SIMPLIFYING STORMWATER ON A COMPLEX SITE

S. Thompson
MWH now part of Stantec

ABSTRACT

Lyttelton Port of Christchurch's (LPC) Coal Yard sits within Lyttelton Harbour at the bottom of the Port Hills. LPC have had issues with stormwater inundating the Coal Yard and maintenance facilities from the stormwater run off on the port hills. The goal of this project was to create an easily maintainable stormwater system to intercept the hill side run off (which is laden with sediment from loess soils) and to separate it from the operational coal yard. In addition the stormwater system was to facilitate short term development and the long term integration of the new haul road to the LPC Quarry which had been inaccessible since 2010 due earthquake damage. This paper will discuss how the solution delivered a successful outcome whilst dealing with complex issues of a highly erodible environment, a fully operational facility and the issues involved with a historical site.

KEYWORDS

stormwater, contamination, port, services, integration, simplified approach

PRESENTER PROFILE

Stephanie is a Senior Water and Wastewater Engineer with over 11 years of consulting experience, with a particular focus on stormwater and wastewater infrastructure. Stephanie has worked on a number of large scale 3-Waters projects both in Australia and New Zealand. Stephanie is currently the Civil Water Team Lead in the MWH Christchurch office.

1 INTRODUCTION

Lyttelton Port is located at the bottom of the Port Hills, approximately 13km from the center of Christchurch. LPC is New Zealand's third largest container port and exports nearly 20% of New Zealand's dairy products. The port is currently undergoing massive development to increase its capacity to accommodate the future international freight demand.

As part of the coal operation, LPC are responsible for managing stormwater runoff from the hillside above the coal yard and within the coal yard itself. Currently, a significant portion of stormwater runoff from the hillside catchment collects in the coal yard during wet weather events. This often causes ponding and associated operational and maintenance issues.

This paper outlines the historical stormwater issues at the Lyttelton Port of Christchurch (LPC) Coal Yard at Te Awaparahi Bay (refer Figure 1) and how this project solved these issues whilst maintaining ongoing access to a fully operational port and Kiwirail railway. The final solution comprises a level of service approach through an understanding of LPC's use and importance of various areas of the site.

Figure 1: Location of the LPC coal yard in Te Awaparahi Bay

2 BACKGROUND

2.1 EXISTING STORMWATER NETWORK

Prior to implementation of this project, the coalyard stormwater was collected by an undersized drainage system in the coal yard and part of the surrounding area. This water was then pumped to a water treatment plant before being discharged to the harbour. The treatment plant was not designed to handle peak wet weather flows, and once inundated, there was a loss of performance that resulted in a higher chance of breaching the conditions of the treatment system discharge consent.

2.2 UNDERSTANDING THE PROBLEMS

There were two key issues impacting port operations in the Coal Yard:

- Flooding

  Historically, a significant portion of the runoff from the port hills and Sumner Road collected in the LPC Coal Yard causing ponding and maintenance issues. As can be seen in Photograph 1, this runoff cascaded down the steep catchment, creating subsequent erosion and scour down the hillside.

Photograph 1: Flooding adjacent to the existing haul road

- Contamination

Detergents and hydrocarbons (fuel, oil, grease etc.) from the washdown area and mechanical workshop and diesel from the refueling station were reaching the water treatment plant. The plant was not designed to treat these contaminants, resulting in a loss of performance of the treatment process and ultimately, potential discharge of the contaminants into the harbour. In addition, coal was being pumped from the hoppers directly into the existing stormwater perimeter drain. This was causing the drain to clog up and resulting in ineffective operation, refer Photograph 2.

Photograph 2: Contamination on the existing concrete road

2.3 APPROACH TO SOLVE THE PROBLEMS

Due to the site complexities, a simplified approach was taken to solving both the contamination and flooding problems at the LPC Coal Yard. This approach included a combination of operational changes and infrastructure upgrades.

3 OPERATIONAL CHANGES TO MINIMISE CONTAMINATION

3.1 COAL YARD OPERATION AND MAINTENANCE

Part of this project involved reviewing the issue of contaminants from the coal yard entering the water treatment plant. Detergents and hydrocarbons (fuel, oil, grease etc.) from the washdown area and mechanical workshop and diesel from the refueling station were reaching the water treatment plant. The plant was not designed to treat these contaminants, resulting in a loss of performance of the treatment process and ultimately, potential discharge of the contaminants into the harbour.

A number of options were considered to prevent contaminants from entering the treatment plant. The port had previously taken an approach of 'it's installed now so we can walk away' so the result of this review was around development and implementation of an ongoing maintenance regime. This included the following:

- Staff training and education on the outcome and impact of certain practices
- Keep records of maintenance on site
- Dry-wipe grease from equipment / parts prior to any wet cleaning
- Use detergents that promote rapid oil/water separation. These detergents are formulated to release oil quickly so that the oil can rise to the water surface instead of remaining emulsified
- Use proper concentrations of cleaners and disinfectants. Excessive amounts of either can cause fuel, oil and greases to become emulsified and pass through the separators
- Do not use water that is hotter than necessary to clean items
- Minimise or eliminate the use of additives such as enzymes, grease solvents or emulsifiers. Enzymes and solvents temporarily emulsify grease, allowing it to pass through the separators
- Do not allow corrosive agents to drain into the grease interceptor.

Over time, implementation of this regime is expected to improve the quality of water reaching the water treatment plant.

3.2 HILLSIDE OPERATION AND MAINTENANCE

In order for the simplifed approach to work effectievley, it was vital that LPC made changes to prevent coal dust entering the hillside stormwater catchment. Prior to this project, coal washdown water was pumped from the hoppers directly into the existing stormwater open channel perimeter drain. This had the potential to cause the drain to clog up and result in dirty coal plumes reaching the ocean outfall and potentially impact on discharge consents. As part of this project, the direct discharges were stopped and changes made to minimise dust entering the stormwater network. This project was about staff training and education as much as infrastructure upgrades.

4 INFRASTRUCTURE UPGRADES TO PREVENT FLOODING

4.1 STORMWATER RUNOFF

The hillside runoff to the proposed system was broken down into eight separate catchments as identified in Figure 1. This included hillside areas both above and below Sumner Road.

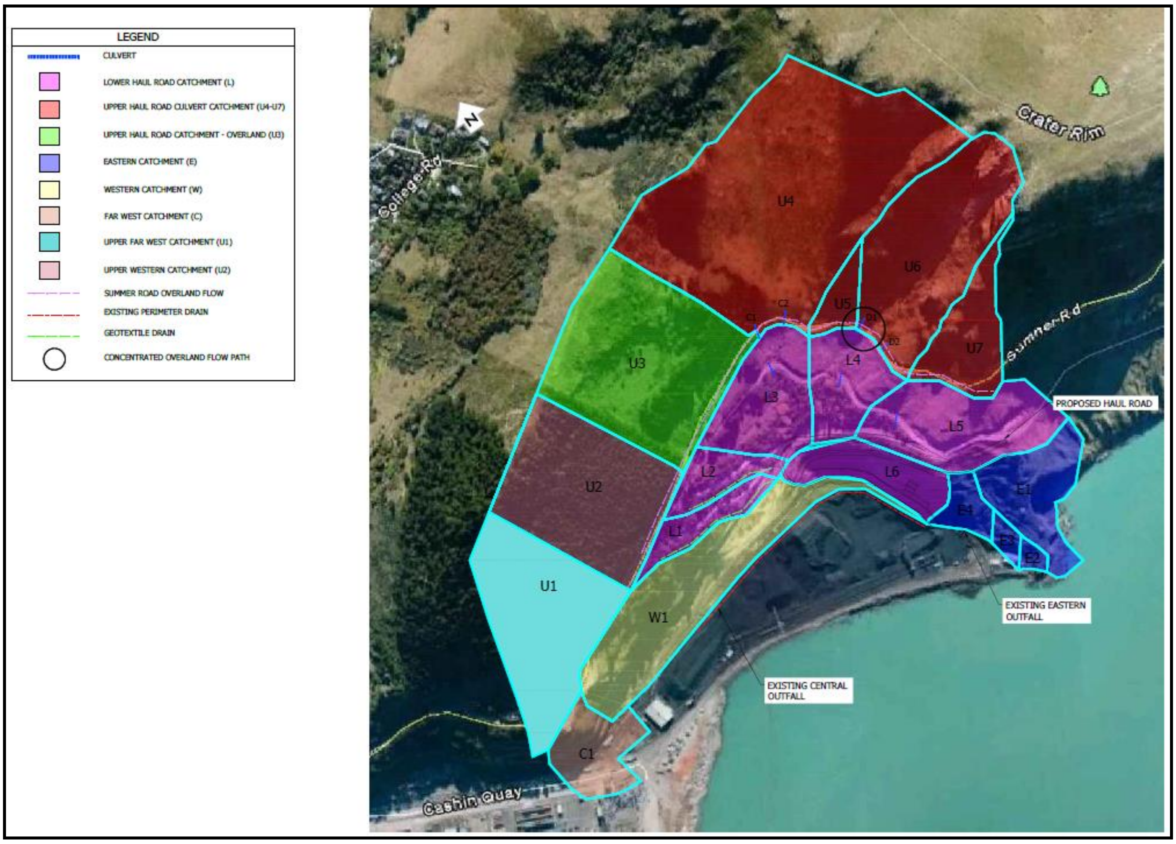

Figure 1: Stormwater catchment plan

Various methods to determine the time of concentration for each of the catchments were considered. The time of concentration was determined using the Hortons value. This was recommended in E1/VM1 BIA as the most suitable for the catchment characteristics. The rainfall intensity based on the time of concentration was then calculated using HIRDs with an allowance for a 2 degree (16%) increase in temperature to allow for climate change as stated in NZS4404:2010 and as required by the Christchurch City Council (CCC) and Environment Canterbury (ECan).

Environment Canterbury Erosion and Sediment Control Guidelines recommend using a runoff coefficient of 0.55 for rural slopes of 20%. The CCC Waterways, Wetlands and Drainage Guide (WWDG) recommend an adjustment factor of +0.2 to the 0.55 coefficient for terrain steeper than 1 in 5. On this basis, a range of coefficients were used to determine an upper (0.75 -0.9) and lower (0.6-0.75) range, with a single value applied to each catchment on a case by case basis.

The level of service adopted for this catchment was a 10% Annual Exceedence Probability (AEP) for the primary catchment and 1% AEP for the secondary catchment. This was in line with industry guidance from NZS4404:2010 and CCC Infrastructure Design Standards.

4.2 EXISTING INFRASTRUCTURE

Sumner Road splits the upper and lower hillside catchment (refer Figure 1). There are four culverts connecting the runoff from Sumner Road to the LPC Coal Yard. Three of these culverts have two large capacity intake sumps, and the other has a single large capacity intake sump. CCC have advised the maximum intake capacity of these sumps is 80 l/s. These culverts are identified as C1, C2, D1 and D2 in Figure x.

The existing culverts under Sumner Road limit the peak flow discharge from the upper catchment into the lower catchment until storage along Sumner Road is exceeded and flow overtops the road. The catchment and design flow analysis allowed for two scenarios:

- Scenario One: Flow from the upper catchment contained by Sumner Road with the exception of culvert peak conveyance. Scenario One is typically applicable to a 5-10 year Average Recurrent Interval (ARI) i.e. primary system design.

- Scenario Two: All flows from the upper catchment above Sumner Road proportionally distributed to lower catchments based on a laminar sheet flow over Sumner Road, less assumed minimum road conveyance. Scenario Two is typically applicable to rainfall events beyond a 10 year ARI i.e. secondary system design.

An existing perimeter drain follows the toe of the hillside around the coal yard. The invert of the perimeter drain undulates somewhat and splits the flow between the eastern and central outfalls. The undulating section in the middle of the perimeter drains ponds before been pumped back to the central outfall.

There is an existing Eastern Outfall which conveys flow from the treatment plant and also the hillside stormwater that enters the eastern section of the existing perimeter drain.

Two open swale drains lined with geotextile fabric exist in the lower catchment. They currently direct water eastwards from an area below Sumner Road. In the future they will be an important feature as they direct a significant portion of flow towards the future haul road

4.3 OPTIONS CONSIDERED

Design options for each of the different catchment were considered in isolation and also in combination where appropriate. The options below are presented from west to east starting with the Far West catchment and finishing with the Eastern catchment. Refer to Figure 2 for an overview of each of the catchment areas.

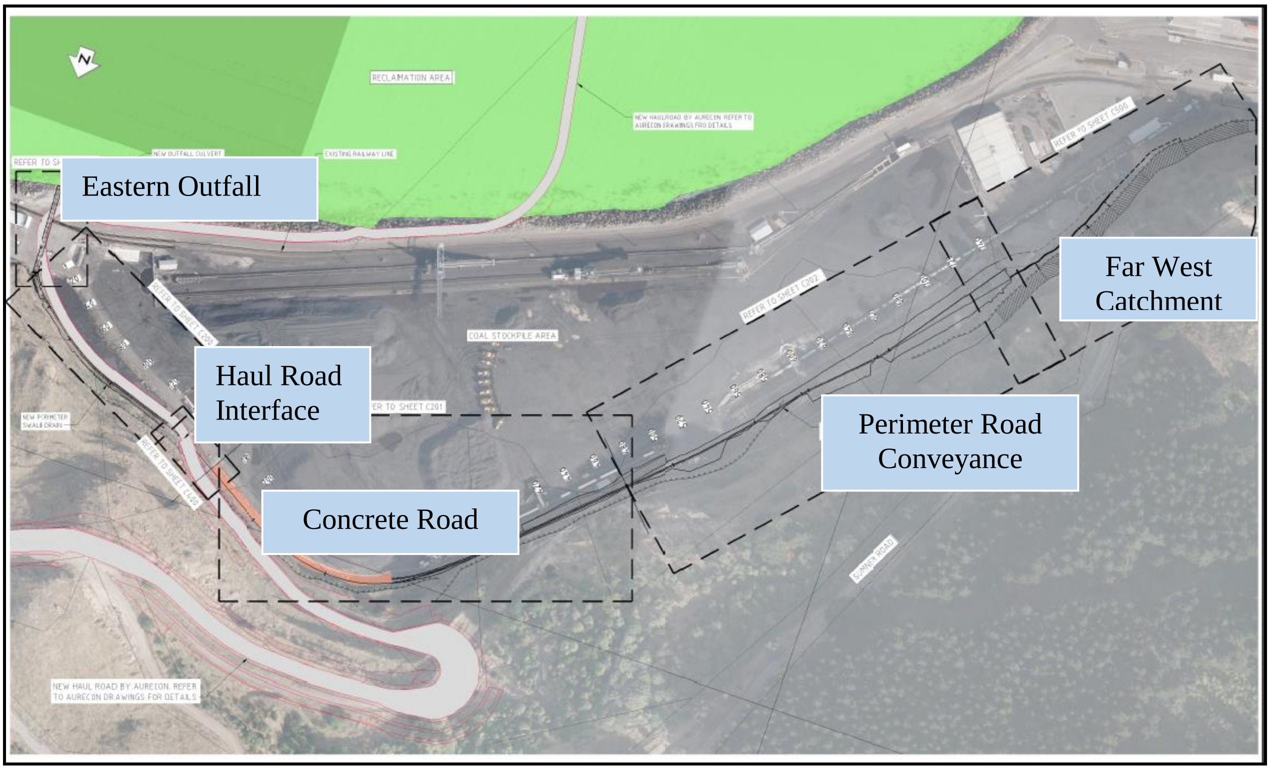

Figure 2: Options assessment areas

1. Far West Catchment

   The Far West catchment discharges flow from the hillside directly above the area of the workshop and vehicle wash bay. Due to the topography and existing structures such as the railway tracks and conveyor, the flow from this catchment was unable to be diverted to the east (to either the eastern or central outfalls) or to the western outfall via gravity. Therefore, the options to manage the stormwater within this catchment included:

   - Option One – Do Nothing and accept the existing flooding and level of service
   - Option Two – Disposal via Soakage
   - Option Three – Storage and Discharge to the Water Treatment Plant
   - Option Four – Pump Station

2. Perimeter Road Stormwater Conveyance

   The Perimeter Road connects the Far West catchment through to the Eastern outfall. There was an existing open channel drain along the edge of the perimeter road although this channel did not have a consistent gradient and resulted in significant ponding over the road. Construction of a new open channel drain would likely require earthworks to ensure an acceptable gradient and swale cross section. The options to manage the stormwater for this area included:

   - Option One – Open Channel Drain
   - Option Two – Buried Pipe Conveyance System

3. Existing Concrete Road

   There is a concrete road between the perimeter drain and new haul road interface. According to LPC staff, this road is approximately 500mm to 1000mm thick. The options considered to manage stormwater flow across this road included:

   - Option One – Overland Stormwater Conveyance System

   - Option Two – Buried Pipe and Bubble-Up System

4. New Haul Road Interface

   The perimeter drain crosses the bottom section of the new haul road. The haul road captures stormwater from a significant area of the hillside and large volumes of water will be added to the perimeter drain from the haul road. The options considered to allow stormwater to pass across the haul road included:

   - Option One – Heavy Duty Culvert to convey 10 year ARI flows and a shaped channel across the road for larger secondary flows

   - Option Two – Heavy Duty Culvert to convey 100 year ARI flows

   - Option Three – Shaped Channel across the road to convey 10 year and 100 year ARI flows

5. Eastern Outfall

   The existing railway is a major constraint which prevents the open channel perimeter drain from continuing directly towards the harbour around the water treatment plant. Taking this into account, the options for discharging the flows included:

   - Option One – Re-Directing the Open Channel Perimeter Drain around the back of the water treatment plant

   - Option Two – High Capacity Piped Outfall

4.4 SOLUTIONS

The options carried forward to construction were chosen on an integrated level of service approach – i.e. providing a lower level of service to some areas and a higher level of service to others. The final preferred solutions comprise the following:

1. Far West Catchment

   Option Three – Storage and Discharge to the Water Treatment Plant. A variance on this option was eventually carried forward to the construction phase. This involved capturing the stormwater part-way up the hill and conveying it to the open channel perimeter drain effectively beheading the catchment and reducing the volume of storage and subsequent treatment required. This solution also reduced the volume of stormwater entering the water treatment plant, minimizing the risk of breach of the discharge consent. Once on site where this option could be properly investigated, construction of this solution proved to be extremely risky and was not completed as part of this project.

2. Perimeter Road Stormwater Conveyance

Option One – Open Channel Drain. The concept of an open channel perimeter drain proved to be the most practical option for controlling stormwater from the majority of the catchments. The open channel drain could be constructed to handle a 100 year return period storm event without the need for additional stormwater controlling features in the hillside. In order to build the drain without encroaching into the hillside, the existing adjacent haul road had to be reshaped and rebuilt. During the construction phase, further complications arose with this option with regards to inaccuracy of the initial survey data and existing coal yard infrastructure. These complications were overcome by widening out the drain in parts and realigning the new haul road to avoid the existing infrastructure.

3. Existing Concrete Road

Option One – Overland Stormwater Conveyance System. The concrete road is uniformly sloped towards the eastern outfall. To facilitate the movement of stormwater along the road, the existing nib walls were required to be grouted to prevent exfiltration of water and scouring. This also prevented coal from spilling over from the coal yard through the wall to the roadway. Whilst this solution is not ideal as it allows for primary and secondary overland flow across the road, it is preferable to removing the entire concrete road and continuing the perimeter drain through this section (an expensive and time consuming operation). The port were happy to accept the reduced level of service associated with overland flow as this road would be used less in the future due to the construction of the new haul road.

4. New Haul Road Interface

Option Two – Heavy Duty Culvert to convey 100 year ARI flows. This option was the most expensive option, however it provided an appropriate level of service for the new haul road interface. This solution was LPC's preference as it prevented stormwater from flowing across the base of the new haul road.

5. Eastern Outfall

Option Two – High Capacity Piped Outfall. The preferred option for the final discharge of the stormwater to the harbour was to install a large high capacity inlet structure at the downstream end of the box culvert and a large concrete box culvert outfall. This solution was selected as the preferred and primary discharge location for the whole catchment. It allowed multiple discharges to be rationalized and the length and complexity of extensions to be minimized as the port reclamation advances in the future.

5 CONSTRUCTION AND SITE COMPLEXITY

There were numerous complexities at this site, including the following:

- Working around an operational port

  LPC is New Zealand's third largest port and the largest port on the south island. The port operates 24 hours a day, seven days a week. The requirement for this project was that port operations could not be affected during construction. Our design therefore had to provide a long term solution for the coal yard flooding and contamination issues whilst ensuring it could be constructed with minimal disruption to port activities. This was particularly challenging when coal was being moved from the yard and loaded on to a ship.

- Kiwirail

  Existing structures and site topography meant the new eastern outfall had to be constructed under the live railway. The final design had to take this into consideration and ensure the outfall could be constructed quickly and easily, ensuring minimal disruption to Kiwirail. Instead of cutting the rail at both ends, construction of the outfall box culvert under the rail was carried out by supporting the rail whilst sliding the culvert underneath.

Photograph 3: Box culvert crossing under the existing railway

- Haul Road project

  Part of the wider Port redevelopment plans include construction of a new haul road to link the Port with Sumner Road and the Gollans Bay Quarry. Stormwater from the completed haul road will be discharged via the same outfall as the perimeter drain. This meant liaison with the haul road designers to ensure our infrastructure was sized appropriately and could be constructed independently of the haul road. In addition, we provided performance parameters to the haul road designers to ensure their stormwater design would be equivalent to the site-wide design.

- Steep catchment covered with loess soils

  Topography and the geotechnical properties of the hillside catchment (predominately loess) meant that special consideration had to be given to the management of high velocities and the potential for scour and slope instability. Any encroachment into the hillside to form an open channel drain along the base of the catchment was considered to be a high-risk activity due to risks associated with stability of the hillside.

- Rockfall potential

  Another issue associated with instability of the hillside was the risk of rockfall above the far west catchment. This meant that this catchment could not be surveyed during the design phase and the design had to be completed based on preliminary data. This catchment was surveyed after rockfall protection was installed prior to construction was commencing.

- Existing unknown services

  There are many services within this site (refer Figure 3) and numerous stages of port development by different parties has led to inaccurate as-built survey records. Although these records were reviewed and referenced during the detailed design phase, there were a number of unknown services discovered during the construction phase.

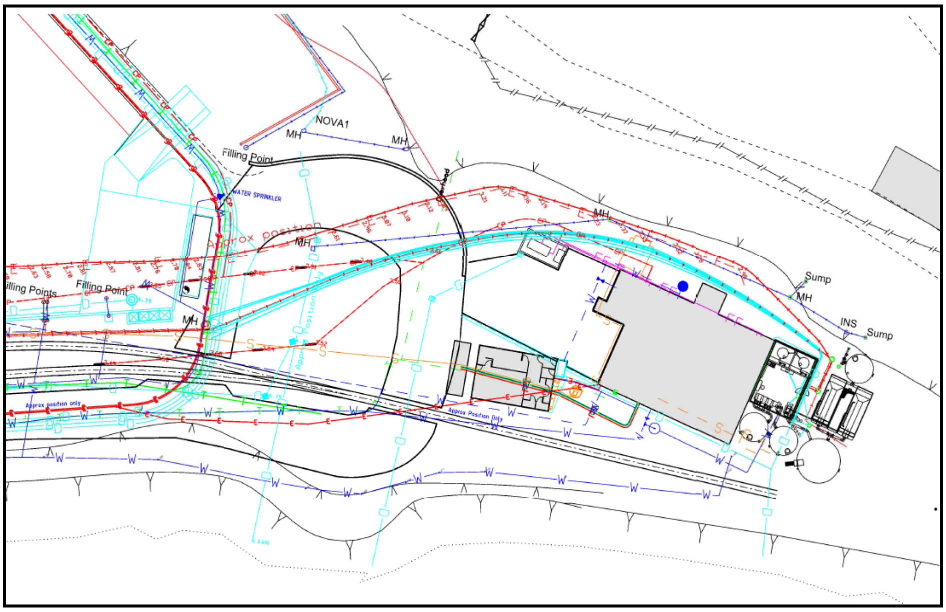

Figure 3: Existing port services

One of the major issues that arose on site was the identification of a number of previously unknown services that clashed with the eastern outfall box culvert. Fortunately, these services were identified through potholing prior to construction commencing, however we had to quickly come up with a solution to either divert the services under, over, through or around the box culvert. We found we could not divert them around the box culvert as the hillside came right up the inlet structure and the other side of the culvert was the ocean outfall. We considered going under or through the box culvert but these options were dismissed due to operational and hydraulic impacts. Therefore, we ended up diverting the services up and over the culvert, refer to Photograph 4.

Photograph 4: Re-route of existing services over box culvert

This solution provided minimal cover over the services so a concrete protection slab was laid between the services and the top of the haul road. LPC were happy with this solution as it gave them access to the services for future maintenance and also allowed the contractor to continue on site without significant delays.

- Proposed extension of the reclamation area

The proposed extension of the reclaimed area as part of the overall Port expansion plans will mean that one of the two existing hillside stormwater discharge points (the central outfall) is no longer available and it is not viable to extend the culvert pipe to continue the discharge to the harbour given the scale of the reclamation as shown by the brown shaded area in Figure 4.

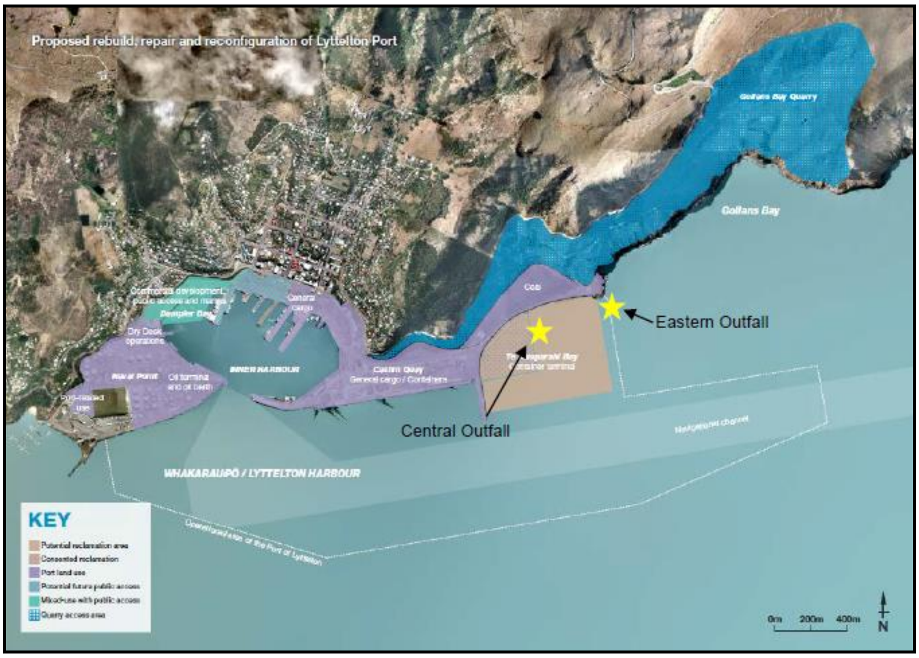

Figure 4: Lyttelton Port Redevelopment including Te Awaparahi Bay Reclamation (Source: Lyttelton Port Recovery plan)

6 CONCLUSIONS

At the date of writing this paper, construction of the Coal Yard Stormwater project has been completed, with the Haul Road project in progress. This project was a successful demonstration of stormwater design at a detailed level whilst consideration of wider port operations at a macro level. A level of service approach was adopted by providing a lower level of service in some areas (i.e. primary overland flow across the existing concrete road) and a higher level of service in other areas (i.e. piping 100 year ARI flows for the new haul road). This approach was developed through an understanding of LPC's use and the importance of various areas of the site. In addition, we made simple operational changes and recommended education for LPC staff around operational practices.

By developing an integrated approach to LPC's primary issues of coal yard flooding and contamination, port operations were able to continue unimpeded whilst infrastructure upgrades were implemented to solve LPC's key problems.