consented in 2015. These consents were extended to 2028 as part of the settlement the Council reached with the Environment Court on the withdrawal of its appeal to the 2015 outfall decision.

2.1.1 Treatment Plant

The Treatment Plant itself will be located on a small site owned by the Council along the eastern side of Old Coach Road at 120m above sea level on the top of the headland between Akaroa and Takamatua.

The plant is physically constrained by its small site and this brings limitations to the treatment options possible and volumes it can handle. A compact ultra-filtration plant is proposed rather than

a traditional plant with oxidation ponds. The plant will have the capacity to process normal flows (up to 14L/s). Sludge will be removed weekly and tankered to Christchurch.

2.1.2 Terminal Pump Station

Much of the pipe network needs to be re-laid or modified along the main route to redirect the flow to the new Treatment Plant via the Terminal Pump Station.

The Terminal Pump Station will require construction of a new building near the town entrance in the car park area, east of the Akaroa Recreation ground. The building will be alongside the road leading to the main tourist car parking area opposite the boat storage compound and adjacent to the designated freedom camping area.

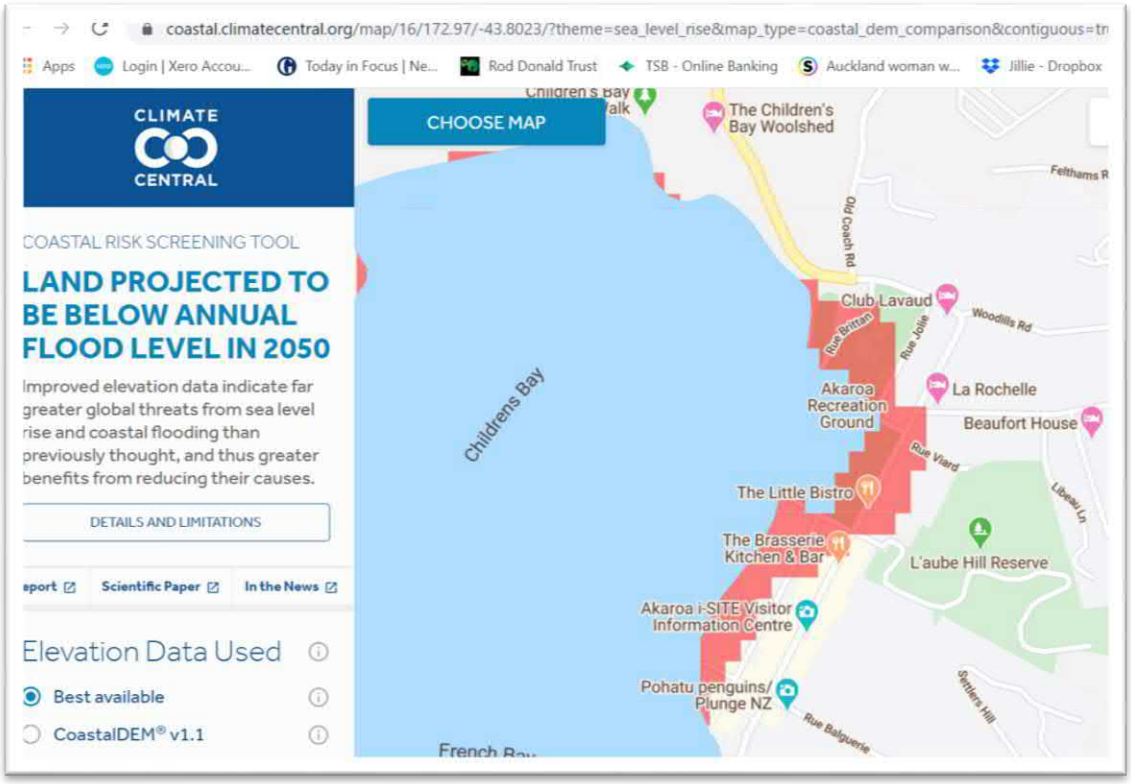
The building will house the pump feeding the rising main to the Treatment plant. Primary raw sewage treatment to screen material to less than 1mm and grit removal to protect the pumps will be carried out here. The building will be opened on a regular basis to empty these solids for trucking away. As part of its Environment Court Appeal withdrawal settlement, the Council was successful in its appeal to relax the odour constraint conditions for the 2015 consent.

The Terminal Pump Station is a large concrete building (7.5m high and 17.5m long). It will be highly visible from the highway entering Akaroa and to any users of the main car and boat park and foreshore area.

The Terminal Pump Station is located on reclaimed land on top of the former Akaroa refuse disposal site and is only slightly above sea level. **The area is projected to be below the annual flood level in 2050[13], within the lifetime of the system. We consider this to be a major risk in the design of the new Treatment Plant system**. The vulnerability of capped landfill areas has been highlighted since the consent was issued in 2015 by the failure at Fox River. We strongly suggest that the location of the Terminal Pump Station is reviewed in light of this and a site found further from the coast.

[13] Climate Risk 2050

Figure 4 Land projected to be below annual flood level in 2050 in red



2.1.3 Pond Site 10

In 2019 the Council purchased "Pond Site 10" land opposite the Treatment Plant site. There is a large and relatively flat paddock at the top of the site, which then slopes steeply down sandwiched between the State Highway and private properties on the western side of Old Coach Road.

The flat area at the top provides space for a 6,000m^3 raw wastewater buffer pond, needed because of the increased flows discovered since a working flow meter was installed and also to avoid the need for bypass flows (which would receive lesser treatment) during heavy rain as had originally been proposed. This pond is needed for all options as its purpose is to buffer the plant when sewage is arriving faster than it can be processed. The raw wastewater pond will be covered and security fenced. The size of the raw wastewater pond is limited by the space available; Beca have calculated that with a raw wastewater pond of this size the network will overflow approximately once every 15 years, while increasing the size to 8,800m^3 (and also increasing the pump capacity slightly) would reduce network overflows to one in 47 years, i.e. virtually eliminating them[14].

The property also opens the opportunity for some further storage ponds and other equipment, but there are limitations due to the steep nature of most of the site.

A treated wastewater storage pond is included for the Glen Bay harbour outfall and for water that will be sent down a purple pipe if this is chosen to go with any of the land based options, but not if wastewater is to be irrigated as this will be pumped directly from the treatment plant to the irrigation storage ponds.

The Inner Bays option also includes a constructed wetland on this site.

[14] Beca report July 2020, p115

2.1.4 Treatment standard

The level of virus and bacteria removal will be relatively good compared to other plants around the country, however, the nitrogen removal is relatively poor. Nitrogen residue expected is 15-30mg/l, which does not compare favourably with other new plants such as the as 4.3mg/l proposed for the Rotorua upgrade[15], to deal with the nitrogen issues caused by its current land disposal site. We will come back to this later in Chapter 4 Inner Bays option where it presents the most serious issues.

2.2 Impacts of the new Treatment Plant components on Akaroa

There were relatively few submitters to the 2015 resource consent, with residents of Akaroa mostly unaware of the potential impacts of locating the sewage treatment plant and the terminal pump station so close to homes and public facilities. Friends of Banks Peninsula did not submit to the process as the plan for the harbour outfall discharge was in-line with the Working Party recommendations in 2010 and the potential impacts of the terminal pump station were not recognised at the time.

2.2.1 Impacts during construction

Constructing the new plant will be disruptive to Akaroa, with large earthworks at Pond Site 10, major works to build the terminal pump station and digging up the streets to upgrade the pipes. This may be disruptive at a time when the town needs to be at its best to keep its visitor industry alive. Domestic visitors have returned to Akaroa, but word is likely to spread quickly, particularly to the Christchurch market, if the town is a construction mess.

2.2.2 Ongoing impacts

The new Treatment Plant will be visible along Old Coach Road, and Pond Site 10 from the State Highway and many parts of Akaroa.

However, it is the ongoing impacts at the Terminal Pump Station that are of most concern. This will be opened at least fortnightly, and is close to the playcentre, skate park and many community amenities such as the main parking area, boat ramp and sports clubs.

The building is constructed on a coastal reclaimed land with a capped landfill under it. This makes it susceptible to sea level rise and storm damage.

Raw sewage overflows will occur here at times when the amount of water flowing through the network is more than the pump can handle.

2.3 Cost component of the new treatment plant

The cost of the treatment plant and associated consented components are bundled in with the disposal costs for the options given in the consultation document. They account for about $30million of the total costs for each option.

[15] Rotorua wastewater upgrade consent application 2018

Chapter 3 Common to all land based options

The three land based options in the consultation document all contain similar features. They are all based on irrigating water to areas that are currently pasture land and will be planted with native trees. They all involve storage ponds, and they are all a considerable distance away from the treatment plant.

In this section we discuss why these land based options all constitute disposal rather than beneficial re-use, the difficulties in finding suitable sites, how the sites and storage have been sized, and their sensitivity to modelling parameters. We also discuss how the levels of I&I in the Akaroa system compound risk.

3.1 Why they are disposal – not beneficial reuse

There is a clear distinction between *disposal* of wastewater and its *beneficial re-use*. This distinction, and its implications for the receiving environment, is an important consideration in this submission.

Under a *disposal* system, the water is distributed to the receiving environment whether that environment needs it or not. The purpose of the irrigation is not to benefit the receiving environment, but to dispose of the maximum amount of water on the minimum amount of land.

When the water is put to *beneficial re-use*, the level and times at which it is irrigated or used are determined by the needs of the receiving environment. For example a garden or farm paddock will be watered only when soil moisture is low and the plants will benefit from the water, not when soils are already moist and additional water would not add benefit, or indeed could be detrimental.

All of the tree irrigation proposals have been sized to dispose of the maximum amount of water on the minimum amount of land possible. Clearly they are disposal systems.

Native trees do not require water to flourish in most parts of Banks Peninsula –and indeed watering at the rate proposed for up to the 40 year expected life of the scheme may well cause harm to their long term health and root strength. Given appropriate land management such as cessation of grazing, native trees regenerate naturally and rapidly grow into strong and diverse forests. Planting is not the most ecologically or cost effective way to restore forest to Banks Peninsula.

3.1.1 Side-benefits do not equate to beneficial use

The consultation document makes much of the side benefits of planting native trees to use the irrigated wastewater. These side-benefits do not in themselves make for beneficial re-use and we express some doubt about the claims made for the use of these areas for public recreation.

While there will be some minor biodiversity and carbon gains from these areas, 30-40ha of native trees is insignificant on Banks Peninsula where there are already extensive areas of native vegetation (Hinewai alone is nearly 1500ha). Much greater biodiversity and carbon sequestration gains could be secured by choosing a cheaper option and dedicating the balance of funds to protecting areas of marginal land where natural regeneration is already advancing. Further detail is provided on this in Chapter 9.

Public access to the sites is mentioned as a benefit, but not included in the costings. This is unlikely to eventuate unless walkways are planned in advance and there are good setbacks for the trees, as the vegetation planted at the level proposed will be too dense to walk through, and walkways and any associated areas such as parking remove areas for irrigation which is tightly sized. A visit to the Duvauchelle tree trial plot aptly demonstrates this. In any case, given the wealth of scenic bush walks already publicly available in the area, these planted disposal areas may not prove very attractive for recreation.

3.1.2 Directing water away from where it is needed

Water is needed most in Akaroa, not out in the land disposal areas. Akaroa is chronically short of water each summer. These land disposal areas are currently farmed and have adequate water supplies to maintain pasture and stock.

Hence not only are the land based options in themselves disposal options, but they also direct the water away from where it could be most beneficially used, the catchment from which it emanates.

3.2 Difficulty of finding suitable sites

The topography and geology of Banks Peninsula present significant challenges to land disposal as most of the land is steep, with the volcanic bedrock coated in a layer of slip-prone loess soil. Stream gullies and ephemeral streams punctuate the slopes, testament to the huge volumes of water that cascade down to the valley floors below in heavy rain events.

A set of design parameters was adopted and used by Council to screen land for suitability, working outwards from the treatment plant. We examine these briefly and question whether they are reasonable and defendable.

3.2.1 Environmental parameters

Slope is a major constraint on the availability of, as irrigation must take place in areas no greater than 19^{o} and with downslopes no greater than 15^{o} to avoid slips.

The storage ponds must be excavated on land with slopes no greater than 4^{o}.

Most of the land on Banks Peninsula is steeper than this. Land matching these criteria is scarce and is either settled, or the best farm land.

Setbacks from streams are 25m from the centre of flowing streams and 10m from ephemeral streams to avoid nitrogen leaching.

3.2.2 Social parameters

The social parameters adopted to select the sites and design the options have been set at levels that appear much less restrictive than those set in the Canterbury Air Regional Plan and for similar activities in the District Plan.

The setback used for irrigation from neighbouring properties is only 5m. This is very close given the shading effects of native trees that are likely to grow to heights well over 5m, and the potential for the water to be odorous[16]). There is no additional setback from residential dwellings. In contrast, the setback from boundaries for plantation forestry in the District Plan is 10m to a boundary or 30m to a residential unit. The permitted activity setback in the Canterbury Air Regional Plan for human effluent surface irrigation is at least 20m from the property boundary. The setback of storage ponds from residential dwellings use is only 100m (and the interpretation put on this by Council is from the water itself, not the earthworks). By contrast District Plan requires activities such as intensive farming to be located 200 metres from sensitive activities (which includes houses). The permitted activity setback in the Canterbury Air Regional Plan requires the storage of human effluent in uncovered vessels to be at least 50m from the property boundary and 150m from sensitive activities (which includes houses).

The standards set by the Canterbury Air Regional Plan and those for similar activities in the District Plan are considerably greater than the minimum setbacks used for the design of the options. **There has been no consultation with the public on these setback distances or any explanation of why they have been set at such permissive levels.** Perhaps this is because geotechnically suitable land has proved to be so scarce, but if so, this should form part of the informed consultation and consideration.

[16] Beca Report July 2020, p70

3.3 Sensitivity to modelling assumptions

The proposed land-based systems all have two main design parameters:

- size of the irrigation area, and,
- volume of storage required.

These in turn are based on modelling, which relies on the following input parameters:

- Anticipated wastewater flows until 2052, including growth
- Long-term application rate (LTAR) that can be sustained, which is dependent on the soil being able to take up the applied nutrients, as well as remaining stable

3.3.1 Impacts on storage volume

These parameters impact most critically on the storage volume required, since it has to deal with excess flows when the total wastewater flow exceeds the ability for it to be irrigated. No storage is required when the water can be irrigated at the rate at which it arrives. Once that limit has been reached, the amount of storage required grows rapidly.

As an example, the following table illustrates the sensitivity of the storage volume to these parameters for the inner bays option (Beca report July 2020, Appendix B p9):

Table 2 Storage requirements relative to land area and I&I levels

Land area	Storage required – 20% I&I reduction achieved	Storage required – no I&I reduction achieved
30 ha	40,000	463,000
40 ha	**24,000**	36,000
60 ha	16,000	21,000
80 ha	15,000	19,000

The green cell highlights the design conditions for the Inner Bays solution where 40 ha of trees will be irrigated, and 20% I&I reduction is assumed.

The light red cells show the effect of either reducing the effective land area available or failing to realise the expected 20% I&I reduction: in both cases, the storage required rises sharply. If both of these issues occur, the dark red cell shows that the required storage grows massively, because there is now not enough land to dispose of all of the water, and therefore it keeps building up.

3.3.2 Assumptions underpinning design parameters

The projected total wastewater volume and long-term application rate are themselves dependent on the following *assumptions*:

- Population growth (permanent and visitor) between now and the end of the consented period (2052);
- Level of I&I
- Amount of rainfall intercepted by the tree canopy
- Ability of the proposed areas to accept extra water to the levels proposed, over their entire area and continuously over many years, without loss of stability or nutrient build-up.

3.3.3 Population growth and limits

Population growth has been modelled by Council based on Statistics New Zealand's medium projections.

The current number of Akaroa residents is estimated at 765 in winter and 2077 in summer, and the growth projections used equates to an additional 75 (10%) winter and 271 (13%) summer residents over the next 35 years. The COVID-19 pandemic creates uncertainty about future population - both permanent residents and visitors. As technology and social change enables more people to work from home it is possible that many more holiday homes (currently estimated at around 60%of Akaroa's houses) will become permanently occupied.

Takamatua residents have argued that their properties should be reticulated to the network if they are to suffer its effects and are relatively close to the new treatment plant. This would also remove the potential for leaching from septic tanks on small, steep, coastal properties. We understand that the potential to reticulate the Takamatua area was one of the factors that influenced the decision to locate the Treatment Plant at Old Coach Road, despite this being a more expensive site option.

There are approximately 170 Takamatua properties on sections of less than 1ha using septic tanks. There is insufficient headroom provided in the system to connect these properties. If most of them were connected there would be no scope for growth in Akaroa.

This serves to illustrate the inherent limit on Akaroa's growth potential that moving to a land based system creates. Under the current harbour disposal system an increase in wastewater flows does not create subsequent downstream disposal issues, because the outflow is not physically limited. **Once a fixed size land based system is in place, there could come a point when the capacity of the system is reached and no more growth should occur until such time as the disposal system capacity had been increased.**

3.3.4 I&I reduction

Reducing I&I has the obvious effect of reducing the total wastewater volume requiring treatment, storage and disposal, proportionally reducing the size, cost (capital and operating) and carbon emissions of the scheme.

It also has a much larger impact than this because rain-derived I&I causes the volume of wastewater to "spike" during rainfall events. In Akaroa the flow during wet weather can be more than ten times the dry-weather flow. This requires extra storage to accommodate this excess volume, both for buffering raw wastewater, and for the treated wastewater prior to land disposal. The table below (derived from BECA report July 2020 Appendix B) shows the impact of I&I reduction on the storage required for the Inner Bays option with the proposed 40ha of land.

Table 3 Storage required for Inner Bays option relative to I&I reduction

I&I reduction	Storage volume required M^3
0%	36,000
20%	24,000
40%	14,000
60%	9,000

If I&I reductions are not achieved, the storage size becomes too large to be workable. On the other hand, a more aggressive 60% reduction in I&I could bring the storage down to a much more manageable 9,000m^3 – small enough for example to store in two 46m diameter uncovered or five 21m diameter covered Kliptanks[17].

3.3.5 Land area

The land areas have been sized based on the minimal land area required given the local conditions, in part because this minimises costs, and also because, for the Inner Harbour option in particular, land meeting the design criteria is very scarce.

[17] https://www.kliptank.com/products/

The minimum land area required for the Inner Bays option has been calculated at 40 ha based on soil acceptance rates. However, this land area rests upon several assumptions:

1. Rainfall interception by the tree canopy will match modelling
2. Measured soil parameters are correct and apply to the entire sites
3. All of the land is available for purchase, and at a price the Council is willing to pay

If any of the above assumptions fail to hold, the effective land area available will be insufficient, and the Council will need to acquire more land, likely by compulsory purchase.

Further, if the effective land area turns out to be less than that calculated *or* I&I reductions aren't achieved, the proposed scheme becomes unworkable. There would be insufficient land to irrigate the year's total wastewater and so the amount required to be stored increases indefinitely.

3.3.5.1 Rainfall intercept

Irrigation to native trees is preferred by the Council (now that there are no farmers willing to partner in a pasture irrigation system) in part because the tree canopy intercepts a proportion of the rain enabling irrigation in wet weather.

All the options have assumed a canopy interception rate of 37%[18]. This is the New Zealand-wide average, but is for Kanuka/Manuka only (native bush overall has a lower average interception rate), and subject to wide uncertainty[19]. Davie urges caution when using the annual averages, because canopy intercept varies with species, tree size, time of year, rainfall type and measurement methodology and is subject to climate conditions[20]. The actual canopy intercept will not be known until the native trees have been planted, established to a stage where there is canopy closure and the effect can be measured.

All of the land-based options rely on this assumed level of canopy intercept in orderto be able to accommodate the required level of irrigation.

The consequence of rainfall interception being less than expected is twofold:

- More land area will be required because the total (rainwater and wastewater) water to be absorbed is higher, ***and,***
- Storage is much greater because there will be more days when it is too wet to irrigate

3.3.5.2 Measured soil parameters

Beca and PDP have carried out soil infiltration testing on all of the proposed irrigation sites. This is to get an indication of the likely moisture uptake over the entire site. These measurements are then used to estimate the maximum long term application rate (LTAR) to avoid soil degradation and failure. This in turn is used to calculate the land area required.

Calculation of the LTAR (and therefore the land area) is an estimate only. For this reason two other engineering reports have recommended they be used with caution:

- Geotech Consulting advised using total additional water as the initial limiting factor, and recommend initially irrigating no more than 250mm per annum, excluding the summer peak of January to mid-March when evaporation rates are higher. They further advised making the available irrigation area as large as possible in case sustained irrigation rates above

[18] Beca July 2020 Appendix B Model, p1
[19] Rowe 2002
[20] Davie 2007, slide 24

250mm (non-peak) per annum are not feasible [21] **The irrigation rate that the land based options presented are expected to cope with is over 400mm pa.**

- EcoEng advised operating a hybrid (irrigation plus outfall) model for several years to lower the risk of soil instability, until the actual maximum take up rate is known[22].

3.3.6 What happens if assumptions prove incorrect

If any of these assumptions – the I&I reduction achieved, the tree canopy intercept rate, the ability of the soil to absorb the water or the overall flows – are significantly out, then the system will be undersized. This means the storage capacity will be exceeded and more water will need to be released to the environment through overflows. **Tektus conclude there is a lack of resilience in the design for variation between actual conditions and the modelled design parameters**[23].

3.4 Why high I&I levels compound the problem and risk

The volume of storage required and the land area required for disposal by irrigation is critically sensitive to the assumption that I&I can be reduced by 20%. It is acknowledged, however, that it is difficult to estimate the reduction that will be achieved from piecemeal improvements because storm water may simply move elsewhere and find another place to leak in. Raw wastewater will also be leaking out of these pipes at present, also making it difficult to assess the true volumes and reductions that may be achieved.

Because maximum I&I occurs during prolonged or heavy wet periods when the least irrigation is possible, the effects of reducing I&I on storage and land requirements can be substantial. Eliminating I&I to the fullest extent possible would significantly bring down the costs and impacts of the land based options.

The Joint Statement of the Working Party states

Regardless of the decision made by Council, as an integral part of the wastewater project, the working party urges the Council to reduce stormwater inflow and groundwater infiltration in to the wastewater network before the project commences. While the Council has indicted that the amount of reduction that can be achieved is difficult to assess, these reductions would reduce the size and the cost of of the entire scheme (including the treatment plant), potentially paying for the work itself. The cost of doing this should be included in all options. [24]

The current proposals do not address the I&I problem satisfactorily, because the target is only a 20% reduction and is for the land based options only. This means money would be wasted building a system that is oversized to cope with all the infiltration. The system will also be left vulnerable to being overloaded if the I&I reductions fail or I&I increases in future due to climate change, further compounding the risks of the other modelling assumptions.

Council staff have argued that by not addressing the I&I now, the system will inherently have growth capacity because I&I can be reduced in the future. However, this piecemeal approach is risky. Firstly, there is a clear link between I&I and sewage overflows. Secondly, it is not possible to predict whether the 20% reduction will be achieved with a piecemeal approach because leaks are likely to emerge higher up the system as lower leaks are fixed, and the leaking system is still left vulnerable to the increased intensity storms and rising sea levels that climate change will bring.

To provide a sustainable solution to the current wastewater problem and future resilience to climate change and earthquakes **now is the time to undertake substantial remediation** (such as lining all

[21] Harrison Grierson 2010, p116
[22] Harrison Grierson 2010, p111
[23] Tektus 2020 (3.24)
[24] Working Party JS 2020 p2

pipes)[25] or to consider a replacement network. Then the correct wastewater system can be designed and future growth planned for up-front, based on known future capacity rather than unknown flow reduction. (Please refer also to Section 1.3)

3.5 Wastewater leaves treatment plant site without testing

Water will leave the treatment site without testing for compliance if one of the irrigation options is chosen because no outflow buffer is incorporated into the system.

The Beca Report states: "*Council has advised that the treated wastewater storage pond should only be included for use with a non-potable reuse scheme and for the option of a harbour outfall from Glen Bay. This is on the basis that, in the absence of a reuse system, wastewater can be pumped directly from the treatment plant to theirrigation storage pond at the instantaneous flow rate hence no storage is required*".[26].

The existing Treatment Plant frequently discharges wastewater that fails to meet its consent standards. The lack of an outflow buffer pond at the Treatment Plant site for the irrigation options leaves the receiving environments at risk of receiving contaminated water that does not meet consent conditions. Inclusion of a suitably designed outflow buffer pond would enable wastewater to be tested prior to release from the plant site, and recycled back to the Treatment Plant for re-processing if it failed to meet consent conditions. This is a particularly important consideration when wastewater is being stored and irrigated close to houses. Tektus recommend the inclusion of a treated storage pond for all options for quality control and to facilitate reuse and disposal quality.[27]

[25] Tektus 2020 (3.17)
[26] Beca Report 2020, P116
[27] Tektus 2020 (4.2)

Chapter 4 Consideration of Inner Bays option

The Inner Bays option is the most complex of the options presented.

Several sites are required and it is a tight squeeze to fit because the flatter land in the Inner Bays is settled. The system is placed close to houses, property boundaries and streams at the minimum allowed by the design setbacks for all the sites, and a wetland with an overflow feature has been added to cope with extreme weather events.

This option is critically reliant on the Council achieving 20% I&I reduction. Without this, the storage and land size will be insufficient and there is no ability to expand on the irrigation sites currently earmarked.

4.1 Highest sensitivity to modelling assumptions

Due to the scarcity of land, the greatest risk with the Inner Bays option is whether the many components of this complex, uncertain and untried system perform as modelled. Assumptions around wetland function, tree canopy intercept rates, storm frequencies and nitrogen uptake will have to work in practice because the expansion capacity is very limited and the catchments drain to shallow inner harbour mudflats. Design parameters are pushed to their limits, so there is little "give" in the system. (Please refer section 3.3.)

If the system turns out to be undersized, then the Childrens Bay overflow will need to be used more frequently than currently planned until further private properties can be purchased. This is likely to be costly, take time and cause considerable community anxiety and offence.

The location of this infrastructure within communities exacerbates the risk and the potential liability for the Council. A storage pond or irrigation that is far from people may smell or be infested with midges, but this will not cause adverse effects. Placing the infrastructure close to people and the sensitive activity of residential living means any problems will cause immediate impacts. If any of the inner bays become nitrogen saturated and smell this will become a very public problem.

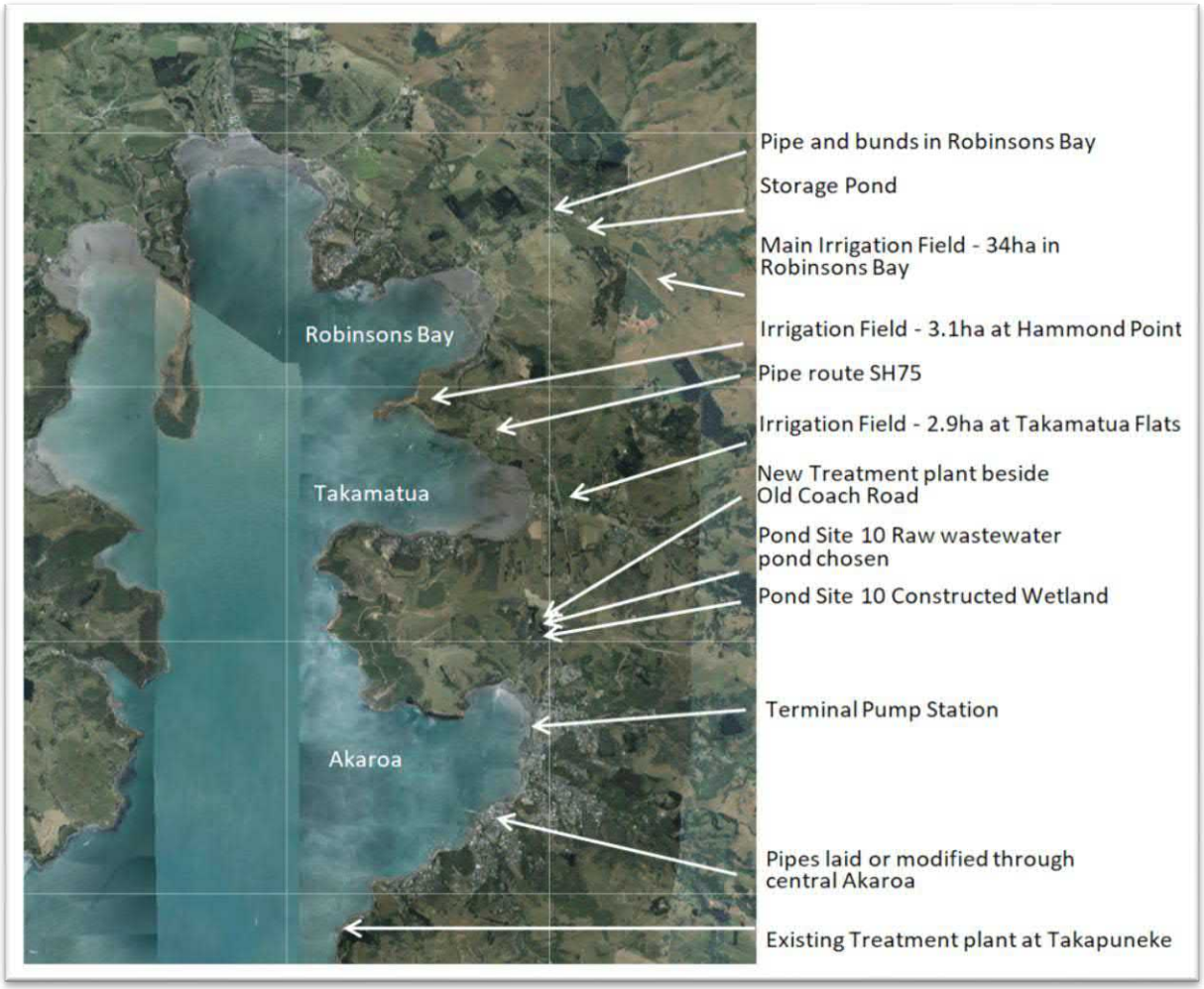
4.2 System design and components

Four different land parcels in Takamatua and Robinsons Bay make up the 40ha needed for the irrigation field area. The largest of these parcels is the Thacker land on Sawmill Road in Robinsons Bay, and this is where the storage pond holding 19,000m^3 would also be sited.

Figure 5 below shows where the Inner Bays option infrastructure would be placed in relation to the new Treatment plant.

This shows the large combined footprint of the new Treatment system with the Inner Bays option. It should be noted that the Duvauchelle scheme will add further wastewater infrastructure into the Inner Bays area on the Duvauchelle golf course and showgrounds should this also become a land based scheme.

Figure 5 Large footprint of Inner Bays infrastructure in addition to Treatment Plant infrastructure.



We now examine each of these sites, working outwards from the new Treatment Plant site. Google satellite images are used to map each of the sites, as these **give a clearer picture of the placement of the sites within communities than the maps in the consultation document**.

4.2.1 Takamatua Valley irrigation site

The site at Takamatua Valley is 2.9ha on the valley floor immediately to the east of the State Highway. It is low-lying and near sea level, with a stream along one boundary and houses to the east and south and a residential settlement downstream on the west side of highway. See Figure 6 Takamatua Valley site below.

4.2.2 Hammond Point irrigation site

The site at Hammond Point is 3.1ha on the headland between Robinsons Bay and Takamatua. There is a settled area on the northern side and two other houses nearby. The land is within Coastal Environment and Coastal Landscape planning zones. See Figure 7 Hammond Point site below.

The area for irrigation is circled green. It is unclear what the Council's intention is for the rest of the site not used for the wastewater and whether it will be retained or sold.

Diagrams in the consultation document indicate there will be an open pasture area between the irrigation plantings and the existing stands of bush. If the land is retained, then there will be an unnatural visual break in the appearance of the headland and unless the open area is fenced and grazed it will become a fire hazard. it

Figure 6 Takamatua Valley site

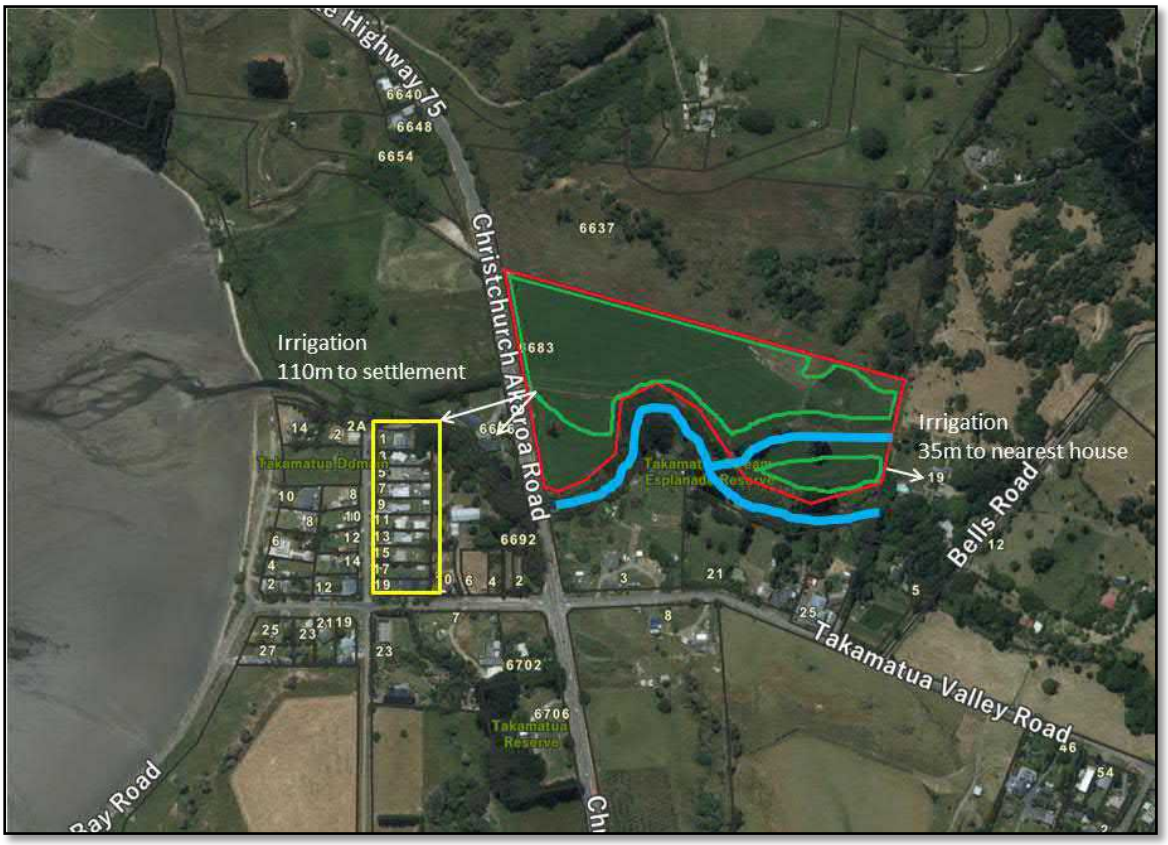


Figure 7 Hammond Point site

4.2.3 Robinsons Bay storage and irrigation sites

The principal site for the Inner Bays option is at Sawmill Road in Robinsons Bay. This includes 2.7ha for the storage pond and 34ha for irrigation.

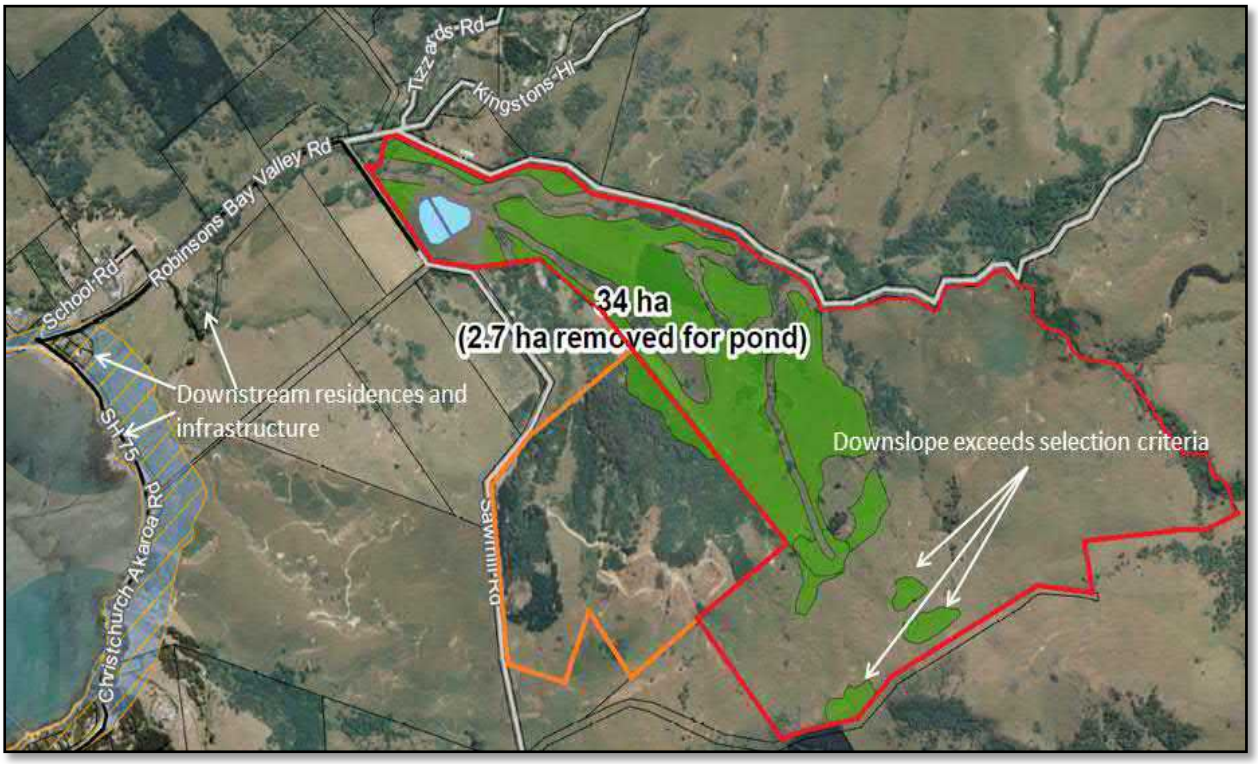
As shown in Figure 8 below, the 34ha is split over two properties. The bulk of it is on [redacted] Sawmill Road, known as the Thacker property, outlined in red. Additional land is also needed and so a strip of adjacent land on neighbouring [redacted] Sawmill Road, the Reid property, is included - outlined in orange.

The Thacker site also includes areas for irrigation on the upper parts of the site that exceed the selection criteria as they are above downslopes greater than 15°.

The large storage pond is divided with a central bund as without this Beca considered it presented an unacceptable safety risk. However, there is considerable infrastructure downstream including several houses and a heritage listed building.

Use of the Reid property compromises the water supply of 33 Sawmill Road, the property immediately below.

Figure 8 Robinsons Bay site



4.3 Pond Site 10 subsurface wetland

The concept of the subsurface wetland at Pond Site 10 was introduced in August 2019 to facilitate the Inner Bays option.

In April 2019 the Inner Bays option was priced at $60,470,000[28]. This made it the most expensive of the options -$6 million more expensive than Goughs Bay and $4 million more than Pompeys Pillar. The proposal at that stage was for a series of constructed wetlands as well as irrigation on the Thacker site, but this required a 40,000m^3 storage pond, given the limited area of land available for the wastewater disposal. This added $8 million to the cost because of the size and construction required.

[28] Beca Report November 2019 Draft Appendix S

The option could have been discarded as too expensive, but instead the wetland was shifted to Pond Site 10 with the added concept of **releasing water to Childrens Bay during extreme weather.** According to the Beca report:

"The subsurface wetland was [sic] been proposed as a result of collaborative discussions between the Council and the Ngāi Tahu parties, who originally suggested the concept."[29]

It further states that one purpose of the wetland is to:

"Address cultural concerns relating to infrequent discharges to harbour of treated wastewater by allowing flows to pass through the sub-surface wetland to provide additional treatment and restore the mauri of the water before being discharged to the harbour."[30]

The retention time for water in the wetland is 2 days in summer and 3 days in winter[31]. This appears to set a benchmark for the acceptable length of time water needs to spend in a wetland to meet the cultural need to restore mauri prior to discharge. This concurs with the report on the Duvauchelle Wastewater scheme which, in reference to the wetland proposed for it, states: *"A minimum of 2-3 days residence time in the wetland is provided to effect meaningful treatment and "passage through land" to address cultural concerns of Ngāi Tahu."*[32]

Ngai Tahu's support for the release water to Childrens Bay during extreme weather brought down the size of the storage pond required in Robinsons Bay from 40,000m^3 to 19,500m^3 and substantially reducing the construction cost and lowering the storage consenting requirements. The option favoured by Council staff was therefore considered viable again.

4.3.1 Inconsistencies in presentation

The wetland at Pond Site 10 is a relatively new concept, and there are inconsistencies with how the wetland is presented in the Beca Report.

- It is unclear whether the wetland will need to be covered with a cage to prevent bird fowling. The example wetland[33] is fully caged, however, the landscape plan in the report and the artist's impression used in the Consultation document do not show caging.
- The visual impacts are unclear – on the one hand, the artists impression shows the wetland as a flat area screened with trees with minimal visual impact, but on the other, the technical diagramshows that substantial earthworks adjacent to the State Highway and states that pond embankments must be kept free of trees and shrubs so that their integrity can be observed.[34]
- The overflow path is unclear. The landscape plan shows it going down the site and out to Childrens Bay at the bottom of the hill. However there is no stream on Pond Site 10 and the report makes it clear that: "*Discharge to the harbour of greater than 2 L/s will be from an overflow pipe from the wetland. This pipe would be directed from the wetland, into the creek on the property opposite the WWTP, and down the hill to Childrens Bay."*[35] The route of this is not shown on a map – but is likely to follow the natural drainage path shown in the dam break analysis.[36]. This comes down the main gully below the wetland site, crosses SH75 in a culvert and drains through the gully in the Akaroa Cottages development to Childrens Bay stream.

[29] Beca Report July 2020, p42
[30] Beca Report July 2020, p42
[31] Beca Report July 2020, p19
[32] Beca Report July 2020 Appendix D, p2
[33] Beca Report July 2020, p45
[34] Beca Report July 2020, p117,119
[35] Beca Report July 2020 p43
[36] Beca Report July 2020 p 121

4.4 Constraints and Risks

The Inner Bays solution is highly constrained by the availability of suitable land – both for irrigation and for the large amount of storage required, and is placed close to homes and communities. Both these factors exacerbate the impacts and risks to people and to the Council if the design does not perform according to the theoretical modelling or if the underlying assumptions prove incorrect.

4.4.1 Difficulty of finding land in Inner Bays

The Beca Report identifies that *"a minimum of 40 ha is required for a practical and workable inner bays irrigation scheme"*[37]. As described, 5 separate sites are needed in the Inner Bays to provide 40ha of land for irrigation and storage that meets geotechnical criteria and minimum system design setbacks from streams, property boundaries and houses.

The difficulty in finding suitable land is illustrated by the Thacker site itself. Despite this being a 114ha block, its provides less than 34ha available for irrigation even with the relaxation of the slope parameter to include some upper areas that significantly exceed the 15° down-slope selection criteria.[38] Therefore a small area on the adjacent 88 Sawmill Road property must be added, as well as the two additional properties at Takamatua and Hammond Point.

All of the identified land parcels carry risks:

- The Takamatua Valley property has already been potentially earmarked for another public purpose – the relocation of Duvauchelle Show to make room for the irrigation of Duvauchelle's wastewater to land currently used as the Show ground and Pony Club. The Beca July 2020 report makes no mention of this issue or what the implications are for either Hammond Point, running an A&P show and Pony Club on irrigated pasture, or the effect on the overall cost.
- The availability of this land is in doubt as the landowner is not a willing seller.
- The property at Hammond Point is currently on the market with a $3million price tag. This is considerably more than the RV +10% we understand the Council is allowed to offer, and could well be sold prior to any decision being made.
- If the Council fails to secure either of these pieces of land through a willing seller process, or by compulsory acquisition then it will need to acquire other land in either Robinsons Bay or Takamatua as indicated on the site screening map given in the Beca report. [39] These are all small sites and close to houses, and owners have not to date been willing to sell to Council – or they would already be earmarked.
- The site at 11 Sawmill Road contains a significant archaeological site.
- Use of the 88 Sawmill Road property compromises a neighbours water supply.

4.4.2 Risks associated with the storage pond on 11 Sawmill Road

Fitting the 19,000m^3 storage pond onto the Thacker Site (11 Sawmill Road) is problematic. See Figure 9 below.

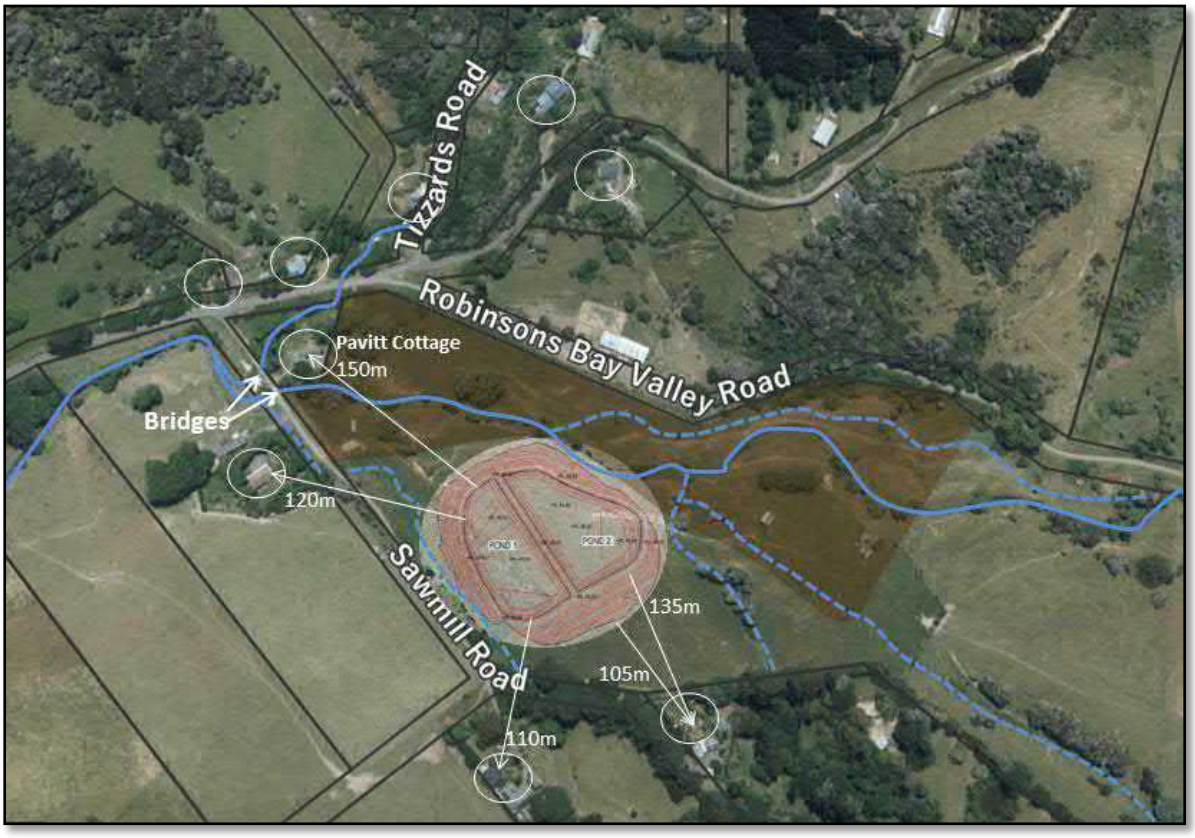
- The pond site is sandwiched between the main Robinsons Bay stream (solid blue line) and two ephemeral streams (dashed blue lines).
- There are houses surrounding three sides of the storage pond area as indicated by the white circles, three are much closer than the 150m permitted setback in the Canterbury Air

[37] Beca Report July 2020, p48
[38] Beca Report July 2020, p59
[39] Beca Report July 2020, Figure 5-6, p45

Regional Plan.[40], and the Pavitt Cottage is at that limit. Note that measurements are done from the edge of the pond. The earthworks are closer again, with the nearest neighbour's house only 105m from the edge of the earthworks as proposed.

- Extensive earthworks are required to level this site, meaning an area of 2.7ha is to be excavated. The earthworks protrude into the main stream in one place. The lower face of the pond is a 4m high bund to be constructed with loess excavated from the higher part of the site and stabilised with cement.
- A double pond with a central bund is designed to reduce the dam break risk to lower properties. A bund has also had to be included along Sawmill Road to lessen the risk of flooding the house opposite should a dam break occur.
- The site has the sawmill archaeological site area (shaded brown) immediately below it. The house between the Tizzards and Robinsons Valley streams is the associated historic Pavitt cottage. Opposite Robinsons Valley Road is the associated historic Schoolmasters house.
- The storage pond size is reliant on the 20% I&I reduction because the land proposed for irrigation is the *minimum viable area*. If the I&I reductions are not realised, or are negated in the future, the storage and land area would be insufficient[41].

Figure 9 Storage Pond Thacker Site



4.4.2.1 Dam burst

Concerns about the risk of this large storage pond expressed at the Working Party meant that a dam burst analysis was conducted by Beca.[42]

[40] Canterbury Air Regional Plan, Rule 7.50
[41] Beca report July 2020 Appendix B Results, p7
[42] Beca Report July 2020, Appendix R

This analysis indicates that there is an increased risk to houses lower in the valley should the dam burst during a storm, with more areas flooded and flood levels under and around houses increased. This increased risk was considered acceptable by Beca and the Council once additional bunding had been added to the design alongside Sawmill road to prevent the ephemeral stream east of the dam flooding the house on the east side of the road.

However, the dam burst analysis has been based on the assumption of a free and unobstructed flow of water. It failed to consider that water flow of the main stream is under a small bridge immediately below the dam site. Should this block during heavy rain (and blockages like this have historically been a common cause of flooding)[43] water could quickly back up below the dam face causing a dam break, and if such a break did happen, this it is likely to cause or increase any blockage.

The images below show the stream in normal and in flood conditions, and the type of debris that comes down in a storm.

Figure 10 Robinsons Bay stream below Sawmill Road bridge in normal conditions

Figure 11 Robinsons Bay stream below Sawmill Road bridge in flood conditions

[43] Tonkin & Taylor 2008, p8

Figure 12 Robinsons Bay stream flowing under bridge across Sawmill Road in normal conditions

Figure 13 Storm debris deposited by Robinsons Bay stream immediately below Sawmill Road bridge

- These factors combine to increase the likelihood of embankments failing during an extreme storm or storm and earthquake.
- Infrastructure downstream includes several houses. Despite the double pond, dam burst analysis identifies a rise in the level of flood waters under and around them should the wall of the storage pond break during storm events, putting these properties at risk.
- The bund along Sawmill Road to protect the house opposite at 8 Sawmill Road, but this could result in more water being directed toward Pavitt Cottage (5 Sawmill Road).

4.4.3 Risks associated with wetland at Pond Site 10

The constructed wetland is not designed to operate in the normal manner where water flows in one end and out the other.

Instead, under normal operating conditions, water will *not* flow through this wetland but only evaporate from it. Water will trickle in at the rate it evaporates, except when the main pond in Robinsons Bay is full and the overflow mechanism comes into play - anticipated as a one in 5 year

event. This raises the question as to whether the water in the wetland will stagnate under normal conditions, whether nutrients will accumulate in the gravel bed, and if so whether they will then flush to the Childrens Bay stream during heavy rain. Tektus also identify this as an issue that requires further investigation. They can find no relevant precedent for this design, and propose consideration of regular base flows through the wetland to mitigate this risk.[44]The discharge of treated effluent to a stream is a non-complying activity, so this matter will need to be further examined at the consenting stage. However it does present another risk to the overall feasibility of the Inner Bays option.

Dam burst analysis indicates some risk to the Akaroa Cottages site below Pond Site 10. The Beca Report states: *"can't avoid some change of sheet flow across this face and properties in this area but should be at management depths".*[45]

4.4.4 Nitrogen leaching

As described earlier in Section 2.1.4 the water leaving the treatment plant carries a relatively high nitrogen loading, and the water will be irrigated year round, even when the ground is already at field capacity. This maximises the likelihood of water and nutrients draining through, or running off the soil when it rains, and is completely contrary to good irrigation practice.[46]

The areas proposed for irrigation at Takamatua and Robinsons Bay contain streams and water bores which have the potential to be directly impacted by nitrogen leaching from the irrigated land. Potential effects of nitrogen leaching include harm to sensitive whitebait spawning areas including the popular Robinsons Bay stream. Both the Robinsons Bay and Takamatua streams flow out to shallow inner harbour bays with large mudflat areas, susceptible to odour if they become too nutrient-rich. Robinsons Bay is important for food-gathering and well known for its whitebait and flounder.

The setbacks from streams are exercised to their limits. Irrigation will take place at 25m from the centreline of flowing streams and 10m from ephemeral streams.

The same may apply in time to Childrens Bay, if the wetland does not remove as much nitrogen as hoped and the overflow system needs to be used more frequently than proposed – due irrigation fields failing, or storage ponds being undersized, or increase in severe rainfall events.

4.4.4.1 Nitrogen issues with other land based systems

Several other land disposal systems have encountered issues with nitrogen leaching, including Rotorua, Ellesmere, Selwyn Huts and Ashburton. In all four cases the land treatment system design was intended to remove nitrogen from the wastewater through uptake via the grown vegetation, soil, and optionally a wetland, and in all the cases the system has failed to perform as designed, with the land treatment systems unable to perform within consent limits for nitrogen:

- Rotorua (Whakarewarewa) is being closed because of nitrogen leaching into and polluting the Puarenga stream, and the wastewater will be returned to Lake Rotorua[47].
- The Ellesmere field has already been increased in size once because of excessive nitrogen loading[48] but still leaches nitrogen into Tramway Drain, breaching its consent conditions. It has been expanded several times.
- Selwyn Huts has never worked satisfactorily and leaches nitrogen into Lake Ellesmere[49]. The local residents will be required to pay for a replacement system.

[44] Tektus 2020 (3.22, 4.33)
[45] Beca Report July 2020 Appendix R, p12
[46] DairyNZ 2011, p9
[47] Rotorua Te Arawa Lakes Strategy Group 2013
[48] ECan R13/8 2013

- Ashburton's wetland has failed resulting in excess nitrogen, blocking of irrigation equipment and regular overflows into the Ashburton river[7]. It fails to perform to this day, and most of the cells are barren and either dry or open water, the latter attracting waterfowl.

The Technical Expert group has noted that nitrogen leaching is a potential issue, and that the movement of groundwater at the sites under consideration has not been fully investigated.

4.4.4.2 Lack of data on nitrogen flux for native trees

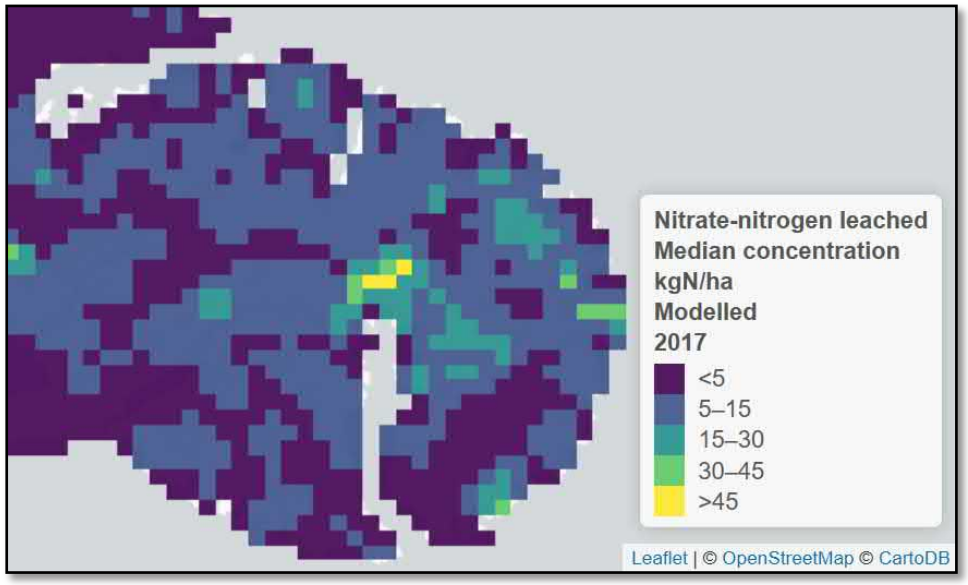
The Duvauchelle native tree trial has yet to produce nitrogen flux results, but an interim report based on literature review only estimates that the system will result in nitrate leaching of 15 - 60 kg/ha/yr, and further notes that regular removal of the grown native vegetation will be required to avoid the captured nitrogen being simply returned to soil[50].

The report further notes that this is similar to pasture farming in Canterbury and "patches of Banks Peninsula". However, the map below from Statistics New Zealand (2019) shows that relatively little land on Banks Peninsula exhibits more than 15kg per ha per year of leaching (turquoise on the map below) and very little at the upper end (>45kg/ha/yr – yellow in the below map). The yellow and green areas in the map coincide with the only dairy farms located around Akaroa Harbour.

If the level of nitrogen leaching was to be in the upper portion of the estimated range (>30kg/ha/yr), it would make this property one of the worst on Banks Peninsula – *the equivalent nutrient loss to a dairy farm*. Further, this estimate may not take into account the high level of soil moisture (field capacity or more) that will be maintained year-round, which will increase drainage, runoff and nitrogen leaching, and is contrary to best practice for irrigation to minimise leaching[51]. Further, maintaining the soil at field capacity may produce anaerobic conditions, impacting the health of the trees and reducing nitrification[52] (the first stage in natural nitrogen breakdown).

As well as environmental harm and reputational risk, there are also potential consenting issues raised by this increase. If irrigation to land is chosen, the Council needs to show good environmental stewardship by improving, not degrading the level of nutrient runoff from the selected irrigation site.

Figure 14 Nitrogen leaching levels on Banks Peninsula



[49] Selwyn Waihora Water Management Zone 2015
[50] Beca Report July 2020 Appendix C
[51] DairyNZ 2011, p9
[52] Tektus 2020 (3.24)

4.5 Highest social impacts

The Inner Bays option has the highest social impacts of the options proposed. This is due to the proximity of the wastewater infrastructure to communities and homes near the Treatment Plant site at Akaroa, in Takamatua and in Robinsons Bay. However, the consultation document neglects to mention these impacts, despite these concerns being well known to Council staff and to the Working Party.

4.5.1 From the storage pond location

The biggest social impact is on Robinsons Bay because the storage pond is located in the upper valley area adjacent to Sawmill Road and a number of houses as shown in the image below. These are not flagged in the consultation document views.

The white arrows indicate the location of the six houses closest to the site. The brown shading indicates the heritage area which housed the mill, millpond, tramway and ancillary buildings. The brown arrow indicates the now abandoned cottage lived in by former mill owner, Frederick Wynn Williams.

Figure 15 Lower part of Robinsons Bay site accurately indicating location of storage pond

- These properties will be severely impacted during the construction period, when the pond (occupying a construction area the size of four football fields) is excavated and the bund and channel along Sawmill Road are constructed. Noise, mud, dust and truck movements will impact on the nearby residents and those down the valley, and this is expected to take up to a year.[53]
- In the event that there are issues such as midges, odour, noise, pest birds, inadequately treated water coming through from the Treatment plant, or health impacts, then these are much more likely to cause adverse effects than if the storage pond was placed further away from homes.

[53] Pers comm Kylie Harris after consultation meeting

- The pond will be surrounded by a high fence and have a gravel road around the bund perimeter. The bunds cannot be planted to screen them because embankments must be grassed to enable leak detection. The pond will be kept as empty as possible for as much of the time as possible, exposing its plastic lining, as its purpose is to provide capacity for large surges of water in wet weather.
- Hence there will be a visual impact from properties that view this site, and from Sawmill Road, Robinsons Valley Road, and further afield from the Okains Bay Road, particularly as the pond will be an industrial structure – both in scale and character - introduced into this visually sensitive heritage landscape.
- It is reasonable for residents to have an ongoing concern about the potential for odour and midges.
- Residents downstream from the storage pond are at an ongoing elevated risk of property damage due to a dam burst and likely to suffer from stress during heavy storms or earthquakes.
- It is reasonable to expect property values in the vicinity of the storage pond and those downstream of it to suffer, and for there to be difficulties with selling properties given the to risks associated with wastewater and the stigma and cultural offensiveness attached to it.

4.5.2 Impacts of the irrigation fields

The irrigation fields at Robinsons Bay will mean that native trees are planted over a significant archaeological site, and it is particularly close to the historic Pavitt Cottage. Dense planting is planned to within 5m of the cottage site boundary which will cause shading at the back of the cottage and obscure views of the heritage site with which it is associated.

The irrigation fields at Hammond Point and Takamatua are also close to houses and to the coast.

4.5.3 Cumulative effects on Akaroa area

The Inner Bays option will add to the effects that Akaroa will experience from the new Treatment Plant. Substantially more earthworks will be required at the entrance to the town on Pond Site 10 to accommodate the wetland, and this may have a lasting visual impact on views of the site from the State Highway and the town.

To compound matters for the residents of Takamatua and Robinsons Bay they will not be reticulated on the network, so they will gain no benefits from the system from which they will bear the effects, but will pay some of the costs from their rates. They will bear the effects of the system and contribute to its cost via rates (in addition to the cost of their own septic systems), but will receive no benefit from it.

4.5.4 Lack of consideration for community concerns

It was **disappointing to see that Council staff failed to include any of these considerations or impacts in their presentation of the advantages and disadvantages of the Inner Bays option** in the consultation document, although they were well aware of the issues. The Working Party was initiated because of the community concerns and it has met with these staff 26 times. A letter signed by 227 people affected by the Inner Bays proposal setting out the risks and concerns they had with this system was tabled prior to staff finalising the consultation document.

The Working Party Joint Statement recognises that community concerns are ongoing in its Executive Summary: "*Many residents in these communities have significant concerns and worries about the potential negative impact on their homes and surrounding environment which is so special to them.*

It will be important that as the Council makes its decision these impacts on these communities are considered and recognised."[54]

4.6 Cultural Impacts

The Inner Bays option has been assessed as meeting Ngāi Tahu cultural values.

We question whether the cultural concerns will be met in practice by the Inner Bays Irrigation scheme, if there is a significant risk of insufficient capacity resulting in direct run-off of wastewater and nutrients to nearby streams and/or increased frequency and volume of overflows from the wetland at Pondsite 10.

Cultural values are not limited to those of tangata whenua[55], and the Inner Bays proposal has a high impact on the cultural values of Robinsons Bay and for Canterbury in general, particularly because of its impacts on a significant heritage site and its surroundings.

4.6.1 Impact on heritage

Robinsons Bay contributes significantly toward Canterbury's heritage because the first power sawmill in the province was erected there in the 1850s on what is now [redacted] Sawmill Road - the Thacker land. The mill owner's cottage still stands on the adjacent site having been subdivided from the main site in May 2000[56] when it was purchased by a descendant of the original mill owners – the Pavitt family, for the purpose of restoring it and retaining it for the entire extended family of descendants to enable a deeply meaningful connection with their ancestral roots.

The Pavitts had pioneered the design and construction of this first mill in early Canterbury in conjunction with Samuel Farr, who later became one of Canterbury's most well-known architects. The mill was an extraordinary achievement, and many of the settlers of the bay and the wider area began life in Canterbury as mill hands. The extent of ancestral connections with this site and the cottage is much greater than the Pavitt family alone. It extends to many families including later mill owners, the Hughes, Saxtons and Williams, and worker such as the Tizzards, Kotlowskis, Sagars, Duxburys, Philips, Stewarts and many more.

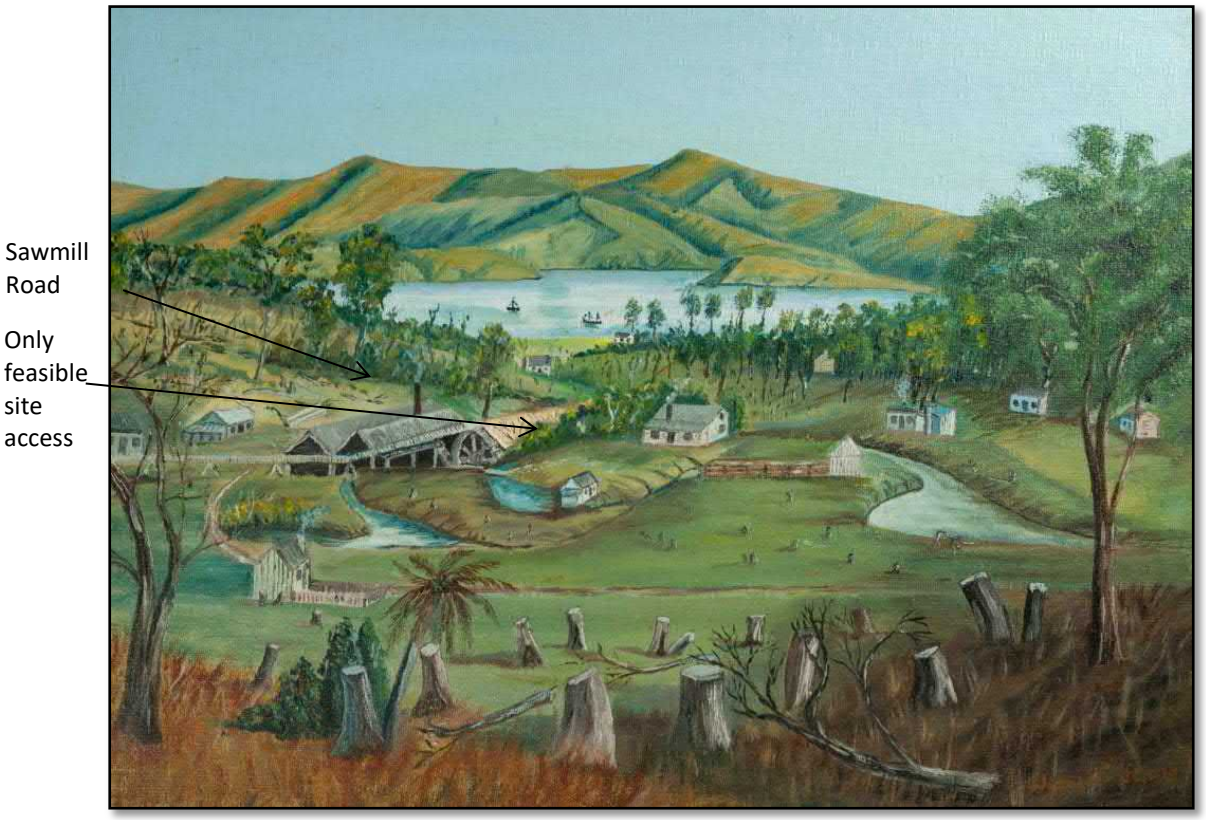
A history of the mill was written in 1991, by Jessie Mould[57], and the site has been marked since 1987 when the Historic Places Trust Christchurch branch erected an information board on Sawmill Road, in conjunction with Orville Williams, who lived in the cottage at the time and was a descendant of the Williams family who owned the mill when it was converted to steam.

Figure 16 below shows the cottage and mill site after the original water wheel had been augmented with the steam driven system. It was chosen by Gordon Ogilvie as the feature image on the back cover of "Banks Peninsula, Cradle of Canterbury", his definitive reference book on the area.

Council staff appear to have been extremely reluctant to acknowledge the existence or importance of this archaeological site and the significance of the area to Canterbury history. Repeated requests made at the Working Party for a heritage assessment were declined and the consultation document does not mention the impacts on this heritage. However, a recent archaeological assessment of the neighbouring Pavitt Cottage property (provided by the Pavitt Family Trust) has been included as Appendix W to the Beca report dated July 2020. This describes the archaeological values of the cottage, the associated mill site on the Thacker land and the heritage character of Robinsons Bay valley.

[54] Working Party JS 2020 p1
[55] MCH Cultural Well-Being
[56] Maxwell and Hubert 2020, p13
[57] Mould 1991, p39

Figure 16 Robinsons Bay Sawmill circa 1870



The impacts on heritage values and archaeological site will be substantial.

- The only feasible access to the Thacker site is across the location of the mill itself.
- The storage pond and its associated earthworks will be less than 150m from the cottage, intruding into the area to the left of the mill as shown in the painting and dominating the area.
- Trees will be planted and irrigated with wastewater over the sites of the historic features evident in this painting – the mill ponds, tramlines, flume and related buildings.

FOBP, and indeed most of the residents of Robinsons Bay and descendants of the mill owner and workers, are passionate about restoring native forest and improving biodiversity, but this area needs to be kept open as a heritage site so that its story can be told and its archaeology undisturbed. This is not an appropriate place to cover in a dense planted forest.

The Pavitt Cottage is particularly at risk. The Pavitt Family Trust funds the maintenance and upkeep of this important heritage building from the income gained from holiday stays. The income will be severely impacted during construction, and then from the stigma, safety concerns and visual impacts of the storage pond so nearby. The cottage is at a physical risk of severe damage should the dam burst modelling prove incorrect, and from shading from trees located 15m from the rear of the house.

It seems an inconsistent application of justice to shift the treatment plant from the Takapūneke site out of respect for the historical and cultural events and values associated with the site, only to blight another significant historical and cultural site with wastewater and its associated infrastructure.

The consultation document neglects mention of these constraints and instead attempts to present a picture of native tree areas with public access. The heritage in Robinsons Bay is mentioned on the

final page of the consultation document with the suggestion of a future opportunity for "*enhancement of visitor information at the historic sawmill site*"[58] As discussed in this submission, if the Council wishes to establish native bush areas for the benefit of biodiversity and carbon sequestration, this is not an efficient or effective use of funds. To state that visitor information about a heritage site would be enhanced when the site itself has been destroyed is disingenuous.

[58] Akaroa Treated Wastewater Consultation document p19

Chapter 5 Consideration of Goughs Bay option

The Goughs Bay option is much simpler than the Inner Bays option. Water would be pumped over the crater rim to a single remote farm on an outer headland area. The area is sparsely populated and no cultural or heritage sites are impacted by the scheme.

The proposed farm at [redacted] Goughs Bay Road is 614ha. Based on the Council costing to purchase the site, we assume that it intends to purchase the entire farm, and retain all of it apart from the dwelling. ($4.2million has been allowed to purchase the site; RV is $5.3million; with a land-only component of $4.6million[59].) The Goughs Bay option therefore has plenty of room for expansion, as the engineers have identified at least 112ha as suitable for irrigation.

With the amount of land available, the entire system can be constructed well within the design parameters, rather than pushing them to the limits, so setbacks from streams and neighbours are much greater. There is no need for a wetland facilitating overflow to the harbour as there is sufficient room at the farm for all the storage. Although the 20% I&I reduction is planned, it is not critical because of the additional irrigable area available.

However, perhaps because Council staff have been so focussed the Inner Bays option, much less effort has gone into detailed design for this option and unfortunately this means that opportunities to work with the landowner and the surrounding community have been missed, and both are now alienated from the process.

5.1 System design and components

The area for the proposed irrigation system is on the headland containing the Crown Island stream. The storage ponds are on the northern side of the stream gully and the native trees would be planted on the southern side as shown in Figure 17 below.

The storage ponds will be built into solid rock and either completely in ground or with only small earthen bunds on the lower side. They will not be visible from public places or any houses, and the nearest house is approximately 700m away and on the other side of the ridge in Hickory Bay. Should the pond fail, then the drainage path is to the Crown Island stream and out to the ocean. There is no infrastructure downstream of these ponds.

The irrigation field will be set back over 100m from the Crown Island stream, but will come up to within 5m of the neighbouring property. This is a grazed farm; there is no sensitive activity adjacent to the irrigation field.

The design is based on achieving 20% I&I reduction, but there is plenty of room to expand.

No wetland is needed because no overflow discharges to waterways are anticipated, meaning substantially less earthworks on Pond Site 10.

[59] Canterbury Maps

Figure 17 Goughs Bay Farm

5.2 Constraints and Risks

There are fewer constraints and risks with the Goughs Bay option than with the Inner Bays option, principally focused on the distance from the plant and altitude. Toward the end of the process there has been concern expressed by residents using the Hickory and Goughs Bay road about the potential environmental and social impacts.

5.2.1 Pumping over hill and distance from the plant.

The longer pipe and distance from the plant are disadvantages for the Goughs Bay system. Pumping over the hill requires more energy and therefore greater operational costs, and staff and contractors will need to travel further to access the site.

The increased risk of pump or pipe failure is identified as a risk by Beca[60], but the level of risk is not quantified.

5.3 Environmental impacts

The wastewater will be the same quality as for the Inner Bays option, and irrigated at the same rate. However, there is much less risk of impacts from nitrogen leaching because:

- The irrigation field is set back much further from the main stream
- The stream itself drains to the open ocean, not to a shallow mudflat
- Once it reaches the ocean it will be rapidly dispersed
- There is no need for any discharge to the Inner Harbour.

[60] Beca Report July 2020 Table 13-1 p150

The trees will be placed in an environment near to naturally regenerating native trees.

5.3.1 Wildside impacts

The term Wildside is a description applied to the outer south-eastern bays and hills of Banks Peninsula because this area contains substantial areas of land protected for its biodiversity value, including the private Hinewai Reserve, the Council's Misty Peaks Reserve, DOC's Ellangowan Reserve, bush covenants on private properties and the Pohatu Marine Reserve. A combined approach to pest control across the different land tenures has developed over the years, led by the Banks Peninsula Conservation Trust, and the Wildside is the area where Pest Free Banks Peninsula aims to start on its ambitious goal to eliminate pests.

There is a focus is on natural regeneration and hence the community is concerned about irrigated native plantings as this may impact the ecology of the area.

The community also doubts that irrigated native trees can be successfully established, given the altitude and exposed nature of the site.

5.3.2 Contaminants

The neighbour below the irrigation field on the headland is concerned about nutrient and emerging contaminants leaching to his property, affecting its antibiotic free status.

The Council should consider providing detailed information about this risk to the community and shifting the irrigation field further back from the boundary given the unconstrained nature of the site.

5.4 Social impacts

The social impacts of this system are also much less than the Inner Bays option:

- The nearest house is 720m from the storage ponds (seven times further than for the Inner Bays option), and there is a hill between it and the storage ponds. These ponds will not be visible from anywhere except the farm itself. The nearest house is also 1200m from the irrigation field, over 50 times further than for the Inner Bays option.
- This means that if issues develop with odour or midges from the storage ponds or irrigation, there is little risk to people.
- No heritage sites are affected.

However, residents of the area have expressed concern about aspects of the option including the impacts during the construction..

The impacts during construction largely stem from the use of the narrow roads to install the pipes. The pipe will be routed up the Long Bay Road, which should be wide enough for a traffic light system during construction. The pinch point is approximately 3kms along the Hickory Bay road before the pipe reaches the farm. An existing farm track that is already used by vehicles will need to be shingled to enable larger vehicles to access the site. Spoil from the dam construction is to be kept on the site.

Construction will be extremely disruptive to local residents and road users for any of the land-based options. The Goughs Bay option will affect fewer people than the Inner Bays option – and perhaps the Council can find a way to compensate the affected residents, or to plan work to minimise the time when this road section needs to be closed.

5.4.1 Cumulative effects on Akaroa

The cumulative effects of the Goughs Bay option on Akaroa would be less because there is no need for the wetland at Pond Site 10 and the ponds and irrigation fields are distant.

5.5 Less Sensitivity to modelling assumptions

While this option is still sensitive to the same modelling assumptions as the Inner Bays option, the risks of critical failure if they prove incorrect is much less because there is ample room for expansion on the site and because the site is distant from sensitive activities such as houses.

5.6 Community and Landowner opposition – an opportunity missed

The most disappointing factors with regard to the Goughs Bay option is that the Council has so palpably failed to work constructively with either the landowner or the community.

5.6.1 Once was willing

The landowner was a willing participant, aiming to use the water to improve his pasture productivity for cattle grazing, until the point where he found that MPI would require stand-down periods for milk or meat from these cattle, and that he alone would face the entire risk should this cause issues. He became worried that neighbours could report compliance concerns to MPI and that regardless of whether he was in breach or not, he would then need to deal with time-consuming and stressful bureaucratic processes.

It seems that the Council, in their dealings with both this landowner and the Pompeys Pillar landowner, were not prepared to accept any of the risk involved with irrigating the wastewater to private farmland. They did not find out and inform landowners of the constraints involved in the first place, nor come up with a plan to manage those constraints and risks when the landowners became concerned. Had they done so, the Goughs Bay option of irrigation to pasture might have continued with a willing owner.

5.6.2 Community values ignored

Similarly, once the landowner was unwilling, and the decision was made to use a native tree irrigation system instead (because this requires less storage), the Council failed to work with the Wildside community and develop an environmental program that met their values and aspirations.

Instead of involving this knowledgeable community in the project and working to find ways to add native afforestation to boost naturally regenerating areas on the farm (including blending the planting in with existing forested areas to restore a far greater area of marginal land), the native trees are placed in the middle of the farm on the most productive land. There has been no attempt to design this as a Wildside enhancing project or to find ways to support the Wildside aspirations as a form of compensation to the people of this area.

5.6.3 High level Fire ponds

Firefighting capability is a matter of utmost importance to remote rural residents and to the Wildside with its huge investment in native forest. While pumping wastewater over the crater rim has its downsides and costs, it also opens the opportunity to create high altitude fire ponds that could be kept full at all times (replacing water lost to evaporation or used for fire-fighting). High altitude ponds are very valuable for firefighting as they enable helicopters to fill monsoon buckets without having to fly water uphill. This greatly increases the speed at which they can transfer water from the source to the fire. A high altitude fire pond at Hinewai was the saving factor during the 2011 fire there.

An obvious site for a fire pond is on the relatively level land near the cabstand en route to the Goughs Bay site.

5.6.4 Renewable energy ignored

A downside to the Goughs Bay scheme is the energy cost of pumping the water over the hill. It seems that no effort has been put into identifying alternative energy sources such as solar panels or wind turbines at Pond Site 10 or on the site to generate this energy. Some energy could potentially also be recaptured as the water makes its way down the hill on the other side.

If this was done it could bring the running costs down and make the system more climate friendly.

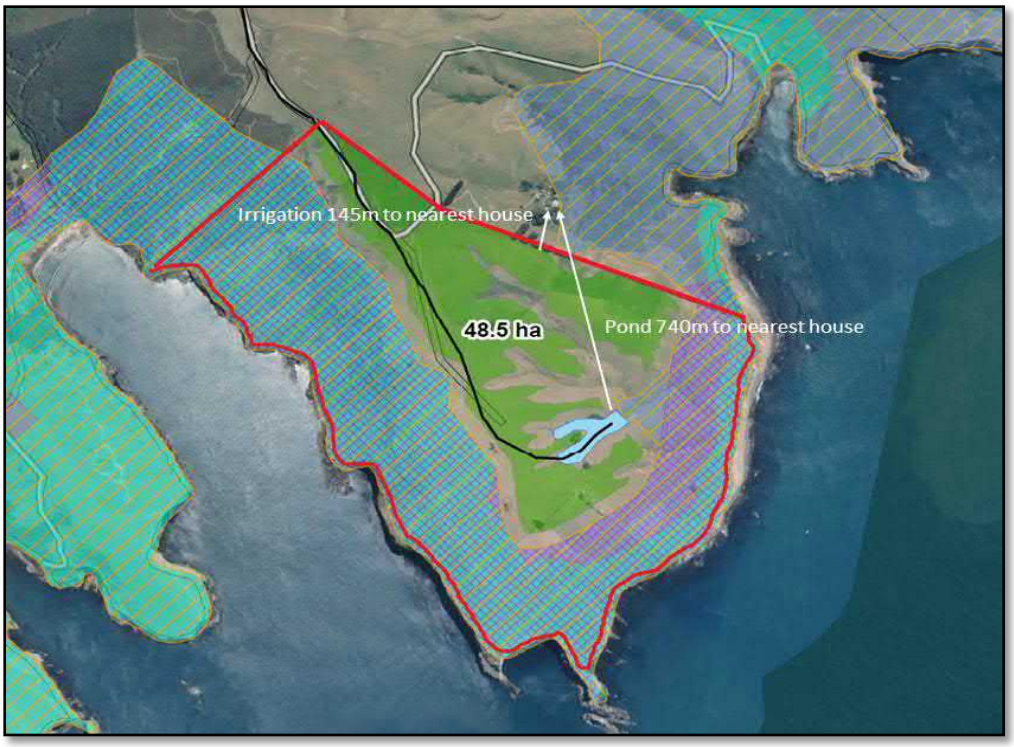
The Goughs Bay option has some potential advantages, and could represent beneficial re-use of the treated wastewater if it was either made into a far more extensive native regeneration scheme, or if the Council were able to ameliorate the landowner and community concerns with regard to a pasture-based scheme. Since neither of these are proposed, we do not support this option in its current form.

Chapter 6 Consideration of Pompeys Pillar option

Like Goughs Bay, the proposed site at Pompeys Pillar is a remote farm with few near neighbours, and with low visual impact on the landscape. The proposed irrigation area is on a pastoral headland, with no streams or areas of ecological sensitivity. The impact on neighbours and the local environment would be minimal, but the scheme again represents a lost opportunity because Akaroa's water would be pumped out of the catchment and used to establish a small area of planted native bush, rather than re-used in Akaroa where it is needed.

The key difference is that, unlike Goughs Bay which was recently purchased by its current owner, the Pompeys Pillar farm has been in the same family for six generations and has strong heritage value and ancestral connections to its owners. The area identified is at the heart of the farm and is financially critical to the farm. Given that this option would likely require compulsory purchase, the injustice brought upon the family would be severe. We consider such a proposal to be a violation of natural justice.

Figure 18 Pompeys Pillar location



We also agree with the concerns expressed by the landowner and Wildside community that establishing native trees on the coastal and windy headland would be very difficult and they could well take many years to establish and be more stunted in form, leading to less canopy intercept.

This could be offset by using more of the land zoned as Outstanding Natural landscape, as it makes no visual sense to plant trees on the centre of the headland and then leave a bare strip in the Outstanding Natural Landscape around the edges. **We consider that any perceived benefits of this option do not justify the social injustice, and hence do not support it.**

Chapter 7 Consideration of Harbour Outfall option

In 2015 a harbour outfall from Childrens Bay formed part of the new Wastewater Treatment Plant resource consent application to Environment Canterbury. This component was declined on grounds that it would have a significant adverse effect from the perspective of tangata whenua and that the Council had not adequately considered alternatives.

The Harbour Outfall now proposed differs from the original 2015 proposal in several key ways:

- The outfall will start at Glen Bay rather than Childrens Bay. It will be serviced by a treated wastewater main passing through Akaroa which can double as a non-potable water supply ("purple pipe")
- The standard of wastewater treatment will be higher than previously proposed; wet weather bypass flows have been eliminated, and ultrafiltration replaces microfiltration achieving a higher level of disinfectant. An outflow buffer pond is provided at Pond Site 10 for the Harbour Outfall option enabling water to be tested prior to release.
- If non-potable re-use is included, the wastewater quality will be further enhanced by UV treatment.

These differences do not address the original reason for declining the harbour outfall, but they do **allow it to progress from a pure disposal system to an enabler of wastewater re-use in Akaroa.**

7.1 Environmental and social wellbeing

Of the four options, the Harbour Outfall has the lowest environmental and social impacts.

The combination of the higher treatment standard and placement of the outfall in the middle of the harbour, into deep water where there would be maximum dispersal, means the effects on Akaroa harbour (including risk to human health) will be negligible, and represent a substantial improvement over the existing outfall.

The social impacts of a harbour outfall on the community would be minimal; while there would be disruption caused by laying the new pipe through Akaroa, this would occur in tandem with the redirecting of the sewer main and other necessary network changes, which are required for all options.

There is no need to acquire land, and there will be no storage ponds or other structures to create visual and social impacts, apart from the treated outflow pond. Because the outfall is in the middle of the harbour, there is no impact on recreational activity at the shore.

7.2 Economic impact and risk

The Harbour Outfall has the lowest cost and risk because:

- It is gravity fed, so is technically the simplest
- The outfall itself requires no electricity to run and generates no operational greenhouse gases
- It has no practical limits on volume, making it the most resilient in the face of climate change and uncertainty around growth. It could readily accommodate expansion, such as reticulating Takamatua and Ōnuku.

7.3 Sustainable development through purple pipe

The pipeline through Akaroa that serves the outfall would double as a purple pipe running through the town centre, taking the first step toward allowing Akaroa to reclaim its wastewater by making it

available in the town. This is in contrast to sinking cost into piping and disposing of the wastewater elsewhere. As noted in the consultation document, adding connections for the first stage of purple pipe reticulation (municipal re-use) is dramatically less costly being $270,000 rather than $3.7 million for the land based options.

Re-using the treated wastewater requires a higher level of treatment than disposal, and the cost of UV treatment has been already factored into the new plant build. If re-use is adopted, any wastewater returned to the harbour would also be receiving this even higher level of treatment - to a level safe for garden watering, including a further 1000-fold virus removal. This would ensure that the health risk from shellfish gathering or harbour recreation activities is essentially zero.

This would commit the Council on a reuse path and could provide a strong incentive to lobby government to develop the regulatory mechanisms required to facilitate private re-use.

7.4 Cultural wellbeing

The Harbour Outfall as proposed still does not address cultural concerns of tangata whenua. In considering this option Council will need to weigh up the following:

- Could Ngāi Tahu cultural concerns be sufficiently mitigated, by, for example, including an expanded wetland scheme similar to the one proposed for the Inner Bays option, and the Duvauchelle wastewater scheme?
- How can cultural wellbeing be integrated and balanced with social, environmental and economic well-being?

Chapter 8 Consideration of Costs

The costs for the four disposal options presented in the consultation document range from $45 million at the low end for the least expensive option (harbour outfall), to $76 million at the high end for the most expensive option (Pompeys Pillar).

These costs include around $30 million for relocating and replacing the current treatment plant at Takapūneke, to address cultural issues. The cost of the disposal options is therefore $15-$46 million.

This compares to a current LTP budget of $35 million for both the new treatment plant and the wastewater disposal, meaning an additional $15-$41 million needs to be budgeted, depending which option is chosen.

All the options are extremely expensive and costs have escalated substantially since the last round of consultation.

8.1 High cost per connection

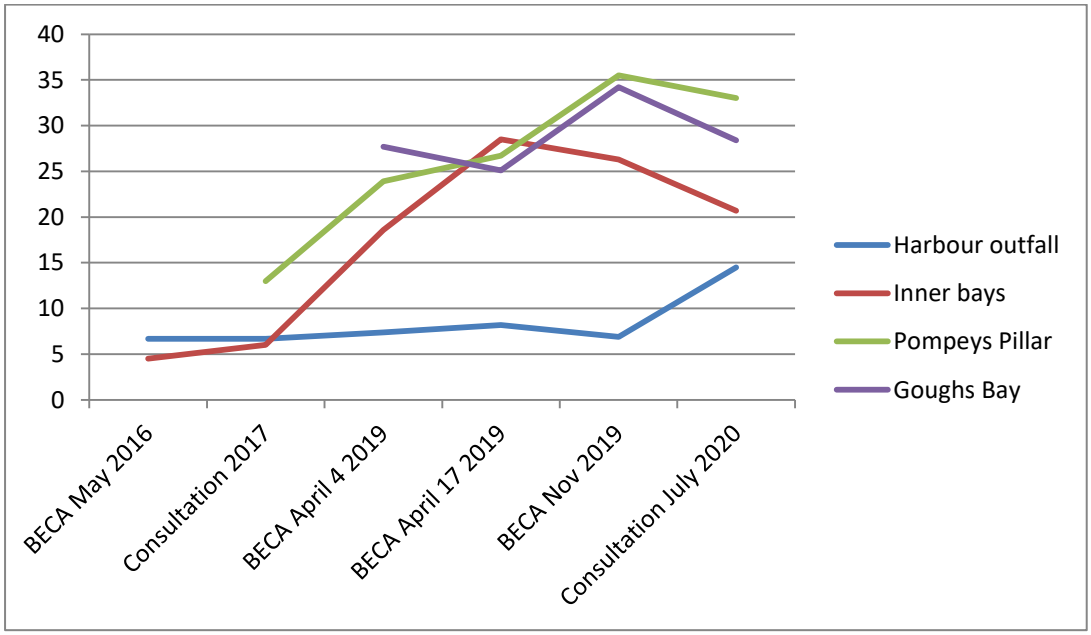
The cost per connection for this project is extremely high: Akaroa has around 830 connections[61], so the total cost is $57,000 - $68,000 per connection. This is substantially higher than the cost of a modern on-site wastewater system such as an Oasis Clearwater.

Given that $30 million is already being incurred by Council to discontinue treatment at the current site and build a new Treatment plant at the other end of the town, we submit that the further costs for the disposal need to be both carefully reviewed and weighed against the overall benefits and risks of the options.

8.2 Cost variability

During the past four years of investigation, the costs of the various disposal options have not only risen dramatically, they have also varied significantly relative to each other. The chart below shows the varying cost of each option, presented at different times to the Working Party.

Figure 19 Changes in cost over time



[61] Pers comm, Kylie Hills Consultation meeting 13 July 2020

The options proposed are similar to those proposed in 2017 but costs have increased by between 116% - 245% since then. This is in part due to the increased volumes since faulty flow meter was replaced and accurate readings taken, meaning that storage ponds and land area required are now much larger. It also reflects a greater understanding by Council staff of the costs and effort involved in the planting and establishment of native trees.

The details of the options have also changed over time, including Pompeys Pillar and Goughs Bay changing from pasture to trees, and the inclusion of a wetland in the Inner Bays option with subsequent reduction in the scale and construction cost of the storage dam.

8.3 Council cost revision

The final CAPEX costs presented in the Beca report (July, 2020) were prepared by Council staff, who reviewed and revised the costs previously prepared by Beca's quantity surveyors in their November 2019 report. The table below lists the November 2019 Beca estimates and the costs after revision by the Council used in the consultation document.

Note: the costs given in the consultation document include the $30 million for construction of the new treatment plant and modifications to the network that are common to all options. We have removed this from the costs below to better illustrate the comparative cost of the disposal options.

Option	Capital cost Beca estimates November 2019	Capital cost Staff revised estimates March 2020	Difference
Inner Bays	$32 million	$27 million	**-$5 million**
Goughs Bay	$40 million (irrigation to pasture)	$35 million	**-$5 million**
Pompeys Pillar	$41 million (irrigation to pasture)	$40 million	**-$1 million**
Harbour outfall	$10 million	$18 million	**+$8 million**

For the two outer bays options, the estimated cost has reduced, which would be expected given the change from pasture to tree irrigation. However, the cost of the Inner Bays option has also fallen substantially, despite the scheme remaining essentially unchanged. The largest change, however, is the escalation of the Harbour Outfall cost by 80%.

The following significant changes were made by Council staff in this revision:

- Overland pipeline costs have all risen significantly, from $300-$550 per metre to as high as $1600 per metre, particularly those required for the harbour outfall which have more than doubled. As a result the cost of the 4.24km pipeline from the Treatment Plant to Glen Bay is now almost as expensive as the 5.25km *high pressure* pipeline to the cabstand, and *more expensive per kilometre*.
- The cost of planting irrigation areas has almost halved. The previous Beca costings included $9 per tree, which is in broad agreement with the costs reported by native forest regeneration groups such as Tāne's Tree Trust, while the new Council-provided cost is only $5 per tree which is low by industry standards .[62]
- The amount of **contingency and overhead** relative to raw build cost has remained relatively unchanged (at 71-80% of construction costs) for the land-based options, but has **increased dramatically for the harbour outfall from 82% to 125%.** Most of this is additional design cost (including $1.9m or 40% of construction costs for the harbour outfall pipeline) despite substantial design having already been carried out for this option prior to the resource

[62] Thompson 2019, p22

consent application in 2015. If the additional design is because of the changed route via Glen Bay, the original outfall from Childrens Bay option should also be included, as it would be the cheapest.

- Harrisons Quantity Surveyors note this discrepancy and suggest this appears to have been an attempt to increase costs for the harbour outfall while reducing costs for the Inner Bays option. They also highlight the number and breadth of exclusions and assumptions applied by Beca, noting that these lead to pricing uncertainty and a real chance of significant variations.[63]

The above changes are significant because they strongly affect the relative cost of the harbour outfall versus land-based disposal. Given the overall level of cost variability, and especially the sudden final change in relative costs, we question their dependability and strongly urge that these changes and the costs in general be reviewed by an independent quantity surveyor.

8.3.1 Anomalies

We also note the following anomalies and issues in the costings:

- The pipe from the fire station (PS-615) to the domain (PS-614) is calculated as 240m, but this distance is over 700m in a straight line
- The I&I reduction cost has very little contingency, and commentary indicates the work will be constrained to budget. Given the critical nature of this component to the Inner Bays option in particular, this adds substantial risk of failure
- The original Beca costings contained a substantial list of assumptions and waivers which highlight the uncertainty in the costings overall.[64]

8.4 Different options have different risk mitigation factored in

When deciding which option to pursue, the Council will need to weigh up the relative cost of each option against the known or potential risks. However, this is made difficult by the uncertainty in the costings.

The land-based disposal options all share the risk that the system will be undersized, which is why Eco Eng recommend a phased approach over many years to determine the true water uptake that can be borne by the chosen site.

However, the two outer bays options have additional land available: at Pompeys Pillar there is an additional 42 ha of further irrigable land closer to the coast that has been excluded because it falls within the coastal and high natural character landscape areas (by way of contrast, the Hammond Point irrigation area also falls within the coastal and high natural character areas, but has not been excluded from the Inner Bays option)[65]; at Goughs Bay a total of 45 ha of year-round irrigating and a total of 112 ha (including areas that can be irrigated in summer only) was identified for spray irrigation to pasture – more would be available for dripper irrigation to trees because of reduced site setback and slope constraints. This means their stated cost includes this risk mitigation factor.

In contrast, the Inner Bays option involves the purchase of the minimum land area required to make the scheme viable, and even securing some of the land identified is in doubt (Takamatua, Hammond Point). To compare like with like, the Inner Bays option should include *double* the current land purchase cost, i.e. include another $3 million as contingency for additional land purchase.

The Harbour Outfall is a low-risk option because it does not have a finite capacity, and the impact on the environment of the harbour and risk to health has already been extensively studied in 2015 prior

[63] Harrisons letter August 2020
[64] Harrisons letter August 2020
[65] Beca Report DRAFT Nov 2019 Appendix G

to the consent application being made (NIWA 2014). We further note that the treatment standard proposed is now higher because the membrane filter has been upgraded from microfiltration to ultrafiltration. In addition bypass flows during very wet weather have been eliminated, so the health impact will be even lower.

8.5 Cost of decommissioning Takapūneke

We note that the project CAPEX costs for moving the treatment plant do not include the cost of the demolition of the existing wastewater treatment plant at Takapūneke, which is likely to be substantial.

8.6 OPEX costs

Unlike the harbour outfall, all of the land-based options have operational costs, ranging from $44,000 to $177,000 per annum, and equating to an additional $53-$213 per connection per year.

Chapter 9 Consideration of carbon

One of the arguments presented in favour of the land-based options is that the native trees would store more carbon than the scheme would emit, thus supporting the Council's carbon neutral goal. In contrast, Council staff argue that the Harbour Outfall option conflicts with this goal because it is carbon negative, i.e. it generates more emissions than it sequesters.

These assertions require some context.

The emissions listed for each option in the consultation document are not just those from the construction and operation of that option. They include the carbon emitted from constructing and operating the treatment plant.

9.1 Emissions from Harbour Outfall

The operational emissions of the Harbour Outfall itself are zero, so on its own the Harbour Outfall disposal releases emissions during construction only.

The amount released by its construction (a total of 157 tonnes)[66] equates to 4.4 tonnes per annum over the scheme's lifetime; this is around *one quarter the total emissions of a single typical house (20.56 tonnes)*[67].

This could be offset by planting just 0.54 hectares of native trees (e.g. on pond site 10). Offsetting the entire operating emissions including those from the treatment plant would require around 5 hectares of planting (assuming one hectare sequesters 286 tCO2e)[68.]

9.2 Emissions from land based schemes

The net emissions sequestered by the land-based schemes over their lifetime range from 4,459 to 8,879 tonnes.

Whilst this is a positive outcome, the benefit needs to be weighed against the cost.

The marginal capital cost of the land-based disposal systems (i.e. over and above the cost of a Harbour Outfall) per tonne of carbon sequestered ranges between $1,092 and $3,856 per tonne depending on the option selected, compared to the current market cost of $25 per tonne.

If the Council wishes to use the treated wastewater's water and nutrients to sequester carbon, it should be seeking to maximise, not minimise the area of trees being established.

For example, the Council could elect to spend the additional funds required for the land-based options for purchasing marginal land to revert to native bush, following the Hinewai model. Based on the current RV for Hinewai of $2,400 per hectare, the additional funds spent on land disposal could instead purchase between 4,000 and 9,000 hectares of marginal land for native regeneration and carbon offsetting, which could offset between 1 million and 2.5 million tonnes over the scheme's lifetime.

9.3 Cost effective carbon sequestration

We strongly support the Council's desire to become carbon neutral, and agree that native forest is an excellent way to achieve this.

[66] BECA Report July 2020, Table 11-10
[67] MOTU April 2014, p12
[68] Beca report July 2020, p143

However, we would argue that this aim could be better met through the purchase of marginal land at low cost, and the natural regeneration process, rather than via a land-based wastewater disposal system and planting native trees at very high cost.

We therefore consider that the carbon benefits presented in the consultation document are simplistic and misleading.

Chapter 10 Summary of views on options

In this section we consider and weigh up the extent to which the options proposed meet the requirements of the Local Government Act to take a sustainable development approach and take account of the social, economic environmental and cultural wellbeing of communities now and in the future.

We then consider whether the Council has considered all reasonably practical options and the advantages and disadvantages of each, including the relationship of Māori to their ancestral land and water sites, and the views and preferences of people likely to be affected or with an interest in the decision.

We consider whether each option is consentable under the Resource Management Act and the risks associated with it.

10.1 Sustainable development approach

We do not consider that the options presented in the consultation document have taken a sustainable development approach.

10.1.1 I&I levels remain unsustainable

As discussed throughout this submission, the Akaroa wastewater network suffers from excessive infiltration. None of the options presented deal with this problem in a manner that is sustainable and provides for the wellbeing of communities now or in the future.

While a 20% I&I reduction is proposed for the land based options, funds have not been prioritised to this, but are subject to a cap. This means the approach is equivocal – 20% might be achieved for the $3million allocated or it might not.

Regardless, the result of not comprehensibly fixing the I&I issue is that storage ponds are much bigger, more expensive and create greater impacts than necessary and more land is required for the disposal than necessary.

In the case of the Harbour Outfall no I&I reduction is planned.

In either case, raw sewage overflows are anticipated at least every 10-15 years based on historical rainfall patterns[69] and the entire system is vulnerable to an increase in raw overflows under the increased intensity of storms and sea level rises that are now inevitable due to climate change.

10.1.2 Water shortages

None of the options address the water shortages experienced by Akaroa every summer, or the increased intensity and frequency of droughts forecast for the area.

The land based options all seek to pump water far away from Akaroa to places where it is not needed, rather than recycling it back into the town for summer use.

The Harbour Outfall option at least facilitates some re-use in Akaroa at minimal cost and the infrastructure created would enable future expansion, but unless there is a clear commitment to this, it too will have little impact on water shortages.

10.1.3 Climate mitigation

The options do not take climate change into account – as described above, leaving the pipes in their current leaking state makes the entire system more vulnerable to the impacts of climate change. The

[69] Beca Report July 2020, p115

sizing calculations have not taken into account either fixing the I&I properly, or conversely that unfixed, the I&I issues are likely to worsen. Nor do they address Akaroa's potable water shortages.

10.1.4 Wise use of funds

For the above reasons, none of the options presented are a wise use of funds. What is proposed is a wastewater system that is extraordinarily expensive, especially when considered on a per connection basis, but still does not address Akaroa's water supply, sewer pipe network or its future resilience to climate change.

We also submit that the costs require a careful review.

- There are mistakes in the cost of Pompeys Pillar that inflate the cost.
- The Goughs Bay cost assumes the Council retains or recoups nothing from the sale of the excess farmland. If this is done to provide expansion capacity this should be noted as an advantage. If it is an error it should be corrected.
- The costs of tree planting used for all the land-based systems are well below the industry norms.
- The Harbour Outfall has much higher design and contingency overheads than the other options, despite being the simplest.

10.2 Four well beings

The following table summarises our consideration of the options under the four wellbeings:

Option	Social	Economic	Environmental	Cultural
Inner Bays	Ongoing impacts on residents and communities Risk of odour, midges, dam break. Destruction of heritage site	High cost option Some required sites may not be available. Sunk cost directed away from re-use. Impact on property values	Significant environmental risk from intensity of irrigation, nutrient load and proximity to streams draining to mudflats	Directs most flows to land and includes wetland. However, risk that it will not function as intended. Impacts on heritage values.
Goughs Bay	Impacts on residents during construction. Impact on landowner	High cost option. Sunk cost directed away from re-use	Irrigation is some distance from streams and these drain to open ocean.	Directs all flows to land
Pompeys Pillar	Impacts on residents during construction. High impacts on landowner	High cost option. Sunk cost directed away from re-use	Irrigation is some distance from streams and these drain to open ocean.	Directs all flows to land
Harbour Outfall	Minimum impacts as construction disruption in town concurrent with treatment plant network upgrade	Least expensive, but still over budget Sunk cost directed toward re-use	Minimum impacts from highly treated wastewater (purple pipe standard). Mid-harbour outfall maximises dilution	Directs most flows to Akaroa Harbour Directs some flow to purple pipe re-use

While Goughs Bay and the Harbour Outfall rate the best, we do not consider any of the options to be appropriate because they do not take a sustainable development approach.

10.3 Have all reasonably practical options been considered

We do not consider that all reasonably practical options have been considered.

10.3.1 Lack of I&I reduction

Because the faulty flow meter was not addressed back in 2010, land based options were developed based on false data and then retro-fitted once the true volume of water was known. This means that the poor state of the pipe network and the levels of inflow and infiltration have not been the primary consideration of the Council, and the problem has only been half-heartedly addressed at the end of the process as part of this attempted retro-fit. The Mahaanui Iwi Management plan very sensibly lists "***Reducing volume of wastewater "***[70] as its first policy, but this has not been addressed first. If this was done comprehensively, then land-contact options of any kind become much more feasible and practical because volumes and variability are greatly reduced.

10.3.2 Treatment standard not meeting public expectations

The public has consistently asked for the treatment standard to be higher – at a minimum so that vegetable gardens can be irrigated and more recently to a potable standard.

The Mahaanui IMP explains: *"We would not put treated wastewater on our vegetable gardens so why would we discharge it to the sea where we get our mahinga kai?"*[71]

Our consultation with the local community indicates that if the water was treated to a standard where it was safe to water and eat salad vegetables then they would indeed like to use this on their gardens. The vegetable garden test is a salient one, determining how people feel about water re-use.

Reducing the volume of wastewater entering the system, principally through I&I reduction and also through water conservation measures enables a higher treatment standard as it reduces the treatment plant size and the amount of retentate left from the cleansing process.

10.3.3 No focus on re-use

Despite overwhelming support for re-use expressed in the 2017 consultation exercise[72], none of the options have re-use as their focus.

We submit that if the I&I reduction had been tackled and the treatment standard improved to a potable level then there would be multiple pathways to re-use of the water including non-potable re-use through the purple pipe, indirect potable re-use via MAR or stream replenishment or direct potable re-use by returning the water to the intake reservoir. A combination of these could then be used to provide sustainable management for all the wastewater flow.

10.3.4 Other cultural solutions have not been explored

A late development was the introduction of a constructed sub-surface wetland to purify and restore the mauri of the water prior to it being piped to the nearest surface water body to drain naturally to the harbour. This raises the question of what other similar solutions would ameliorate cultural concerns and enable wastewater treated to a potable standard to be re-used or dispersed to the harbour at times when re-use uptake is not sufficient.

[70] Mahanui IMP 2013, p280
[71] Mahanui IMP 2013, p281
[72] Beca Report July 2020, p154

10.4 Consideration of consenting issues

10.4.1 Inner Bays

Friends of Banks Peninsula considers that it would be difficult to obtain consent for the Inner Bays option as it is a non-complying activity that has high social, cultural and environmental impacts, fails to provide a resilient wastewater and water supply infrastructure for Akaroa and fails to provide sustainable management. It does not comply with the permitted standards of the Canterbury Regional Air Plan.

The scheme is hugely complex, puts wastewater infrastructure much too close to communities, is highly constrained by the availability of suitable land and at high risk of failure if any one of the many design parameters on which it is based proves inaccurate. Such failure could lead to direct run-off of wastewater and nutrients to streams and to the Harbour and a need to acquire further expensive and difficult to procure land.

In our view the Council pursues this option it would be at serious risk of saddling itself and the community with a myriad of unachievable consent conditions and a costly white elephant. We recommend that the Council does not proceed with this option.

10.4.2 Goughs Bay

Notwithstanding that the Goughs Bay option could be designed in a much better way we submit that this option is consentable. It has lower social and environmental impacts and risks and does not rely on any form of discharge to waterways. It fails in sustainable management because it does not address the resilience of Akaroa's water supply or sewer network, but mitigates this to some extent by having scope for expansion on the site should the current sizing prove insufficient. It complies with the permitted standards of the Canterbury Regional Air Plan.

It is a discretionary application because it does not rely on any form of discharge to waterways and is much simpler than the Inner Bays option. It puts the wastewater at some distance from communities and sensitive activities meaning that it does not carry the same risks of odour, midges etc impacting on people in the long term, is less constrained in terms of its expansion potential and does not put downstream infrastructure or the environment at risk.

In our view, although this option is more expensive to establish and to operate, it carries less risk, and there is plenty of room for expansion.

We suggest that if the Council considers proceeding with this option it:

- Works with Dr Hugh Wilson and the Wildside community to design a native tree system that enhances the Wildside
- Includes high level fire ponds as an integral part of the system
- Works with the landowner to provide adequate compensation for loss of farm areas and find ways for him to gain a benefit from the scheme
- Provides some compensation to the residents affected during the road construction and works with them to identify when it would be least disruptive to work on the narrow Hickory Bay road.
- Finds ways to minimise the cost of pumping the water over the hill through the use of renewable energy.

10.4.3 Pompeys Pillar

Pompeys Pillar is also a discretionary application, but we argue it is less consentable than Goughs Bay because there would be greater social impacts on the landowner, and establishing native trees on the coastal headland is likely to be more difficult, slow and prone to failure. We recommend that the Council does not proceed with this option.

10.4.4 Harbour Outfall

As discussed, the Harbour Outfall rates the best under the social and environmental considerations and risks, and in its new proposed configuration takes the first step towards a sustainable future for Akaroa, but fails to provide for cultural wellbeing.

The fundamental issue for a harbour discharge is consistent across all the relevant planning documents and the Council's Integrated Water Strategy. Put simply - discharge of wastewater to waterbodies or the marine area is to be avoided unless there is no practical alternative.

A new wastewater system must be safe and efficient and serve the community well into the future. In considering practicality and weighing costs the Council must consider the establishment cost, on-going operational and maintenance costs and the risk of future costs if the system does not perform as required, or greater capacity is needed. Council should also take into account the additional funds that will still be needed to improve Akaroa's water supply and to fix the sewer pipe network.

Our view is that the Inner Bays scheme is not technically, socially, culturally or environmentally practical.

Goughs Bay and Pompeys Pillar have higher costs, do not support sustainable development, and may be technically challenging because of the difficulty establishing planted native trees at these locations. Pompeys Pillar imposes a severe social injustice upon the owners via compulsory purchase of their seventh generation land. Council needs to decide whether they consider them to be practical options; in our view they are not.

If a Harbour Outfall is found to be the only practical option, we ask the Council to take all available measures to mitigate the cultural concerns by passing all the water through a wetland system or other land contact system prior to discharge mid-harbour.

We suggest that this becomes achievable if wastewater volume is reduced by fixing I&I, encouraging household water conservation and by enabling re-use in Akaroa

We note that there is flat land on the Takamatua Headland opposite Pond Site 10 previously identified in 2016 as suitable for a wetland. There are also flat areas on the Council's large Misty Peaks Reserve that could potentially be used, if this fitted in with a distributed re-use system, for example.

While the Harbour Outfall takes a first step toward a sustainable future by enabling purple pipe re-use, and the process has now thrown up a method by which cultural concerns could be addressed, we would disappointed if this was the option selected by the Council. Although much cheaper than the other options it is still very costly and leaves the Council with little incentive to spend more on extending the purple pipe and repairing the sewer network. ***It is therefore likely to remain predominantly an unsustainable disposal system.***

10.5 Options not sustainable management

We oppose all the options presented as none of them represent sustainable management, are hugely expensive and fail to prepare Akaroa for a resilient future.

It would be a misuse of public funds for the Council to construct a costly new wastewater disposal system based on any of the options proposed in its consultation document. We cannot see how it could be sustainable and integrated management to spend many millions of dollars building a wastewater system that is extremely expensive per connection, but leaves Akaroa with its sewer network of broken pipes, increasingly vulnerable to climate change effects, raw sewage overflows, and with worsening water shortages. The Tektus review similarly concludes that issues with the four proposed options collectively challenge the basis for those options, to the point that further consideration of alternatives is warranted and could lead to a solution that achieves improved and

broader benefits. They further assert that Akaroa's overall water management now has a rare opportunity for forward-thinking and future-proofing[73].

We strongly urge the Council to stop and rethink its path forward. It needs to set aside the current options and instead adopt a new integrated solution, focussed on reducing the wastewater volume, re-using treated wastewater where it is needed and wanted and recycling pure water back to the Akaroa catchment. We believe a solution can be found that is acceptable to the whole community, addresses Akaroa's issues and creates resilience for future generations.

[73] Tektus 2020 (2.9, 3.1, 4.1)

Chapter 11 Building blocks for an integrated solution

We suggest that most of the building blocks to a sustainable solution have been identified during the long process of getting to this point.

11.1 Opportunity to address sustainability issues is now

It is critical that infrastructure of the size, complexity and cost of the proposed wastewater scheme is fit for purpose for the long haul under the climate and pandemic changed future that we face.

The costs of adaptation to climate change and now the global pandemic crisis mean that Council funds will be more and more stretched.

The decision on the new Akaroa Wastewater system made by Council now provides the opportunity to change the current paradigm – in tandem with the country – and to find a holistic solution.

The community seeks to use this window of opportunity when major capital is being committed to set Akaroa on a sustainable path.

People have consistently asked for the solution to include treatment to a potable standard so that the water can be used for drinking or any other uses without health concerns.

Now they are also demanding that the sewer pipe network is fixed first.

Failing to make this decision now will saddle the area with an unsustainable system and all the problems this will bring for many years, as seen in Auckland and Wellington[74].

An alternative solution to the four discharge/disposal mechanisms currently proposed would achieve improved and broader benefits that *promote the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach*.

11.2 Fixing the network

The Council have estimated the amount of I&I reduction that can be reasonably expected from their planned targeted repairs (such as manhole repairs/replacement and some main pipe replacement) as 20%. This will only reduce the average I&I from 61% to 55%, (because the reduction of 20% applies only to the I&I component, it is not a 20% reduction in total volume). This still leaves a much greater level of I&I that the Water New Zealand trigger value of 30%[75] beyond which system rehabilitation is likely to be successful. To reduce I&I to even the recommended upper limit of 40% would require a 57% reduction. On this basis the 20% target is an unreasonable baseline[76].

Further, the level of I&I indicates the existing network regime is in a poor state and, long-term, the current network is likely to be further compromised. It is imperative therefore that Council consider other approaches that achieve greater reductions at this stage, before investing in the Treatment plant and disposal system; it may also be more cost-effective in the long term to replace part or all of the network with a pressure sewer regime, or to line the existing pipes[77]. This would provide several benefits (including future climate and earthquake resilience), but specifically, a significant reduction in I&I to bring down the size and therefore cost of the new system.

[74] https://www.rnz.co.nz/news/national/414409/wellington-council-to-borrow-up-to-16m-to-fix-broken-pipes
[75] Water New Zealand I&I Vol 1 2015 p33
[76] Tektus 2020 (3.19)
[77] Tektus 2020 (4.7, 4.8)

We note that Beca considered the possibility of replacing some or all the network with a pressure sewer, but ruled it out on the basis of cost and disruption. Given the direct relationship between the volume of wastewater to be treated and the cost of that treatment and disposal (both capital and operating costs), improvements to the network could likely pay for themselves.

There are two alternatives for achieving a major reduction in I&I:

- **Cured In Place Pipe (CIPP)**: Tektus consultants estimate physical works cost of around $4.5 million to line the entire network. However, this may not be necessary: lining the lower portion only is likely to achieve most of the reduction, with the funds left over available to deal with intrusions in the private network. A similar approach is being taken in Ōpōtiki, where it was found that lining the main pipes was the most cost-effective solution[78].
- **Replace some of or the entire network with a low pressure system**: this approach is significantly more expensive (around $27 million to replace the entire network), but has the advantage of being completely sealed, so is impervious to infiltration, and is a more permanent solution providing greater resilience against climate change. The additional cost may therefore be recouped in the long term. Again, a partial solution to address the lower section of the network may be appropriate and more cost-effective. Tektus suggest replacing the network below RL5m (up to the eastern side of Rue Lavaud) at an estimated cost of around $6.1 million for the physical works. This partial solution would mitigate threats to the low lying parts of the network from increased ground water pressure cause by rising sea levels.[79]

Fixing the network may be costly; building and operating a treatment plant and disposal system that is twice the size needed is also costly. Taking into account the risks associated with continuing to service a network that is deteriorating and susceptible to climate change, *not* fixing the network may be more expensive in the long run.

11.3 Focus on re-use

Council staff and engineers have looked at non-potable re-use via a purple-pipe network, but appear to have focussed on non-potable re-use for toilet flushing only. Experience overseas has shown there are many ways to recycle highly treated wastewater, including:

- Stream replenishment (returning the treated water to the stream just below where it was taken)
- Managed Aquifer Recharge
- Non-potable network (purple pipe) to the gate for outdoor uses such as garden watering
- Non-potable network (purple pipe) to the houses for toilet flushing (and potentially other uses such as washing machines if the treatment level is high enough)
- Indirect potable reuse: treat to potable standard and return to the streams *above* the intake
- Direct potable re-use: treat to a potable standard and return to the potable supply reservoir

Any of the options could be combined with some form of land contact to address cultural concerns. We now consider the feasibility of each of these options.

11.3.1 Stream replenishment

In summer Akaroa often has water shortages, leading to watering restrictions. This year the problem was particularly acute, with a total watering ban coming abruptly into force. As a first step towards

[78] Tektus 2020 (3.18)
[79] Tektus 2020 (4.9, 4.14, 4.15)

genuine recycling, the treated wastewater could be returned to the Grehan Stream, just *below* from where it was taken, avoiding concerns around contamination of the water supply.

A well-designed stream discharge solution, similar to the subsurface wetland proposed for the Inner Bays option, would seem to align with the Ngāi Tahu position that it is appropriate to pass even highly treated wastewater through or across land for Papatūānuku to cleanse. We suggest it could be worth additional discussion with Ngāi Tahu representatives to consider options for some continuous flow through a wetland, before conveying the water back to the Grehan Stream.

Tektus suggest an ecological evaluation to assess erosion risk in response to grade and substrate, and to quantify existing stream condition. Flow dispersal to the stream could be via further land contact, such as a filtered strip or vegetated swale[80].

11.3.2 Managed Aquifer Recharge

Managed Aquifer Recharge (MAR) is an indirect re-use method where highly treated wastewater is returned to aquifers, usually through either infiltration beds or by injecting it into deep bores[81].

The Council considered MAR as a possible solution, but did not proceed beyond initial investigations. The primary concerns related to potential contamination of water supplies and the underlying geology in Banks Peninsula not being conducive to injection: deep bore injection disposal options were also explored, but only based on one exploratory bore at the site of the treatment plant, and discounted on the basis of a lack of open connected fractures and low permeability ground conditions.

The geology of Banks Peninsula is highly complex, and exhibits great variability between locations. The two deep bore injection test bores were located close together, in an area thought to be a major vent, and less likely to be fractured[82]; other locations may be more favourable for this method.

Furthermore, the Beca report explains that in the context of MAR, Council staff determined that potential connectivity between the groundwater injection and groundwater abstraction for potable supply presented a significant risk to water supply security in Akaroa, and determined that the option should not be considered further. Research indicates positive pathogen removal capacities across a 40-80m separation distance between the infiltration and abstraction well locations[83], suggesting it should be entirely feasible to safely return highly treated wastewater to the Akaroa basin, given the size of the area and the relatively low number of water extraction points – there are only three stream collection points and two active wells in the entire Akaroa basin[84]. Any residual risk could be further mitigated by treating the wastewater to a potable standard, a common and successful approach overseas[85].

With regard to cultural acceptance, the Beca report indicated a neutral/medium score for deep bore injection, and a worst score for MAR relative to cultural acceptance. However, with further understanding of this solution, potentially together with ground-level pre-treatment via a sub-surface wetland or similar, this may be a more acceptable approach for mana whenua than water body discharges and, potentially, comparable to discharge to land[86].

Given the reduced footprint and potential cost benefits, this represents a lost opportunity to find a more practical solution; the land required by MAR is significantly less than that the four proposed

[80] Tektus 2020 (4.30)
[81] Lundh 2009
[82] Hampton, S communication to the Working Party
[83] Lundh 2009
[84] Canterbury Maps (water supply)
[85] Tektus 2020 (3.28)
[86] Tektus 2020 3.36

options, offering benefits over the proposed options relative to the LGA four wellbeings. Tektus find there is "robust merit" in further exploration of MAR in combination with reverse osmosis[87].

We suggest Council considers re-looking at MAR as a potential method for reusing Akaroa's wastewater in a way that is low impact, sustainable and culturally acceptable. If water is treated to a potable standard then reuse of Akaroa's existing unused bores presents an opportunity that would not contaminate water supplies.

11.3.3 Non-potable re-use network (purple pipe)

The Beca report states *"A fully reticulated non-potable reuse network has not been used before in New Zealand and is not currently supported by the Ministry of Health and the Canterbury District Health Board."*[88] For this reason the consultation document proposes only a modest re-use system for municipal watering and toilets, and even this is optional. The key concern cited is that plumbers may incorrectly cross-connect the potable and non-potable pipes and contaminate the drinking water supply.

However, there are examples of purple pipe re-use already being implemented in NZ on a smaller scale, such as Golden Valley subdivision, Kuaotunu, Coromandel Peninsula, which includes a purple pipe system for domestic toilet flushing.[89.] Very high-quality effluent is in part disinfected and returned to each lot as non-potable reclaimed water for toilet flushing. On-site recycling is also becoming more common, such as Oasis Clearwater systems for sewage and Hydraloop for grey water.

Some regions (such as Kapiti Coast) have included a water conservation requirement for new developments into their district plan, which may include a greywater diversion system and rainwater collection (KCDC, 2009a). The ECan Land and Water Regional Plan does not specifically prohibit reuse, and the use of alternate systems is provided for within the wider objectives and policies of the Regional Plan: reuse is promoted to reduce the residual effects of discharges of contaminants, and ECan aims to enable water conservation and water efficiency through the collection, use and reuse of water, and alternative sewage disposal technology. It further promotes that local authorities should encourage water conservation and water efficiency through the collection, use and reuse of water, provided that the health of individuals of the community is not put at risk. Taumata Arowai is likely to further address the regulatory regime around reuse, by providing national-level leadership and oversight[90]

We urge the Council to lobby central government to put the regulatory framework in place to support treated wastewater "purple pipe" re-use, for both toilet flushing and external uses such as garden watering; the latter has the potential to take a significant proportion of the water.

11.3.4 Reverse Osmosis treatment and potable re-use

We recognise that New Zealand is not yet legally or culturally ready to drink recycled wastewater, however the recent severe water shortages in Auckland have prompted the mayor to declare that Aucklanders need to "get used to" the idea of recycling wastewater.[91.]

As envisaged for Auckland, full recycling of wastewater would see the water coming out of the wastewater treatment plant given further treatment and passed through a natural filter such as a wetland, before another round of treatment to ensure it was at a drinkable standard. In Akaroa the options are then to return it to the drinking water reservoir, to the Grehan stream upstream of the water supply intake, or into the ground to replenish the aquifers.

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[87] Tektus 2020 (3.34,4.27)
[88] Beca July 2020 piii
[89] MfE 2003, p103
[90] Tektus 2020 (4.46)
[91] https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12330425

Reverse Osmosis can be and is successfully used for large scale wastewater treatment, such as at Bedok, Singapore, where industrial effluent and municipal wastewater is recycled into pure water for high-tech industrial use and drinking water replenishment. Many other examples can be found including in Australia and the United States. . From an analysis of existing RO treatment plants it appears the maintenance cost and energy usage of Reverse Osmosis by volume is comparable to the Ultrafiltration MBR already proposed[92].

In addition to cost, Council staff have highlighted the issue of retentate requiring disposal. Retentate volumes can be minimised by recycling it back through the treatment plant for further treatment, similar to what Beca propose for the ultrafiltration membrane; again this is accepted practice[93].

We strongly encourage the Council to add Reverse Osmosis as a final purification stage, which would recycle the treated wastewater back to clean water, making it safe for re-use in all ways, including indirect or direct potable re-use. Doing this would alleviate Akaroa's water shortages and make it a showcase for sustainable water management.

11.4 Putting the building blocks together

We consider that the building blocks needed for a sustainable solution have all been identified. Some, such as Reverse Osmosis and MAR need some further research and the estimated costs being made public.

The issue for the Council is how to implement it in an affordable manner and to get through the consenting process to do so.

The baseline for the cost and timeframe of an alternative solution comes from the existing proposals on the table. The cheapest of the land based options proposed is a capital cost of $54 million to $63 million. The timeframe for implementation is 8 years before this is fully operational and the existing plant at Takapūneke could close. The harbour discharge would cease at about the same time as it would for the land-based options proposed.

This creates a large baseline budget and the timeframe needed to develop an integrated system for Akaroa that solves issues with all three waters and sets it on a resilient future path. We suggest how this might be staged in the final chapter of our submission. We have called our proposal an "Integrated Reduce Reuse Recycle" system.

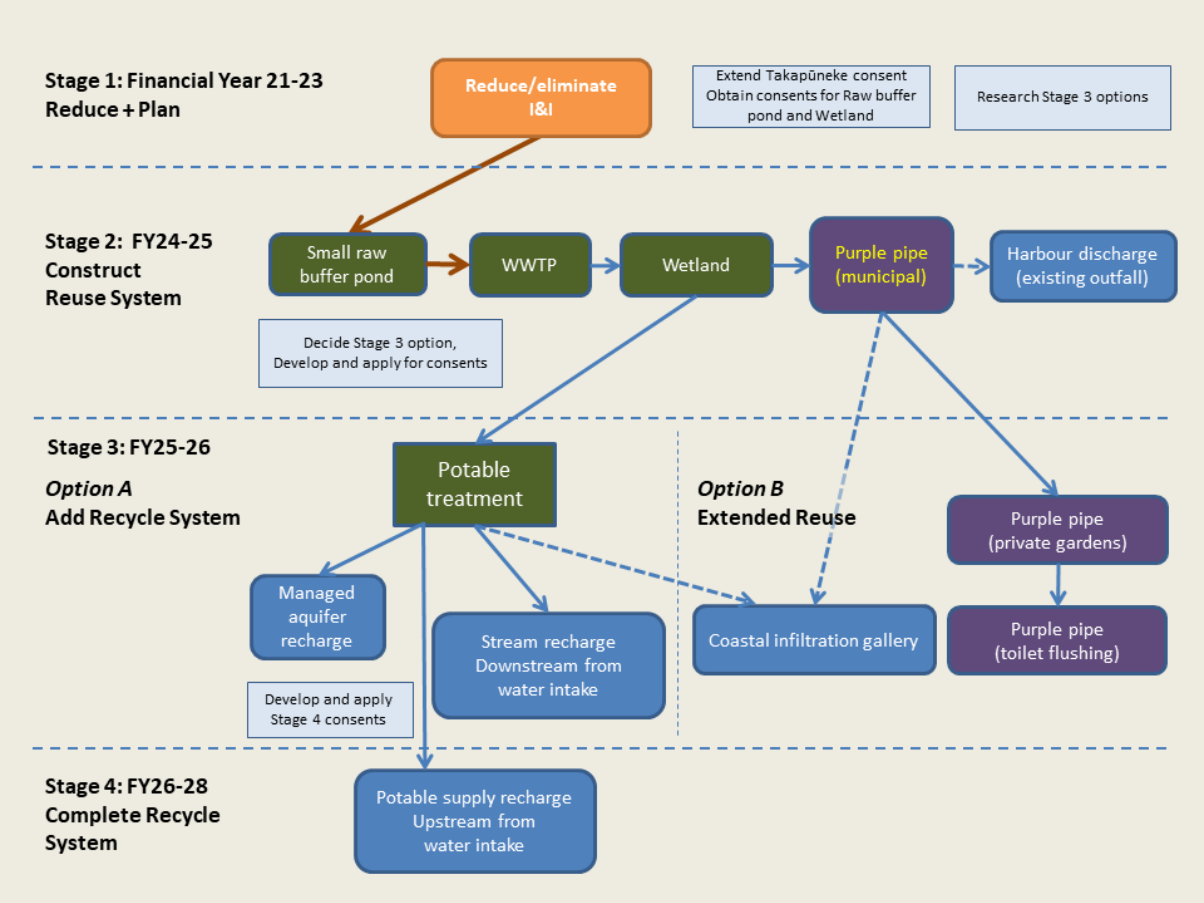
[92] Tektus 2020 (4.23, 4.24)
[93] Tektus 2020 (4.22)

Chapter 12 Taking a staged approach

The system we proposed takes a classic approach to waste minimisation – starting with reducing the waste, then reusing waste, and finally recycling what cannot be reused back to its original form, in this case pure water.

We envisage the Council implementing this system over an 8 year period, enabling the costs to be spread over time. The timeframe could also be extended if needed for financial reasons, as the principal cultural issues driving the need to shift the plant and eliminate offensive harbour discharges are making steady progress. . Taking this approach allows reuse to be staged and scaled in response to changing perceptions and regulation[94].

Figure 20 Integrated Akaroa Wastewater concept based on a Reduce, Reuse and Recycle philosophy



12.1 Stage 1 Reduce and Plan

Use budget already allocated to reduce the volume of water as much as possible, principally by tackling the I&I issues thoroughly. This is the key to future resilience, to designing an appropriately sized system, to minimising raw sewage overflows and to provide headroom for future growth. It deals with a problem that must be addressed and frees up limited space at the treatment plant site for other components.

[94] Tektus 2020 (4.37)

As already noted, the focus needs to be on the lower parts of the town where groundwater infiltration is likely to be highest, and where rising sea levels will exacerbate the problem, and the Council could either line the existing pipes at a cost of $4.5 million or replace part or all of the network with a pressure system for a cost of $6.1-$27 million

While the I&I work is in progress, there is time to gain consents for new components of the treatment plant (the raw buffer pond and the wetland), consent to extend the life of the existing plant and to research and plan later stages.

We do urge the Council to reconsider the location of the Terminal Pump Station and move it from its current vulnerable location on the coastal reclaimed landfill site, and to amend the consent accordingly.

Collaborate with the Ngāi Tahu parties to reach consensus on how to make both re-use and the disposal of excess flows culturally acceptable via a wetland or other land contact approach.

This work can commence using funding already allocated in the LTP and aim to complete over two years.

12.2 Stage 2 Construct a reuse system

We envisage this stage commencing in the 2024 LTP and being the highest cost component, as it would involve building the new WWTP at the top of Old Coach Road. However, this is likely to be a smaller plant than currently costed and there may no longer be the same need for raw sewage storage due to the I&I reduction. This would give more space at Pond Site 10 to construct a **wetland to further treat all of the wastewater after the ultrafiltration process, restoring mauri**.

If space is still constrained, then alternative locations for wetlands have been previously identified, including to the flat land across the State Highway from Pond Site 10.

The outflow from the wetland would be to a pipe running through Akaroa to the *existing* outfall. This can be laid at the same time as the new pipe taking wastewater to the Terminal Pump Station. The pipe will provide an initial purple pipe reuse network through Akaroa, enabling the watering of public parks and flushing public toilets. The water will be treated to a very high standard, as the inclusion of purple pipe in the system means water will be UV treated and tested prior to entering the wetland. It may need some filtering to remove any grit particles that have been introduced by the wetland to avoid clogging irrigation jets.

The plant at Takapūneke will be able to close once the new plant is in place. This would be several years earlier than under any of the proposed land-based options, and represent a major step toward reducing the cultural offensiveness of the current Akaroa system.

12.3 Stage 3 Introduce recycling or extend reuse

We envisage Stage 3 commencing in 2025, subject to funding being available and the regulatory framework being in place.

We suggest two possible options at Stage 3. Either to add potable treatment to enable water recycling or to extend the purple pipe reuse network. Use of the existing harbour outfall would cease during Stage 3 under either option.

Option A: treat to a potable standard and introduce recycling

Our preference is for potable treatment. We have held many meetings with **the community who repeatedly and consistently request that the water be treated to a potable standard.** This would turn the water from a waste product into a desirable and worry-free resource, opening up many options for direct beneficial reuse and alleviating Akaroa's water shortage issues. It would be a low footprint option as once the water had been treated to a potable standard there is no need to contain it in a separate pipe network.

We envisage potable treatment being achieved through the addition of reverse osmosis (RO) to the already highly treated water that has been through the ultra-filtration plant and the wetland. Issues raised by the Council staff have been the cost of reverse osmosis and the level of retentate remaining that still has to be dealt with. However, reverse osmosis is used widely for wastewater reclamation, particularly in conjunction with membrane filtration, which removes most of the contaminants and reduces maintenance of the RO membranes. Retentate volumes can be minimised by sending it back through the treatment plant, similar to Beca's design for the MBR ultrafiltration system; again this is standard practice[95].

Potable treatment opens many possibilities of recycling such as:

- **Managed Aquifer Recharge:** this was supported by the Working Party, but trials that were about to commence were cancelled by Council due to health concerns. Treatment to a potable standard alleviates these concerns. As well as providing further land contact, recycling the water through the aquifers brings the added advantage of boosting their levels to prevent salt water incursion resulting from sea level rise.
- **Stream recharge (downstream):** currently stream takes in Akaroa are limited by the need to retain minimum flow levels, which is often not possible in summer. Returning potable water to the streams would replace the flows taken and may be a way to reduce water shortages. Grehan Stream is the obvious candidate to be recharged because of its proximity to the treatment plant.

Option B: extend the purple pipe network for non-potable reuse

An alternative for reuse is to extend the purple pipe system to include private properties throughout Akaroa:

- **Reticulate non-potable water to property boundaries:** Council staff have identified that a substantial portion of the potable water supplied in summer is used for outdoor use. Therefore, reticulating non-potable water to the property boundary maximises the amount of reuse during summer when pressure on the water supply is at its greatest, and minimises disruption by avoiding the need to re-plumb existing buildings.
- **Extend non-potable reticulation to houses for toilet flushing and other internal use:** this increases the level of reuse still further (and all year round) but comes at a significantly higher cost and with substantial disruption as houses would require re-plumbing.

This option would require standards and regulation of reclaimed non-potable water to be put into place first.

Common to both options: coastal infiltration gallery

Both options are likely to require some form of disposal for water that cannot be reused. For Option A, this might result from the need to temporarily suspend stream recharge owing to stream flow conditions, while for Option B some form of disposal will be required for when reclaimed wastewater volumes exceed demand.

A coastal infiltration gallery could be used to disperse excess flows. This idea has was previously suggested in 2016 and not taken up[96], however there is a key difference between the situation then and now: the water is treated to a higher standard (minimum of purple pipe standard under Option B or potable standard under Option A), and all of the wastewater receives full treatment (no bypass flows).

[95] Tektus 2020 (4.22)
[96] Beca report July 2020, p18

12.4 Stage 4 Introduce full recycling

The final stage closes the loop and achieves full recycling, by returning the fully treated water to the potable supply by one of two means:

- Indirect potable reuse: recharge the Grehan stream some distance above the water supply intake, or
- Direct potable reuse: return the recycled water to the reservoir at L'Aube Hill.

Indirect potable reuse is by far the most common method used worldwide, because it ensures the recycled water is constantly blended with fresh water to alleviate any issues around degradation over time, and it substantially reduces the "yuck factor" of drinking recycled wastewater. Direct potable reuse would only be considered if there were reasons why stream recharge might not be possible or desirable.

This step would require standards and regulation of reclaimed potable water to be put into place first. We envisage this step being introduced in FY 2026 or later.

12.5 Conclusion

At the end of this path, Akaroa would have a `truly resilient and future focussed wastewater system integrated with its potable water supply system. The cultural issues of a wastewater treatment plant on a sensitive site and harbour discharges would be addressed, the stormwater infiltration into the wastewater system greatly improved, a more resilient potable water supply for Akaroa in place and the flow levels of its main stream better assured.

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Appendix 2 Endorsements

324 people have endorsed this submission as of August 23. We ask the Council to redact the addresses and email addresses before releasing this submission to the public and can provide a redacted version to assist.

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Richard Florance	Takamatua	
Richard Lovett	Robinsons Bay	
Richard Troughton	Takamatua	
Robin Tiffen		
Robin Walker	Takamatua	
Robinsons Bay Bach Trust / Brian Eves	Robinsons Bay / Sumner.	
Rodney Innes	Takamatua	
Roger Hovenden	Prestons Park, Christchurch	
Roger Thomas	Amberley	
Rose Lindley	Mt Pleasant	
Ross Blanks	Robinsons Bay	
Ross Ruddenklau	Akaroa	
Roz Rickerby	Akaroa	
Russell John Noble	Woolston, Chch	
RUTH W WARREN	ROBINSONS BAY	
Sarah Abbott	Christchurch	
Sarah Claire Anderson	Redwood Christchurch 8051	
Sarah Raxworthy		
Sarah Solomon	Silverdale, Auckland	
Sean Connell	Christchurch	
Sharni Connell	Takamatua	
Shaun Huddleston	Akaroa	
Silke Lassen	Akaroa	
Simon Hadfield	Robinsons Bay	
Simon Tipping	Akaroa 7520	

Simon Trotter	[redacted] Akaroa [redacted]	[redacted]
SONIA JANE SHEPHERD	Robinsons Bay, Banks Peninsula	[redacted]
Stacey Naish	[redacted] Akaroa	[redacted]
Stephanie Berry	[redacted] Pigeon Bay	[redacted]
Stephanie Connell	[redacted] Takamatua	[redacted]
Stephen Carswell	[redacted] Akaroa	[redacted]
Steve LeLievre	[redacted] Takamatua	[redacted]
Stuart Jeffrey	[redacted] RD1 Akaroa	[redacted]
Sue Lovett	[redacted] Robinsons Bay	[redacted]
Sue Ritchie	[redacted]	[redacted]
Sue Strez	[redacted] Takamatua	[redacted]
Sue Thurston	[redacted] Takamatua, R.D 1 Akaroa	[redacted]
Sue Wilson	[redacted] Akaroa	[redacted]
Suky Thompson	[redacted] Robinsons Bay	[redacted]
Susan Bruce	[redacted] Takamatua R.D.1	[redacted]
Suzanne Church	[redacted] Akaroa	[redacted]
Sylvia McAslan	[redacted] RD 3, Akaroa	[redacted]
T Jones	[redacted] Lyttelton	[redacted]
Tanya Moore	[redacted] Robinsons Bay. P O Box 434 Christchurch.	[redacted]
Taryn Whaitiri	[redacted] Tai Tapu	[redacted]
Teena Irwin	[redacted] Akaroa	[redacted]
Thomas Moore	[redacted] Northwood, CHCH 8051	[redacted]
Tim Adair	[redacted] cashmere	[redacted]
Tim Herbert	[redacted]	[redacted]
TOBY JOHN SMITH	[redacted] Akaroa [redacted]	[redacted]
Toby smith	[redacted] Robinsons bay	[redacted]
Todd Raxworthy	[redacted]	[redacted]
Tom Brennan	[redacted] Takamatua	[redacted]
Tony Fisher	Landowner - Robinsons Bay Valley Road.	[redacted]
Tony Muir	[redacted] Takamatua	[redacted]
Tony Rhodes	[redacted] Akaroa	[redacted]
Tracey Pottinger	[redacted] Akaroa.	[redacted]
Trev Bedford	[redacted] Takamatua	[redacted]
Wayne Sceats	[redacted] Lyttelton	[redacted]
Wendy Bradley	[redacted]	[redacted]
Wendy Fleming	[redacted] Akaroa	[redacted]
William Adair	[redacted]	[redacted]
Yvonne Marshall	[redacted] Akaroa	[redacted]

Appendix 3 Tektus Consultants Engineers Memo

MEMO

TO	FRIENDS OF BANKS PENINSULA INCORPORATED
FROM	TEKTUS CONSULTANTS LIMITED, JACK TURNER & EMILY AFOA
SUBJECT	AKAROA WASTEWATER • REVIEW OF PROPOSED DISPOSAL SOLUTIONS
DATE	21 August 2020

1 Introduction and Scope

1.1 This memo summarises our review relative to Christchurch City Council's (CCC) proposed Akaroa treated wastewater options, notified for consultation on 21 July 2020. We provide a brief comment on the state of the industry, to demonstrate the basis of our assessment seeking a sustainable development approach that is resilient to changing climate conditions and future uncertainty; a critique of the current solutions proposed, focusing on CCC's preferred option to discharge to land via the Inner Bays Irrigation Scheme; and present alternative solutions.

2 Background

2.1 Akaroa's current public wastewater treatment plant and harbour outfall at Takapūneke are in a culturally and historically sensitive location and need replacement. Christchurch City Council have gained consent for a new full tertiary wastewater treatment plant with membrane filtration to be built on Old Coach Road and for a new pump station in the boat park at Children's Bay. This assessment encompasses proposed disposal of treated wastewater effluent from the future plant.

2.2 Akaroa's public water supply is currently served by six consented water takes – two groundwater (18L/s combined), and four surface water (55.6L/s combined) (Stewart, La Roche, Currie, & Pink, 2015). Water resources are in Akaroa are limited, and peak summer demand is typically coincident with large numbers of seasonal visitors. As a result, water restrictions are relatively common – with Feb-Mar 2020 a more severe, and recent, example.

2.3 Climate change and future resilience is a considerable concern and requires due consideration in all future infrastructure planning. *Climate Change Projections for New Zealand* (MfE, 2018) predict trends of reduced rainfall and increased temperatures in Northern Canterbury. *Climate change projections for the Canterbury Region* (NIWA, 2020) refine this assessment for the region, identifying five climate zones – of key relevance Banks Peninsula (and the coastal strip north of Amberley), with relatively mild winters, and rather high annual rainfall with a winter maximum. Key predictions include:

a. Increased annual number of dry days
b. Decreases in summer rainfall of 5-15% for Bank Peninsula (by 2090 under RCP8.5)
c. Increased accumulated potential evapotranspiration deficit (PED), therefore increased drought potential
d. Reduced mean annual discharge from surface waters and mean annual low flow
e. Scenario assessment for sea level rise. **At 0.65 metres of sea level rise (predicted for 2070-2155, if achieving emissions targets), every high tide is above the spring tide mark (compared to 10% now).**

The potential combined effect of these parameters, particularly for summer, is reduced surface and ground water quantity available for supply and an increase in seasonal demand. Furthermore, low lying infrastructure is at risk of inundation by rising sea level and groundwater levels – including storm surge, coastal inundation coastal and erosion (MfE, 2017). This is further reinforced by coastal hazards research commissioned by CCC

and reported in 2017 (T&T, 2017), which predicts changes for the area relative to different Representative Concentration Pathways (RCP).

2.4 New Zealand's first national climate change risk assessment has been completed to help the Government identify where it needs to prioritise action to make New Zealand more resilient – being the newly-released *National Climate Change Risk Assessment for New Zealand – Arotakenga Tūraru mō te Huringa Āhuarangi o Aotearoa* (MfE, 2020). This identifies: "Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise" as an extreme risk, and in New Zealand's top ten most significant climate change risks based on consequence and urgency.

2.5 *Te Wai Ora o Tāne Integrated Water Strategy* (Christchurch City Council, 2019) seeks to "support the ongoing recovery activities following the earthquakes and set a path for our future management of our water resources and water services and associated infrastructure". Drawing upon the Urban Water Principles – Ngā Wai Manga the strategy references sustainable and integrated water management and highlights 11 key strategic issues including, of particular relevance:

a. Treated wastewater discharges into Akaroa Harbour
b. Responding/adapting to the anticipated effects of sea-level rise on water resources and related infrastructure
c. Long term availability of water for water supply
d. Long term sustainable wastewater treatment and disposal
e. Infrastructure efficiency and resilience

The document presents long-term aspirations with implementation over a horizon extending beyond 100yrs. It sets annual commitments to reporting on implementation plans and progress, and six-yearly reviews to encompass changing national and international state of knowledge.

2.6 The *Water Services Regulator Bill – Taumata Arowai*, enacted Aug-20, implements the Government's decision to create a new regulatory body to administer and enforce the new drinking water regulatory system, while contributing to improved environmental outcomes from wastewater and stormwater networks. A complementary Bill, the *Water Services Bill*, introduced Jul-20, is intended to give effect to Cabinet's decisions on reforming the drinking water regulatory framework, and Taumata Arowai's new wastewater and stormwater monitoring functions. The *Water Services Bill* comprises a significant part of the Government's response to the Havelock North Drinking Water Inquiry which found the contamination was a result of systemic failure across service provision, regulation, and source protection (noting all aspects of the system were implicated). With significant change in the Water Industry, this poses opportunity for considerable reform from continuing the status quo and is likely to bring comprehensive oversight and greater consistency, particularly in our collective transition to climate risk adaptation.

2.7 There is currently no regulatory framework for the reuse/recycling of treated wastewater in New Zealand. Careful consideration of all regulatory aspects including, for example, the Building Act, Health Act (drinking water supplies), and Resource Management Act, is required to ensure appropriate risk prevention mechanisms, monitoring and compliance programs, and/or verification systems are implemented to effectively manage public health risk. Given availability and quality of potable water supplies are identified as a national risk due to climate change, this may be a task tackled by Taumata Arowai.

2.8 Australian Guidelines for Water Recycling provide relevant guidance in response to increasing climate variability and population levels leading to serious water shortages across many areas of Australia. There, alternative sources of water are becoming more important as water restrictions become more widespread. Two areas are addressed – augmentation of drinking water supplies and managed aquifer recharge. Both methods are a form of indirect augmentation – similarly utilised in Singapore, the United Kingdom, and the United States of America

– whereby discharge of highly treated recycled water into a receiving body such as a river, stream, reservoir or aquifer (through indirect injection or soil aquifer percolation), before re-treatment and subsequent supply as drinking water. This allows for additional time, additional treatment, and dilution. Detention time, the time between augmenting the water supply and extracting (blended/diluted) recycled water for reuse, is a key parameter enabling operators and regulators to assess recycled water treatment and recycled water quality and, where necessary, to intervene before water is supplied to consumers.

2.9 Overall, this is an ever evolving and exciting area with wide-reaching implications across our existing social fabric. **Opportunities for forward-thinking and future-proofed solutions are often inter- if not multi-generational, responding to the understanding and perspective of that time, and Akaroa's overall water management regime is now at that juncture.**

3 Christchurch City Council Proposed Solutions

3.1 This a complex issue, and one which has been subject to extensive and comprehensive investigations over many years. From our reading of the consultation material and other preceding documents, the comprehensiveness and quality of this assessment work is commendable. That being said, the four discharge/disposal solutions resolved and proposed by CCC and CH2M Beca pose several questions which we maintain should be carefully considered before a decision is made on the preferred solution. **These issues collectively challenge the basis for the four options, to the point that further consideration of alternatives is warranted.** This appears pivotal to achieving the purpose of the Local Government Act 2002 (LGA) and its four well-beings – i.e. *promoting the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach* (LGA Section 3(d) – Purpose).

3.2 The consented wastewater treatment plant is a full tertiary wastewater treatment plant with membrane filtration, to be located at 80 Old Coach Road.

a. Design water quality standards of 15 mg/L Total Nitrogen, increased to 30 mg/L for the short-term summer peak and 7 mg/L Total Phosphorus (Table 2-6 Proposed Wastewater Quality Standards; CH2M Beca, 2020). Concept design provides for future dosing to ensure treatment of peak summer load meets the design threshold of 15 mg/L Total Nitrogen, should the 30 mg/L short-term threshold be declined.

Inflow and Infiltration (I&I) to the existing wastewater network

3.3 The position on network I&I in the context of the treatment plant and discharge/disposal options is summarised through Section 2.2 of the CH2M Beca report. This identified that "the Council selected a 20% I&I reduction as likely to be achievable for the Akaroa wastewater network" – based on results of using Distributed Temperature Sensing (DTS) and experience from other councils in New Zealand. CH2M Beca further outline that it "will be very difficult and costly to reduce groundwater derived I&I in Akaroa to this extent". We also note that the stated target 20% reduction is relative to the existing I&I rates, rather than an overall network flow reduction.

3.4 **The 20% reduction target seems to underplay the problem** in this context, given the modelling results for the year 2052 annual flow projections (based on CCC population projections) shown in Table 2-3 of the CH2M Beca report indicates that in an average year, groundwater infiltration contributes 43% and rain derived inflow and infiltration contributes 18% of the total flow – with total I&I being 61% of the total annual flow. A 20% reduction in I&I would lead to a residual I&I rate of 55% of the total wastewater flows to the treatment plant – a number measurably below best practice guidance.

3.5 The WaterNZ guideline Infiltration & Inflow Control Manual, 2015, proposes Key Performance Indicators for I&I across New Zealand (Figure 1). These are based on Groundwater Infiltration (GWI), Rainfall Dependent Inflow and Infiltration (RDII), and a Wet Weather Peak Flow factor, defined by stormwater inflow (SWI). Overall, KPI

targets for RDII and GWI are in the order of 40% combined (refer Table 6-1 in Figure 1, sum of GWI_1 and $RDII_1$), with a collective trigger value of 30% (refer Table 6-2 in Figure 1, sum of RDII and GWI_1).

Table 6-1 Typical Ranges for Key Performance Indicators

Key Performance Indicator	Typical Range
GWI_1	<20%
GWI_2	>170 and <270 l/p/d
GWI_3	0.5 – 1.1
$RDII_1$	<20%
SWI_1	<5

Table 6-2 Threshold Trigger Values

Key Performance Indicator	Threshold Value
RDII	10%
GWI_1	20%
GWI_2	280 l/p/d
SWI	8

Figure 1: Extract of Tables 6-1 & 6-2 from the WaterNZ Guideline for Infiltration and Inflow Control Manual, 2015

3.6 It is also not clear from the current reporting as to how seasonal differences are impacted by the high existing and target I&I rates. It would be beneficial to understand the seasonal differences in summer period peak population loads, aligned with dry soil conditions – and the storage/disposal design requirements in this period. Versus winter periods with low population flows, but likely higher proportion of I&I, together with wet soil conditions limiting the timing/potential for land disposal. This would likely further emphasise the significance of the current I&I loads (existing and target).

3.7 That being said, Appendix B to the CH2M Beca report includes Table 6 which "shows that the maximum storage volume is most sensitive to reductions in I&I. Maximum storage generally occurs during the winter period and after a series of significant rainfall events which cause a large I&I flow into the storage. Therefore, reducing the I&I flow significantly reduces the maximum storage volume required." This reinforces how significant the I&I rates are to the overall disposal system and storage design.

3.8 Targeted network upgrades to improve I&I are noted in the report but with little detail. These upgrades are briefly outlined in Appendix AD of the CH2M Beca report (largely based on replacing 2km of 225mm diameter pipework) and indicate that they will be budget constrained (estimated at $2.68M with $3.32M allowed in the Concept Estimate Whole Scheme High Level Summary), but contribute to the 20% reduction goal. We also note that the network upgrade referred to in Section 9.1 of the CH2M Beca Report, ostensibly for I&I reduction, appears to overlap with network modifications required to facilitate the new treatment plant (primarily the 2km of 225mm PVC pipe replacement outlined in Appendix AD).

3.9 The report also notes that a "key consideration is that most of this infiltration occurs in low lying and older parts of the network located near the coastline. These parts of the network may be at or below the level of shallow groundwater which is also tidally influenced." This raises several concerns – particularly around future climate and earthquake resilience.

3.10 Further – "It has been found at other similar locations (e.g. Motueka) that **fixing individual infiltration points causes shallow groundwater levels to rise slightly until the groundwater finds another place to leak into the sewer." This suggests limited benefits to localised network improvements and supports a wider scale network assessment and solution.**

3.11 CH2M Beca conclude that **"It is recommended that a 20% reduction in I&I is retained as a reasonable basis for network improvements."** This appears to be largely based on CCC's direction conveyed through the CH2M Beca report around targeted network improvements and the inherent limitations in that regard. **However, we strongly question this adopted position and discuss this further as follows.**

3.12 The extent of groundwater infiltration is significant (noting the WaterNZ KPI target of less than 20%, see Figure 1), suggesting potentially extensive issues with the network. Limited detail is included in this regard, and there is

no discussion on the relationship between the existing network and potential damage caused through the Christchurch earthquakes – nor future resilience to further ground movements and climate change.

3.13 Interestingly, and in contrast to the above understanding, the RPS New Model Build Calibration Report in Appendix A of the CH2M Beca report states in respect of ground infiltration that: "*The model audit report alluded to the fact that the catchment may see some ground infiltration flows. However, although this may seem reasonable given the topography and land use of the surrounding area, the flow survey data from 2013 (Phase 1 Calibration) suggested that ground infiltration was not present. As such there was no need to utilise the Ground Water Infiltration module in the Akaroa wastewater model. This was also found to be the case for the Phase 2 Calibration (2017-18). However, it should be noted that the 2017-18 flow survey in particular, was carried out during the summer months; during a particularly dry period. It is therefore a recommendation that to fully understand the potential for ground infiltration that a long-term flow survey is carried out. This will enable seasonal variation to be understood across the catchment with regards to slow response flows.*" The RPS report notes the model did not show ground infiltration contributions, as anticipated by CCC and now known to be a significant contributing factor, due to the short flow survey period during a dry summer. It concludes this is a major limitation to the model, specifically for use in scheme design and recommends long term flow survey to understand seasonal variation in these potential flows, also recommending further work on the model prior to designing future network upgrades.

3.14 Based on the significant I&I rates, mostly, seemingly attributable to groundwater infiltration (contrary to the RPS reporting above), CH2M Beca also acknowledge an alternative approach to the network. "*As an alternative to remediating the existing network, the entire wastewater network could be completely replaced, either using pressure sewer or a combination of gravity plus pressure sewer.*" But this is ruled out on the basis of prohibitive costs and disruption – and "has not been incorporated into scheme proposals thus far." In this regard, it would be valuable to better understand the feasibility of remediating/lining the network to prevent I&I, or to more clearly understand the constraints. We address this further below.

3.15 **Evidence highlights that the existing network regime is in a poor state given the quantum of I&I currently experienced, and long-term, the current network is likely further compromised relative to future climate change and earthquake resilience.** With reference to Figure 2 below (drawn from CCC / Canterbury Map GIS data), the lower portions of the network appear to have invert levels in the order of RL1m[1]. As highlighted in paragraph 2.3 above, the CCC coastal hazards research indicates potential for a 1m sea level rise (SLR) over a 100 year horizon, which combined with storm tides and wave set-up, could lead to total coastal inundation levels for Akaroa North in the order of RL3.2m. Hence over this timeline, there is real potential for the functionality of the existing gravity networks in low-lying areas of Akaroa to become compromised. This is a common scenario for council's around New Zealand (close to the coast and of a low elevation, together with shallow groundwater levels), and will likely be a particular focus of Taumata Arowai.

[1] Relative Level (RL) is the vertical distance between a survey point and the adopted datum. In this instance Canterbury elevation contours with reference to the New Zealand Vertical Datum 2016 (NZVD2016), which is the official vertical datum for New Zealand.

Figure 2: Images from Canterbury Maps GIS data – highlighting lower-lying areas of gravity WW network with invert levels of approximately RL1m.

3.16 The existing networks are also typical of systems built earlier in the 20th century, and utilise brittle materials such as earthenware (EW) and asbestos cement (AC) that are not resilient to ground movement. These older parts of the network may have been impacted as a result of the Canterbury earthquakes, as well as age and typical ground movements from settlement and groundwater variations.

3.17 **It is hence pivotal that consideration be given to a comprehensive rehabilitation programme or replacement network at this juncture.** For example, a pressure sewer replacement regime – as touched on in the CH2M Beca report. This would provide several benefits (including future climate and earthquake resilience), but specifically, a significant reduction in I&I through which to base the wastewater treatment/disposal design. While it may not ultimately be the preferred outcome, given the current extent of I&I it is appropriate to consider this option further. We address this further below.

3.18 Such an approach would be in-line with experience from other councils. A recent example is the Ōpōtiki Sewerage Project. Here, the "sewers under the Opotiki township were first installed in 1956 and most of the pipework is still in service today [similarly for Akaroa]. Pipes are reaching the end of their life and the system is not working for the town as it should be… At the March 2017 Council meeting, Council resolved to rehabilitate the existing sewers." Following successful pilot repairs in 2015-16, an options analysis in 2016-17 found that rehabilitation of the network by repairing private property pipe lines and relining main pipe lines was the most cost effective solution compared with full replacement. For context, the population of Ōpōtiki is approximately 9,300. Given the tenfold scale of permanent population, as compared with Akaroa, the "find and fix" pilot programme may be an effective mechanism to substantially reduce I&I for Akaroa, rather than extensive investigations.

3.19 **Overall, the 20% target I&I reduction (and resulting 55% I&I rate to the wastewater treatment plant) is an unreasonable baseline from which to approach the treatment discharge/disposal design on – as is currently the case**. Questions remain on the resilience of the existing network to future conditions, and combined with the evidential poor condition relative to significant I&I rates (particularly groundwater), alternative network solutions should be carefully considered at this point, rather than overdesigning the treatment/disposal system.

Disposal to Land – Inner Bay Irrigation Scheme

3.20 The Inner Bays Irrigation Scheme proposes use of four separate land parcels for 40 h of land disposal via drip irrigation to native plantings and storage of treated wastewater effluent in a double-celled pond holding

19,000m^3. In addition, 6,000m³ covered raw wastewater storage is proposed at the wastewater treatment plant. The scheme outline (Section 5.1) includes reference to 1,000m³ treated storage; however the report later states CCC has advised that treated storage will only be provided in this option if the non-potable "purple pipe" reuse scheme is also implemented (Section 9.2.13).

3.21 Furthermore, a proposed 3,800m² subsurface wetland provides additional storage and facilitates infrequent (approximately once per 5yrs) overflow via the Children's Bay Creek to the Harbour:

a. The option for a subsurface wetland (providing passage through land) was identified, through hui with Ngāi Tahu representatives, as a suitable solution to enhance the mauri of treated wastewater plan effluent (considered as having severely degraded mauri).
b. The influent to the wetland is treated to a high degree by the treatment plant. Therefore, the wetland provides additional storage and a polishing function, primarily addressing cultural concerns by connecting treated wastewater to Papatūānuku and restoring the mauri of the water prior to infrequent discharges to the harbour.

3.22 We consider it is a viable option to maintain the health and functionality of the sub-surface wetland, while reserving storage volume for when required, by restricting flow to approximately match evapotranspiration requirements. However, we note:

a. The literature provides mixed performance results on the efficacy of nitrogen removal, although consistently indicates opportunity to improve nitrogen removal efficiency through aeration, cyclic filling of the system to restore bed aerobic conditions, dosing, and/or through managing detention times.
b. We have not identified in the literature similar systems without at least nominal base flow through the system. **We propose further consideration is required in response to potential accumulation risk and subsequent pulse loading with the absence of throughflow for up to 5yr periods, particularly for nitrogen but also potential emerging contaminants.**

3.23 Banks Peninsula soils, topography, geology, land use, and catchment configurations make large scale year-round wastewater land application of treated domestic wastewater technically challenging. The design and sizing for the Inner Bays Irrigation Scheme (and the Outer Bays Schemes) is based on a number of key assumptions, including (Appendix B, PDP Irrigation modelling): 20% reduction in I&I, population growth parameters, 37% interception of rainfall by the tree canopy (assumed mature), plant available water and evapotranspiration rates, year-round irrigation except for when daily rainfall is in excess of 50mm/day, and long-term acceptance rate of the soils.

3.24 **Due to the constrained space available, there is a lack of resilience in the design for variation between in-situ properties and the modelled design parameters.**

a. The design sizing for storage ponds – both of treated and raw wastewater – is sensitive to reductions in I&I. It is considered critical that I&I is more robustly addressed, if significant reductions in I&I can be achieved, then the current system is oversized. If the intended 20% I&I reduction cannot be achieved, the proposed site will have insufficient capacity which may result in more frequent discharged from the subsurface wetland to Children's Bay Creek than intended.
b. With year-round irrigation proposed to achieve design flow rates based on available storage, soils may remain at field capacity for extended periods of time. Potential geotechnical concerns need to be addressed, in addition to risk of inducing anaerobic conditions that negatively impact plant health (associated with slope stability, interception, and estimated evapotranspiration rates). Nitrification is an effective treatment concept and it is important that the aerobic status of the irrigation field is preserved for this process.

c. The rate of application affects the fate of Nitrogen, with higher application rates resulting in increased N-leaching and potentially increased N_2O emissions. The current design for land disposal within the Inner Harbour areas predicts nitrate leachate of 15–60 kg/ha/yr which is considered comparable to grazed pasture. This could be concluded as no net change from existing, as land is currently grazed pasture; however, Statistics NZ shows Nitrate-nitrogen leached from livestock as <30 kg/ha/yr. Given the considerable investment to upgrade the treatment system, it would be appropriate to consider an improved outcome from existing for the proposed irrigation fields. It is, however, an improvement on existing treated wastewater effluent quality of 25.4 mg/L Total Nitrogen from the current Akaroa wastewater treatment plant (2017-2019 data, Appendix C).

Deep Bore Injection (DBI) and Managed Aquifer Recharge (MAR)

3.25 Both DBI and MAR have been discounted as discharge/disposal mechanisms in the Akaroa context. However, in our view, legitimate potential remains for further consideration of these options to resolve a future-resilient water management regime. Our rationale is outlined as follows.

3.26 The CH2M Beca report summarises that: *Based on the results of the deep bore drilling investigation, and the considerable cost of conducting further investigations at other sites with no indication of likely success, a decision was taken by Council staff to discontinue bore injection as a possible wastewater disposal option.*

3.27 In respect of MAR, CCC resolved on 5 August 2019 that: *Central government has embarked on a comprehensive programme of regulatory reform to ensure the safety of community drinking water supplies. In this context I* [on behalf of CCC] *consider that managed aquifer recharge presents too great a risk to Akaroa's drinking water supply to continue exploring this option further.*

3.28 Appendix E of the CH2M Beca report (Deep Bore Injection Investigations) included a valuable literature review of existing deep bore discharge regimes in New Zealand and beyond. Several findings were significant; however the Perth example was of particular relevance. This summary is relevant to both DBI and MAR. The CH2M Beca report explains that (with emphasis added): "*In 2010, Perth began a three-year trial of a groundwater replenishment scheme, modelled in part off the Orange County scheme. Wastewater is treated at the Water Corporation's Beenyup facility in Craigie* ***to drinking water standards*** *(****including ultrafiltration, reverse osmosis and ultraviolet disinfection stages****) and pumped to two recharge sites 13 km offsite.* This has been a success." Note also that this regime has since been expanded due to the first stage success together with a heightened awareness of pending climate change impacts (Water Corporation, 2019).

3.29 Appendix F addressed MAR, building on research and investigations relative to DBI. There is also research on this area in New Zealand, including this article – Managed Aquifer Recharge – A Potential Water Treatment Method in New Zealand – which indicated positive results and good potential for MAR.

3.30 The supporting CH2M Beca Interpretative Report on Feasibility Investigation of Deep Bore Injection (Appendix E Deep Bore Injection Investigations) outlined two key assumptions:

a. The expected flows from the wastewater treatment plant are currently in the order of 15 litres/second (l/s).
b. A target of 4-5 l/s per deep bore.

3.31 The report notes that: *Deep bore injection could be used as an alternative to a harbour outfall and compliment other disposal and reuse options. The injection methodology sought to avoid interference with springs and other supply wells in the area by targeting strata below sea level and set back from the coast such that direct discharge to the harbour was avoided and a minimum travel time of one month could be demonstrated to meet cultural requirements.*

3.32 The report then concludes that: *Based on the results of the investigative drilling, deep bore injection **at the proposed wastewater treatment plant site is not feasible**. Due to the lack of open connected fractures and low permeability ground conditions, the exfiltration bore capacity was very low and not feasible for deep bore injection. Even at shallower depths i.e. above sea level, the ground conditions encountered were unlikely to be suitable for disposal of treated wastewater*.

3.33 In contrast, the report states: *Other sites could be investigated for deep bore injection however this investigation shows how variable the ground and groundwater conditions can be around Akaroa. There are water supply bores in the area that show suitable hydraulic capacity for bore injection, however these are generally used for public water supply and mixing of the waters may not be acceptable to the community. Bore injection further up the catchment away from the coast is a possibility however injection would need to be at depth to avoid spring interaction and impact on water quality for instream and groundwater users. These matters would need to be considered as part of a feasibility study*.

3.34 Given the acknowledged variability in geological conditions across Banks Peninsula, and the associated variability in permeability rates, it seems a missed opportunity to discount this approach on the basis of only two nearby boreholes within the future treatment plant site with overlying loess soils – each achieving discharge flow rates in the order of 0.7-0.8 l/s. The report acknowledges broader potential for higher flow rates elsewhere on the peninsula, and records known boreholes with higher hydraulic conductivity. Further, **if the treatment plant discharge rate were proportionally reduced by targeting an improved best practice, or even leading practice I&I rates for the network, then the number of boreholes required, and associated cost could also be reduced. The land area requirements for both DBI and MAR are significantly less than the four proposed options, and the associated benefits of this approach could hence be tangible relative to the LGA four well-beings**.

3.35 Furthermore, the CH2M Beca report explains that in the context of MAR: *Council staff determined that potential connectivity between the groundwater injection and groundwater abstraction for potable supply, presented a significant risk to water supply security in Akaroa, and determined that the option should not be considered further.* This could be explored further given the potential separation distances achievable on Banks Peninsula – evident by the outer bays land disposal options put forward. The MAR research noted above indicated positive pathogen removal capacities across a 40-80m separation distance between the infiltration and abstraction well locations. The Perth successes are a further present-day example of the potential for MAR.

3.36 We note the CH2M Beca report indicated a neutral/medium score for DBI, and a worst score for MAR relative to cultural acceptance. However, with further understanding of this solution, potentially together with ground-level pre-treatment via a sub-surface wetland or similar, this may be a more acceptable approach for mana whenua. It would also be valuable to understand if the scores posed in the multi-criteria analysis were determined by the assessment team alone or in consultation with Ngāi Tahu. It is our interpretation that discharge to ground via DBI or MAR would be preferable to a surface water or coastal outfall solution – and potentially comparable to discharge to land.

3.37 Collectively overall, this suggests strong merit in further exploration of DBI and MAR in other parts of Banks Peninsula – away from the primary drinking water supply catchment for Akaroa. As identified in the supporting CH2M Beca Interpretative Report (Appendix E Deep Bore Injection Investigations), *DBI could be used as an alternative to a harbour outfall and compliment other disposal and reuse options.* Later we discuss the benefits of combining Reverse osmosis with MAR.

Harbour Outfall

3.38 The proposed harbour outfall option is based upon the 2014 consent application for which consents were declined – a mid-harbour outfall where the depth of water is greatest (about 8m depth at mean sea level) to provide the most efficient dilution and dispersion of wastewater released:

a. While an improvement on the original design, with elimination of bypass and inclusion of a "purple pipe" non-potable reuse option, we consider direct discharge to the harbour remains unlikely to be a suitable solution on cultural grounds.
b. Ngāi Tahu submitters for the 2015 hearing notes that the cultural impacts of the discharge would not be satisfied until all the effluent made contact with Papatūānuku (land) before entering any water body. This aligns with the more recent Ngāi Tahu statement noting that by passing wastewater through or over Papatūānuku (land) and allowing for natural filtration to occur, the eventual receiving water is not impaired.

4 Alternative Solutions

4.1 Based on our review of the consultation material, we are of the opinion that an alternative solution to the four discharge/disposal mechanisms currently proposed would achieve improved and broader benefits. Specifically, relative to *promoting the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach*.

4.2 In the following subsections we outline a number of components. We do not propose a single solution but consider each of these elements, whether singularly or jointly, could contribute to a more sustainable solution for utilising and/or disposing of treated wastewater effluent. It would be appropriate to workshop further with stakeholders, particularly Te Rūnanga o Ōnuku, to appropriately address opportunities to enhance the mauri of the treated wastewater effluent prior to discharge to the ultimate receiving environment. In all scenarios we recommend:

a. Greater action to reduce I&I, and better understand the contributing proportion of I&I under winter conditions when irrigation to land is most constrained.
b. Inclusion of at least the 1,000m³ treated storage area proposed at the wastewater treatment plant, for quality control, and to facilitate a non-potable reuse scheme (either now or future proofed) and/or diversion to alternate disposal options.

Enhanced Reduction in Inflow and Infiltration

4.3 The peak design flow rate for the wastewater treatment plant has influenced many factors in the proposed disposal options, including storage volume and land area requirements for disposal to native plantings and suitability of managed aquifer recharge. Assessment for all solutions was informed by the 14 L/s peak design flow (treating 1,200 m³/day) for the consented treatment plant design. Noting, we understand the design peak flow rate remains unchanged since the discovery of the faulty flow meter in 2017 and knowledge of increased I&I. The impact is the design now includes a raw wastewater pond at the plant site to buffer peak wet weather flows and diurnal peaks during the peak summer period.

4.4 We note inflow and infiltration was not previously a significant issue, as ultimate disposal of treated wastewater was to the harbour and therefore not volume limited.

4.5 The WaterNZ guidance (Figure 1) supports a greater reduction target than the 20% proposed in the existing design. The current 20% target reduces combined I&I from 61% to 55% of average annual flow. A reduction target of 57% is needed to meet the KPI of 40% combined Groundwater Infiltration and Rainfall Dependent

Inflow when using the existing network as a baseline. This is particularly relevant considering potential increased groundwater intrusion with the effects of climate change.

4.6 Increasing the I&I reduction target from 20% to 57% has the effect of reducing the storage volume required for the Inner Harbour land disposal option from 24,000m³ to ~10,000m³ (assuming 40Ha irrigation area and 0% population flow reduction, per Appendix B Table 6). This reduction in storage will provide future resilience for the wastewater treatment plant and provide design efficiencies for all possible disposal options.

4.7 One alternate to reduce I&I beyond 20% that does not appear to have been addressed is a widescale renewal using Cured in Place Pipe (CIPP), rather than full replacement of the network.

a. CIPP lining provides quantifiable structural strength to a pipeline, can suit various loading conditions and pipe shapes, and offers minimal loss of capacity (which may be offset by reducing groundwater infiltration).
b. Given the significant contribution of I&I to the network an approach taken by other Councils has been to avoid costly investigations and start on the basis of full renewal. Any sections of network in good condition when CCTV'd to design for renewal are then excluded from the total cost.
c. Total length of wastewater reticulation is ~17km with an average nominal diameter of ~150mm, together with a total of ~400 manhole chambers in the entire network, serving approximately 900 dwellings (CCC 3-Waters Network Asset Map)
d. Based on standard rates of $150/m to supply & install lining to existing pipes, $240 per lateral to cut out lining and retain lateral connections to the network, and double the number of manhole repairs and replacements (50 × internal, 50 × external, 50 replacement – likely focused in the lowest coastal sections of network) the cost of physical works to line all 17km of public network and repair/replace just over one-third of the manholes would be ~$4.5 million. This accounts for a 20% P&G rate.
e. For additional context, a CIPP solution to line the 2km pipe proposed to be renewed in the CH2M Beca scenario (Appendix AD), while maintaining the same number of manhole repairs and replacements, would reduce the predicted cost from $2.7 million to $0.9 million using the linear rate for CIPP lining above.
f. This indicates that the total estimated cost of $4.5 million to line the entire network would be needed, $1.8 million more than currently allocated, but the solution would reduce the combined costs for treatment plant and disposal options, releasing funds for future reuse and recycling options and improving overall system resilience.
g. This proposed solution does not directly address surface water intrusion via access manholes in low lying portions of the network that will be impacted by sea level rise, potential for cross-connections from stormwater network into the wastewater system, nor groundwater intrusion via lengths of private network prior to connection to the public network. However, the cost estimate conservatively assumes lining of the entire public network – it may be reasonable to consider reallocation of funds from upper portions of the network which are more resilient to climate change, or newer portions less likely to require renewal, to initially focus energy in the lower lying older parts of the network at greater risk. Similarly, a "find and fix" solution, as undertaken by Ōpōtiki District Council, may also prove effective.

Upgrade Existing Network to Low Pressure Wastewater System

4.8 In addition to repairs of the existing network to reduce I&I, it is also important to consider network replacement at this juncture. This is reinforced by the referenced WaterNZ guidance which outlines that: "The option of replacement of the asset should be considered and a financial comparison against renewal performed. A cost/benefit analysis should also be used to compare the option of re-lining pipes versus replacing pipes, and to determine the most cost effective method of rehabilitation (re-line vs. replace) for a particular project area." It further highlights that: "The useful life of pipe rehabilitated using CIPP is expected to be 50 years, while pipe

replacement (open trench or pipe-bursting) is 50 – 100 years" – noting challenges to further rehabilitation of lined-pipes beyond that 50-year life span.

4.9 Full or partial replacement of the network would have the added benefit of a prolonged, extended asset life span – circa 100 years – which is significant in the context of predicted climate change impacts. With this horizon, we can anticipate sea level increases to the extent that would impact the existing network hydraulics and pose surface-level inundation risks, coupled with increased groundwater pressures, particularly on the lower-lying areas of the network. This collectively lends weight to closed-conduit pressurised sewer systems – as identified in the CH2M Beca report.

4.10 The CH2M Beca report highlights that: "As an alternative to remediating the existing network, the entire wastewater network could be completely replaced, either using pressure sewer or a combination of gravity plus pressure sewer. This would involve extensive construction works affecting every household connection in every street, and may also require a financial commitment from landowners as leakage from privately owned laterals is a contributor to overall I&I. This scenario would be prohibitively expensive as well as disruptive and so has not been incorporated into scheme proposals thus far."

4.11 Construction works would indeed be extensive with works required on every lot (in the case of total replacement). However, works in the road network would be limited largely to the comparatively shallow and directionally drilled installation of small diameter PE/plastic pipes. This has many benefits, including keeping excavation depths to a minimum because of the high ground water levels, and shallower depths to improve access for maintenance or repair work with lesser associated traffic and residential disruption. The life-cycle costs should be carefully considered in this regard; noting the limited lifespan of remediated/lined existing pipe networks, and potential for 100-year + horizons for new PE pipes.

4.12 Pressure sewer systems operate like conventional gravity sewers, but rely on pump stations, commonly located on individual private properties, and which grind up solids and transfers all the waste to the treatment plant (with no treatment on site). The combined power of each individual pump moves the sewage to the treatment plant. Such systems are becoming common place around New Zealand, particularly in growth areas, and with Christchurch leading the way relative to replacement networks in response to the 2010/2011 earthquakes. Vacuum Sewer Systems have also been pioneered by CCC for replacement networks in areas of Christchurch; however we understand the results to be inconclusive at this point (WaterNZ paper, 2018).

4.13 There is potential for parts or all of the existing network to be replaced by a pressure solution – noting the existing planned approach with a centralised pump station to facilitate the replacement treatment plant at the north end of Akaroa. Relevant design guidance is now provided by a recently-released WaterNZ publication, Pressure Sewer National Guidelines.

4.14 For a partial pressure system approach, as an example arrangement, this could target lower lying areas of the network with higher risks from sea level rise and shallow groundwater levels with associated infiltration, while maintaining gravity flows from high-ground areas. This approach would likely result in several public pump chamber / wet wells within the network, and rely on further individual pump systems on private lots in the lower-lying areas. Consideration could be given to pressure networks below a surface level of RL5m, roughly aligning with the eastern berm of Rue Lavaud, such that belowground wastewater infrastructure in these lower-lying areas would be complete closed conduits.

a. Based on a nominal length of wastewater reticulation of ~6km replaced with small bore PE pressure sewer pipes – with 3km of trunk pressure and 3km of low pressure networks, together with a nominal number of trunk pressure wet wells (8) and 180 lower-lying sites fitted with low pressure pump chambers.

b. Based on estimated rates of between $150-180/m to supply & install new PE pressure sewers, $50,000 for trunk network wet wells, and $20,000 allowed for each on-site low-pressure chamber, the cost of physical works would be ~$6.1 million. This accounts for a P&G rate of 20%.

4.15 A complete shift to a pressure system would rely on small pump chambers on each private lot, and would be unusual given the moderate to steep topography across much of the existing urban extents. That being said, an indicative price estimate is summarised as follows:

a. Total length of wastewater reticulation of ~17km replaced with small bore PE pressure sewer pipes, together with low pressure pump chambers on all lots (circa 900) and in-network trunk pressure wet wells.
b. Based on estimated rates of $180/m to supply & install new PE pressure sewers with in-road trunk pressure wet wells, and $20,000 allowed for each on-site low-pressure chamber, the cost of physical works would be ~$23.7 million. This accounts for a lower P&G of 10% based on the higher capital value.

4.16 Table 1 summarises the options proposed to reduce I&I and increase resilience of the wastewater network in response to climate change. The preferred option would incorporate Full CIPP lining, a Partial Pressure System, or perhaps a combination of Partial Pressure in the low-lying areas, with "find and fix" CIPP lining for higher-elevation portions of the network. Regardless, we consider greater investigation is warranted to enhance I&I reduction from the 20% currently proposed to achieve the 57% reduction required to meet industry key performance indicators.

Table 1: Comparative options to reduce I&I

Option	Cost	Comment on Concept Option
Current Option (replacement)	$2.7M	2km pipe renewal via replacement, 50 manholes repaired, 25 manholes replaced. Possible surface intrusion via manholes due to rising sea level.
Current Option (CIPP lining)	$0.9M	2km pipe renewal via lining, 50 manholes repaired, 25 manholes replaced. Possible surface intrusion via manholes due to rising sea level.
Full CIPP Lining	$4.5M	17km pipe renewal via lining, 100 manholes repaired, 50 manholes replaced. Possible surface intrusion via manholes due to rising sea level.
Partial Pressure System	$6.1M	3km trunk pressure network, 3km low pressure network, nominal (8) trunk pressure wet wells, 180 lower-lying sites fitted with low pressure pump chambers. Sealed network prevents water intrusion.
Full Pressure System	$23.7M	17km pressure network, 900 sites fitted with low pressure pump chambers. Sealed network prevents water intrusion. Unlikely to be preferred option given topography across existing urban extents.

Land Disposal

4.17 If land application is to proceed, given variability in application rates and ability for the system to respond as modelled, we recommend commitment to compliance monitoring and application in stages, perhaps over years.

4.18 This may be initiated with reduced application rates, or limiting application to summer periods, to provide knowledge regarding current unknowns and to validate the assumptions used in modelling assessments. The ultimate intention would be to set functional environmental limits for wastewater application to native planting in the Banks Peninsula to mitigate and protect for geotechnical, public health, environmental, social/cultural, and economic risk. Over this staging period, an alternate disposal source would be required to balance predicted flow, options including stream recharge or harbour outfall (discussed further as follows).

a. Irrigation modelling does not take into consideration the effects of climate change, presenting long term results based on 1972 to 2018 data. While summer increase in soil water deficit and reduced rainfall may support summer application of treated wastewater to native plantings, even a small increase in winter rainfall (NIWA, 2020) may increase storage requirements or frequency of overflow to the Children's Bay Creek.
b. There is currently little information available on the nutrient uptake from wastewater by native vegetation, with research in progress by Dr Brett Robinson. The provided assessment (Appendix C; Brett Robinson Reports) concludes that a more accurate assessment of the likely N-leaching under NZ-native vegetation will be provided in an updated report, originally anticipated early 2020. Any updates to the research outputs will further inform the design parameters used.
c. Both Nitrogen and Phosphorus removal are enhanced through reduced loading or periodic removal of the vegetation; **nutrient uptake diminishes as trees mature.** It is also noted that plant selection and weed control, particularly during establishment, will be critical success factors. Greater confidence is recommended to demonstrate these elements are factored into the life of the system – with regard to long term site specific nutrient uptake coefficients and nutrient pathways. The provided assessment (Appendix C; Brett Robinson Reports) appears founded on a 50-yr design life for the system, which could be extended through reduced application rates or periodic harvesting of the native vegetation.

Reverse Osmosis

4.19 **Inclusion of reverse osmosis removes risks to human health associated with disposal of treated wastewater to receiving environments, and facilitates a future potable reuse scheme via either indirect reuse (stream recharge, upstream of existing water takes; MAR) or direct reuse (plumbed to the water supply; to the WWTP, potentially using the existing raw water supply pipe passing the WWTP from the Takamātua Stream). Both options provide increased resilience for Akaroa's water supply in response to climate change.**

a. Reverse osmosis is a water purification process that uses a partially permeable membrane to remove ions, unwanted molecules, and larger particles from drinking water, resulting in very high-quality water.
b. Emerging Contaminants include chemicals, microorganisms, and nano-chemicals (i.e. pharmaceuticals, chemicals in personal care products, and natural steroid hormones). They are different from traditional persistent organic pollutants (i.e. DDT) due to bioactive properties. Apart from chemical industry discharges, the primary source into the environment is from wastewater treatment plant effluents. With particular reference to Emerging Organic Contaminants, **full removal is not achieved by primary & secondary wastewater treatment processes but can be with reverse osmosis.**

4.20 Membrane filtration (pre-treatment) and Reverse Osmosis (RO) can be used for large scale wastewater treatment. Reverse Osmosis (RO) units singularly have specified permeate flows, specific to each device and tested at different temperatures.

a. Reverse Osmosis units come in small units with the ability to combine multiple units in series to act as a single unit to increase the volume intake. This allows for more flexibility within the design for placement and set up of the reverse osmosis system within the allowable space for the treatment plant. As shown on Filtec NZ website you can see multiple membranes stacked together. Each membrane is around 2m in height with a flow range of 45–180 m^3/day.
b. Through a well-designed process of proper pre-treatment of the water before flowing through the Reverse Osmosis membranes, as well as the use of anti-scalant chemicals and low fouling membranes, the Bedok Wastewater Treatment Plant in Singapore (32,000m^3/day) were able to reduce frequency of membrane cleaning to six monthly periods.

4.21 Membrane filtration (hollow fibre ultra-filtration, in tank, low pressure) has been specifically included in the concept design to remove suspended solids and pathogens from the treated wastewater. Reverse osmosis uses nano membranes that are sensitive to blockages from larger particles.

a. **Ultrafiltration provides good pre-treatment filtering more contaminants (i.e. than microfiltration) before the reverse osmosis process which in turn results in less frequent cleaning, and possibly less replacement and discard of membranes.**
b. Additionally, pre-treatment may include addition of anti-scalant chemicals as well as using membranes with anti-scaling / fouling properties.

4.22 Reverse Osmosis Concentrate

a. Reverse osmosis concentrate (also referred to as retentate) from wastewater reclamation in water reuse retains concentrated toxic bio-refractory organics and developing technologies for their removal is essential. A 2019 paper reviews innovative treatment technologies for organic contaminants within, and proposes an integrated treatment process comprising forward osmosis, pre-coagulation, short-time and/or solar-driven advanced oxidation processes (e.g. a rotating advanced oxidation contactor), and post-biological treatment is proposed as an energy-saving and cost-effective technology for reverse osmosis concentrate treatment.
b. A study into the Impacts of Reverse Osmosis Concentrate Recirculation on MBR Performances identified the return of the RO concentrate to the membrane bioreactor (MBR) could be a good alternative for the reduction of concentrate quantities before disposal to the environment. However, it was noted that there was some increase in membrane fouling in the MBR, dependant on careful management of operating parameters.
c. A recent study in support of Tasman District Council's Motueka WWTP Upgrade highlights: "The chemical waste generated by this plant (backwash of CIP ['clean in place' chemicals for membrane maintenance] and retentate) will be returned to Pond 2 which is large enough to provide sufficient dilution and assimilation of the backwash. Existing membrane filtration plants in New Zealand at Dunedin Airport, Dannevirke, and Matamata use this method of backwash disposal."

4.23 The Singapore Water Reclamation Study ("NEWater Study") uses **microfiltration, reverse osmosis, and ultraviolet technologies to purify treated wastewater prior to blending the treated water with reservoir water for indirect reuse.**

a. Cost for production and transmission of water was S$1.30/m³ in 2003
b. The system caters for 10,000m³/d.
c. The average unit power consumption is from 0.7 to 0.9 kWh/m³
d. It was noted that blending treated water with alternate water supplies after reverse osmosis will provide trace minerals, which have been removed in the reverse osmosis process, necessary for health and taste.

4.24 For context and comparative purposes, we have reviewed documentation prepared in support of the Queensland Urban Utilities Water Reclamation Plant at Luggage Point; specifically their Planning Study/Report dated June 2010. Section 8.15 *MFRO Plant Renewals* outlines projected membrane replacement costs, with A$4,700,000 for Microfiltration (MF) membrane replacement every 10 years, and A$2,100,000 for RO membrane replacement every 5 years budgeted for. This system caters for up to 14 Ml/d – or 162 l/s – orders of magnitude larger than the flow rates anticipated in Akaroa. Scaled by an order of magnitude, this could indicatively equate to NZ$230,000 every 5-yrs for Akaroa. However, we note the Queensland plant may benefit from cost efficiencies (due to scale), but the proposed Akaroa Plant offers a higher degree of pre-treatment within its current design (ultrafiltration compared to microfiltration) which will extend the life of the RO

membranes. Furthermore, Akaroa is sized to process the peak summer average daily flow but is anticipated to operate at lower flow rates for much of the year, which may further extend the life of the membranes.

Deep Bore Injection (DBI) and Managed Aquifer Recharge (MAR)

4.25 As outlined in Section 3, there remains potential for DBI and/or MAR to form part of the overall solution for Akaroa. DBI has been discounted on the basis of two closely located bore hole trials at the treatment plant site, despite acknowledgement of variable volcanic geology across Banks Peninsula with known potential for higher permeability rates. MAR has been discounted due to regulatory barriers and perceived risks of cross-contamination of water supply springs – despite an ever-changing regulatory framework and potential for MAR to be located at distances away from supply springs, or for water quality to be further enhanced with RO prior to aquifer recharge.

4.26 There is evidence to support such an approach, including successful adoption of MAR via DBI in Perth forming a critical part of the overall water management regime for western Australia. In that case, wastewater treatment included ultrafiltration, reverse osmosis and ultraviolet disinfection stages prior to direct injection to the underlying aquifers which in turn provide Perth's main municipal water supply source. This is supported by the Australian Guidelines for Water Recycling: Managed Aquifer Recharge, the world's first MAR Guidelines based on risk-management principles that also underpin the World Health Organisation's Water Safety Plans, which reinforces that MAR is the purposeful recharge of water to aquifers for subsequent recovery or environmental benefit, rather than a method for waste disposal.

4.27 Collectively, there is robust merit in further exploration of DBI and MAR in other parts of Banks Peninsula – for example, away from the primary drinking water supply catchment for Akaroa or after RO. As identified in the supporting CH2M Beca Interpretative Report (Appendix E), *DBI could be used as an alternative to a harbour outfall and compliment other disposal and reuse options.* There is real potential for DBI and/or MAR to provide cost-effective options to manage residual disposal needs while building up toward maximum re-use without direct discharge to surface-level water bodies.

Subsurface Wetlands

4.28 A similar subsurface wetland design was proposed in the previous treated wastewater disposal options publicly notified in 2016 (prior to identification of faulty flow meters) (*Akaroa Wastewater - Concept Design Report for Alternatives to Harbour Outfall*; CH2M Beca, 2016).

a. Surface area of ~0.7Ha area at 0.5m deep plus a 0.7Ha storage pond at 2.5m deep, treating a 6L/s design flow with a two-day residence time.
b. The infiltration gallery was a structure composed of locally sourced rock with a central slotted or drilled pipe 20m long and running along its length, buried in the beach in the intertidal zone.
c. These systems were not supported by Ngāi Tahu representatives, on the basis that treatment was not using a natural process and ultimate disposal was still to the harbour via a coastal infiltration gallery.
d. We can understand the reticence of Ngāi Tahu to accept this solution as suitably recognising te mana o te wai. The subsurface wetland is a lined and engineered system, which then discharges via an engineered solution providing no measurable improvement to water quality direct to the harbour in the beach in the intertidal zone, and therefore insufficient to mitigate cultural concerns.
e. It is noted the previous publicly notified design did not provide for raw wastewater storage and included bypass of primary treated flows direct to the harbour on average two days per year.

4.29 Since the solutions proposed in 2016, Ngāi Tahu representatives appear more supportive of sub-surface wetland solutions. Ngāi Tahu representatives consulted on the Duvauchelle disposal solution (discussed further as follows) which discharges during winter periods (when land disposal is unavailable) via sub-surface wetland

to Pawsons Stream, and proposed the sub-surface wetland in the current Inner Bay Irrigation Scheme which discharges infrequently to Children's Bay Creek.

4.30 We propose enhanced subsurface wetland design, developed in conjunction with Ngāi Tahu representatives, may provide an alternate solution to reduce or avoid reliance on constrained land disposal options:

a. Maximise reductions in I&I to reduce peak wet weather storage requirements (target 57% reduction).
b. Inclusion of proposed UV treatment to meet Australian Guidelines for Water Recycling (AGWR) disinfection requirements for Viruses, Protozoa, and Bacteria, given absence of current NZ legislation and guidance.
c. Maintain appropriate minimum residence time in the wetland, indicative target 2-3 days.
d. Relatively simple modifications to the design would make it more effective for nitrogen removal – careful plant selection, vertically fed, pulse fed, and aerated. A constructed wetland with vertical flow can potentially reach 90% removal of nitrogen, phosphorous and BOD.
e. While the relationship will not be linear, indicatively doubling the previous design to provide for the 14 L/s design flow of the treatment plan 3 Ha would be required to provide sufficient capacity for all flows to pass through the wetland system. Suitable locations would need to be identified; however, this could be completed using the previous analysis to identify land disposal areas, with considerably less land required.

4.31 A well-designed stream discharge solution after flows have been disinfected and passed through the enhanced subsurface wetland, has improved alignment with the Ngāi Tahu position that it is more appropriate to pass even highly treated WW through or across land for Papatūānuku to cleanse. It may be appropriate to consider such a wetland as part of a staged solution supporting stream or harbour disposal (discussed further as follows), and as an interim measure until a reuse solution is tenable.

Stream discharge

4.32 We propose stream recharge could provide beneficial reuse for a portion (i.e. balancing "purple pipe" demand or DBI/MAR capacity) or for all (as a standalone solution) of the treated wastewater, supplemented by:

a. Maximised I&I reductions (target 57% reduction).
b. Enhanced disinfection to achieve Australian Guidelines for Wastewater Recycling non-potable reuse standards.
c. Treated wastewater storage at the treatment plant to enable quality control, and to direct water for either non-potable reuse or to a wetland.
d. Utilisation of treated wastewater for non-potable use (or future potable use with change in regulation)
e. Enhanced wetland treatment prior to discharge to streams, flow dispersal method to be designed in conjunction with Ngāi Tahu – preferably setback from watercourse, via filterstrip or vegetated swale and at an angle sensitive to the direction of flow.

4.33 Stream discharge is not considered as a discrete option within the current application material. However, infrequent overflows from the proposed subsurface wetland are proposed to the Children's Bay Creek. There is no assessment of the existing stream condition, likely due to the infrequent nature of intended discharges (approximately once per 5yrs, flows range from controlled wetland outflow of 2 L/s up to 14 L/s full flow of the treatment plant). We propose consideration of regular base flows through the wetland to the stream, considering:

a. An ecological evaluation to assess erosion risk in response to grade and substrate (likely highly erodible loess soils), and to quantify existing stream condition and base flows to inform suitable mixing. The catchment is not large, so may limit suitable flow rates, and it is unknown if the stream maintains permanent flow in the upper reaches adjacent to the proposed wetland site.
b. Discharges via ~620m of stream corridor from Christchurch Akaroa Rd to Children's Bay Creek mouth

c. The length of watercourse allows for considerable detention time to interact with the stream substrate.
d. It is anticipated the stream grade and heterogeneity will enhance aeration and dissolved oxygen with mature vegetation in the stream gully providing bank stability and shading along the riparian margins.
e. We note what appears to be a flax wetland area at the Children's Bay Creek mouth (Figure 3). It is not known if this is natural or planted (perhaps a pā harakeke) and whether it is providing formal or informal water quality treatment. However, there is potential to further enhance natural treatment of flows in the Children's Bay Creek prior to discharge to the harbour.

Figure 3: Google Street View image of the Children's Bay Creek looking upstream from Children's Bay Rd

4.34 The proposed wetland for the Duvauchelle Wastewater Scheme will irrigate to land (via spray to the golf course, meeting ARWG standard for spray irrigation) during summer months and discharge to Pawson's Stream in winter months, due to limitations identified with infiltration to land. This proposal has been developed in consultation with Ngāi Tahu.

a. The 1 ha wetland with 5,000m³ additional storage treats 1.2 L/s and has a residence time of 2-3 days.
b. Discharge is managed to achieve a minimum level of dilution in the stream at all times, e.g. 20 times dilution within the mixing zone and 100 times dilution with the total flow.
c. Discharge preferably be allowed to vary depending on base flow in the stream, e.g. during wet weather when stream flows are higher, higher wastewater discharge flows would be allowed
d. Wastewater is fully mixed with receiving waters before it reaches the coastal marine area.

4.35 On the basis of the Duvauchelle model, aiming to achieve comparable or better design parameters, we propose alternate stream discharge options may be more suitable than the currently proposed Children's Bay Creek and would facilitate a greater portion of flows to the streams:

a. Provide disinfection, enhanced wetland treatment, and maximise I&I reductions, as discussed prior.
b. Discharge to streams with larger contributing catchments, for example Grehan Stream, Balguerie Stream, and Aylmers Stream all of which ultimately discharge to French Bay, thereby recharging streams within the Akaroa catchment.
c. These streams also have consented water supply takes, and so discharge could provide stream recharge downstream of the existing water take for enhanced environment flows, particularly during summer months.

d. Concerns were raised regarding stream discharges in the CH2M Beca 2016 options report with regards to mixing, referencing wet weather bypasses, and increased contaminant loads. Bypass is eliminated in the current design through provision of additional raw wastewater storage at the treatment plant. Regardless, specific assessment would be required to define suitable seasonal discharge limits for both low flow conditions and high flow (given these stream pass near residential and commercial buildings).

4.36 We note the just-released update to the National Policy Statement for Freshwater Management, August 2020, provides further context – particularly in terms of environmental bottom lines for various contaminants in freshwater habitats.

Reuse of Treated Effluent

4.37 We agree with the background work in this area, and proposed that reuse of treated effluent should be future-proofed and provided for through the overall water management regime in Akaroa, pending clarity in regulatory oversight on this issue. This should be developed in conjunction with other disposal mechanisms that can be staged and scaled over time, responding to changing perceptions and regulation.

4.38 There are several permutations in this regard, including purple pipe / non-potable reuse, and full water supply reuse. Consideration could also be given to discharging to the water supply take streams to supplement and buffer the consented water takes, and recycle the treated effluent for further treatment through the raw water treatment systems. Alternatively, the treated effluent could be directed to the water supply treatment plant via an existing raw water pipe; although we note this is less likely to be acceptable and is not commonly utilised overseas (one example identified in Namibia). We also note an alternate reuse of that pipe if the Takamātua supply take is not required.

4.39 There is precedence of this in other countries; particularly where water shortages and/or demand is at critical levels. We note existing systems in Australia (i.e. South East Queensland & Perth) discharge recycled water to existing storage dams or via managed aquifer recharge, avoiding direct reuse and direct discharge to the final receiving waterbody, but indirectly contributing to the water supply regime and overall system resilience. In this regard, we highlight the addition of UV treatment to meet disinfection requirements for Viruses, Protozoa, and Bacteria from the Australian Guidelines for Water Recycling (AGWR), given absence of current NZ legislation and guidance.

4.40 For context, the CH2M Beca report states “A fully reticulated non-potable reuse network has not been used before in New Zealand and is not currently supported by the Ministry of Health and the Canterbury District Health Board.” This is reinforced by communications included in Appendix G to the report. However, attention is drawn to overseas examples and guidance, to broad recognition of the drivers for utilising this resource (including the current water shortage issues in Auckland), and to the role that Taumata Arowai will take in driving this from a regulatory perspective.

4.41 Section 9.2.6 Enhanced Disinfection for Non-potable Reuse reinforces the current state of play in this regard: “There are no nationally accepted guidelines in New Zealand that deal specifically with the reuse of treated municipal wastewater in urban areas. Any municipal wastewater recycling scheme is likely to be subject to the requirements of the Health Act and the Local Government Act. Consultation with the Ministry of Health and other Government agencies is needed to ascertain the acceptability of the Australian framework in the absence of New Zealand regulations and guidelines.” Either way, a future focused solution should be resilient to this option.

4.42 The MfE Sustainable Wastewater Management: A handbook for smaller communities from 2003 (part 9) includes a summary of a development scheme called the Golden Valley subdivision in Kuaotunu, Coromandel Peninsula. This comprised a subdivision of 40 residential lots that was designed and constructed in 2000 with a

pumped MEDS (modified effluent drainage servicing) collection system. In that case, *filtered septic tank effluent is conveyed in 50 mm pressure sewer lines from a pump within each septic tank to a central recirculating sand-filter treatment plant located in an enlarged and landscaped central median strip on the access road serving the development.* ***The very high-quality effluent produced is in part disinfected and returned to each lot as non-potable reclaimed water for toilet flushing****. The remaining effluent flow is not disinfected, but pumped to an area of steep terrain where it is to be irrigated by driplines into eucalyptus planted plots. A portion of treated effluent will be held in storage for firefighting purposes.*

4.43 Additionally, because of the use of a fully sealed reticulation system, there will be no infiltration into the system, thus protecting the treatment plant from excess flows. The treatment plant performance, including the operational status of all mechanical units and effluent quality readings from treatment stages, is remote monitored by sensors, with the resulting information transferred to computer surveillance at the operating company's headquarters in Auckland. This is a design-build-operate (DBO) project where the performance of the overall treatment system is remote monitored by offsite specialists, but with locally trained service people on standby callout to deal with any operational events that need attention.

4.44 This demonstration case is a positive indication for the potential of wastewater reuse – at least for toilet flushing, as well highlighting the I&I benefits associated with a pressure sewer network. This is worth further investigation.

4.45 There is an ever-increasing technological focus on this area, and a recent advancement that has gained media attention over the past few years is the hydraloop – an at-source domestic grey water recycling unit. The system claims to ensure *perfect and certified recycled water quality to save up to 45% on domestic water consumption. With a Hydraloop system you recycle up to 95% of shower & bath and optionally 50% of washing machine water so you recycle and reuse up to 85% of total in-house domestic water.* Bold claims, but this is at least an example of how the related technology is evolving, with increased potential and realisation for water reuse. The advantages of at-source approaches for water reuse include reduced regulatory barriers (specifically in terms of municipal water supplies) and the reduced potential for cross-contamination. We note that a communal reuse system via a 'purple pipe' would not preclude individual property owners from pursuing further on-site measures.

4.46 The regulatory framework in respect of water reuse continues to evolve, but remains uncertain, unclear, and unresolved. We note the following matters of relevance:

a. An article from the WaterNZ journal titled Greywater Reuse Compliance, 2015 (page 34), noted the following on regulatory compliance of grey water in NZ at that time:
   i. Compares NZ regulation for greywater to overseas, but not overly helpful or detailed
   ii. Acknowledges that a growing number of NZ households are using some form of unregulated and unreported greywater disposal system
   iii. Greywater systems discharging into the environment must comply with the Resource Management Act 1991, Building Act 2004, Health Act 1956, and Local Government Act 2002.
   iv. Some regions (such as Kāpiti Coast) have included a water conservation requirement for new developments into their district plan, which may include a greywater diversion system (KCDC, 2009a).
b. In Kāpiti, *from February 2008, all new homes built on the Kāpiti Coast had to install either a 10,000 litre rainwater tank to supply toilets and outside taps, or a fresh greywater garden irrigation system and a smaller 4500 litre rain tank supplying toilets and outdoor taps*. A progressive approach.
c. The ECan Land and Water Regional Plan does not specifically prohibit reuse, and the intentions of use of an alternate system are provided for within the wider objectives and policies of the Regional Plan. We note that policy 4.13 promotes reuse to reduce the residual effects of discharges of contaminants. Further, other methods section 5.3.5 states that ECan will *enable water conservation and water efficiency through the*

collection, use and reuse of water, and alternative sewage disposal technology. It further promotes that local authorities should encourage *water conservation and water efficiency through the collection, use and reuse of water, provided that the health of individuals of the community is not put at risk* [this reflecting one of the primary barriers].

Taumata Arowai is likely to address this regulatory gap, providing national-level leadership and oversight. It is expected that Taumata Arowai will manage risks to drinking water safety while responding to risk to potable water supplies (availability and quality) due to the effects of climate change and also giving effect to Te Mana o Te Wai. Given increased strain on potable water supplies nationally, we anticipate stormwater harvesting, grey-water reuse, and wastewater recycling to feature in future water resilience planning and guidance.

Harbour Outfall as part of a staged alternative solution

4.47 The current Waimate-based Oceania Dairy pipeline discharge consent process presents a helpful reference. In that case, the Panel chairman Paul Rogers highlighted that policy 23 in the New Zealand Coastal Policy Statement (NZCPS) specifically allows for coastal discharge, with conditions, while iwi management plans take a different stance. Submitter's evidence on behalf of Ngāi Tahu presents strong opposition to the proposal; however, that of K. Hall representing several Rūnanga, concludes that there is too much uncertainty to determine whether the application is generally consistent with relevant policies. A strong emphasis is placed on the lack of certainty on the potential environmental impacts of the discharge on the coastal water values and the lack of context relative to cumulative effects. It is evident that a balance will need to be made in determining the outcome of this application; to what extent and what angles remains unclear.

4.48 Direct harbour discharge as the sole solution is unlikely to be acceptable from a cultural perspective. However, with enhanced treatment to mitigate health risks and refined wetland design to connect waters with Papatūānuku prior to discharge, we propose it may be a suitable solution to support staging of alternate solutions.

a. Given lack of clear regulatory guidance, there are potential time delays with progressing various non-potable "purple pipe" reuse options. This allows for:
   i. incrementally increasing the extent of Akaroa serviced over time.
   ii. potential regulatory changes extending to include future potable reuse.
b. Land disposal options require additional information to validate the assumptions used in sizing and ensure predicted environmental impacts are adequately mitigated (refer 4.17 and 4.18). Partial discharge via a Harbour Outfall could balance the shortfall in land application rates – with flows to the harbour reducing as land application rates increase (or alternate beneficial reuse schemes are implemented).
   i. This option incurs considerable additional cost due to the need to construct the land irrigation infrastructure, in addition to maintaining a harbour outfall, but is considered necessary to reduce risk associated with the lack of resilience in the Inner Bay land disposal design for variation between in-situ properties and the modelled design parameters.
   ii. The Harbour Outfall will support provision of a "purple pipe" network, as currently proposed.

4.49 For any staged solution including a harbour outfall (similar to stream re-charge as a staged or complete beneficial use) we expect the following would be implemented:

a. Maximised I&I reductions (target 57% reduction).
b. Enhanced disinfection to achieve Australian Guidelines for Wastewater Recycling non-potable reuse standards.
c. Enhanced wetland treatment prior to discharge to the harbour to enhance the mauri of the treated water.

Yours sincerely,

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Appendix 4 Harrisons Quantity Surveyors Letter

HARRISONS

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21 August 2020

Lee Robinson
Saunders Robinson Brown
PO Box 39
Christchurch 8140

Dear Lee,

Re: - Akaroa Wastewater Project

Thank you for the information you have provided.

On first review, it appears Council are simply attempting to increase costs for their least preferred option, the harbour outfall, whilst reducing costs for their preferred option, the Inner Bays.

I understand the harbour outfall is the simplest option, and has progressed some way through the Resource Consent process.

However, the considerable contingency allowance included for the harbour outfall option seems at odds with this, more so compared to the other, perhaps more difficult, options which contain lesser contingency allowances.

In their reports, BECA list a number of exclusions and assumptions. Most are fairly typical however some are not. The following are a number that stand out: -

- Foreign exchange rate fluctuations and costs (more so now considering C-19),
- All quantities and dimensions are approximate,
- Measurements are based on GIS and Google Maps,
- Estimates include allowances for land purchase based on average CCC Rateable Valuations
- Pond / dam excavated material to be stock piled onsite,
- The estimates are to be considered high level concept design estimates and as such BECA allow an accuracy range of -20% to +30%,
- BECA state they are solely reliable on the information provided by others, and have not sought to verify it.

These simply lead to pricing uncertainty and a real chance of significant variations.

We will provide a more in-depth analysis of the reports you have provided in due course.

We expect the above assists and, should you have any questions, please do not hesitate to contact me.

Yours faithfully,

Stewart Harrison
Managing Director

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REVIEW ARTICLE

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A review of the evidence for endocrine disrupting effects of current-use chemicals on wildlife populations

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ABSTRACT

This review critically examines the data on claimed endocrine-mediated adverse effects of chemicals on wildlife populations. It focuses on the effects of current-use chemicals, and compares their apparent scale and severity with those of legacy chemicals which have been withdrawn from sale or use, although they may still be present in the environment. The review concludes that the effects on wildlife of many legacy chemicals with endocrine activity are generally greater than those caused by current-use chemicals, with the exception of ethinylestradiol and other estrogens found in sewage effluents, which are causing widespread effects on fish populations. It is considered that current chemical testing regimes and risk assessment procedures, at least those to which pesticides and biocides are subjected, are in part responsible for this improvement. This is noteworthy as most ecotoxicological testing for regulatory purposes is currently focused on characterizing apical adverse effect endpoints rather than identifying the mechanism(s) responsible for any observed effects. Furthermore, a suite of internationally standardized ecotoxicity tests sensitive for potential endocrine-mediated effects is now in place, or under development, which should ensure further characterization of substances with these properties so that they can be adequately regulated.

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Table of contents

1. Introduction and methods

Two recent global reviews of endocrine disruption (ED) in wildlife and humans (Bergman et al. 2012; Kortenkamp et al. 2012) have comprehensively addressed the issue of whether ED is damaging individuals and populations. Here we focus only on the evidence for effects on wildlife. For the purposes of this review, we consider that ED is occurring when a chemical has interfered directly with the endocrine system, either by interaction with hormone receptors or by alteration of hormone synthesis or metabolism, and has thereby caused adverse effects which are observable in wildlife. This is in line with the widely accepted World Health Organisation definition (WHO/IPCS 2002), although it should be noted that the Endocrine Society considers interference with any aspect of hormone action to constitute ED (Zoeller et al. 2012). In broad terms, both Bergman et al. (2012) and Kortenkamp et al. (2012) followed the WHO definition.

Bergman et al. (2012) concluded *inter alia* that:

> Wildlife populations have been affected by endocrine disruption, with negative effects on growth and reproduction. These effects are widespread and have been primarily due to POPs [Persistent Organic Pollutants]. Bans of these chemicals have reduced exposure and led to recovery of some populations.

Kortenkamp et al. (2012) also concluded that some wildlife populations had been harmed by ED, and they provide a list of so-called chemicals of concern, some of which are not POPs as listed by the Stockholm Convention, but which have been the subject of other regulatory action [e.g. tri-organotins; alkylphenols (APs)]. None of these substances were restricted specifically because they present an unacceptable

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risk from ED properties, as such, but simply because their fate and adverse effects (which may or may not have been caused by an endocrine mechanism) in the environment were deemed unacceptable. All can be described as legacy chemicals, which have been subject to regulatory action resulting in withdrawals from use or sale, but in some cases they are still widespread in the environment due to their persistence (e.g. Rasmussen et al. 2015), and may cause harm in some sensitive species.

There is no doubt that some legacy substances have caused (and are still causing) adverse endocrine-related effects (i.e. ED) in wildlife populations. The reader can find further information in various publications in addition to Kortenkamp et al. (2012) and Bergman et al. (2012), as shown in Table 1. Yet, the most important question to be answered is if, and to what extent, current-use (non-legacy) chemicals are causing ED in the environment.

Substances with ED properties which have not already been restricted are now subject to specific regulatory action in several jurisdictions such as the European Union and the United States (EU 2009, 2012; USEPA 2015). New testing methods specifically developed to identify and evaluate potential endocrine disrupting substances (EDSs) are available from the Organisation for Economic Cooperation and Development (OECD 2016), Japan and US-EPA. Few current-use chemicals have yet been systematically subjected to the whole testing suite (e.g. under the US-EPA's Endocrine Disruptor Screening Program – EDSP), as this is an animal-intensive, long and costly endeavor (ca. 1 million US dollars per substance). Nevertheless, studies looking at endocrine activity or endocrine-mediated effects are routinely performed in mammals and conducted, when triggered, in ecotoxicological test species (e.g. using the Fish Short Term Reproduction Assay – OECD TG 229 – and the Amphibian Metamorphosis Assay – OECD TG 231 for screening or in more extensive higher tier tests). However, many current-use or non-legacy chemicals are subject to comprehensive environmental hazard and risk evaluations (e.g. registered biocides and pesticides), including partial and sometimes full lifecycle tests, which probably detect the adverse apical effects of many ED modes of action without necessarily identifying the chemical as endocrine-active (e.g. Weltje et al. 2013). In the interests of improving our general understanding of the level of protection afforded, it is worth investigating how ED effects can be attributed to current-use chemicals, and the extent to which the problem may be restricted to legacy chemicals.

This paper therefore aims to review the reports cited in Kortenkamp et al. (2012) and Bergman et al. (2012) in which population-level effects in wildlife under field conditions have been attributed to current-use chemicals, with only a brief survey of the effects of legacy chemicals. However, some additional studies, mainly those published since 2012, will also be discussed where informative. This review, while not claiming to be exhaustive, covers many animal groups, from invertebrates (crustaceans and mollusks), through lower vertebrates (fish, amphibians, and reptiles), to higher vertebrates (birds and mammals). Types of ED discussed include sexual disruption, stress-response perturbation, and thyroid system disruption. The papers referenced by Kortenkamp et al. (2012) and Bergman et al. (2012) had already been screened for scientific quality and reliability, but additional publications here have been evaluated informally using the principles of Klimisch et al. (1997). Any known quality shortcomings in papers referenced in this review are discussed in the text.

As with almost all epidemiological and field evidence, certainty in establishing the causes of observed effects is hard to obtain. The causality issue is generally approached iteratively by testing hypotheses in laboratory and field experiments and then returning to the field to confirm whether controlled experimental findings agree with the field response. Of course, this is sometimes difficult or impossible if large or rare species are the focus of attention. Experimental confirmation is one of the criteria proposed by Hill (1965) for assessing the strength of association between a disease and a putative cause. Others include the scale of the effect, its consistency or reproducibility, its specificity to the putative cause, the temporal sequence observed (i.e. did exposure occur prior to the effect), the presence or absence of a gradient of effect (i.e. a dose-response), the biological plausibility of the effect, the effect's agreement with current knowledge, and finally, whether removal of the exposure leads to recovery.

Hill's criteria are a valuable method for establishing causality; however, rarely can all be addressed in a given case, and as such they should be treated flexibly considering the question in hand. However, they allow an assessment of the strength of an association between possible cause and effect. They have therefore been adopted with minor changes in wording for use in the current review (see Section 3). For further discussion on the strengths and weaknesses of the Hill criteria for ED assessment see Bergman et al. (2015).

The purpose of this review is to gain a broad picture of the severity of endocrine-related effects of current-use chemicals in wild populations in comparison with those caused by legacy chemicals, and to assess whether stricter regulatory testing regimes based on new EDS-sensitive assays are likely to detect potential environmental problems which would otherwise be missed.

It should be noted that one area of "current-use" that will not be dealt with in this review concerns the continuing effects of naturally-occurring phyto-estrogens (e.g. β-sitosterol), phyto-androgens (e.g. stigmastanol), and other natural materials in pulpmill effluents. These have a range of adverse effects on downstream fish populations, and the reader is referred to various reviews (Servos et al. 1996; Pait and Nelson 2002; Jobling and Tyler 2003; Van den Heuvel et al. 2010) for more information.

2. Evaluation of reports of ED which may be linked to currently used substances

Research on ED in wildlife has been repeatedly reviewed over the past 20 years (e.g. Ankley and Giesy 1998; Tyler et al. 1998; Van Der Kraak 1998; deFur et al. 1999; IPCS 2002; Jobling and Tyler 2003; Matthiessen 2003; Zala and Penn, 2004; Mills and Chichester, 2005; Porte et al. 2006; Bergman et al. 2012; Kortenkamp et al. 2012). This paper does not

Table 1. Summary information on impacts in wildlife populations caused by legacy substances with endocrine disrupting properties.

Legacy substance or process	Summary of adverse endocrine-mediated effects in wildlife	References
Tri-organotins	The effects of tri-organotins on mollusks are probably one of the best documented examples of wildlife damage caused by legacy chemicals with ED properties, although the precise mode(s) of action is still not entirely clear. In essence, tri-organotins [especially tributyltin (TBT) derived from antifouling paints, but also triphenyltin (TPT) to a lesser extent], caused masculinization of aquatic mollusks, which led to widespread population declines and local extinctions. The secondary effects also damaged whole invertebrate communities and impacted other phyla such as crustaceans and ascideans. Recovery in many mollusk communities began soon after TBT was globally banned by the International Maritime Organisation from use in antifouling paints on shipping in 2008, but some effects are still detectable near marinas and harbors due to the remaining residues in sediments.	Bryan and Gibbs (1991) Matthiessen and Gibbs (1998) Alzieu (2000) Oehlmann et al. (2007) De Mora (2009) Matthiessen (2013)
Polychlorinated biphenyls (PCBs), polychlorinated dibenzo dioxins (PCDDs), polychlorinated dibenzo furans (PCDFs)	PCBs (the production of which was banned globally under the Stockholm Convention in 2001) are probably now a significant contributor to ED in wildlife. PCDDs and PCDFs are also listed under the Stockholm Convention for reduction of unintentional releases. However, PCBs are still entering the environment through leaching from old equipment such as electrical transformers. Some members of this family of very persistent and bioaccumulative substances, as well as the similar PCDDs and PCDFs, have been implicated in reproductive failures in top predators ranging from mustelids, cetaceans and pinnipeds to reptiles and birds. Significant residues and effects are present in Arctic wildlife resulting from long-distance transport of PCBs and other organochlorines. Some congeners are able to produce estrogen-like effects, while others interfere with the immune and thyroid systems.	De Swart et al. (1996) Murk et al. (1996) Grasman et al. (1998) Robertson and Hansen (2001) Fossi and Marsili (2003) Basu et al. (2007) Sonne (2010) Jepson and Law (2016) Jepson et al. (2016)
Polybrominated diphenyl ethers (PBDEs)	These persistent and bioaccumulative compounds are similar to PCBs and have been widely used as flame retardants, although several congeners have been listed for elimination under the Stockholm Convention since 2009. They are widely present in the fatty tissues of a range of wildlife, from fish to mammals, although there is no direct field evidence for adverse apical effects. However, they have been associated with thyroid hormone imbalances in wild seals and eagles, and laboratory experiments have shown that environmentally-relevant PBDE concentrations can cause thyroid disruption leading to a variety of adverse effects such as (*inter alia*) delayed metamorphosis in amphibians, reduced eggshell thickness and abnormal courtship behavior in birds, and damaged neurological functioning in mustelids.	Hall et al. (2003) Birnbaum and Staskal (2004) Yogui and Sericano (2009) Cesh et al. (2010)
Perfluorinated compounds (PFCs)	PFCs have a variety of uses, but examples of particular environmental concern are perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) which are used to make textiles water-resistant and as components of fire-fighting foams. Production and use of PFOS have been restricted under the Stockholm Convention, with some exemptions. PFCs are widely found in vertebrate top predators, sometimes at concentrations thought to be biologically active against the thyroid system on the basis of laboratory experiments, although there is little evidence for their adverse effects in the field.	Giesy and Kannan (2002) Houde et al. (2006) Peden-Adams et al. (2009) Stock et al. (2010) Lindstrom et al. (2011)
DDT/DDE and other organochlorine pesticides	The widespread use of DDT for insect control in the 1950s and 1960s caused eggshell thinning in birds, particularly some raptors such as sparrowhawks (*Accipiter nisus*), white-tailed eagles (*Haliaetus albicilla*) and ospreys (*Pandion haliaetus*). This led to frequent reproductive failure when the birds tried to incubate their eggs. It was later discovered that the active moiety was a metabolite of DDT, p,p′-DDE. The precise mechanism of action is almost certainly the ability of p,p′-DDE to inhibit synthesis of a prostaglandin* hormone in the eggshell gland, which subsequently interferes with normal calcium metabolism. Since DDT was withdrawn from use in most developed countries in the 1970s, raptor populations have largely returned to their pre-DDT levels, although part of this recovery is possibly attributable to additional factors such as improved bird conservation measures. p,p′-DDE has also been implicated as one cause of sexual abnormalities (male to female sex reversal) in aquatic reptiles such as alligators (*Alligator mississippiensis*). DDT-use is still permitted under the Stockholm Convention for disease vector (e.g. mosquito) control in the tropics, and is continuing to cause impacts on certain wildlife around the globe. Many other organochlorine pesticides (e.g. dieldrin; mirex; chlordane) are able to interact in a damaging fashion with the endocrine systems of wildlife, generally causing various types of feminization, and have themselves been banned under the Stockholm Convention.	Ratcliffe (1967, 1970) Lundholm (1997) Grasman et al. (1998) Dawson (2000) Guillette et al. (2000) Henny et al. (2010)
Alkylphenols and alkylphenol ethoxylates	Alkylphenol ethoxylates (APEs) were widely used in certain types of detergent and other products, but have now largely been withdrawn from use or voluntarily phased out in regions such as the European Union and the USA. Both APEs and their degradation products (e.g. nonylphenol and octylphenol) are weakly estrogenic, and can induce a variety of sexual abnormalities in aquatic vertebrates such as fish. They used to form a significant part of the estrogenic load in sewage and industrial effluents, and as such once contributed to the widely observed estrogenic effects on fish populations, which included the occurrence of widespread intersex in several species. Estrogenic abnormalities caused by alkyphenols have also been observed in other vertebrate populations, e.g. birds.	Sheahan et al. (2002) Dods et al. (2005) Kovarova et al. (2013)

*Unlike systemic hormones, prostaglandins act locally in tissues, but they are nevertheless part of an organism's chemical signaling system. As such, disruption of prostaglandin signaling is considered to fall within the definition of ED.

attempt to be another exhaustive review. Its purpose is to evaluate field studies which have identified apparent ED (or at least endocrine activity which might be causing adverse effects) resulting from current-use chemicals, to consider the strength of the evidence, and to assess the likely population impacts of the effects in comparison with those caused by legacy EDS. Some laboratory experiments which help to interpret the field data are also referred to.

2.1 Impacts on invertebrates

A major difficulty with the study of ED in invertebrates is that their hormone systems are poorly understood by comparison with the vertebrates (DeFur et al. 1999). Much more research is therefore needed on how invertebrate hormones operate, and in the meantime our knowledge of ED in this large and disparate group will remain limited. However, there is no doubt that at least some invertebrates are subject to ED, as the cases of growth regulators in insects and of tri-organotins in mollusks make clear (see Table 1). Nevertheless, even in the latter well-studied case, there remains a lack of clarity about the precise mode of endocrine action (Oehlmann et al. 2007).

An exception to this general concern can be found in the insects whose endocrine systems have been closely studied in order to assist with culturing beneficial insects (e.g. silkworms and honeybees) and for the development of insecticides. In particular, the functions of the insect hormones (hydroxy-)ecdysone and juvenile hormone are well-understood, and various insecticides known as insect growth regulators (IGRs) have been specifically developed to disrupt these systems (Weltje 2013). This is not the place to discuss the effects of these insecticides on target arthropod pests, but it would be relevant to summarize their unintended effects on non-target insects and other arthropods such as crustaceans which share similar hormone systems.

However, there are almost no reports of such effects in the field, although whether this is absence of evidence or evidence of absence is unclear. There is no doubt, however, that several IGRs are able to interfere not only with insect development, but also that of crustaceans (McKenney 2005). In one case (Walker et al. 2005), it was suspected that the juvenile hormone antagonist methoprene, which had been used for mosquito control, might have been responsible for a large decrease in lobster (*Homarus americanus*) catches in Western Long Island Sound (WLIS) in the USA. Laboratory experiments established that it is highly toxic to stage II lobster larvae, reducing survival significantly over 72 h at a nominal concentration of 1 μg/L. However, Walker et al. (2005) presented no data on methoprene concentrations in WLIS, and the mosquito control campaign in the area had used malathion, resmethrin, and sumethrin simultaneously with methoprene, making attribution of causes very difficult. Biggers and Laufer (2004) found other substances with vertebrate endocrine activity in sediments and lobsters of WLIS, and speculated that the effects seen in lobsters may have been caused by the combined effects of several contaminants, but it is not possible to draw conclusions about whether the decrease in lobster catches was a result of ED, any other type of chemical exposure, or non-chemical factors.

Other mosquito control campaigns have used methoprene sprayed over wetlands such as mangrove swamps and salt marshes, and some studies have been conducted of ecological side-effects (e.g. Lawler et al. 1999; Russell et al. 2009). However, at the rates of methoprene application used for mosquito control (~10–20 g/ha), the side-effects reported for crustaceans and insects have been minor or non-existent, although the available data are sparse.

The main body of information about probable ED in invertebrates in the field, with the exception of that related to organotins, concerns crustaceans and mollusks exposed to estrogenic substances including ethinylestradiol (EE2), mainly via sewage treatment works (STW) discharges. These studies were conducted on the assumption that invertebrate hormone systems might have some similarities with those of vertebrates (Jobling et al. 2004), although in fact they are quite different. It should be borne in mind when studying this work that although mollusks seem to be responsive to vertebrate sex steroids, they do not appear to contain the vertebrate estrogen receptor (Scott 2012, 2013), so the mode of action of estrogens in these taxa remains speculative.

Moore and Stevenson (1991) described the presence of intersexuality in benthic harpacticoid copepod crustaceans (*Paramphiascella hyperborea*) found in the Firth of Forth, Scotland. Twenty-eight out of 30 individuals (93%) collected near a STW discharge were found to be intersex on the basis of morphological indicators, but the condition was found to be very rare in other samples from the Forth and elsewhere. Unfortunately, no firm conclusions can be made about the possible causation of this effect as measurements were not made of vertebrate estrogenic activity at the study site, and no attempt has been made to replicate the effect under laboratory conditions.

A similarly inconclusive report (Sangalang and Jones 1997) described the presence of intersexuality in lobsters (*H. americanus*) caught in the coastal waters of Nova Scotia, Canada. Intersexuality was manifested as the presence of oocytes in testes. Although some of the affected animals were caught near sewage discharges, no measurements were made of vertebrate estrogenic activity, and the authors of the study were unable to conclude whether the effects were a natural background phenomenon or related to estrogen exposure. Once again, no attempt was made to investigate these effects in the laboratory.

A more conclusive study was made by Chesman and Langston (2006) and Langston et al. (2007) of the bivalve *Scrobicularia plana* collected from the Avon estuary in southwest England. This gonochoristic species was collected from the estuary at monthly intervals for 17 months, and histological examinations were made of the gonads. Between July and August, the proportion of males fell to 28–35%, a statistically significant alteration of the sex ratio. A mean of 21% of the individuals were intersex (males with ovotestis), while samples from six other estuaries in southwest England showed no effect on sex ratio. The authors (Langston et al. 2007) also reported results from 10 other estuaries in the area, in which 17 out of 23 populations displayed intersex,

with up to 60% of males being affected. It was speculated that the effects in the Avon estuary might have been caused by an estrogenic sewage discharge, but the data cannot be directly used to support this conclusion as no measurements of estrogen contamination were made. However, Langston et al. (2007) also conducted experiments in which they exposed maturing *S. plana* for 1 month to sediments spiked with mixtures of vertebrate estrogens and their mimics (nominal concentrations of 100 μg/kg wet wt. estradiol [E2] and EE2, plus 1000 μg/kg wet wt. octylphenol (OP) and nonylphenol – NP), after which the treated animals were transplanted to the Avon estuary for a further 4 months. There was no confirmation of these exposure concentrations, and the laboratory exposures were well above those found under most environmental conditions. However, this dosing regime led to a statistically significant mean of 44% of the males showing signs of intersex compared with 0–7.7% of controls, and the treatment also caused small (14–27%) but statistically significant increases in mean oocyte diameter. It therefore appears possible that the longer exposures experienced by wild *S. plana* may have been responsible for the levels of intersex observed in these populations.

The subject of biomarkers of estrogen exposure in mollusks has been reviewed by Porte et al. (2006), and this review will only describe the more significant field studies. Mollusk data of a more convincing nature than those discussed above have been obtained from bivalve populations in Canada. Wild freshwater mussels (*Elliptio complanata*) (10 per site) were collected by Gagné et al. (2011) from upstream and downstream of two treated sewage effluent discharges in the St Laurence River. At both effluent discharge sites, the proportion of females increased significantly from 30% upstream to 80% downstream, and male vitellogenin (VTG)-like protein (measured as alkali-labile phosphate (ALP), which is not entirely specific for VTG) was elevated downstream by between 50 and 66%. Elevation of VTG in males is a well-known marker of estrogen exposure in fish and amphibians (see below), and it has been presumed that the same applies to mollusks, although this has been challenged (Scott 2012, 2013). VTG-like protein (ALP) in females was also apparently increased at the downstream site, but this was not statistically significant. Female gonads downstream were in early vitellogenesis, but egg production was not underway and downstream gonadosomatic indices (GSI) were low. Experimental work (Gagné et al. 2001) has been able to reproduce some of these effects in the laboratory, and an attempt was also made to study caged *E. complanata* at the field sites where effects had been noted (Bouchard et al. 2009). Unfortunately, this latter study was flawed due to very high (60%) mortality in the downstream cages, and ALP was induced at only one of the two sites. Gagné et al. (2001) also conducted a study with *E. complanata* held downstream from a single STW discharge and showed elevations of ALP of >50% compared with the upstream reference, but mortality rates in the caged mussels were not reported. They also showed that *E. complanata* has specific estrogen binding sites on cytosolic proteins, which may be the receptor mediating the increase in ALP.

Sounder experimental work was conducted by the same research group (Quinn et al. 2004) using freshwater zebra mussels (*Dreissena polymorpha*) held in tertiary treated sewage effluent for 112 days during gametogenesis and all remained in good health. ALP increased in both sexes by up to 100% in males and over 300% in females. The volume of testicular interstitial tissue also increased, although no adverse apical effects were reported. Analysis of the effluent showed that E2, EE2, and bisphenol A (BPA) were all present, although a definitive quantification was not conducted.

A field study has also been conducted of possible estrogenic effects in European marine bivalves (Ortiz-Zarragoitia and Cajaraville 2010). Samples of 15–20 mussels (*Mytilus galloprovincialis*) were taken every 2 months over 15 months from two Spanish estuaries, the Oka and the Abra. Both have a history of urban and industrial pollution, but the Oka was also affected by polycyclic aromatic hydrocarbons (PAH) from the *Prestige* oil tanker spill in the year prior to sampling. There was no true reference site although the Abra estuary has been remediated to some extent. Up to 75% oocyte atresia was observed in the Oka and up to 25% in the Abra, although it should be noted that atresia can be a natural occurrence at certain stages of the life cycle, and it may not solely be the result of ED. ALP in females only varied as expected with the reproductive cycle, and there were no differences in male ALP between the two sites, except for one date when ALP in Oka males was nearly double that in the Abra males. Given that ALP was only elevated in males on one occasion in the more contaminated estuary, and that estrogen concentrations were not reported, these data do not provide clear evidence of ED. The severe oocyte atresia in the Oka may have been related to ED, but seems more likely to have been due to PAHs interacting with the aryl hydrocarbon (AH) receptor rather than the result of an estrogenic effect.

In summary, the field evidence for the impact of insect hormone regulators on crustaceans is essentially non-existent, and the same applies to reliable studies on the possible effects of vertebrate estrogens on that group. However, there is some evidence that bivalve mollusks have shown various forms of feminization and consequent presumed reproductive impairment as a result of exposure to presumably estrogenic sewage effluents or other sources of estrogens. The causal evidence for this is rather weak, and mechanisms of action have not been clarified, but laboratory experiments (in addition to those of Langston et al. (2007) which used very high exposure concentrations) in which bivalves have been exposed to vertebrate estrogens provide limited support for the hypothesis. For example, Nice et al. (2003) ran an experiment in which Pacific oyster (*Crassostrea gigas*) larvae (7–8 d post-fertilization) were exposed for 48 h to NP concentrations (nominal: ranging from 1 to 100 μg/L) and then were reared in clean water for 10 months, during which reproduction and development of the next generation took place. Nice et al. (2003) showed that up to 30% of the surviving adults were functional hermaphrodites, while no hermaphrodites appeared in the controls. These changes in sex ratio resulted in reduced gamete viability, which led to poor embryonic and larval development in the next generation. However, the

reliability of this study is questionable given that measured concentrations of NP (from <1 to 2–9 μg/L) were much lower than the nominal values and sample sizes appeared small.

Despite these observations, no studies have been made of damage to invertebrate populations exposed to EDSs other than organotins, so it is unknown whether the biochemical, physiological, and histopathological changes reported above have led to population-level impacts in practice. This situation may change when the endocrinology of invertebrates becomes more thoroughly understood, and it should not be assumed that this large and important group of organisms is unaffected by currently-used substances.

2.2 Feminisation of fish, amphibians, and reptiles related to sewage discharges

Feminisation in fish and other aquatic vertebrates has been intensively studied since it was first discovered in the 1980 s that sewage discharges were able to induce VTG in caged male rainbow trout (*Oncorhynchus mykiss*) (Purdom et al. 1994). Most STW effluents contain a complex mixture of natural and synthetic estrogens, some of which (e.g. E2) are steroidal and some non-steroidal (e.g. BPA) (Rutishauser et al. 2004). Most that have been identified do not fall under the category of current-use chemicals, being either natural substances like E2 or partially phased out and/or very weakly potent substances such as NP and BPA. An exception to this is EE2, which is still a major component of oral contraceptives and appears in most treated STW effluents at low ng/L concentrations. On the basis of *in vitro* assays, Rutishauser et al. (2004) report EE2 to have a potency relative to E2 of only 1.19, but the situation is different *in vivo*. Thorpe et al. (2003), for example, showed that EE2 is 11–27 times more potent than E2 at inducing VTG in juvenile rainbow trout (*O. mykiss*), while E2 is in turn 2.3–3.2 times more potent than estrone (E1). Furthermore, EE2 is considerably more resistant to degradation than most other estrogenic steroids. This means that for many treated STW effluents, EE2 is likely to be the major contributor to overall estrogenic activity by comparison with the other steroids. Non-steroidal substances such as NP are likely to contribute only a very small fraction of overall activity, again because their potency at the estrogen receptor is extremely low (by at least a factor of 10^4) in comparison with E2 and EE2 (Jobling and Sumpter, 1993). For the purpose of this review, it is therefore considered appropriate to examine reports of estrogenic effects in wild fish and amphibians living near sewage discharges, and to ascribe a significant proportion of these effects to EE2. The opposite effect, i.e. masculinization of female fish, has been reviewed by Matthiessen and Weltje (2015) but this phenomenon appears to be uncommon and of lower importance compared to feminization.

The major body of work on estrogenic effects in fish emanates from the research teams at Brunel and Exeter Universities, United Kingdom, who have thoroughly studied the relationship of estrogenic effects in roach (*Rutilus rutilus*) and exposure to treated sewage. Jobling et al. (1998) took roach from eight UK rivers and showed that in five, the proportion of intersex males was between 40 and 100% compared with <20% in reference site fish. Intersex was defined as the presence of ovotestis or feminized gonoducts. Furthermore, fish from all but one site had more marked intersex severity than reference fish. Mean male plasma VTG was elevated by factors of up to 100 in intersex fish, and by up to >10 in histologically normal males. Even more severe feminization was observed in two other rivers, the Aire and Nene (Jobling et al. 2002a). In subsequent work (Jobling et al. 2002b), it was shown that only 17.4% of moderately intersex fish and 33.3% of severely intersex male fish were able to produce milt, compared to 97.6% in intersex-free reference male fish. If milt was produced by intersex males, its volume was reduced by 50% in comparison with histologically normal males, and sperm motility and fertilization success were also reduced by 50%. Although this was a significant degradation of reproductive ability, it should be noted that most roach populations do not appear to be under threat (Freyhof and Kottelat 2008; Johnson and Chen 2017).

However, although estrogen concentrations were not simultaneously measured at the time of sampling, Jobling et al. (2006) showed that both severity and incidence of roach intersex at 45 sites were positively correlated with the predicted estrogenic risk modeled on the basis of expected estrogen inputs from upstream STW discharges. Furthermore, a range of experiments with roach and other species exposed to STW effluent dilutions have been able to replicate many of the effects reported from the field (Rodgers-Gray et al. 2001; Bjorkblom et al. 2009; Lange et al. 2011). In addition, Harris et al. (2011) showed in an elegant experiment with roach taken from estrogen-contaminated locations that reproductive performance (fry production) in semi-natural breeding groups was negatively correlated with individual intersex severity, and reproductive performance was reduced by up to 76% in the most severely intersex individuals. It has also been convincingly demonstrated (Geraudie et al. 2010) in 474 roach sampled over 18 months from a site where there was no detectable estrogenic or mutagenic activity that no intersex fish were present, and mean male plasma VTG was only 24 ng/ml (rising to 120 ng/ml during the spawning period). The sex ratio did not deviate from 1:1. This clearly shows that the natural background rate of estrogenic abnormalities in roach can be very low, although this may not be the case in all fish species (Bahamonde et al. 2013).

Finally, although the severity of intersex in roach appears to increase with age, it should be pointed out that mildly feminized roach exposed to estrogens for less than a full life cycle are probably not reproductively compromised. This was demonstrated by Hamilton et al. (2015) who showed experimentally that the male offspring of STW effluent-exposed females had only weakly feminized testes after exposure to 100% STW effluent for up to 3 years and 9 months, and they were able to reproduce normally. Furthermore, there was no evidence that the exposure history of the females had any influence on the reproductive performance of their male offspring. It is also worth noting that exposure to estrogens can even enhance reproductive success in fish by increasing fecundity, although it is not known if this can also lead to increased population size (Parrott et al. 2017).

Field studies with other fish species caught near STW discharges around the world have produced similar results to those obtained with roach (e.g. Aravindakshan et al. 2004; Kavanagh et al. 2004; Kirby et al. 2004; Game et al. 2006; Leusch et al. 2006), although effects may be hard to detect in some places (e.g. Pottinger et al. 2011). Furthermore, species vary considerably in their sensitivity to estrogens (e.g. Caldwell et al. 2012). In several such studies, estrogen concentrations in the sampled environment were measured, thus making the link between estrogen exposure and reproductive effects stronger (Vethaak et al. 2005; Vajda et al. 2008). For example, Vethaak et al. (2005) reported median estrogen concentrations in waters receiving Dutch STW effluent in 1999 of 0.4 ng EE2/L, 1.0 E2/L, 1.0 ng E1/L, 45 ng BPA/L, 300 ng OP/L and 990 ng NP/L, and Vajda et al. (2008) reported that mean E2-equivalents for a receiving water in the USA in 2003 and 2005 were 3.4–11 ng/L. At 35 sites on five UK rivers, Johnson and Chen (2017) predicted similar mean E2-equivalents (0.6–3.2 ng/L). Taken overall, these combined concentrations of estrogens are largely able to explain reported incidence of feminization in fish. Finally, a meta-analysis of VTG induction field data from 13 fish species from around the world (Desforges et al. 2010) showed that human population size (a surrogate for estrogen and other anthropogenic contamination) upstream of the sampled fish populations explained 28% of the variation in male VTG.

There have been many other reports of putative estrogenic effects in wild fish (e.g. Hashimoto et al. 2000; Nagler et al. 2001; De Metrio et al. 2003; Scott et al. 2006, 2007; Körner et al. 2007), but these cannot all be directly linked to sewage discharges and EE2, due to often remote sampling locations. Evidence suggests that some of these effects may be related to the bioaccumulation of persistent estrogenic materials (such as some organochlorines), and as these have generally been phased out of use (even though they still exist in the environment), they fall outside the scope of this review.

Despite this large body of work with fish, much of it considered robust and reliable, the question still remains about whether the undoubted estrogenic effects on reproductive variables that have been observed are a threat to fish populations (Johnson and Chen 2017). An approach to this question was made by Kidd et al. (2007) and Palace et al. (2002, 2009) who dosed an experimental lake in Canada (Lake 260) with EE2 three times weekly for 3 years during the ice-free season, and followed the fathead minnow (*Pimephales promelas*) population for 7 years. Annual mean measured levels of EE2 ranged between 4.8 and 6.1 ng/L, with a maximum weekly mean of 8.1 ng/L (Park and Kidd, 2005), but it should be pointed out that these concentrations are approximately an order of magnitude higher than those generally found in rivers downstream of treated sewage discharges. Two comparable lakes were used as EE2-free reference sites. VTG levels in whole-body homogenates of male fatheads rose from ~0.5 μg/g wet wt. to 2000–12,000 μg/g after 7 weeks. In Year 1 of the treatment, male testes displayed delayed spermatogenesis, widespread fibrosis and malformed gonoducts. In Year 2, male GSI was only 0.40 compared with 1.39 and 2.27 in the reference lakes. By Year 3 of the treatment, four out of nine males were shown to have ovotestis (the small sample size was due to a population crash). By Year 4 (i.e. 1 year after treatment had ended) all reproduction had ceased and catch per unit effort had dropped from between 5 and 100 before treatment to 0.7, and the population was almost extinct.

Interestingly, the populations of three other fish species in the lake experiment with EE2 did not collapse, though two declined, and there were indirect secondary consequences for some invertebrate populations in the ecosystem (Kidd et al. 2014). The authors speculate that the differences in fish species response could be due to inherent differences in sensitivity, differences in exposure due to habitat requirements, differing longevity, and differing stages of development during the treatment. Furthermore, the relationship between sex ratio and reproductive success (the so-called mating function) varies widely between fish species, and this also has an impact on the population response to endocrine disruptors (White et al. 2017). It is apparent from these results that VTG induction does not automatically indicate that the population will collapse, but its predictive value for population-level effects is enhanced if combined with measures of abnormal gonadal histopathology.

Apart from the experiment in Lake 260, there have not been any other unequivocal demonstrations of fish population declines or collapses that can be firmly attributed to EE2 or to estrogens generally. This was pointed out over 10 years ago by Mills and Chichester (2005) and little has changed. This is at least partly due to the difficulty of measuring fish reproduction and population variables under field conditions and making firm associations with causative factors. The lack of evidence for population declines is probably also partly attributable to the fact that some fish populations which are targeted by anglers (e.g. roach in the UK) are re-stocked regularly. Despite their expense and complexity, there is clearly a need for further large-scale experiments like that of Kidd et al. (2007), and it would also be helpful if improved population models for important fish species could be employed to allow more confident extrapolation from laboratory data. However, there is little doubt that the estrogens in treated sewage discharges are able to cause adverse effects in some downstream fish populations with potential implications for their stability, and that EE2, due to its high relative potency compared with E2, plays a major role in this.

There is no evidence for estrogenic effects in wild amphibians related to sewage discharges, although it is known from laboratory experiments that in males VTG can be induced by estrogen exposure and they can experience a range of effects on reproductive potential. In one of these (Sowers et al. 2009), northern leopard frogs (*Rana pipiens*) were exposed from egg to metamorphosis (~2 months) to 0, 10, 50, and 100% treated STW effluent. The total mean measured estrogenic activity of the effluent was 1.7 ng E2 equiv/L, with a mean EE2 concentration of 0.21 ng/L. Relative potencies for this calculation were obtained from *in vitro* data by Rutishauser et al. (2004). 50 and 100% effluent caused a 4 and 7 d delay in metamorphosis, respectively, as well as producing 37 and 64% ovotestis, respectively. There were no effects on sex ratio or female gonadal development, but non-specific effects on thyroid histology. It is likely that a 7 d

delay in metamorphosis, which may or may not have been due to ED, could have significant consequences for survival and reproductive success in adult amphibians (e.g. Semlitsch et al. 1988).

The only field-relevant data for effects in amphibians caused by estrogen exposure derives from the EE2 experiment in Lake 260, Canada (Park and Kidd 2005). As well as showing that caged amphibian larvae were adversely affected by the EE2 concentrations in the lake (reduced hatching success in green frogs *Rana clamitans* between 4.8 and 6.1 ng/L), they found that larvae of wild mink frog (*Rana septentrionalis*) sampled in 2001, 2002, and 2003, possessed intersex gonads with an incidence of 2.4, 0 and 28.6%, respectively. No intersex gonads were observed either before EE2 dosing started, or in the reference lakes, and there were no effects on sex ratio in Lake 260. It is not known to what extent intersex testes in mink frogs would be damaging for reproductive success, but by analogy with fish (e.g. Harris et al. 2011) one might expect severe intersex to have such effects.

As with amphibians, there are almost no field studies of reptiles exposed to estrogen-containing sewage effluent. Tada et al. (2007) studied VTG induction in 320 male freshwater turtles (*Chinemys reevesii*) caught from four pond sites, three of which were contaminated with sewage-derived estrogens (0.52–1.7 ng/L E2 equivalents, determined by a yeast estrogen screen). Only five turtles showed elevated serum VTG levels (1.1–5.9 μg/ml) compared with the other males from the contaminated sites (0.1–0.74 μg/ml), and overall there were no significant differences between the contaminated and reference ponds. It appears from other studies (e.g. Irwin et al. 2001) that aquatic reptiles may be insensitive to estrogen concentrations in the surrounding water.

2.3 Feminisation of amphibians related to intensive agriculture

It has been suggested that amphibian populations in the USA have become feminized in areas of intensive agriculture (Hayes et al. 2002). More specifically, it has been hypothesized that exposure to the triazine herbicide atrazine, which is very widely used for control of weeds in intensively grown maize and soybean crops in certain countries, may be causing elevations in aromatase enzyme activity, which could lead to inappropriate increases in E2 titers in male amphibians and consequent feminization (Hayes et al. 2002).

Hayes et al. (2003) conducted both laboratory experiments and field studies on this issue. In the experiments, newly-hatched leopard frogs (*R. pipiens*) which developed from eggs collected in the field (Sensiba Marsh, Wisconsin) were treated with atrazine in a static-renewal design at nominal concentrations of 0, 0.1, and 25 μg/L. Actual concentrations were reported to have been measured but no data were presented. All males were sexually differentiated at metamorphosis, but 36 and 12% at 0.1 and 25 μg/L, respectively, were claimed to be showing testicular dysgenesis syndrome (underdeveloped testes, poorly structured testicular lobules, and low numbers of germ cells). However, the data underpinning this claim are not presented, and no statistics are presented. An additional claim, that 29% of the frogs at 0.1 μg/L and 8% at 25 μg/L showed "varying degrees of sex reversal", i.e. oocytes in the testis, is also not backed up with statistics. The data did not conform to a monotonic concentration-response, although that does not necessarily mean that they are erroneous.

In the fieldwork by Hayes et al. (2003), 800 *R. pipiens* were sampled from each of eight sites across the central USA in 2001, the aim being to take newly metamorphosed individuals. Sex and gonadal histopathology were recorded from a subset of individuals. No atrazine was detected at a reference site, but all other sites contained atrazine, at 0.2–6.7 μg/L. As with the laboratory experiment, no statistics were presented, but it was claimed that no testicular disorders were present at the reference site, while ovotestis at incidences of 10–90% occurred at the other sites. One site also showed gonadal dysgenesis (poorly developed testicular lobules), but no abnormalities were seen in females. There was no apparent relationship with atrazine as the highest incidence of testicular abnormalities occurred at 0.2 μg/L. Analyses for other pesticides (simazine, hexazinone, diuron, and norflurazon and several others) were negative in all but one case (0.39 μg/L metolachlor).

Hayes et al. (2003) suggested that atrazine is likely having a significant impact on amphibian populations, but their data as reported are unable to support this conclusion. Nevertheless, their work triggered a large number of studies aimed at investigating the matter further.

Attempts to replicate the experimental results of Hayes et al. (2003) have not been successful. For example, Jooste et al. (2005) conducted an outdoor microcosm experiment in South Africa in which 4 d post-hatch clawed frogs (*Xenopus leavis*) were exposed to atrazine in 1100 L microcosms for up to 10 months. Nominal atrazine concentrations (three replicates/concentration) were 0, 1.0, 10, and 25 μg/L, and weighted mean measured concentrations were 0, 1.4, 12.1, and 30.8 μg/L. Test solutions were replaced after 80 d. At metamorphosis (larval stage 66), mean incidence of ovotestis (i.e. oocytes present within the testicular tissue) was 57, 57, 59 and 39%, respectively, and mean numbers of oocytes per male were 9.5, 9.8, 8.5, and 11.1, respectively. Mean numbers of eggs in the resulting juvenile males at 10 months were low ($\leq$2 per individual). There were no statistical differences between treatments and control and no relationship between atrazine concentrations and ovotestis.

Du Preez et al. (2008) ran a well-conducted experiment in which *Xenopus laevis* were raised in mesocosms from 96 h post-fertilization in measured concentrations of atrazine (0, 1.1, 10.4, and 24.8 μg/L, static-renewal) and then allowed to breed while continuing to be exposed. Treated male frogs were mated with both treated and untreated females, and a range of reproductive endpoints were measured in both F1 and F2 groups. In summary, there were no treatment-related effects, either on clutch size of the F1 adults, or on hatching success, time to metamorphosis or sex ratio of the F2 offspring. There were low background incidences of segmented and single testes, and ovotestis [termed testicular ovarian follicles (TOF) 5–15% in F2 frogs], but these occurred randomly and were not treatment-related.

In addition, two thorough, blinded experiments with *X. laevis* larvae (Kloas et al. 2009) exposed to atrazine concentrations up to 100 μg/L from 8 days post-fertilization (dpf) to 83 dpf or metamorphosis failed to show any effects on sex ratio or incidence of intersex. Thus, the experimental work by Jooste et al. (2005), Du Preez et al. (2008), and Kloas et al. (2009) has consistently failed to find reproductive effects from atrazine in clawed frogs.

In other reliable studies, a variety of experiments with the same species as that used by Hayes et al. (2003), *R. pipiens*, have also failed to find significant effects of environmentally-relevant atrazine concentrations on a range of variables including hatchability, survival, time to metamorphosis, metamorphosis success, growth, sex ratio, GSI or gonadal abnormalities such as ovotestes (e.g. Allran and Karasov, 2001; Orton et al. 2006; Langlois et al. 2010; Knight et al. 2013).

However, considerable attention has been focused on amphibian populations living in areas of intensive agriculture. Reeder et al. (1998) sampled 341 cricket frogs (*Acris crepitans*) from up to 8 pond sites in Illinois, USA, in 1993–95, of which 2.6% overall showed ovotestis. At some sites, the incidence of ovotestis was up to 25%. A long list of contaminants in water was analyzed for, but only atrazine, metolachlor, cyanazine and chlorpyrifos were detected. Concentrations of atrazine ranged between 1 and 70 μg/L. There was no significant relationship between presence of ovotestis at a site and atrazine ($p = 0.07$). However, there was a significant relationship between sex ratio alteration (excess females) and polychlorinated biphenyls/polychlorinated dibenzofurans (PCBs/PCDFs), so it should be considered that legacy substances such as some organochlorines may be an underlying cause of these reproductive anomalies in amphibians.

Hecker et al. (2004) sampled adult *X. laevis* from eight sites in South Africa, some in maize-growing regions exposed to atrazine and others in non-maize-growing regions, with between 10 and 20 males and females taken per site. Water samples were analyzed for simazine, atrazine and its major metabolites, and terbutylazine. The frogs were analyzed for plasma testosterone (T) and E2, gonadal aromatase activity, and GSI. Atrazine concentrations ranged from <0.1 to 4.1 μg/L, and combined atrazine metabolites were ≤ 2 μg/L. There were no correlations between gonadal aromatase activity or GSI and concentrations of any measured agrochemicals, but there were negative correlations between atrazine and/or its metabolites and plasma T in females and males. There was also a negative correlation between atrazine and a metabolite and E2 in females. These effects on steroid hormones were of questionable biological significance (1.7–3.5-fold reductions in these hormones). Overall, atrazine or co-applied pesticides did not appear to be damaging sex steroid homeostasis, although this possibility could not entirely be ruled out.

Murphy et al. (2006a) sampled green frogs (*R. clamitans*) and other frog species for 2 years from three areas of intensive maize growing and three nonagricultural areas in Michigan. Atrazine levels in water were generally low (≤ 2 μg/L), although at one site the maximum measured concentration was 250 μg/L. Biological variables measured included GSI, plasma T, E2, 11-ketotestosterone (11-KT), and gonadal aromatase activity. Atrazine concentrations were not correlated with any biological variable. Plasma hormone levels varied between areas, e.g. the E2/T ratio was elevated in adult males and females in agricultural areas in 2002, but not in 2003, while in juvenile males, E2/T was elevated in 2003. There were insufficient male aromatase data for statistical analysis, but female aromatase was elevated at agricultural sites in 2002 and not in 2003. In a second paper from the same study, Murphy et al. (2006b) reported the incidence of hermaphrodites (i.e. intersex individuals) in three species, *R. pipiens*, *R. clamitans* and *R. catesbeiana*. There was a low incidence of testicular oocytes at both agricultural and nonagricultural sites, with greatest incidence in juvenile *R. pipiens*. There were no consistent differences between agricultural and nonagricultural areas. However, in one year (2003) the incidence of ovotestis in juvenile *R. pipiens* was higher at agricultural than nonagricultural sites. Ovotestis overall was not correlated with mean atrazine levels, but ovotestis in juvenile *R. pipiens* was correlated with maximum atrazine levels in 2003 only.

Smith et al. (2005) sampled 207 adult clawed frogs (*X. laevis*) in autumn 2002 from maize-growing areas (MGA) and non-MGA (NMGA) in South Africa, the sampling sites being those described by Hecker et al. (2004). A male secondary sexual characteristic (laryngeal mass), and testicular histology were measured. There were low incidences of ovotestis in MGA (2%) and NMGA (3%), and no differences in laryngeal mass or testicular cell volumes (especially spermatocytes and spermatozoa) between areas. There were no correlations with the presence of atrazine.

Northern leopard frogs (*R. pipiens*) and green frogs (*R. clamitans*) were sampled by McDaniel et al. (2008) every autumn for 3 years from up to 33 sites in intensive agriculture areas (maize and soy), two sites in agricultural reference areas, and four nonagricultural reference sites in SW Ontario, Canada. A large suite of pesticides was analyzed for in the water (including atrazine), and frogs were analyzed for plasma VTG, T, 11-KT, and E2; gross morphology, and male gonad histopathology. Ovotestis (termed testicular ovarian follicles or TOF) was significantly more prevalent in intensive agriculture areas (42%) compared with reference sites (7%), but VTG was only detected in one male from an intensive area, and no other significant differences were observed. The effect on ovotestis did not correlate with atrazine alone, but did correlate with a mixture of pesticides and nutrients (including atrazine), and the numbers of pesticides per site also correlated with effects. Median atrazine levels were 0.068–0.78 μg/L in intensive agricultural areas, 0.045–0.39 μg/L in reference agricultural areas, and LOD-0.090 μg/L in nonagricultural reference areas. The authors concluded that the data provide only limited evidence for estrogenic activity, and testicular oocytes were generally present in individuals from all areas at low levels.

Other studies have not explicitly looked for the effects of atrazine, but have simply reported levels of abnormalities in amphibians from agriculturally-intensive and non-intensive areas without analyzing for pesticide residues. For example, Mosconi et al. (2005) found relatively minor biomarker effects in *R. esculenta* from an intensive farming area in Italy by comparison with a relatively pristine area. McCoy et al. (2008)

found somewhat greater effects in Florida toads. 20 or more cane toads (*Bufo marinus*, now known as *Rhinella marina*) were collected over 2 years from each of five areas with agricultural activity ranging from 0 to 97% of the area within a 5.6 km^2 zone around the sampling point. The number of male gonadal abnormalities increased from 2 to 5 along the agricultural gradient, and the frequency of intersex gonads increased from 0 to 40%. Male T titers (but not E2) decreased, and secondary sexual characters were either feminized (skin mottling score up from 4.5 in nonagricultural site males to eight in intersexes) or demasculinised (forearm width reduced from 1.5 to 1.3 cm in intersexes; number of nuptial pads reduced from 2.5 to 1.5 in intersexes). Overall, males from agricultural areas had hormone levels and secondary sexual characters that were intermediate between intersex toads and toads from nonagricultural areas.

Reeder et al. (2005) tackled the issue from a new direction by measuring the presence of intersex in archived frog samples. Archived gonads of 814 cricket frogs (*A. crepitans*) sampled in Illinois between 1852 and 1996 were examined for ovotestis. This showed the highest incidence of intersex (11.1%) occurred in 1946–59, declining to 2.7% in 1980–96, a level similar to 1852–1929 (1.2%) before the widespread use of synthetic chemicals. The paper does not include data on levels of contaminants in the frogs, but the authors suggest their results may be explained by the high levels of dichlorodiphenyltrichloroethane (DDT) and PCB use in the 1940 s and 50 s. They also point out that intersex levels were high before atrazine was introduced on maize in Illinois (1959), and that intersex had declined to near background levels in 1980–96, even though atrazine was being very heavily used by then in Illinois. It was also noted that intersex was most common in urban and industrial areas, a fact which also suggests that atrazine (or other agricultural chemicals) was not the main causative factor.

Knutson et al. (2004) took a strictly ecological approach and addressed the issue of whether intensive farming operations are affecting amphibian populations. The study was conducted in 2000/2001 in 40 farm ponds in Minnesota, comparing the impact of land use in their immediate vicinity (intensive maize/soybean growing, livestock rearing, or low intensity agriculture) on their amphibian populations. Total species richness over a season and reproductive success (numbers of eggs and larvae), were measured over the 2 years. Up to 10 species were recorded, including *R. pipiens*, which had been claimed by Hayes et al. (2003) to be sensitive to the effects of atrazine. Knutson et al. (2004) showed that species richness was statistically indistinguishable in ponds from intensive agriculture areas compared with reference areas, while livestock rearing caused some reduction in reproductive success, probably due to disturbance and excessive nutrient inputs (although it seems possible that natural and synthetic steroids may also have played a part). Unfortunately, measurements made of pesticide contamination in the ponds were not published, although levels of atrazine were reported to be low in a sub-set of ponds (<0.1 –0.5 μg/L). Furthermore, the presence of ovotestis and other abnormalities were not recorded. However, it is evident that if sub-lethal biological effects in pond amphibians were being caused by the chemicals used in intensive agriculture, they were not translated through to population or community damage.

Finally, Pickford et al. (2015) studied nine breeding sites of common toads *Bufo bufo* in England and Wales. Using passive samplers and *in vitro* assays, they detected weak androgenic and estrogenic activity in water at some locations, but toad hatching rates and low levels of intersex were not correlated either with local agricultural operations or with levels of endocrine activity. There was, however, a negative correlation ($r^2 = 0.45$) between the proportion of male toads present after extended exposure and the amount of estrogenic activity as measured by the Yeast Estrogen Screen. It was concluded that substances other than plant protection products were responsible for this effect, although operational difficulties limited any further conclusions.

An assessment of all the available field evidence does not reveal a clear and consistent picture of endocrine activity in amphibians which can be linked to atrazine or intensive maize-growing alone. Furthermore, there are significant concerns about the repeatability of the early work reported by Hayes et al. (2003) – see Van Der Kraak et al. (2014). Some studies (e.g. Knutson et al. 2004; Reeder et al. 2005; Smith et al. 2005; Murphy et al. 2006a, 2006b) have failed to find abnormalities which can be consistently linked to agricultural intensification, while others have reported generally low levels of sexual abnormalities (e.g. Pickford et al. 2015). In some places (McDaniel et al. 2008) there is a correlation between effects, such as incidence of ovotestis, and a complex of different pesticides rather than any single one. However, severity of ovotestis is generally low (one or two oocytes per testis) even though incidence can exceed 40% (McDaniel et al. 2008). Some studies (e.g. McCoy et al. 2008) also report elevated ovotestis incidence in intensively farmed areas without providing evidence for a link with atrazine. In others (Hecker et al. 2004), some correlations of endocrine activity with the presence of atrazine have been found, but they generally involve relatively minor changes in hormonal variables such as plasma T and E2. Correlations do not, of course, prove causality, and the evidence of laboratory experiments with amphibians exposed to atrazine suggests that concentrations of this herbicide found in natural waters pose a minimal risk to amphibians (Van Der Kraak et al. 2014).

Even though there is not a strong link between atrazine concentrations and amphibian sexual abnormalities observed in the field, the effects that have been observed in some places may be partly due to the presence of other substances such as organochlorines, which could be causing mixture effects in certain locations (Reeder et al. 1998), or to other factors related to modern agriculture, which have not been implicated to date or quantified. However, the weight of evidence suggests that even where such effects are occurring in the vicinity of intensive maize-growing, they tend to be of relatively low severity, such as small changes in hormone titers or mild ovotestis. Crucially, there are indications from several species living in farm ponds that these effects are not being translated into damage at the population level (Knutson et al. 2004), and good evidence from one species (*A. crepitans*; Reeder et al. 2005) that the incidence of

ovotestis peaked long before the era of agricultural intensification and use of atrazine.

In a recent weight-of-evidence review by Van Der Kraak et al. (2014) it has been suggested that there are many more likely causes than atrazine-related ED for the global decline in amphibian populations, including the fungal disease chytridiomycosis, habitat loss, and climate change. They also draw attention to the fact that regional withdrawals of atrazine use (e.g. in 2004 in the European Union) have not led to recoveries of amphibian populations.

2.4 Impaired stress response in fish, amphibians, birds and mammals

2.4.1 Fish and amphibians

The response to stress in vertebrates is hormonally mediated by the hypothalamus-pituitary-inter-renal/adrenal (HPI/A) axis. In brief, stressors such as physical threats trigger synthesis of corticotropin-releasing hormone by the hypothalamus, which in turn stimulates release of adrenocorticotropic hormone (ACTH) by the pituitary. The ACTH then causes the inter-renal tissue in the head kidney of fish to produce the active hormone cortisol (corresponding to the closely-related corticosterone in higher vertebrates, which is produced by the adrenal gland). Cortisol/corticosterone together with catecholamines such as adrenalin helps the animal cope with stress by modifying its physiology. Cortisol prepares fish to adapt to the stressor by instigating a suite of changes including stimulation of heart rate, glucose mobilization, fat metabolism and osmoregulation. For a general discussion of these processes, see Pottinger (2003). Altered cortisol levels can cause immunosuppression and may have additional effects on growth and reproduction (Hontela 1998).

Research conducted in Canada in the 1990 s by the research group of Hontela showed that this cortisol response could be damaged in fish and amphibians by exposure to pollutants, and the early work has been reviewed (Hontela 1998). A wider review of pollution damage to the hormonal stress response in vertebrates as a whole was later published by Pottinger (2003). Both reviews made it clear that although interference with the hormonal stress response is likely to have implications for fitness, the precise functional significance of alterations in cortisol titers remained to be uncovered. To date this situation has not materially changed.

Hontela (1998) found that chronic exposure in the field to mixtures of pollutants or single substances can damage the ability of fish and amphibians to make the normal cortisol response to stress. At least some of these effects appear to be a specific impact on the hormone system caused by relatively low contaminant concentrations interfering directly with the production of cortisol rather than a secondary effect caused by a systemic toxic response, and as such they could be regarded as a form of ED (provided an adverse effect is caused). Fish (yellow perch *Perca flavescens*; Northern pike *Esox lucius*) and amphibians (*Necturus maculosus*) caught in areas polluted by mixtures of heavy metals (Cd, Hg, Zn), PCBs and PAHs, or by heavy metals or pulpmill effluent alone, produced 20–50% less plasma cortisol than reference organisms when subject to brief confinement stress. It was also found in ACTH challenge tests that the ability of the inter-renal tissue of the head kidney to produce cortisol had been reduced in field-sampled *N. maculosus* by 30–70%. The consequences of this effect were not explored but, while not adverse in themselves, it is expected that the ability of fish and amphibians to make metabolic, vascular and immune compensations for stress would be impaired, and that there might therefore be secondary consequences for growth and reproductive success.

Subsequent work has thrown more light on the widespread nature of this response to pollutants in lower vertebrates, and found it occurring at many different types of polluted site. Similar observations to those observed in yellow perch and northern pike from Canada (i.e. a diminished ability to produce cortisol after transient stress) have been made in marbled sole (*Pleuronectes yokohamae*) from polluted areas of Tokyo Bay (Kakuta 2002), and in caged rainbow trout (*O. mykiss*) exposed in the field in Canada to treated STW effluent for 14 d (Ings et al. 2011). Further work with yellow perch (Laflamme et al. 2000) also showed that fish from Canadian metal-contaminated lakes (up to: 16 μg/L Zn; 0.6 μg/L Cu; 0.18 μg/L Cd) exhibited a depressed cortisol response. Several of these studies also conducted ACTH challenge experiments with fish and confirmed that the cortisol-producing inter-renal tissues had been damaged (Laflamme et al. 2000; Kakuta 2002).

However, some studies have failed to find these effects in fish from other polluted areas, such as rainbow trout (*O. mykiss*) and brook trout (*S. fontinalis*) from selenium-contaminated streams in Canada (Miller et al. 2009a), and white suckers (*Catastomus commersoni*) from Canadian agricultural drains contaminated with selenium (0.4–26.7 μg/L) and ten pesticides (<0.005–7.3 μg/L) (Miller et al. 2009b).

Other studies have only looked at the basal cortisol level in unstressed organisms. For example, Hopkins et al. (1997) found that basal cortisol levels in male toads *Bufo terrestris* were elevated by factors of 5–9 in areas contaminated with coal ash waste by comparison with reference sites. A similar increase in basal cortisol titers occurred when uncontaminated toads were transplanted for up to 12 weeks to the ash-contaminated sites. Again, while changes in basal cortisol levels are not adverse in themselves, it is to be expected that large changes would have implications at the apical level.

More recent work on the damaged stress response in fish has been conducted in the UK by Pottinger et al. They have studied three-spined stickleback (*Gasterosteus aculeatus*) populations living in English rivers receiving treated sewage effluent. This work shows that perturbations of the cortisol response to brief confinement stress are related to proximity to sewage discharges (Pottinger et al. 2013, 2016). Furthermore, long-term water quality data suggest that sewage is not the only source of this perturbation. Variation in 14 water quality determinands explains 30–60% of the variation in hormonal stress reactivity, irrespective of whether the river is sewage polluted or not (Pottinger and Matthiessen 2016b). One of the chemical variables that might be responsible in part for the effects is nitrate, although this remains to be proven, and it appears likely that mixtures of

several contaminants may contribute. Experiments in which female fish from areas where the stress response was damaged were held in clean water for 5 months and then stress-tested showed that the damage is unchanged over this period, but it is currently unknown if this is due to genetic or other causes (Pottinger and Matthiessen 2016a).

It should be noted that the mechanism of damage to the stress response system in fish is probably more complicated than simple impairment of the ability of the inter-renal tissues to produce cortisol when stimulated by ACTH. For example, there is some evidence that the pituitary corticotrope cells which produce ACTH itself are atrophied in fish from polluted environments in Canada (Hontela et al. 1992). As pointed out by Pottinger (2003), this could be due to direct toxic effects of pollutants on the pituitary, or to prolonged negative feedback suppression by corticosteroids, or to some other mechanism. It is, therefore, not necessarily the result of a direct interaction with the endocrine system.

2.4.2 Birds

The situation in higher vertebrates such as birds and mammals has some similarities with that in fish, although fewer data are available. For example, Wada et al. (2009) sampled tree swallow nestlings (*Tachycineta bicolor*) from mercury (Hg) contaminated and reference rivers in Virginia, USA, where relative mean levels of Hg contamination in nestling blood were 354 μg/L compared with 17 μg/L at reference sites. The plasma corticosterone response to confinement stress varied with nestling age. The strongest relationship with Hg was observed in late-stage nestlings (13–17 d) where the corticosterone baseline in contaminated areas was elevated by 103% (from ~2.5 to 5 ng/ml plasma), while the stress-induced level was depressed by 27% (25 ng/ml at reference site, 18 ng/ml at Hg site) in comparison with reference nestlings. However, in younger nestlings, the corticosterone response in the Hg area appeared to increase by comparison with reference sites, suggesting that the mercury had to bioaccumulate to a certain level before effects occurred. It was not made clear if the reduced corticosterone response to stress was statistically significant.

Mayne et al. (2004) studied nestling tree swallows (*Tachycineta bicolor*) and eastern bluebirds (*Sialia sialis*) in 2000/2001 from pesticide-treated and reference orchards in Ontario, Canada. Nests were sprayed with up to 7 individual pesticide products and 5 pesticide mixtures containing a total of 19 active substances, but it was also noted that eggs of swallows and bluebirds from treated orchards contained p,p′-DDE mean levels of 1.14 mg/kg wet wt. and 25.0 mg/kg, respectively, compared to 0.22 and 1.35 mg/kg at the reference sites. In tree swallows, there were no effects on basal corticosterone or on stress-induced levels. However, ACTH challenge produced a statistically significantly higher level of corticosterone response in potentially exposed swallows (mean 82.6 ng corticosterone/ml blood compared with 67.2 ng/ml). There were no correlations of these effects with pesticides. In contrast, potentially exposed bluebird chicks were significantly less responsive to ACTH challenge than reference chicks (mean 45.1 ng/ml blood compared with 58.2 ng/ml), a possible sign of abnormality in the adrenal tissue, and this was negatively associated with p,p′-DDE in eggs. Other studies of adrenal abnormalities in birds have produced less clear-cut results (e.g. Baos et al. 2006).

2.4.3 Mammals

The work of Mayne et al. (2004) on tree swallows and eastern bluebirds is noteworthy, because they showed that residues of a legacy substance (p,p′-DDE), and not a suite of currently used pesticides, were linked to the effects on ACTH responsiveness. Work on adrenal effects in mammals also seems to link endocrine changes with legacy organochlorines. Detailed research, summarized by Bergman (1999) and first described by Bergman and Olsson (1985), described postmortem adrenal hyperplasia in 3 species of seal, mainly 159 gray seals (*Halichoerus grypus*), found dead around the Baltic Sea between 1977 and 1996. Prevalence of hyperplasia varied from 0 to 100%, and was most common and severe in older animals (>15 years). It was suggested that this condition was related to organochlorine contamination, although residue data were not given in this paper. However, later work strongly suggested that the condition was associated with high body burdens of PCBs and DDT residues, and Bergman et al. (2012) state that the pathological signs are suggestive of Cushing's Disease (hyper-secretion of corticosterone), although no measurements of corticosterone have been made in wild seals. This pathology has not been observed in seals outside the Baltic, but has been seen in beluga whales (Lair et al. 1997).

It should be noted that studies of adrenal (and other) pathology and its possible links to contaminants in marine mammals should be treated with a degree of caution, because it is impossible to be sure about cause and effect in the stranded animals which form almost the entire sampled population. For example, Kuiken et al. (1993) studied postmortem adrenal pathology and organochlorine contaminant levels in 28 stranded harbor porpoise (*Phocoena phocoena*) found on the shores of Britain in 1990–1991. Adrenal hyperplasia was present, but it was not associated with elevated levels of organochlorines (HCH, DDE, DDT, dieldrin, PCBs) in blubber. The authors suggested that the hyperplasia probably resulted from the chronic stressors which had led to death rather than from the organochlorines in their tissues. Nevertheless, given the similarity of the cortisol/corticosterone stress response system in all vertebrates, it is not unreasonable to conclude that the effects seen in some fish, amphibians and birds are also potentially occurring in mammals.

In summary, there is a weight of evidence from many sites that the ability of fish, birds, and probably amphibians and mammals to make a normal hormonal response to stress, can be damaged by exposure to a wide range of contaminants acting at low concentrations, some of which are current-use materials (such as heavy metals, and mixtures present in sewage and pulpmill effluent) and some legacy pollutants (such as various organochlorines), although the causal and mechanistic evidence implicating specific substances is rather weak. Furthermore, damage to the cortisol response in individual

fish appears to be permanent. The major question which remains to be answered, however, is whether any of these effects are actually causing adverse apical damage in wildlife populations. At present, there is no evidence that this is occurring, so the effects may not constitute ED as such, although it seems reasonable to speculate that the fitness to survive and reproduce of affected individuals may be compromised as a direct result of chronic modulation of their stress hormone systems. It should also be noted in passing that the effects described above are entirely distinct from the suppressive effect which acute stress-induced elevated levels of cortisol can have on circulating steroid hormone titers (e.g. Pankhurst and Van Der Kraak 2000).

2.5 Thyroid disruption in fish, amphibians and birds

The thyroid hormone system in vertebrates is mediated through the hypothalamo-pituitary-thyroid (HPT) axis (Blanton and Specker 2007; Zoeller et al. 2007). Following environmental stimuli acting on the hypothalamus, the pituitary synthesizes thyroid-stimulating hormone (TSH) which in turn triggers the synthesis of thyroxine (T4) and some triiodothyronine (T3) by the thyroid gland. However, the majority of T3 (the active hormone) is synthesized from circulating T4 in peripheral target tissues via the action of 5′-iodothyronine deiodinase. The complexity of this system potentially allows EDSs to impact at many points, including on hormone synthesis, transport, and peripheral activation (Crofton 2008). In fish and amphibians, thyroid hormone is essential for the control of early development and for metamorphosis. In addition, it has a major influence on growth and reproduction. With relatively minor differences, thyroid hormone plays similar roles in the higher vertebrates.

Most of the contaminants which have been implicated in damage to the thyroid system (PCBs; polychlorinated dibenzo dioxins – PCDDs; DDT and other chlorinated pesticides; polybrominated diphenyl ethers – PBDEs) are legacy chemicals which fall outside the scope of this review (see Boas et al. 2006). For example, detailed early work by Leatherland et al. (reviewed by Leatherland 1998) showed that polychlorinated hydrocarbons including various PCB congeners were mainly responsible for thyroid perturbations in fish and predatory birds from the Great Lakes. The link between PCBs and thyroid effects in Great Lakes herring gulls (*Larus argentatus*) is particularly clear (McNabb and Fox 2003). A more recent example (out of many) involved a study of fish (shiner surfperch *Cymatogaster aggregata* and Pacific staghorn sculpin *Leptocottus armatus*) in San Francisco Bay, USA, which showed reductions in plasma T4 and perturbations in T3/T4 ratios that were strongly correlated with PCB body burdens (Brar et al. 2010).

However, some thyroid-active substances are still in use (e.g. perchlorate; some heavy metals such as mercury etc.) and will be considered further. The clearest evidence is that related to perchlorate, an oxidizing agent mainly derived from ammonium perchlorate used in solid rocket fuels. Perchlorate is known to inhibit iodide uptake by the thyroid gland, thus interfering with normal synthesis of T4, which in turn abrogates negative feedback on TSH, thereby leading *inter alia* to thyroid follicular hyperplasia and hypertrophy. Mean perchlorate concentrations in contaminated streams in Texas studied by Theodorakis et al. (2006) ranged from 1.45 to 23.09 μg/L (max. 150 μg/L), with nothing detected in the reference rivers. They sampled fish, the central stoneroller (*Campostoma anomalum*) and amphibians, the cricket frog (*A. crepitans*), in three perchlorate-contaminated streams, and two reference streams in 2001–2003. Fish from the contaminated sites had increased thyroid follicular cell hyperplasia (in up to 20% of follicles), follicle epithelial hypertrophy, and depletion of T4-rich colloid in the follicles (in up to 12%), and these variables changed seasonally. In contrast, no colloid depletion or hyperplasia were evident in the frogs, but some hypertrophy was present at the most contaminated sites, and hypertrophy was correlated with mean perchlorate in water across all sites. This is strong evidence for inhibition of thyroid hormone synthesis, and is supported by many laboratory experiments with fish and amphibians exposed to perchlorate (e.g. Goleman et al. 2002; Bradford et al. 2005).

Perchlorate has caused similar effects in other amphibian populations (Carr et al. 2003). Bullfrog tadpoles (*R. catesbeiana*) collected from a perchlorate-contaminated site showed a five-fold lower hindlimb/snout-vent length ratio than reference tadpoles. The thyroid gland volume was 2.5-fold smaller in the contaminated larvae, probably because the reference animals had developed more rapidly to metamorphic climax. Western chorus frog tadpoles (*Pseudacris triseriata*) living in an ephemeral pond contaminated with perchlorate showed gross abnormalities of the thyroid gland including colloid depletion and follicular cell hypertrophy. Overall, these frogs showed delayed development of thyroid-hormone sensitive structures. It is to be expected that severe developmental delays could lead to adverse effects at the population level, but this is difficult to measure and has not been demonstrated to date.

Other contaminants which have been associated with thyroid modulation in the field include mercury, other heavy metals, and PAHs derived from partial combustion of oil products. Zhou et al. (2000) studied a fish, the mummichog (*Fundulus heteroclitus*), in Piles Creek, New Jersey, which was polluted with mercury and petroleum hydrocarbons. Mean mercury levels in sediment were 11.2 mg/kg (max. 200 mg/kg), although Cu, Zn and Cd were also elevated (625, 628, and 5.8 mg/kg sediment, respectively) (Khan and Weis 1993; cited in Smith and Weis 1997). Piles Creek fish had enlarged thyroid follicles (×6.7) in comparison with a reference site, follicular hyperplasia, and a 60% elevation of plasma T4, but no differences in T3. These effects could be simulated by exposing fish to Piles Creek sediments in the laboratory for 1 month. It seems likely that mercury was mainly responsible for the thyroid effects, because Smith and Weis (1997) showed that the fish had reduced growth and longevity compared with reference sites, prey capture was slower, and predator avoidance poorer. These changes are symptomatic of the developmental and neurological damage which mercury can cause, partly via its effects on the thyroid.

However, other work suggests that some PAHs are also thyroid-active and may have contributed to the effects in Piles Creek. Gentes et al. (2007) sampled nestling tree

swallows (*Tachycineta bicolor*) from nest boxes in three areas of wetlands contaminated with tar sands mine tailings in Alberta, Canada. Mean contaminant levels were 140–207 ng total PAH/g sediment, 1010–2273 ng alkylated PAH/g sediment, and 10.3–68 mg/L naphthenic acids in water, compared with 81.5 ng/g, 175.9 ng/g and 0.3 mg/L, respectively, at the reference site. Plasma T3 was slightly elevated in swallows at the study sites (reference: 1.60 ng/ml; study: 1.37–2.57 ng/ml). Plasma T4 was not significantly affected, but T4 was elevated in thyroid gland by ~100%. The results suggest that T4 synthesis by the thyroid was increased (the opposite effect to that caused by perchlorate), as was deiodination of T4 to T3 in peripheral tissues. The authors indicate that these changes could have negative effects on metabolism, behavior, feather development and molting, but it is not clear whether apical changes such as these would actually have occurred. Although PAH exposure could have been responsible for the effects, it was also suggested that environmental factors such as food availability may have been a factor.

The involvement of PAHs in thyroid modulation in wildlife was given support by Hersikorn and Smits (2011). They raised wood frog (*Lithobates sylvaticus*) tadpoles in enclosures on reclaimed oil sands wetlands of different degrees of maturity, and compared them with controls raised on reference sites. Metamorphosis was delayed (24%) or halted in tadpoles raised on freshly produced tailings, while development proceeded normally on old tailings and reference sites. The T3/T4 ratio was lowest in tadpoles raised on fresh tailings (max. reduction of 45%). No measurements were made of PAH concentrations, but it is reasonable to suppose, based on the evidence of Gentes et al. (2007), that they were elevated.

Heavy metals other than mercury have also been associated with thyroid effects. Kulczykowska et al. (2007) studied 32 white stork nestlings (*Ciconia ciconia*) near a copper smelter in Poland and compared them with 48 sampled near a town and in a reference area. Near the smelter, serum T4 was significantly reduced, by 58%, while serum melatonin (a free radical scavenger) was increased by 150%. Levels of Zn, Mg and Cd in nestling blood near the smelter were 16.60, 2933, and 5.06 mg/L, respectively, compared with 9.38, 1469, and 2.57 mg/L in blood of nestlings near the town and reference area. It is not clear which of these metals, if any, was responsible for the thyroid effects, but there was obviously a relationship with the presence of the smelter itself.

Finally, Sowers et al. (2009) and Mosconi et al. (2005) have demonstrated thyroid abnormalities in amphibians raised in diluted sewage effluent, or sampled from an intensive agricultural area, respectively. Sowers et al. (2009) showed that 50 and 100% STW effluent caused a 4–7 d delay in metamorphosis of northern leopard frog larvae (*R. pipiens*). There were nonspecific effects on thyroid histology – no hyperplasia or hypertrophy was observed, but small differences in follicular cell shape were recorded. This possibly suggests that the effect was not endocrine-mediated, but represented some nonspecific systemic toxicity. The frogs (*R. esculenta*) from an area of mainly cereal production in Italy (Mosconi et al. 2005) exhibited T3 and T4 titers which were increased by a factor of two in summer by comparison with a reference area. However, no data on thyroid histopathology or contaminant levels were presented, so it is impossible to conclude whether these frogs were experiencing endocrine influences as the fluctuations in hormone titers were probably within the natural range.

Considering the thyroid dataset as a whole, there is no doubt that some wildlife populations are experiencing chemical-related perturbations of the thyroid system, although in some cases the effects are probably nonspecific systemic toxicity. In other cases, however, it is likely that substances, such as perchlorate, mercury, and PAHs are causing more or less direct modulation of the thyroid cascade in a variety of vertebrates from fish to birds. Unfortunately, only in one case (fish exposed to Hg and PAHs: Smith and Weis 1997; Zhou et al. 2000) do we have evidence that this modulation has been causing adverse apical effects at the population level, but it seems likely that such effects, due to a variety of substances, are more widespread. For example, biologically significant delays in amphibian metamorphosis and interference with normal neurological development in a range of species will have adverse consequences for individuals and probably populations. More research is required to measure the extent of such effects in wildlife populations experiencing thyroid modulation.

3. Discussion and conclusions

Based on the Hill criteria (Hill 1965), Table 2 summarizes the strength of evidence for ED resulting from current-use chemicals, while Table 3 does the same for legacy chemicals. Effects (and their putative causes) have only been included if they have been demonstrated in the laboratory for related taxa. The strength of evidence (in terms of the amount of data considered reliable) has been graded 2 for strong, 1 for weak, and 0 for unknown. We acknowledge that this grading is somewhat subjective, but nevertheless consider it to be a helpful way of summarizing the data. Particularly relevant factors include whether there is a well-established endocrine mechanism, whether population damage has occurred, and whether there has been any experimental confirmation. Other important criteria include whether or not the putative endocrine effects are reproducible (i.e. consistency of effect), and whether the effects are clearly linked to the putative endocrine cause (i.e. specificity of association). The remaining criteria are also useful but often cannot be addressed due to lack of data.

Taking Table 2 on current-use chemicals first, it is apparent that the case for EE2 in sewage effluents, in combination with natural estrogens, causing adverse effects in wild fish (and to a much lesser extent, amphibians, and reptiles) is reasonably strong. There is even evidence of damage to the breeding capability of some affected fish populations, although convincing evidence for actual population declines or extinctions only exists for the large Canadian lake experiment with EE2 (Kidd et al. 2007) in which the exposure concentrations were relatively high compared with most locations downstream of sewage effluent discharges. Other missing evidence includes the lack of data from before the era when estrogens were discharged in sewage (i.e. a temporal sequence is lacking), and the availability of only weak

Table 2. Strength of evidence for endocrine effects of current-use chemicals in the field, using criteria modified after Hill (1965). Strength of evidence: 2 = strong/large; 1 = weak; 0 = unknown.

	Evidence for:									
	An endocrine mechanism	Population damage	Experimental confirmation	Consistency of effects	Specificity of association	A temporal sequence of cause/effect	Gradients of effect	Wide geographic extent	Decreased effect after reduced exposure	Total
1. Invertebrates – possible estrogenic effects of EE2 and other estrogens in sewage effluent	0	0	1	1	1	0	1	1	0	5
2. Fish (amphibians/reptiles) – estrogenic effects of EE2 and other estrogens in sewage	2	1	2	2	2	0	2	2	1	14
3. Amphibians – possible estrogenic effects of intensive agriculture, including atrazine	0	0	1	1	1	1*	1	1	0	6
4. Vertebrates – impaired endocrine stress response to multiple contaminants	1	0	1	2	1 (multi-factorial causes)	0	1	1	0	7
5. Vertebrates – thyroid effects linked to perchlorate and other contaminants	2 (perchlorate) 1 (other)	1	2 (perchlorate) 1 (other)	1	1 (multi-factorial)	0	1	1	0	9 7

*Some evidence for stronger effects before the use of atrazine in intensive agriculture.

evidence for recovery when estrogenic discharges are remediated. Such remediation has hardly begun, mainly due to the high cost.

The other cases summarized in Table 2 for field effects of current-use chemicals are weak by comparison with estrogens and fish. Perhaps the least convincing is the idea that intensive agriculture, particularly that employing the herbicide atrazine, has caused feminization in wild amphibians. Probably the most compelling evidence against this hypothesis is that archived amphibian testes show prevalence of intersex which peaked long before atrazine was used, and declined during the period when atrazine-use was high at the end of the twentieth century to levels seen in the nineteenth century. Also, populations have not recovered in areas where atrazine was withdrawn from wide-scale use, and none of the other causality criteria appear to support the hypothesis.

The case of thyroid effects in vertebrates is interesting. There is some evidence that interference with thyroid function in fish can be caused by exposure to mercury and possibly also PAHs, and that this can lead to a series of apical impacts on development and behavior that are probably damaging at the population level. Furthermore, the thyroid effects of perchlorate on wild fish and amphibians are clear, even though there is no evidence that populations have been affected, and no examples of recovery have been observed. Overall, however, the strength of association between various current-use chemicals and thyroid effects in wild populations is at present rather weak, and more data are required.

Another weak case, perhaps again due to lack of data, concerns so-called estrogenic and other effects in mollusks and crustaceans. There is no doubt that exposure to estrogenic effluents causes elevations of ALP in some mollusks, but the mode of action is unknown (it may not even be ED), and there is no evidence for resulting adverse apical effects at the population level. There is weak experimental evidence that estrogen exposure in bivalves can cause reproductive damage, and only limited field evidence of this. Surprisingly, there is also no hard evidence for the adverse effects of ecdysone- and juvenile-hormone active insecticides on non-target insects and crustaceans, although this is not necessarily evidence of absence. More research in this field would be desirable.

Finally, there is a presently weak case for damage to the hormonal stress response in vertebrates caused by a range of unrelated contaminants, some of which are current-use chemicals. There is little experimental evidence, rather sparse information on modes of action, and no data about possible adverse apical effects on populations. However, this area is under-researched in comparison with the huge body of work on sex steroids and thyroid hormones, and it seems probable that damage to the stress response may be widespread in the vertebrates. The effects that have been observed can occur at low concentrations and some, at least, appear to result specifically from interference with the HPI/A axis, so they seem unlikely to be the result of systemic toxic action. It remains to be seen, though, whether the fitness of affected individuals to survive and reproduce is being impacted.

Table 3. Strength of evidence for endocrine effects of legacy chemicals in the field, using criteria modified after Hill (1965). Strength of evidence: 2 = strong/large; 1 = weak; 0 = unknown.

	Evidence for:									
	An endocrine mechanism	Population damage	Experimental confirmation	Consistency of effects	Specificity of association	A temporal sequence of cause/effect	Gradients of effect	Wide geographic extent	Decreased effect after reduced exposure	Total
Tri-organotins and mollusks	1	2	2	2	2	2	2	2	2	17
Polychlorinated biphenyls (PCBs), polychlorinated dibenzo dioxins (PCDDs), polychlorinated dibenzo furans (PCDFs)and vertebrates	1 (multi-factorial)	2	1	1	2 (multi-factorial)	1	2	2	1	13
Polybrominated diphenyl ethers (PBDEs) and vertebrates	1	0	1	2	2 (multi-factorial)	0	0	2	0	8
Perfluorinated compounds (PFCs) and vertebrates	1	0	1	1	1	0	0	2	0	6
DDT/p,p'-DDE and other organochlorine pesticides and vertebrates	1	2	2	2	2	2	2	2	2	17
Alkylphenols/alkylphenol ethoxylates and vertebrates	2	1	2	2	2	0	2	2	1	14

In only one of these cases, that of fish and amphibians exposed to EE2 in sewage, would it be true to state that the effects are widespread – indeed, they appear to be global wherever dilution of sewage is limited, although the precise threshold for effects is unclear. The remaining examples of effects due to current-use chemicals seem to be locally distributed, although more research may substantially widen any cause for concern. It should also be pointed out that establishing the existence of population declines and linking these to a likely cause is extremely difficult, so in many cases the best that can be expected is to identify effects on fitness, which are likely to result in population damage.

Turning to Table 3, which summarizes the strength of evidence for endocrine effects in the field caused by legacy substances, it is clear that this group of chemicals has a greater body of evidence supporting population effects than the current-use group of chemicals. The two strongest cases are those of tri-organotins in mollusks and organochlorine insecticides in predatory birds, both of which undoubtedly caused effects on a wide scale, which resulted in population and community crashes. The case for the PCBs and related chlorinated hydrocarbons having caused, and still causing, adverse population-level effects in many vertebrate species is also strong, only being limited by the logistical and ethical objections to the conduct of experiments in top predators, and by the fact that continuing exposure in some cases has probably prevented substantial population recoveries.

The evidence in the case of PBDEs and PFCs is somewhat less robust, but widespread exposure to, and bioaccumulation of, these chemicals combined with their toxicological properties suggests that they are contributing to the population-level effects on top-predators, which have been fairly well established for the PCBs. There is also little specific field evidence on the APs, but although it is reasonable to suppose that they contributed to a limited extent at one time to the estrogenic effects of many STW and other discharges, current aquatic concentrations of APs (at least in the USA) now appear to be below harmful levels (Coady et al. 2010).

On an optimistic note, it is considered that the current regulation of chemicals in general, and specific programs aimed at screening for and characterizing ED properties in particular, may be leading to further environmental improvement. Many of the legacy chemicals have POP-like properties, which is not the case for current use or new chemicals. Since POPs are being phased out globally, chemicals possessing POP characteristics are typically screened out during product development. Further, the general increase in environmental toxicity testing requirements for chemicals is likely to detect more sensitive apical adverse effects that would not have been captured previously. For instance, in Europe, the guidance document for aquatic ecotoxicology of pesticides went from 62 pages (European Commission 2002) to 267 pages (EFSA Panel on Plant Protection Products and their Residues 2013) in about a decade and further guidance documents are in development. The results of the additional testing and consequent risk assessment procedures are lowering acceptable

exposures, and are tending to result in safe uses that protect the environment from both non-endocrine and endocrine-mediated adverse effects. In addition, the development of new ecotoxicological screens and tests with diagnostic sensitivity to EDSs has enhanced the regulatory tool box. Some of the OECD's internationally-standardized *in vivo* toxicity screens and tests with fish, amphibians, and mammals, as well as *in vitro* assays, now have specific diagnostic ability to detect substances that can perturb the (anti)estrogenic, (anti)androgenic, steroidogenic and thyroid systems (OECD 2016). Additional diagnostic assays for use with other taxa, including invertebrates, are under development. As screening programs (e.g. US-EPA's EDSP) and other legislation begin to implement these, our ability to identify and regulate substances with ED properties will be further improved. However, it is too early to state that availability of the new EAS-sensitive diagnostic assays will actually lead to improvements in environmental protection.

In conclusion, with the exception of the estrogenic effects on fish of EE2 and related estrogenic substances in treated sewage, it appears that legacy chemicals have caused, and in some cases are still causing, much more severe and widespread damage to many wildlife species than current-use chemicals. This conclusion must, of course, be accompanied by a significant caveat concerning the need for continued monitoring and research on these issues. Furthermore, the advent of improved regulatory testing does not imply that releases of new chemicals with side-effects including endocrine activity are necessarily a thing of the past, although they will likely become less common as they will be picked up earlier (i.e. in the substance discovery phase).

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Declaration of interests

The authors' employment affiliations are as shown on the cover page. The lead author is an independent consultant in ecotoxicology, while the other authors are employed as ecotoxicologists in the crop protection industry. The preparation of the paper was the professional work product of the authors and the synthesis of information, conclusions drawn and recommendations are the exclusive positions of the authors and not necessarily those of their employers. None of the authors have appeared in any legal or administrative proceedings related to the contents of the paper. CropLife International supported and encouraged this project by funding the time of the lead author, but the other authors received no funding from CropLife. An earlier version of the paper was circulated to CropLife, the European Crop Protection Association, and the authors' employers, but no significant comments were received. CropLife International (https://croplife.org/) is a group of companies and industry associations involved in developing and marketing crop protection products. It champions the role of agricultural innovations in crop protection and plant biotechnology to support and advance sustainable agriculture.

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