GEOG309

Research for Resilient Environments and Communities

Impacts, Assessments and Recommendations for Stormwater Drainage Management in Okains Bay

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Thomas Costello, Harrison Cullen, Florence McKenzie,
Maya Thordarson & Abbey Webb

Supervisor: Sam Hampton

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University of Canterbury
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Executive Summary

This report addresses prominent flooding issues in Okains Bay caused by sediment build-up and neglect of drainage infrastructure. Using field assessments and GIS analysis, critical areas and conditions of the stormwater drainage system were identified, aiding in identifying causes where the Okains Bay community has observed flooding impacts. This analysis has resulted in the following recommendations to reduce the impacts of rainfall events within Okains Bay.

Recommendations:

- **Immediate Actions:** Clear sediment, improve drainage pathways, and restore system functionality
- **Optimization:** Improvements to pre-existing ditches, swales and culverts, plant riparian species
- **Adaptations (Where Appropriate):** Add sediment traps, retention ponds, and larger culverts
- **Naturalisation:** Encourage water to follow its natural pathways (Paleo Drains) and use native plants to increase resilience.

Making these changes while incorporating Māori Principles ensures the system fulfils its purpose while respecting cultural values. Combining these recommendations and practical engineering will make the system more resilient towards future rain events and reduce the impact of rainfall events.

Visual assessment of the drainage system was done through a site visit, and GIS analysis was utilised to map the catchments, paleo drainage systems, and current man-made infrastructure. This process helped to identify several pressure points where the system is inadequate in handling the water flow, guiding fixes to enhance flood management in the area.

Identified issues include sediment build-up, numerous unmaintained and inadequate culverts, roadside drains, and cross-valley drains. Specific points within the system have been determined for use as case studies. These case studies enable an understanding of the current extent of the issues. Literary reviews across various relevant subjects provide a broader understanding of the issue and solutions, including: “Impact and management of sea level rise on intertidal drainage networks”, “Potential drainage systems to utilise within Okains Bay”, “Drainage management within rural New Zealand”, and “Classification of

waterways and the associated legislative requirements, regulations". These reviews used evidence from pre-existing literature to create informed solutions and recommendations.

Acknowledgments

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Introduction

Okains Bay is a low-lying coastal valley located on New Zealand's Banks Peninsula (Figure 1). Okains Bay consists of a complex estuarine environment and experiences flooding associated with high levels of rainfall, which is exacerbated by an inadequate stormwater drainage system. Significant inundation is expected following long periods of rainfall or storm events, posing risks to the local community, infrastructure, and agricultural production.

The community's residents have raised numerous concerns for years about the frequency of flooding, causing inundation of properties and roads following prolonged periods of rainfall, and the accumulation of sediment. Impacts have increased over the last few decades, with local residents indicating maintenance of the valley floor drainage system has not occurred for over 40 years. Prior to this, it was said that the local Drainage Board was responsible for clearing sediment from the system.

Figure 1. Okains Bay (highlighted in red) location in relation to Christchurch and Banks Peninsula. (Google Earth Pro, 2024).

Drainage Background

White et al. (2017) suggest that stormwater networks in New Zealand are typically designed to drain off low-intensity, frequent rainfall events, emphasising why having a drainage network able to handle the change in climate from climate change is crucial. In association with this, Rural New Zealand presents complex hydrological challenges due to diverse landscapes such as valleys, mountain ranges, and coastal plains. “Effective water flow management is essential for protecting agricultural productivity and community safety" (Ballantine & Tanner, 2013).

In areas such as Okains Bay, climate change is a highly prominent issue, especially in this context, where intertidal flows are influential, therefore, having a structured system that adheres to modern regulations and requirements is essential. The National Policy Statement for Freshwater Management (NPS-FM) 2020, emphasises the classification of waterways based on their ecological health and cultural significance, which is critical in guiding stormwater management practices" (New Zealand Government, 2020) in New Zealand.

Māori Incorporation

Modern systems prioritise a rapid runoff approach, which is not always the right solution for a unique environment. It is essential to consider sustainable designs inspired by Māori principles, such as Mātauranga Māori and the concept of mauri. These offer an approach that aligns contemporary water management with traditional Indigenous values" (Voyde & Morgan, 2012). Using these principles in the design process will reflect a harmonious combination of contemporary and traditional Māori values. This offers an approach to flood risk management that respects Māori culture and beliefs while aligning with New Zealand's modern-day culture and environmental heritage.

Study Aim

This project focuses on the assessment, analysis of the current drainage infrastructure in Okains Bay and provision of suggested improvements in modifications and management. Addressing the persistent flooding in Okains Bay requires a mix of both practical and environmentally conscious solutions that cater to the coastal valley's unique environment. This study aims to identify and resolve significant issues and weaknesses within the drainage infrastructure system. Integrating geographic analysis, modern engineering solutions, and traditional Māori values enhances flood resistance and the community against future rainfall events. This approach ensures the drainage infrastructure aligns with practicality, cultural heritage and environmental policy.

Site Characteristics

The landscape of Banks Peninsula is predominantly the eroded extinct shield volcanoes from the Miocene-Pliocene period (Sewell et al., 1988). Individual lava flows have resulted in the many steep-sided cliffs and spurs alongside deep valleys. The bays formed as flooding occurred within the area alongside the influence of the rise in sea level. Okains Bay valley floor consists of fine marine sands and is positioned between steep side walls of basaltic composition (Stephenson & Shulmeister, 1999). A low dune environment extends up the valley inland from the beach, with the Opara Stream entering from the northern end. Over time, this has created a small estuary environment.

Okains Bay is a low-lying environment with limited infrastructure. There are houses, a school, and a museum in the area. Okains Bay has a very limited drainage system, does not have access to potable water, and has minimal utilities.

Methodology

Field Assessment

A site visit to Okains Bay collected primary data using the application Field Maps to gather photos and field observations. This application enabled the researchers to collect data using mobile devices to collect geographic data while working offline. Prior to data collection, the symbology of geographic features of points and lines was established. During the data collection, specific symbology was allocated to culvert lengths, drainage connection points, cross valleys and the conditions of these variables. Photos were taken of specific locations to highlight the conditions of pre-existing drainage systems, water flows, and standing water in Okains Bay. This enabled the establishment of the current condition of drainage systems within the area. Before the field visit, Okains Bay received over 20mm of rainfall, observations made post this event highlighted how small-scale precipitation events can have significant effects due to the absence of adequate drainage infrastructure.

GIS Analysis

Catchment Areas and Paleo Drainage Systems

The process of GIS analysis started with identifying catchment areas and paleo drainage systems. To do this, a digital elevation model (DEM) was created and imported into ArcGIS Pro. This identified the elevation of the ground in 20-centimetre increments. A layer was added using watershed tools, including flow direction, accumulation analyses, current flow directions and paths. This allowed for the hydrological behaviours of the valley and its interactions with the valley's infrastructure to be captured. Additionally, paleo drains were identified while utilising the DEM, elevation map, and artificial drains were added as a new layer.

The next phase involved assessing the performance of the drainage pathways. The start of this process involved creating connections between each catchment. By following the flow paths to see the journey the water takes within specific parts of the system; that way, the systems contributions via runoff could be identified. Using visuals collected, areas of high water were cross-referenced, followed by photos of the drains in the poorest conditions. This was critical in planning the solutions to track where the water came from, how much water it was, and the flow path to culverts (location of the blockages in all cases assessed in depth). Furthermore, the terrain was cross-sectioned to see if the cause of inadequacy was related to terrain height. These findings helped guide the development of targeted solutions, such as culvert upgrades, enhancing canals, and installing sediment traps.

Utilising identified main drainage pathways and catchments were determined based on the main drainage pathways to define the area in which each pathway drains. Using the rational method ($Q = 2.78C\ I\ A$), the runoff was calculated in litres per second (l/s) for each of these sub-catchments based on a rainfall event of 10mm/hr (CCC, 2020).

Results

Interpretations

Okains Bay’s topography directs and influences drainage pathways (Figure 2). Historically, the bay filled due to rapid coastal progradation, where sediment build-up created a stable coastline. The fill is primarily composed of fine sand and, has mainly occurred over the past 2000 years due to the increased erosion from coastal Southern Canterbury. The eroded sediment is then carried up the coast by the Southland Current and deposited into Okains Bay. This led to the formation of 58 distinct ridges (Stephenson and Shulmeister

1999). 48 of these are beach berm and foredune complexes, while the remaining 10 are transverse dune ridges. Dunes are high zones on the valley floor.

The valley floor at Okains Bay consists of a soil type classified as loam over sandy loam, whereas the southern hillsides are primarily composed of silty loam identified (Figure 3). This distinction in soil types has significant implications for drainage and water retention. The loam over sandy loam on the valley floor is poorly drained, which leads to prolonged water retention and an increased likelihood of flooding during heavy rainfall events. In contrast, the silty loam on the southern hillside is lighter and of medium density, allowing for more efficient drainage. As a result, runoff from the hillside is more rapid and directed towards the valley floor, where drainage issues can become exacerbated.

Rainfall data collected from a NIWA station at Akaroa over the past year reveals several significant rainfall events. Including an event during the field study visit where 26mm of rain fell in a short period in late July (Figure 4). Observations during this rainfall event, combined with the collected data, provide valuable insights into the hydrological response in Okains Bay. The interaction between the catchment’s topography, soil types, and rainfall patterns highlights the challenges of managing drainage in the area, especially during intense storm events.

The catchment at Okains Bay is divided into several sub-catchments, particularly on the southern side of the valley (Figures 5 and 6). These sub-catchments are vital in water movement through the area, especially during storm events. A map of the sub-catchments illustrates how storm water from the southern slopes flows and connects to the drainage system. The variability in area and runoff between these sub-catchments underscores the need for a detailed analysis of drainage flow under different conditions. These sub-catchments were grouped based on the drainage pathway they connect to, shown in Figure 5.

Condition analysis in Figure 5, shows that the roadside drainage heading Southwest to Northeast or vice versa is in bad condition. Regarding the cross-valley drainage, it is mostly in good condition or in an unknown condition due to the inability to accurately assess some drainage pathways due to them being on private land.

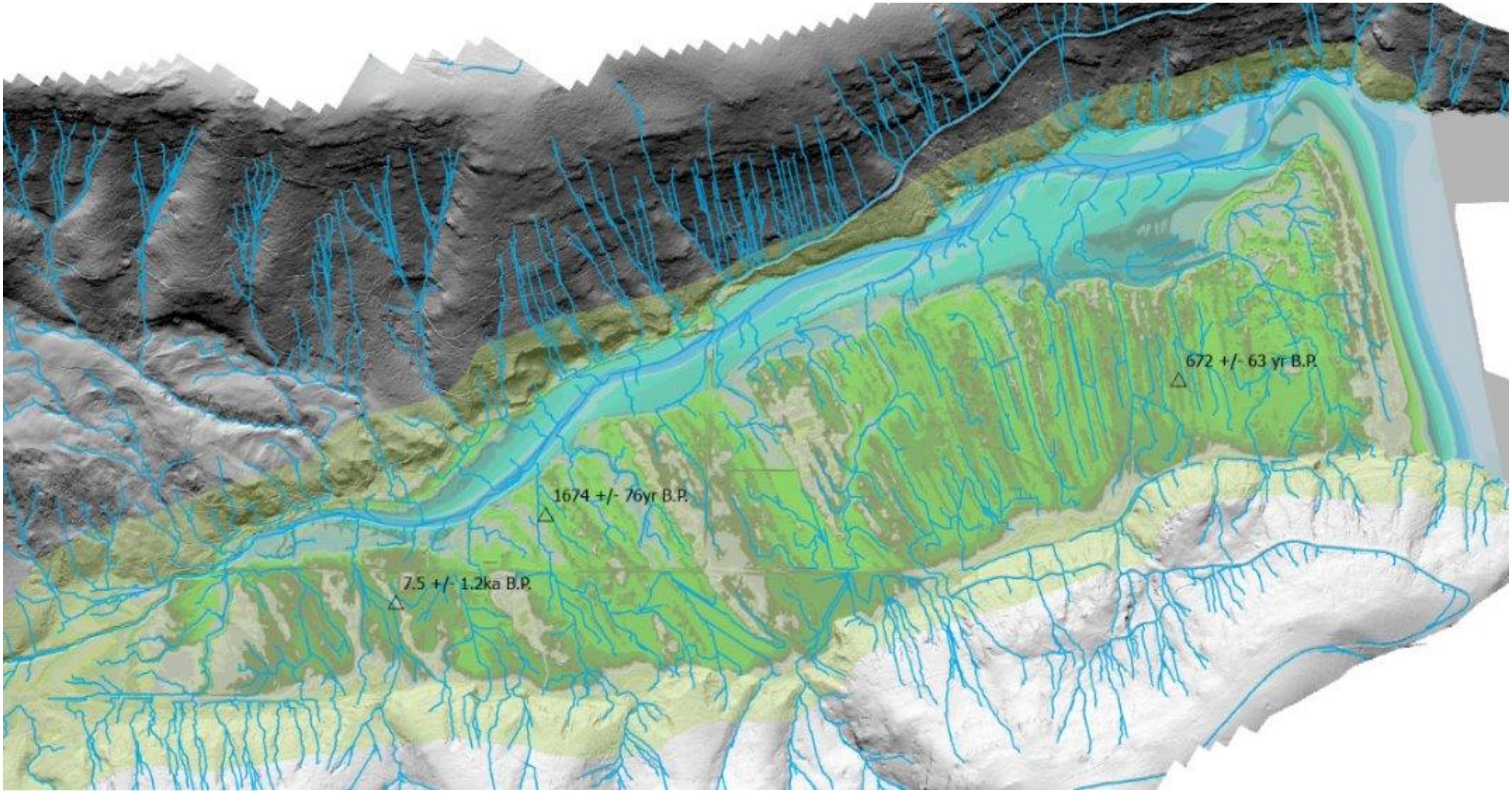


Figure 2. Dune topography and Paleo drainage pathways (blue) at Okains Bay.

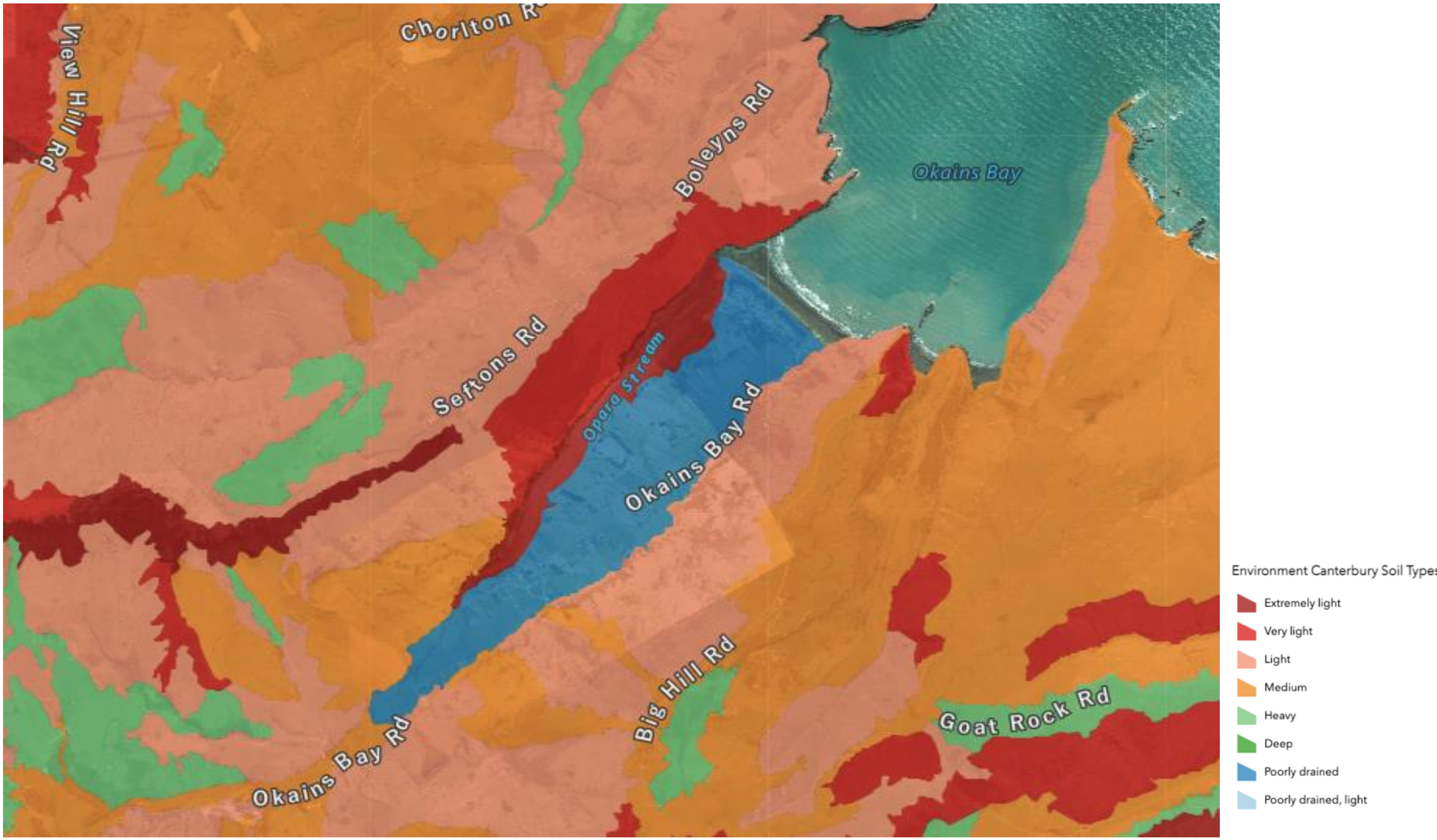


Figure 3. Soil type Map of Okains Bay from (Canterbury Maps. 2018) Environment Canterbury Soil Types. Landcare Research NZ.

Figure 4. Rainfall data from a NIWA monitoring station at nearby Akaroa (Environment Canterbury (ECAN. 2024). Rainfall for Akaroa EWS (NIWA)).

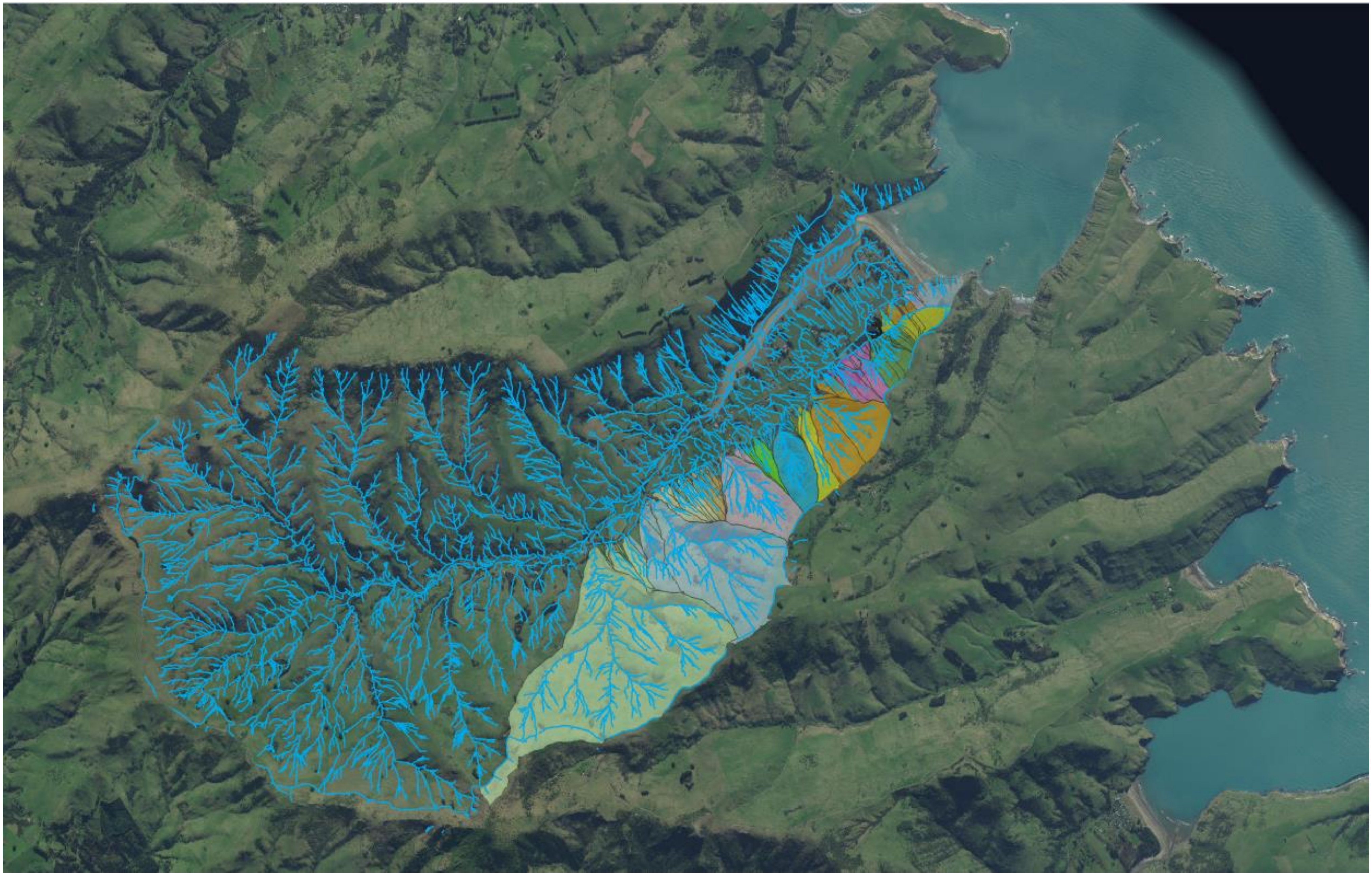


Figure 5. GIS analysis in ArcGISPro of drainage pathways (blue) and catchments drained on the Southern Hillside.

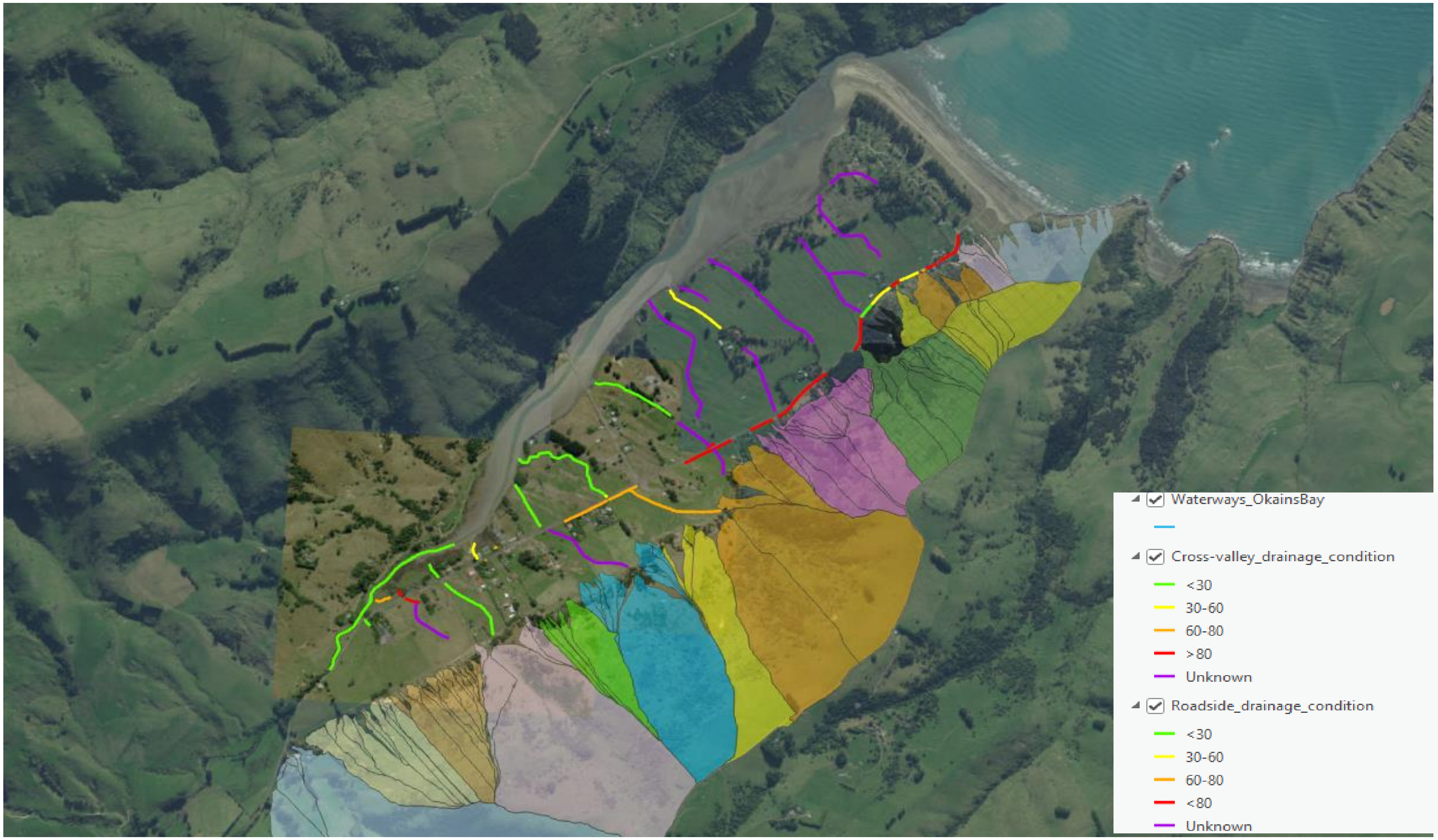


Figure 6. GIS analysis of current conditions of roadside and cross-valley drainage (<30 is good condition, >80 is poor condition).

Critical Points within the Drainage System (Pinch Points)

Pinch Point One

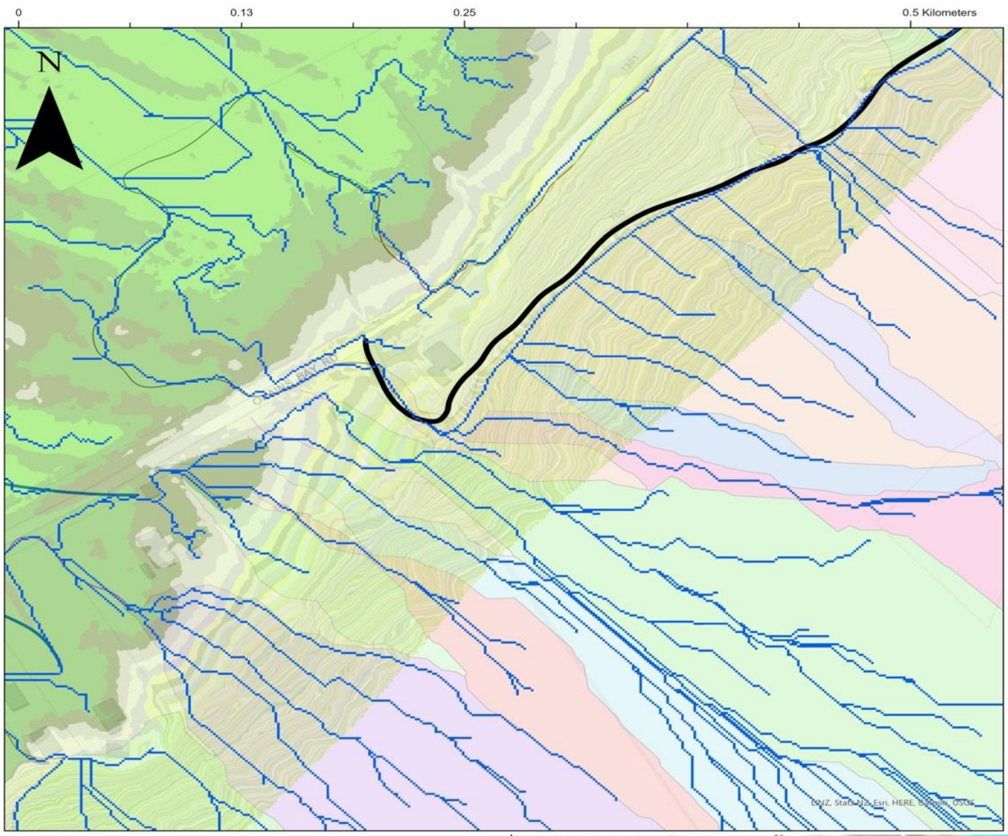
One of the most notable examples of poor drainage management in Okains Bay is the shut-off/blocked culvert at the bottom of Big Hill Road. Big Hill Road acts as a major drainage pathway for the area above the road, which in a 10mm/hr rainfall event would drain 3L/s of runoff. This culvert is a critical drainage pathway from the southern hillside, facilitating the movement of runoff across the road and down into the valley. However, the culvert has been shut off by request of an adjacent landowner to the council, preventing water from following its earlier drainage route. This obstruction has significant implications for water flow management, as it disrupts the holistic drainage system and leads to water accumulation along the roadway and resultant sedimentation. Given its role in managing runoff from the hillside, addressing this obstruction is essential for improving the performance of the drainage infrastructure at Okains Bay.

Pinch Point Two

Pinch Point Two is located near the upper reaches of the flatter valley floor (Figure 8) which relies on efficient cross-valley drainage. However, the visible bottleneck in Figure 4 could not be assessed as the issue was not discovered until after the site visit. The area of interest is a naturally occurring paleo drainage path. The water travels northward (bottom to top of map) through the drainage channel, often causing surface flooding in the surrounding fields. This paleo drain has been improved through human intervention. The primary cause of flooding along this path seems to be significantly overgrown vegetation, causing blockages in the flow path, and resulting in sediment build up. The culvert underneath Okains Bay Road is also a cause for concern as substantial amounts of sediment have partially submerged the culvert under silt and sand-type material.

Pinch Point Three

Mid valley floor lies Pinch Point Three (Figure 9). Like the previous example, this part of the system suffers from extensive vegetation overgrowth along the cross-valley drain (thick blue line). The system in place for this part of the valley has also been improved through man-made enhancements, but it seems no further work has been done since whenever these happened. The same issue is evident at the entrance and exit of the culvert under Okains Bay Road. Due to excessive vegetation around the culvert, its condition is relatively unknown, but it is evident that a blockage is occurring, likely due to the overgrowth. This part of the system is an excellent example of areas experiencing issues that likely could be resolved with regular maintenance and upkeep.



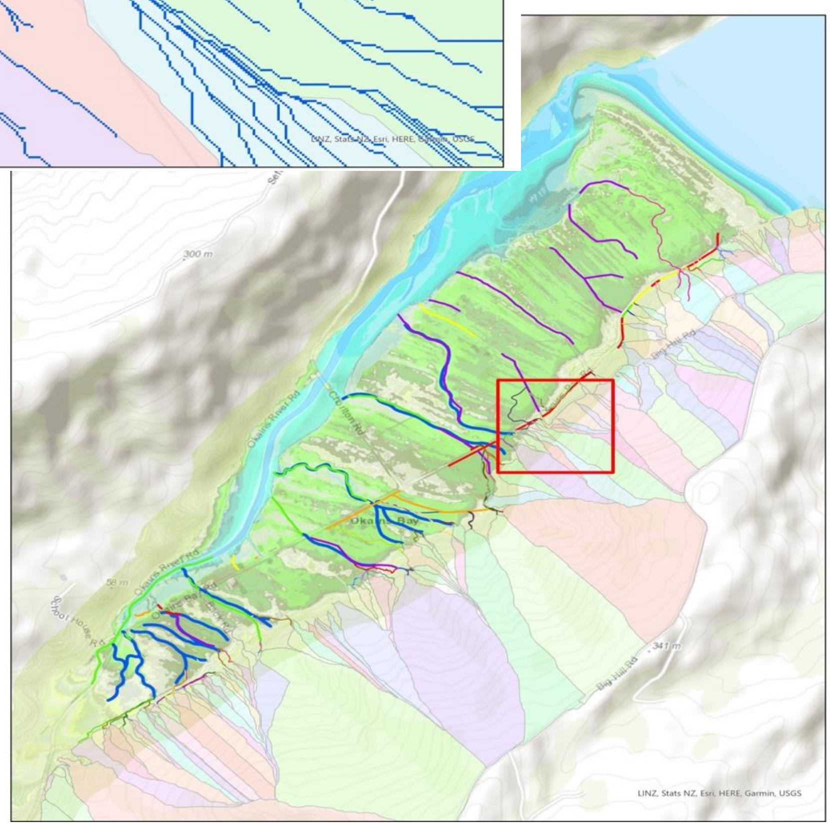
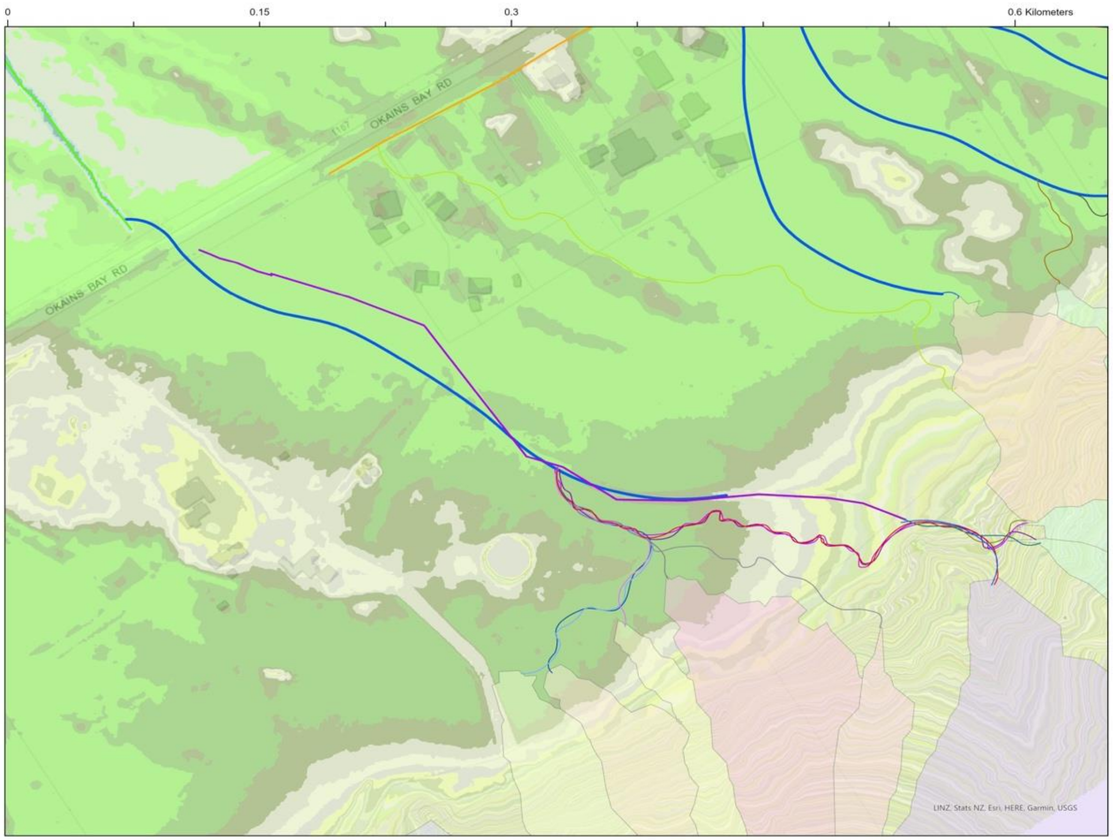


Figure 7. Big Hill Road Pinch Point.

Catchments Directly Sourcing: 8

Total Catchment Area: 490 009 m2



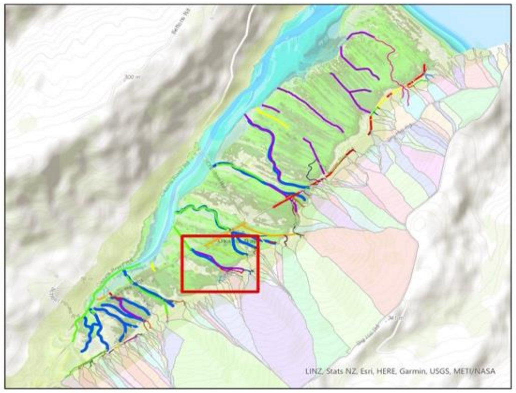
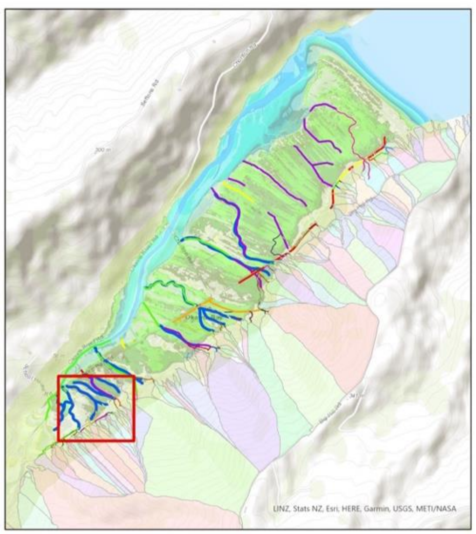


Figure 8. Pinch Point two. A paleo drain that is sourced by 15 sub-catchments along the valley wall. The drainage pathway is sourced by an area of 193,039.8 m2.

Catchments Directly Sourcing: 15

Total Catchment Area: 193 039.8 m2



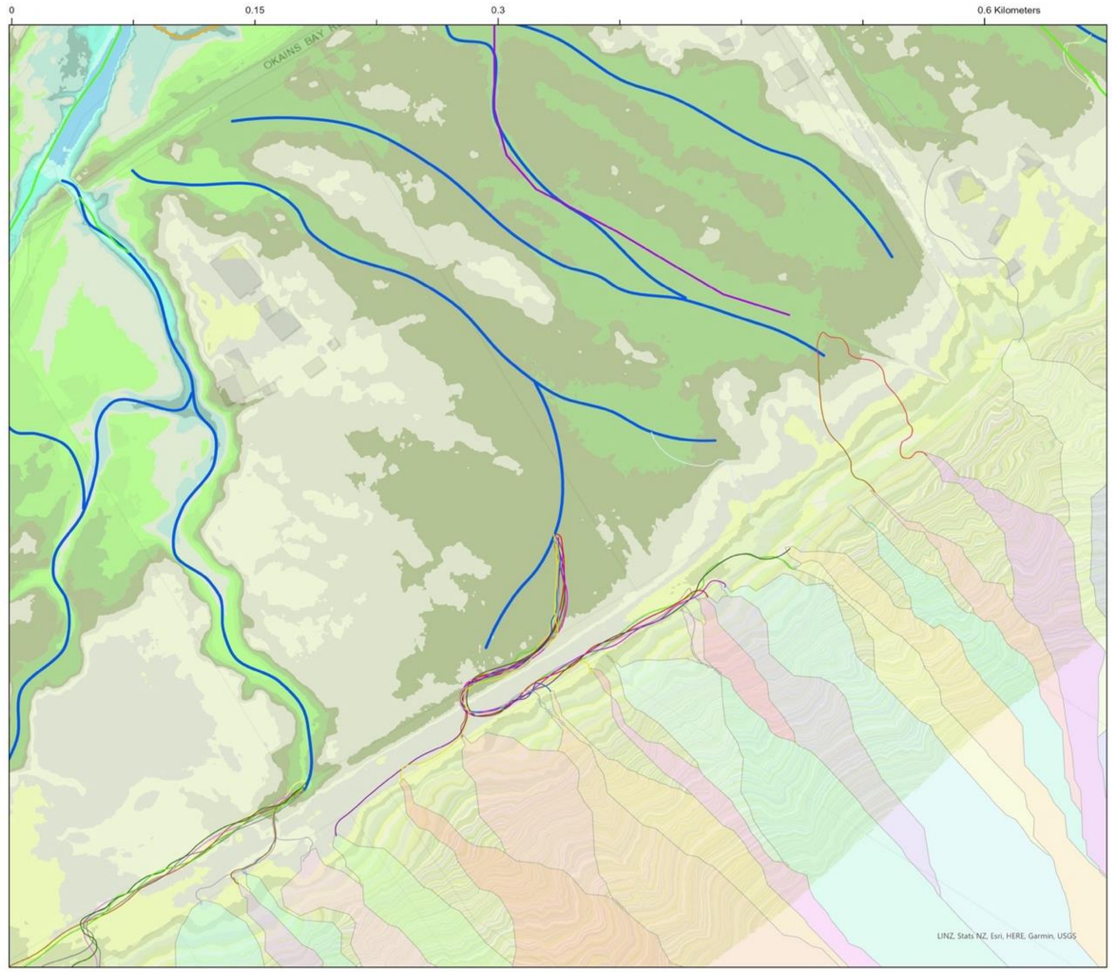


Figure 9. Pinch Point three, A paleo drain which is sourced by eight sub catchments along the valley. Sourced by a total catchment area of 490,009 m2.

Discussion

The underlying natural geology of the Okains Bay Valley floor was key in the original drainage layout. This crucial to the alignment and maintenance of existing and new drainage pathways. The system's current state is unmaintained, outdated, and ineffective in removing water from the system. There is significant blockage and sediment infill throughout the system. With some blockages causing considerable disruption throughout the system (i.e., Closing off of Big Hill Rd culvert). Regarding rising sea levels, alterations in the system are the key to addressing changing base levels and ensuring the drainage system's long-term effectiveness.

In each option considered in the following section, several implications need to be considered:

- Cost
- Regional / National regulations
- Community compliance/engagement

This study has not considered these due to complexity and scope limitations. Therefore, these are potential solutions that can be considered at the discretion of the local community and consultation with Koukourarata Rūnanga, CCC and ECan.

Sediment runoff

The Okains Bay area experiences levels of sediment runoff, which fills up existing drainage systems and covers the existing environment, reducing the limited drainage infrastructure in place. The steep terrain of Okains Bay influences higher erosion rates due to the following variables: exposed soils to raindrops, vegetation removal, climate, size of disturbance, slopes and soils (Draft Erosion and Sediment Control Field Guide for Contractors, 2010). Due to Okains Bay frequently experiencing precipitation events enables, concentrated high-energy flows of water to generate erosion, landslides and washouts. Sediment buildup in the natural and engineered drainage systems contributes to surface flooding.

Management of sediment sources is critical in reducing the sediment load introduced to the drainage system. Table 1 provides a summary of potential measures to reduce sediment runoff. Further assessment and tools to minimise sediment impacts are found at https://esccanterbury.co.nz/start/.

Solution	**Purpose**	**Limitations**	**Maintenance**
Benched Slopes	To reduce the flow of runoff by decreasing the volume and velocity going down the slope.	Compliance with regulations, avoid constructing nearby property boundaries without protective measures, stabilisation of disturbed areas, e.g. vegetation, division of slope faces/direct runoff to outlets that are stable.	Repairing damages after rainfall/storms, repairing erosion at diversion outfalls when required, clearing sediment to maintain flow capacity when required.
Pipe drop structures and flumes	To temporarily transport runoff without erosion.	Severe erosion can occur if the structure fails, risk of damage if foundations are not stable, requires regular maintenance and monitoring.	Inspection is required frequently – especially after rainfall events, the inlet needs to remain clear, watch for overtopping of water, adjustments of the length when required.
Sediment basins	To capture and retain sediment from areas experiencing disturbance.	It is not as effective in removing fine silts and clays that are in suspension, larger areas of construction, periodic maintenance can be costly, and effectiveness can be reduced without regular maintenance.	Inspection is required after heavy rainfall events, removal of accumulated sediment, check for damage, check for blocked outlets.
Sediment traps	To retain and capture sediment from areas experiencing disturbance (Figure 12).	Only effective in smaller drainage areas, not as effective in trapping silts and clays, tend to fill quickly and require maintenance, maintenance can be costly.	Inspection is required after heavy rainfall events, removal of accumulated sediment, check for damage, check for blocked outlets.

Table 1. Suggested options to reduce sediment runoff in the Okains Bay area (Frantz, 2021 & Draft erosion and sediment control field guide for contractors, 2010).

Immediate solution and following options for improving the system

To improve the drainage network at Okains Bay, several solutions have been considered, and four options have been categorized to minimise flood risk.

These proposals are in order of rank:

Critical solutions that need to occur immediately

- Option A: optimisation of the current drainage system
- Option B: adaption of cross valley drainage system
- Option C: the naturalisation of the drainage system

For options A, B, and C to be effective, the critical solutions must occur first. Once the critical proposal is complete, the community can move the system into options A, B, or C, each of which would prove effective.

Critical solutions have been assessed as solutions that would immediately reduce the impact of flooding before any engineering or vital modifications to occur.

Options A, B, and C implement a variety of hard engineering, regeneration, and drainage design modifications to have long-lasting flood management approaches within Okains Bay.

Each option offers proposals to improve the critical pinch points identified in Figures 7, 8 & 9 to allow the points to remove the excess water in the drainage system efficiently.

Within any option, maintenance is required regularly in each proposal for each to function accordingly.

Critical Solutions

Improving the current system and reducing flood risk within Okains Bay is critical (Table 2). Before any other plan, these immediate critical plans should be completed, while decisions on future options are decided and implemented.

Tables 3 and 4 provide costing estimates for excavating the infilled sediment from the roadside and cross-valley drainage. A generic width of 2m for all ditches was used with a depth of 1m. The cost estimate was calculated using Build 2 construction excavation rates of $65 plus GST per cubic meter of earth removed. The total cost of public drainage is EST

~$221 858. The private drainage total is EST ~$407,708.62. There are two properties (Property Titles 254887 and CB47C/415) that have considerably more drainage to be cleared compared to any other properties; these were the most significant cost contributors

For the system to function, each component must operate effectively. The total cost of excavation is $629 656.62, with 35.23% falling onto the public roadside cost, and the remaining 64.77% is on the private land costing (Table 5).

This leads to the question:
Should the burden of cost be on individual property owners when it is a required system for community resilience?

This question needs to be answered by all concerned, including individual residents, property owners, and local councils.

Options	Purpose	Specific locations	Specifics
Excavation of currently filled drains and critical points	Manual and permanent excavation and relocation of sediment from critical points within infilled drainage systems	Entire roadside and cross valley current drainage network	Table 3 Table 4 Table 5 64.77% cost is on private property 35.23% cost is on public land Who is responsible? Equation 1
Reconnect the disjointed system	Reconnect drainage networks to allow for an efficient and coherent water flow system across the valley floor	Entire drainage system	Excavation Reconnect the areas in the drainage network that have been separated
Maintenance of the current roadside drainage	Frequent maintenance of sediment removal within infiltrated drainage systems to allow for efficient water flow	Roadside ditches/cross valley areas that are frequently blocked Culverts and connection points	Routine manual maintenance of infiltrated culverts and connection points

Table 2. Critical options / proposals that need to occur immediately before any other option is considered.

Equation 1. Estimated costs equations for roadside & cross-valley systems

$$Excavation\ amount = depth\ (1m) * width\ (2m) * length\ percent\ fill\ average$$

$$Excavation\ cost = \$65 + GST\ (15\%)\ per\ cubic\ meter\ of\ earth\ removed$$

Category	Length (m) approx.	Excavation amount (cubic meters)	EST $65 add GST (per cubic meter)	Total Sediment (cubic meters)	Total cost ($)
30 – 60% (45% average)	160	144	10764	2968	221858
30 – 60% (45% average)	320	448	33488		
Over 80% (90% average)	1320	2376	177606		

Table 3. Estimated excavation amounts and cost of Roadside Public Drainage Areas.

Property title	0-30% (15% average)	30 – 60% (45% average)	30 – 60% (45% average)	60-80% (70% average)	Over 80% (90% average)	Unknown	Total excavation amount (cubic meters)	Cost (EST $65 add GST per cubic meter)	Total sediment	Total cost
1177884			56		209		426.6	31888.35		
CB656/47			9	65			99.1	7407.725		
CB404/219	292						87.6	6548.1		
CB46C/376		65		13			76.7	5733.325		
254887	403			204		28	462.5	34571.875		
254885				152		109	212.8	15906.8	5455.5	407798.625
CB17B/1120	170						51	3812.25		
940726	258						77.4	5785.65		
CB47C/415		242				1330	2877.8	215115.55		
CB30K/736						379	542	40514.5		
CB23K/760						271	542	40514.5		

Table 4. Estimated excavation amounts (m^3) and cost of cross valley private properties.

	Total Sediment	Estimated cost	%
Public	2968	221858	35.23
Private	5455.5	407798.625	64.77
Total	8423.5	629656.625	

Table 5. Comparison between Private and Public total amounts.

Option A: Optimisation of the current drainage system

This option employs options to improve the current drainage system without changing the design of the current culverts and connection points. With details outlined in Table 6.

Options	Purpose	Locations	Engineering designs
Ditch re-design	Offers fast and efficient channel for diverting excess water away from the area	Ditches areas less than 5m in width along the road	Ditch design with a depth of 1 metre and width of 2 metres. See Figure 10.
Swale re-design	It provides benefits to water quality and sediment runoff and allows for water infiltration.	Swales in areas wider than 5m in width along the road	Swale design with a depth of 1 metre, width of 3 metres, and main channel width of 1.5 metres. See Figure 11.
Planting along the network	Addition of riparian plants alongside stream banks for increased stability and naturalisation of the system	Drains that flow into the estuary Stream with Flap Gate Along roadside areas away from roads and accessways	Riparian planting areas alongside swale and ditch designs. See Figure 10 & 11.

Table 6. Proposals considered in Option A.

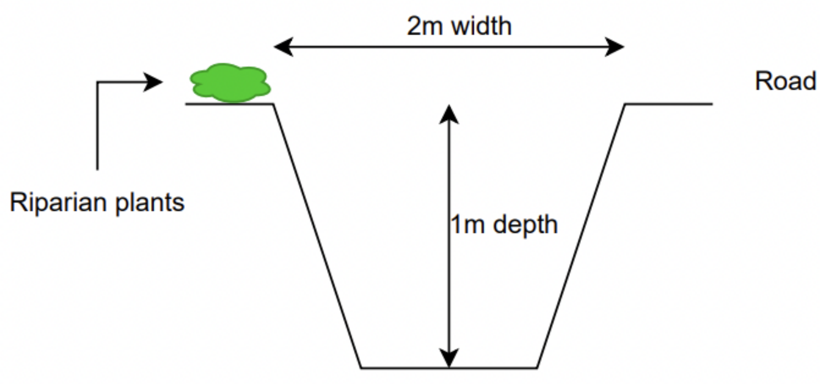


Figure 10. Traditional ditch design. Ditches allow for fast and effective water diversion from the area through the simple design. Deep and steep, allowing water to flow directly through without interruptions. However, it does not provide erosion control, sediment reduction or pollution reduction.

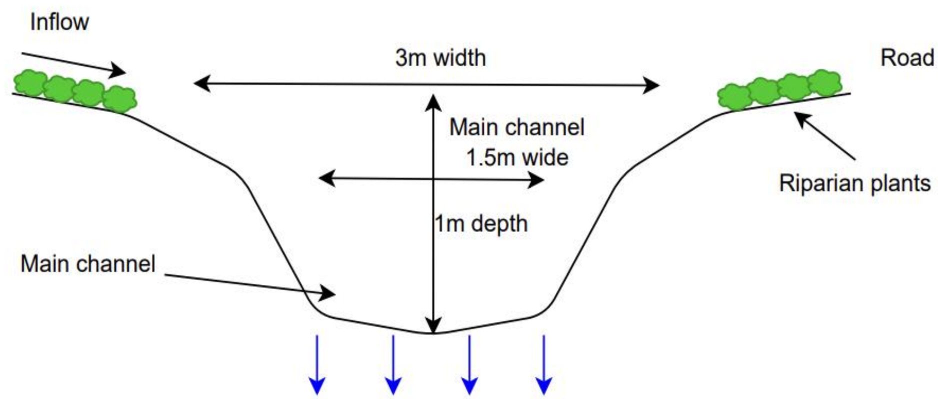


Figure 11. Swale design. Swales have a shallow, curved shape, allowing for a wider width to be covered at the top. Improving water infiltration into the soil and controlling water quality and sediment runoff.

Option B: Adaption of cross valley drainage system

Adaption of the cross-valley drainage system introduces hard engineering options that enhance the existing maintained drainage network (Table 7). Note, proposed engineering designs need to align with ECAN and CCC regulations for each engineering solution.

Options	Purpose	Description	Specific locations	Engineering Designs
Sediment traps	Implementing sediment traps on the upstream side of culverts, allowing for efficient and free water flow and sediment drop out.	Sediment traps are small inline ponding basins that treat stormwater and runoff by allowing sediment particles to settle out. Removing the sediment from the system enhances water quality and minimises environmental impact. Sediment traps allow for a fixed maintenance point rather than sediment being cleared from the entire system (NZ Landcare Trust, n.d).	Pinch point A (Figure 7). Culverts with regular sediment accumulation.	Allows for unrestricted water flow without obstruction of sediment. Requires routine maintenance. See Figure 12.
Detention ponds	Allow water to be captured and slows release reducing sediment load. Sediment drop out due to change in flow energy.	Detention ponds allow for the slow release of water, reducing peak flows and downstream flooding. Sediment and pollutants can settle out, improving the quality of water released. Detention ponds can support ecological benefits by providing habitats for aquatic plants and wildlife (Western Environmental Liner, 2020).	Bottom of Big Hill Road (Figure 7).	Allows for sediment settling and slower release of water. See Figure 13.
Single culvert re-designs	Increases the amount of water able to move through the system, decreases blocking.	Increasing the culvert dimensions allows more water to flow through. Gabion baskets should be installed in open areas (along the estuary section) to direct water flow and reduce erosion due to flow and tides.	Areas where blocking and stagnant water is pooling above the culvert.	Re-designing the culvert complying with modern standards, allowing for efficient water flow. See Figure 14.
Double culvert re-designs	Double culvert allows for alternative flow path in case of one culvert being blocked. Appropriate for areas with wider channels to allow for sufficient adequate water flow.	Designing two culverts in locations of wide water channels will allow for the water to move efficiently through the system rather than being overloaded. In open areas (along the estuary section), the installation of gabion baskets to direct water flow will reduce erosion due to flow and tides.	Flap Gate location (Figure 17). Within areas of wide water channels where one culvert would be ineffective.	Double culvert re-design allows for efficient water flow and alternative flow paths in the case of singular failure. See Figure 15.

Table 7. Proposals considered in Option B.

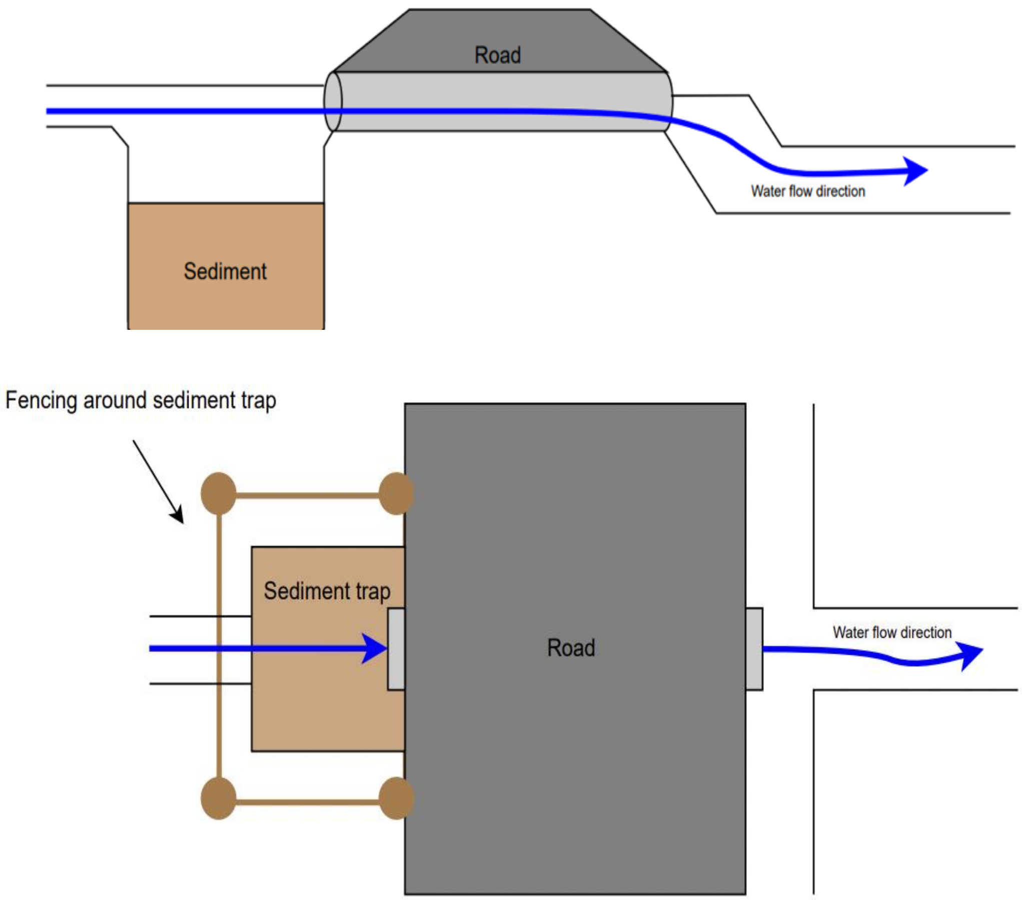


Figure 12. Design for possible sediment trap solution. Cross section and plan view.

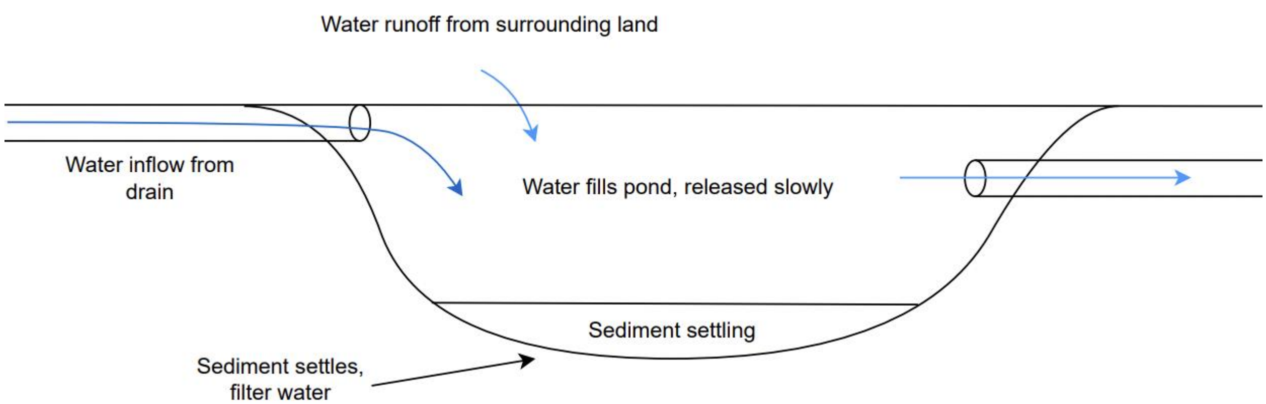


Figure 13. Detention pond design.

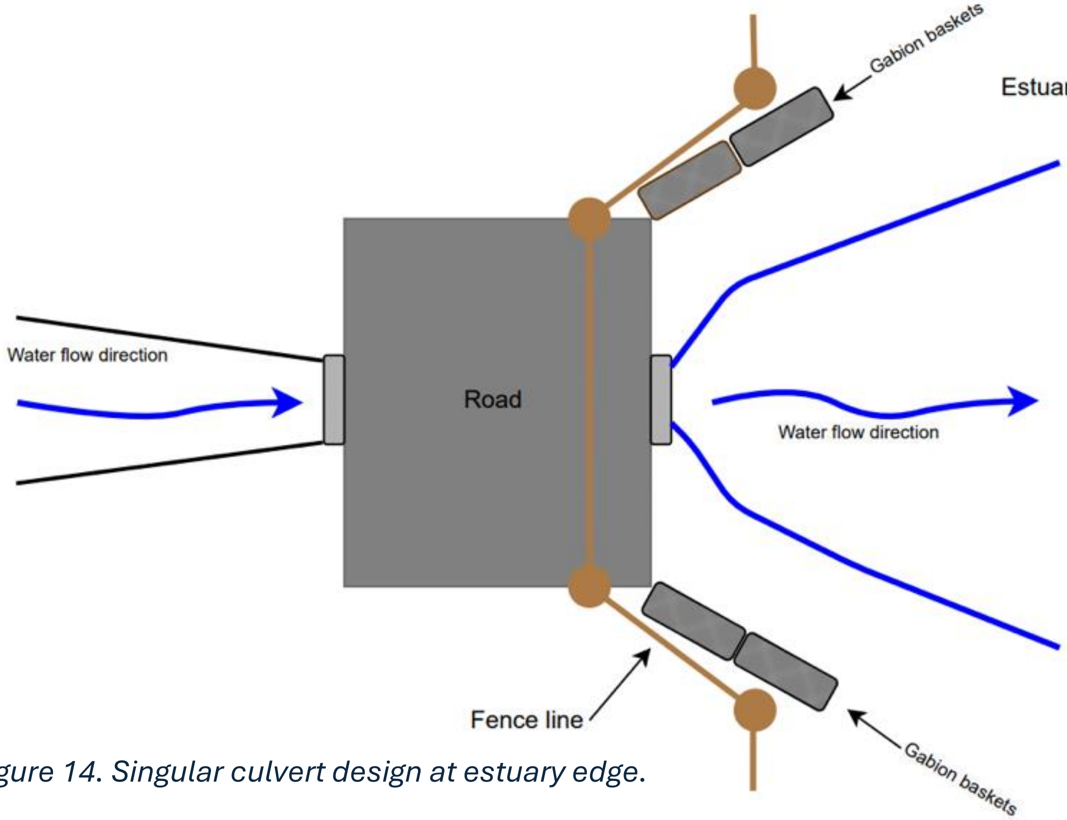


Figure 14. Singular culvert design at estuary edge.

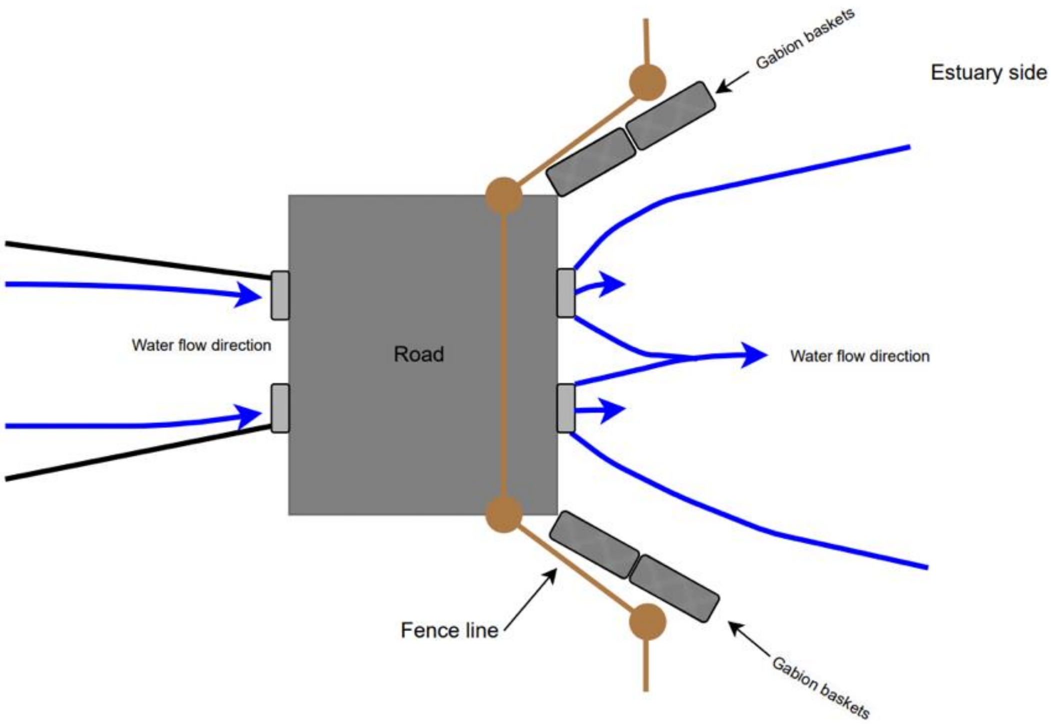


Figure 15. Double culvert design at estuary edge.

Option C: The naturalization of the drainage system

Naturalisation looks to restore or reflect the natural systems within the connected estuary waterway networks. This naturalisation is focussed where the current drainage systems are limited constrained by the existing topography of the valley floor. The following are potential options to naturalise the system, allowing for adequate flood water flow and mitigating future amplifying climate change effects.

Options	Purpose	Specific locations	Engineering design
Moving the current drainage system inland	Climate change management mitigates against future land loss due to sea level rise.	Flap Gate system (Figure 16).	Moving drainage system design upstream improves system resilience towards sea level rise Figure 16. A culvert is suggested at the new location (Figure 14).
Naturalizing the system	Effective at controlling erosion rates, acts as a pollutant filter, and is an effective option to act as a climate change/base level rise barrier.	Harris Stream regeneration (Figure 17).	Naturalisation restoration efforts for the Harris stream, allowing direct ditch to stream water transport. Riparian planting and fencing are recommended for stream integrity and longevity. See Figure 17.
Community driven	Community involvement with the surrounding environment, better understanding of future implications, and education.	Sediment trap (Figure 12). Harris Stream (Figure 17). Other pinch points/general areas requiring regular manual maintenance.	Community/landowners' effort to conduct routine maintenance to clear sediment from selected drainage systems.

Table 8. Proposals considered in Option C.

Flap gate:

The flap gate, currently located in Figure 16, has been established by NIWA (Institute of Water and Atmospheric Research) as a risk to fish passage and has not been observed to improve fish passage (Fish Passage Assessment Tool, 2024). Due to these variables, it would be suggested that two options should be considered:

i) The removal of the flap gate
ii) Moving the flap gate upstream

If option ii) is considered, it will need to follow the Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (NES-F) and National Policy

Statement for Fresh Water Management (NPS-FM). The Canterbury City Council (CCC) will need to be notified about the “placement, alteration, extension or reconstruction” (NES-Freshwater: Fish passage, 2023) of the flap gate and how this will enable fish to pass.

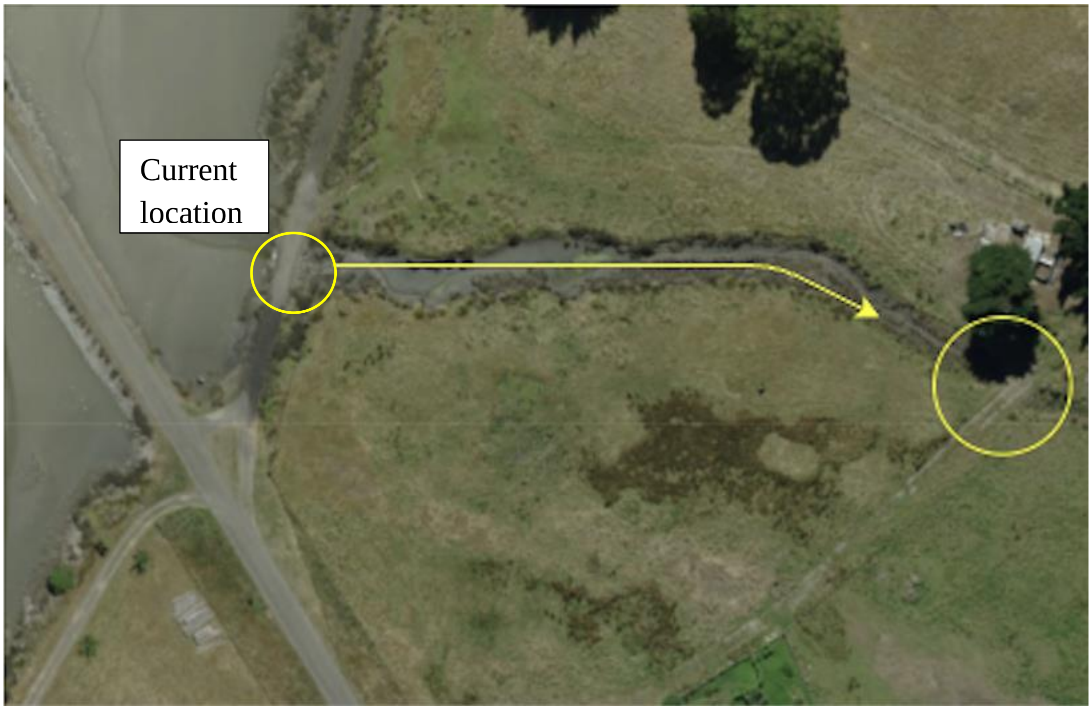


Figure 16. Current location of flap gate and proposed location to move the system.

Naturalisation

Naturalisation looks to the past for solutions now and in the future. A key approach can be to transitioning the current drainage system in Okains Bay to a naturalised system. By modifying and adapting the cross-valley drainage system several key benefits can be achieved for the community and environment while reducing impacts from rainfall events and combating the effects of climate change.

The proposed drainage system to naturalise is that found within the section of Beach Road and Chorlton Road intersection (“Cemetery Corner”) to the Big Hill Road Corner. This was once a water way the drained from the hillslopes across the valley floor to the estuary. However, this system was intersected and abandoned by the implementation of the cross-valley drainage network.

The proposal for this waterway (Figure 17) would be to retire the surrounding land either side, with fence lines set from the waterway at a minimum distance (5 metres) from the channel bank edge. GIS analysis identified that the 1.5 metre contour signifies the channel bank edge, providing a demarcation for setbacks to occur from. Establishing a 10-metre buffer zone around the stream, using the parameters defined for the low points and channel delineation, ensures the protection of critical waterway areas (Hampton, S., per comms Sept 2024). This buffer zone, enclosed by a fence, will prevent livestock from entering and contaminating the water, significantly improving water quality by stabilising banks.

Gates and connections between existing stock paddocks and routes have been incorporated to reduce the impact on grazing and maintain farm operations. With crossing to contain culverts and being fenced stock will not have direct access to the waterway, increasing water quality.

Planting native vegetation between the fence line and the waterway will enhance riparian protection, stabilises the banks, and promote the filtration of sediments and pollutants. Additionally, this approach will increase biodiversity by providing a natural habitat for various species, contributing to ecosystem health.

Beyond environmental improvements, a naturalised system offers cultural, educational, and recreational benefits. It provides an authentic landscape that reflects the area’s natural heritage, fostering community pride and offering learning opportunities for locals and visitors. With rising concerns about climate change, such systems enhance the area's resilience by improving flood control, water retention, and overall ecological sustainability.

Naturalisation will make stream systems an asset and, in time, will change the overall habitat and environs of the valley floor. This naturalisation process has been utilised within Okains Bay, with the stream network west of the Cemetery.

The initial cost of installing fencing and conducting planting can be high, and there would be ongoing maintenance requirements for the riparian areas, including vegetation management. Fencing and planting will also reduce usable land, which may impact landowners, especially in areas with smaller catchments. Furthermore, compliance with permits and regulations related to waterway management may add complexity to the project. Balancing these upfront investments and constraints with the long-term environmental and community benefits will be crucial to the success of the naturalisation effort.

Harris Stream is the proposed name for the naturalisation of the valley drainage network (Figure 17). It is named to recognise the significance of the Harris family in Okains Bay's history and acknowledge their property as being critical to this proposal. Within this study, it has been recognised that this is an old waterway channel bypassed by the development of the cross-valley drainage system. This proposal is to establish this as a natural waterway that benefits the community, restores the mauri (life) to this system, reduces sediment input into the estuary, creates indigenous habitat, and provides an adaption of the storm water system for future events and climate change impacts.

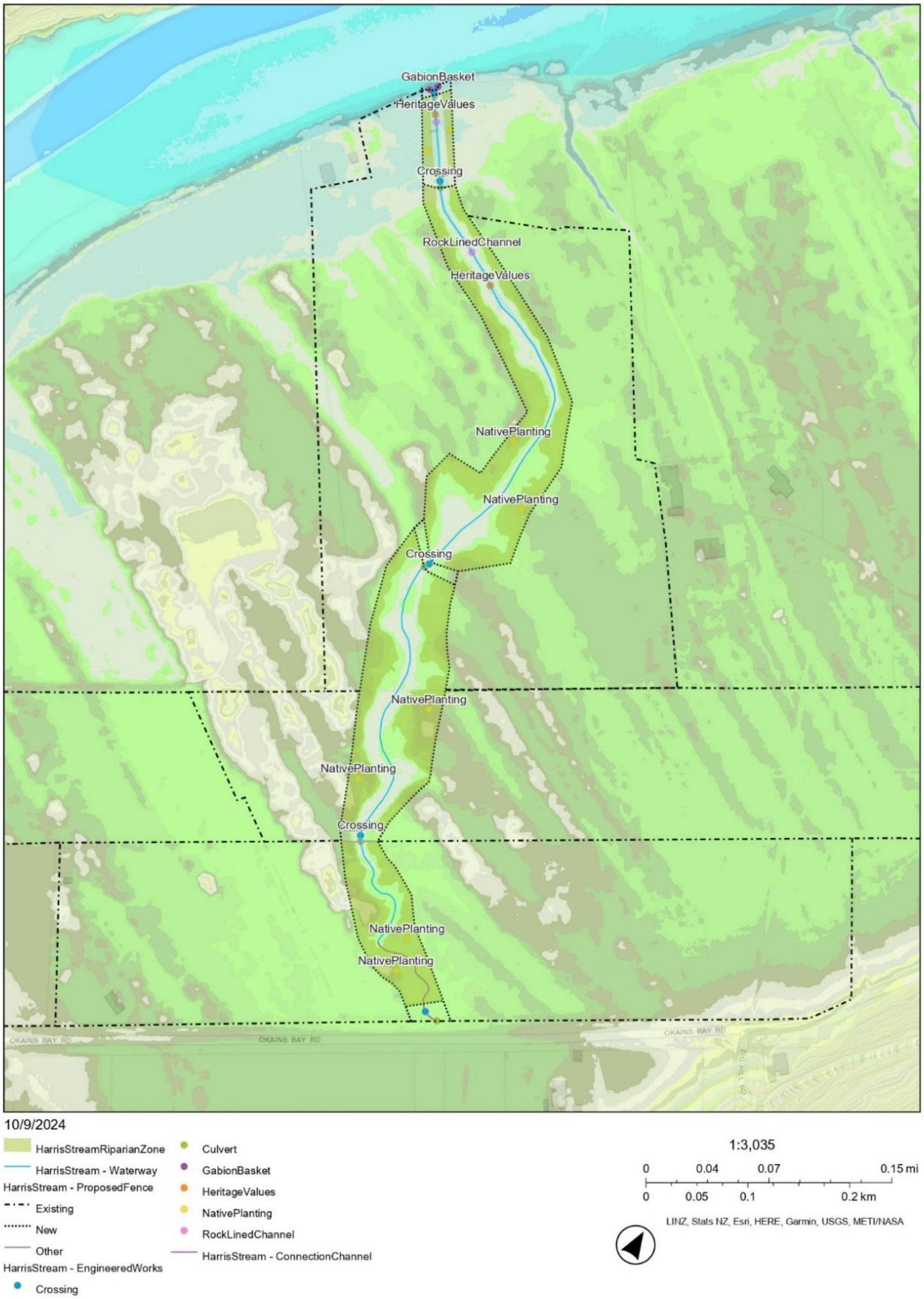


Figure 17. Naturalization of the Harris Stream through planting, fencing and allowing ditch to move into a stream.

Opara Estuary Huanui Pathway

In 2014, Hampton et al. (2024) developed a proposal for the Opara Estuary Huanui Pathway, an estuary side walkway connecting the campground to the main valley, directing visitors from walking on the road to the main settlement of Okains Bay. Within this study, engineering geology testing and analysis of ditch-derived 'loessic' sediment have appropriate properties for compaction to be used as a rigid base for pathway construction. Related to this study as this is the excavated material from the cross-valley drainage network. In short providing an end use for excavated sediment, reducing transportation and disposal costs.

In implementing the Opara Estuary Huanui Pathway, further benefits include reduced erosion, land reclamation, community resilience, and cultural significance. Solutions considered in this are considered in Table 9.

Solution	Purpose	Benefits	Source	Location
Basaltic rip rap:	Shoreline stabilisation due to the strength and durability components.	Minimise erosion conditions from high-energy wave activity and heavy rainfall.	Able to be sourced from local geological composition.	Figure 18 and 19.
Culverts:	Stabilise the soils neighbouring the river and create resilience during flooding events (Figure 14).	Provide flood barrier, reduce overflow of water and prevent soil erosion (Khan, 2023).		River side located in Figure 18 and 19.
Gabion baskets:	Wire mesh holds the stones together, enabling water to flow through.	Control erosion, the river lining and slope stabilisation.	Locally sourced basaltic stones.	Targeted locations in Figure 18 and 19.
Land reclamation:	Build up the road along the estuary that has previously been eroded.	Offers flood protection to pathway infrastructure.	Local basalt. Excavated sediments from excavation and ongoing sediment trap maintenance.	Figure 18 and 19.
Elevated boardwalk:	Boardwalk. A long-term boardwalk won't be eroded by the influence of sea level rise, rainfall events and climate change (Ferreira, 2023).	Promote awareness of the values of the local ecological system. Public walkway.		Over the river, estuary shown in Figure 18.

Table 9. Solutions considered in the implementation of the Opara Estuary Huanui Pathway.

Figure 18. Opara Estuary Huanui Pathway with suggested basalt rip rap, culvert, gabion basket, reclamation, boardwalk, pathway, raised existing and reclaimed road.

Figure 19: Opara Estuary Huanui Pathway close-up highlighting the locations of basalt rip rap, culverts, gabion basket, reclamation, boardwalk, pathway, raised existing and reclaimed paper road.

Additional Local Usage of Excavated Sediment

When covered by geotextile excavated “loessic” sediment can provide an effective compactable material to form engineered features. In addition to the engineered solutions outlined in Tables 6, 7, 8, inundation bunds (also termed berms and stop-banks) could also be constructed in areas at risk of inundation.

Localised inundation bunds are embankments constructed with excavated sediment from the maintained drainage system. Using these locally sourced materials reduces costs as dumping is not required. Compacted bunds can be covered with a geotextile and planted to protect and minimise erosion.

It is proposed that inundation bunds be used to protect assets or productive land from sea level rise and flooding events. Two examples of inundation bunds placement to protect low lying properties are indicated in Figure 20. Bund placement in these examples extend the 1.5m contour height towards the estuary edge. Inundation bunds need to be located to connect with surrounding topographic highs and account for incised drainage so to not result in surface water collecting behind the embankment or resulting in the diversion of surface water runoff.

Figure 20: Proposal of inundation bunds to protect low lying assets and productive farmland. Localised protection provides by inundation bunds constructed from excavated sediment from drainage network. Inundation bunds depicted as orange lines extend from lower land areas to meet 1.5 m contour line, depicted as green lines. A) Areas at low lying levels proximal to Chorlton Road Bridge. B) Low lying areas of St John the Evangelist Church and the Vicarage.

Conclusion:

This report addresses the stormwater drainage management in Okains Bay, which is driven by the accumulation of sediment and limited drainage infrastructure. This report intends to provide evidence to understand the current drainage system, present immediate and future management options. Therefore, partaking in a field assessment and Geographic Information Systems analysis highlighted key problematic areas and pinpointed locations that experienced severe flooding. This study has provided recommendations that can be used to improve Okains Bay's flood management, which include:

- Immediate action: remove sediment in the drainage structure, enhance pre-existing drainage pathways, and restore the existing system to functionality
- Improve: upgrade the pre-existing culverts, ditches and swales, and plant riparian vegetation to improve soil stability
- Adapt: introduce (where required) larger culverts, retention ponds and sediment traps to improve stormwater drainage
- Naturalise: recover the natural paleo drainage pathways and plant native vegetation to reduce erosion

Incorporating Māori principles is vital to reflecting the culture's values and highlighting Māori's connection with the land. Combining engineering and ecological practices will improve sustainability and resilience to high precipitation/storm events by reducing the frequency of floods in Okains Bay.

Addressing these challenges is essential in maintaining a robust drainage system, especially with rising sea levels and climate change causing greater impact. The immediate actions are vital to reconnecting existing drainage pathways within Okains Bay. In contrast, the proposals offer solutions for a more effective and resilient drainage system that will be sustainable and adapt to the natural environment.

Collaboration between the community and landowners is vital as these solutions rely on conjoined engagement and responsibility. If enhancement and maintenance of the drainage systems are prioritised, this will create community well-being and environmental resilience.

The main limitation our project held is the limited time frame this project had. Initially, a community meeting was considered with the local tangata. The meeting would have allowed the community to share their personal experience of the area's history and to explore co-design ideas with Marae Whaakata, Tini Arapata Marae and the Okains Bay community. The group's supervisor, Sam Hampton, has discussed potentially carrying on with this project and could discuss the contents of this project with the targeted groups. Additionally, due to the location of Okains Bay, only one field visit could be completed. The field observation was completed during a rainfall event, and although providing key insight into the failing drainage system, another data collection day when the system wasn't flooded would have allowed for the infrastructure quality and cause of blocking to be investigated. Another limitation is the skillset of the group. Modelling through GIS software was considered to simulate drainage management devices and the impact on sediment accumulation and runoff, along with modelling of spot heights.

Despite these factors, it is important to take a holistic approach to understand the Okains Bay environment effectively. The issues Okains Bay is facing are interconnected. A holistic approach enables awareness of the interrelationships of topography, geology, sea level rise, paleo-drainage, and climate, all of which have influential roles. Considering these relationships will lead to more comprehensive solutions.

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