GREYMOUTH FLOOD WALL UPGRADE DESIGN
GEOTECHNICAL REPORT

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Riley Consultants Ltd 1 copy

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GREYMOUTH FLOOD WALL UPGRADE DESIGN
GEOTECHNICAL REPORT

1.0 Introduction

Riley Consultants Ltd (RILEY) has been engaged by Good Earth Matters to provide geotechnical input for the design of upgrading works of the flood protection system along both sides of the Grey River downstream of the rail bridge. The details of the floodwall upgrade are provided in the construction documents completed by others, the main elements of the project from a geotechnical standpoint being:

- Concrete floodwalls founded on existing stopbanks over a length of around 1500 m
- A new section of stopbank around 1 m above existing ground level and 140 m long
- A new section of stopbank around 4 m above existing ground level and 110 m long
- Raising of existing stopbanks by 0.2 m to 0.7 m over a length of around 1300 m
- Minor raising/re-contouring of existing stopbanks over a length of around 2800 m.

The design standard for the upgrade is for 600 mm freeboard in a 1:50 flood, and a higher standard of 600 mm freeboard in a 1:150 flood where new floodwalls are proposed.

1.1 Scope

The overall aim of the investigation is principally to provide information to assist the overall design of the upgrade project. The desired end result is to confirm that relevant geotechnical issues have been taken into account and that the risk of failure of the various structures in terms of geotechnical failure modes is acceptably low for the adopted design standard. The geotechnical work is not a condition assessment of the existing stopbanks as such; rather confirmation is required that the proposed works do not exacerbate existing geotechnical risks for the proposed design standard. The purpose of this geotechnical report is to document the results of the investigation, and to summarise conclusions and recommendations on geotechnical aspects of the project.

2.0 Geological Setting

Published information (Ref 1) for the site indicates the existing stopbanks adjacent to the Grey River upstream of the estuary (i.e. upstream of the Goods Shed on the true left and Cobden Island on the true right) are generally underlain by river gravel, sand and silt of young river flats. Estuarine deposits are indicated around the periphery of the estuary south of the Fisherman’s Wharf area, and marine gravel and sand are indicated along the river banks downstream of the estuary. Significant reclamation efforts have occurred along the banks of the river including training levees and revetments at the river mouth.

At the upstream limit of the true left stopbank, the Cobden Limestone of Peter Range is encountered. This limestone is regionally westward dipping at an angle of around 27°.
3.0 History of Flood Wall Development

From 1979 development of a flood protection scheme in Greymouth had been underway. In 1986, North Tip Road was raised, along with installation of the gated culvert at Range Creek.

Following severe flooding in 1988, a new system of stopbanks and floodwall was proposed. Construction of the new infrastructure was completed in 1991, and no significant upgrading of the scheme has been undertaken since. The nature and extent of reclamation work and stopbank construction previous to the events of 1979 have not been reviewed in detail, however it is understood that significant historical activity has occurred in the area, and variable quality fill is likely to exist beneath the current floodwall arrangement.

A series of performance and risk reviews have been undertaken since completion of the flood wall in 1991, and key relevant findings from these reports (Ref 2, 3) are summarised below.

Cobden

- A specific area of low quality historic fill within a reclaimed river channel in the area of Taylor St has been identified, and there has been an associated settlement issue
- The earth stopbank is subject to significant seepage resulting in landward-side flooding, and the majority of this flow is inferred to be via the aforementioned area of historic fill

Mawhera Quay

- Flood wall seepage area has been identified around the intersection with Boundary St, and west toward Johnston St pump station. Water pressure has been observed beneath the adjacent road pavement in this area.

4.0 Basis for Investigation

As a condition assessment of the existing stopbank is outside the scope of this report, investigation has been targeted around areas where significant stopbank raising will occur. This is to ensure that the additional floodwall height is appropriately designed and detailed so as not to negatively affect the existing stopbank stability. The key areas selected for targeted investigation generally incorporate a raise for the 1:50 AEP flood standard of more than 200 mm. Investigation has therefore been targeted at:

- Two Bridges
- Mawhera Quay
- Goods Shed
- Fisherman’s Wharf
- Cobden around Range Creek Culvert

Note that the section of stopbank at Cobden around Taylor St previously identified as having deficient foundations will not be modified under the proposed works, and has not been targeted for investigation.
The scope of the investigation was derived after a walkover inspection and assessment of the key areas in terms of geotechnical risk. A draft programme of investigation was derived and agreed with WCRC.

5.0 Fieldwork and Laboratory Testing

A programme of sub-surface investigation has been undertaken, including excavation and logging of 24 test pits. Test pit locations are indicated on the drawings in appendix A, and test pit logs are included in appendix B. Machine drillholes were undertaken by CW Drilling. The fieldwork was overseen by technicians or geologists from RILEY and logs are presented in terms of the New Zealand Geotechnical Society Guidelines. Initially hand augers were attempted in some locations but were abandoned at an early stage due to difficulties with gravels.

Laboratory tests have included particle size distribution on selected samples, and a standard Proctor compaction test on a sample of existing stopbank material. Results are included in appendix C.

6.0 Geotechnical Considerations and Recommendations

Observations from the investigations along with comments and recommendations for specific locations are detailed in the follow sections. In each case geotechnical failure modes are considered, these may include:

- Seepage effects and internal erosion
- Slope stability
- Settlement
- Loss of support or undermining
- Foundation instability or overstressing

All of the above failure modes may not be applicable in all locations.

6.1 Two Bridges

This area is located at the base of a large limestone bluff, adjacent to the railway line. The railway appears to have been founded on bedrock, and water flow is exiting the base of the outcrop via open defects and a large solution cavity to the river via covered drains.

To achieve the design stopbank crest level in this area, an earth fill up to 4 m above existing fill height is required. The culvert beneath the fill draining seepage flows from the bluff area is cracked and deformed and will require replacement. In addition a small bridge will be replaced by a culvert. The vertical height from the existing culvert inverts to final stopbank crest level is around 7 m.
6.1.1 Investigations and Geotechnical Model

Four test pits and two boreholes were completed in the two bridges area. Ground conditions generally comprise limestone bedrock overlain by dense river gravels 1 m to 2 m deep, overlain by soft river sediments around 1 m thick, overlain by a minimum of around 1.5 m of granular fill. SPT values in the soft river sediments are very low (as low as 0) increasing to typically in excess of 30 in the denser gravels. The fill is variable in composition and in places contained wood fragments, steel and brick inclusions. Groundwater seeps were noted near the base of the test pits, but flows were only modest. Groundwater level within the pits and boreholes was similar to the level of the adjacent river. However, during drilling of DH3 a higher water table was observed within the underlying rock. The water pressure was not artesian (i.e. stabilised below ground level) however was some meters higher than the piezometric level in the overlying alluvium. It is inferred that interconnected defects within the limestone bluff adjacent to the site provide conduits for water from the bluff, which exit at various locations including the two open drains observed on site, as well as subsurface seepage points, and possibly higher elevation drainage points at times of heavy rainfall and high water pressures within the bluff.

A stability assessment of the proposed fill embankment slope has been completed using a two-dimensional limit equilibrium model. The assessment indicates that the presence of the soft alluvial sediment underlying the existing fill results in acceptable factors of safety under the additional loading of the proposed stopbank fill. However in the event of elevated groundwater levels within the stopbank such as may occur in the event of heavy rainfall locally resulting in seepage pressures from beneath/behind the stopbank from the limestone bluff, factors of safety approach 1 (i.e. a state of failure). Removal of the existing fill and underlying soft sediment, and founding on denser alluvial sediments was then modelled. The resulting factors of safety are around 1.7 for the normal (observed) groundwater profile, and 1.5 for a postulated adverse groundwater profile associated with high seepage rates from the underlying bluff or a rapid drawdown scenario from recession of river flood level. The results are summarised in table 1, and printouts of the stability analysis are included in appendix 4. Note that high water levels in the Grey River do not represent a critical load case for this section of stopbank on the landward side, which is well buttressed by the railway on the landward side.

<table>
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<td>New stopbank constructed on existing sediments – normal groundwater levels</td>
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<tr>
<td>New stopbank constructed on existing sediments – high groundwater levels</td>
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</tr>
<tr>
<td>New stopbank foundation excavated to dense alluvial sediment – normal groundwater levels</td>
<td>1.7</td>
</tr>
<tr>
<td>New stopbank foundation excavated to dense alluvial sediment – high groundwater levels</td>
<td>1.5</td>
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Table 1: Factors of Safety

In addition liquefaction and excessive settlement are significant risks. Liquefaction of this very loose soil is likely in even a moderate earthquake with subsequent major slumping and settlement of the fill embankment. It is therefore recommended that the existing fill and soft underlying sediments be undercut, and the stopbank fill founded on the dense underlying sediments.

6.1.2 Key Considerations

Geotechnical considerations for the area include:
1. The strength of the sand/silt in situ river sediments is low, and it is recommended that the area be undercut to allow founding of the stopbank and proposed culverts on dense materials. Some of the existing fill may be able to be re-used. The plan and depth extent of undercutting will require conformation on site.

2. Seepage flows from the bluff must be adequately drained to ensure that seepage pressures do not build up within the stopbank fill. The old culverts are scheduled for replacement, and the new culverts should be carried through to interface with the rock bluff. Detailed logging of the rock bluff should be undertaken at the time of construction, and drainage works installed for any open defects in the rock face, so that all seepage flows are collected and passed through the culverts beneath the stopbank fill. Free draining fill materials should be used up to the level of the existing railway, as the lower portion of the stopbank will not be required to retain water due to the site geometry.

3. Erosion protection of the new stopbank is required, as it forms the outside of a river bend and will be impacted by the main channel of the river during flood flows. Heavy rock protection should be allowed for the full extent of the stopbank batter.

4. The necessary sub-excavations are below the river level and groundwater inflows should be expected. Careful management of these inflows and the natural springflows are required by contractors to ensure that fill standards are not compromised. In particular contingency measures should be in place such as pumps and construction methodology to minimise the time of exposure within the lowest excavation levels.

5. The existing fill embankment where it supports the railway is relatively steep, and design concepts should aim to avoid any significant destabilising effects. It is recommended the existing fill is not undercut except for minor trimming of the face and that temporary slopes do not exceed the existing slope.

6.2 Mawhera Quay

This refers to the section of stopbank incorporating existing prefabricated concrete retaining walls that run adjacent Mawhera Qy and Richmond Qy roads. It is proposed to install a freestanding concrete wall around 0.9m high along the crest of the existing stopbank.

The design stopbank cross section is known from a drawing supplied by the WCRC (reproduced in figure 1). This incorporates a sloping, low permeability upstream core zone extending around 2.5m vertically. The core then runs horizontally into the centre of the stopbank, and ties into a “clay core” cutoff indicated to be 6m deep within founding soils. The landside batter is supported by 2 low precast concrete retaining walls. The main potential issues associated with the floodwalls are seepage along or near the interface with the underlying soils, and foundation resistance to various potential failure modes. Due to the low height of these walls settlement or bearing capacity are not likely to be issues.
6.2.1 Investigations

Six shallow test pits and one drill hole were completed along this section of stopbank

(a) Floodwall Section

Generally the supplied design stopbank profile was confirmed by the investigation, although pits only extended to around 0.5m deep to ensure damage to the existing stopbank was minimised. Laboratory testing including 2 particle size distribution tests on each of the sloping silty gravel core and general fill zone were completed in addition to a standard compaction test on core material. Grading curves for the samples are indicated in figure 2. Laboratory testing indicates the low permeability upstream core is a silt with sand and gravel that is expected to effectively limit seepage flows. The grading of the adjacent gravel fill has been checked for filter compatibility with the core, and is found to generally comply with the “no erosion” criteria. The materials exhibit a degree of gap-grading, however given the short duration of any seepage flow through the upper part of the stopbank, it is considered unlikely that piping features or internal erosion would develop.
The drill hole was located to the west of the section near the intersection of Mawhera Qy and Richmond Qy roads, where seepage has been experienced in recent flood events. The borehole was located on the landward side of the 6m deep clay cutoff indicated in the supplied design drawing. The materials encountered by the drill hole generally comprised fill to around 3.4m, gravel and sandy gravel to around 7m, with sand and gravelly sand below this to the hole target depth of 10m. None of the sediments encountered in the hole would provide significant resistance to seepage flow from the adjacent river, and as the stopbank central clay cutoff extends only 6m, it is interpreted that seepage flows are able to pass beneath the cutoff zone and discharge in the stopbank toe area. It is also quite likely that the clay cutoff is not very effective in reducing flow or pressure in the upper founding soils. and minimal head loss due to seepage is occurring in even the near surface soils.

The permeability of the founding soils at this location are likely at the upper limit of the hardfills tested, as the nature of the founding gravel soils is similar. Based on various correlations from grading curves the permeability is assessed as in the range 4 to 8 x10^{-4} m/s. This is significantly higher than the in situ permeability test, but this test appears to give an unrealistically low permeability.

Based on previous transient groundwater modelling we have undertaken for stopbanks a head loss due to seepage can be derived, based on permeability. A head loss of only 1m is predicted at the toe of the stopbank (i.e. the carriageway), and thus for only moderate flood events artesian pressure is predicted beneath the carriageway. This is consistent with the observed heaving of the carriageway seal in previous flood events i.e. artesian uplift pressure exceeds the weight of the overlying materials.

Figure 2: Plot of Laboratory Grading Curves

(b) Area of Observed Seepage Pressure
6.2.2 Key Considerations

(a) Floodwall Section

For design of the floodwall RILEY recommends the following:

1. The wall be located near the river-side of the stopbank, with the footing cast insitu directly on the low permeability core zone after removal of topsoil etc, and extending onto the free draining bulk fill zone.

2. A key be incorporated in the footing to increase resistance to sliding. The key should be located within the free-draining gravel rather than the low permeability core, to ensure minimal disturbance to the core zone.

3. During construction, the core zone should be exposed and tested to ensure it has appropriate density and moisture content to act as a footing foundation and water retaining material for concrete structure interface. It may be appropriate to re-condition the core zone by addition of water/scarifying/re-compaction.

4. The footing should found on the low-permeability zone a minimum width of 200mm and preferably more. It is possible the low permeability material may not be encountered or at marginal thickness at tentative founding level (for example if hardfill thickness is greater than about 300mm). For this scenario placement of low permeability soil will be required to create a continuous seepage barrier, as it may not be desirable to lower the founding wall level.

5. A worst-case overturning and uplift stability check be undertaken including full water pressure on the wall face, and full water pressure along the foundation slab (i.e. seepage pressure assuming a crack forms at the interface). A factor of safety greater than 1.0 would be appropriate for such an extreme flood case if the flood level is taken to the top of the wall.

6. To ensure erosion/deterioration at the river-side foundation interface of the wall does not occur, it is recommended that a filter fabric detail down the face of the wall and between the core and riprap be incorporated. Riprap should be placed on the fabric against the base of the wall and marry in with the existing rip rap.

7. Wall stability should be checked for failure modes of uplift, sliding and overturning. A typical required factor of safety is 1.5 for these modes, for a conservative assumption of a flood level at the top of the wall. This water level is higher than the 1% AEP flood level. We recommend that the base width be a minimum of 1m, in order to provide a minimum seepage length. Each of these failure modes should be checked for a triangular uplift distribution i.e. headwater at the upstream end to zero at the downstream toe. We have considered placement of a drain at the landward toe, but due to the free draining hardfill we consider this is not required. Also it is most likely no seepage will reach the downstream toe, and even if it did would be expected to be only modest flows.

8. Consideration should be given to the detail at the end of the walls ie how seepage is minimised around the end of the wall.

(b) Area Of Observed Seepage Pressure

At this position there is a risk of initiation of erosion by a ground heave mechanism possibly leading to a breach of the stopbank by piping. Although the risk of initiation is high (particularly in floods greater than encountered to date) there must be other factors present for a breach to potentially occur. The gravel soils are unlikely to hold a roof or be highly erodible in seepage flow and thus gross enlargement of a piping hole is unlikely. Some loss of the finer fractions within the matrix may occur, leading to higher permeability and flow rates. In a worst case scenario if sufficient erosion occurred the crest may slump and/or the walls be undermined and then the crest may overtop if the flood is high enough at the time.
The short duration of peak flood loading would reduce this risk. Overall the risk of a breach in say a 1:100 flood event is assessed as moderate to low.

The options to improve stopbank security could involve;

- Seepage reduction measures
- Drainage / buttressing
- Combination of the above

It appears the existing clay cutoff at this location is not fully effective. Seepage reduction measures could involve a deep cut off using plastic concrete or conventional concrete. These however are very expensive solutions and more suited to large dams. Drainage or buttressing are considered more cost effective options. These are described below.

(a) Raising of the ground to add weight. This would involve removal of existing seal and placing fill.
(b) A deep toe drain or similar. This would be a trench backfilled with highly permeable gravel excavated to the maximum practical depth.

Option (b) above is considered most cost effective solution. Further design analyses are recommended to develop the concept, in particular the required geometry, grading and required design standard. Option (a) would be very disruptive as a significant fill depth may be required. With any option there are various practical constraints to be considered.

6.3 Goods Shed

A new section of stopbank up around 1 m high is required adjacent to the existing Goods Shed.

6.3.1 Investigations

Three test pits up to 4 m depth were completed in the Goods Shed area. Fill comprising variable silt, sand, gravel and boulders and was encountered to at least 2 m depth. The soils encountered are generally considered to be an appropriate foundation for the proposed stopbank in terms of strength and potential settlement. Some permeable materials were encountered along with boulders.

6.3.2 Key Considerations

The new stopbank requires a competent foundation, and an appropriate detail for keying the low permeability upstream core zone into the foundation to limit foundation seepage.

All loose, permeable or soft materials require removal from the stopbank footprint, an undercut over the whole footprint of 0.5 to 1 m is envisaged. In places a deeper sub-excavation may be required either over the whole footprint or as a cut off for seepage control. The typical cross section for the new stopbank should incorporate an upstream silt core and downstream free draining shoulder similar to the existing stopbanks in the area. The upstream core zone should be keyed into in situ ground. The recommended new stopbank cross section is indicated in drawing 09828-5.

6.4 Fisherman's Wharf

A freestanding wall around 0.9 m high is proposed for the Fisherman’s Wharf section of stopbank.
6.4.1 Investigations

Four test pits were completed in the area. These pits revealed an upstream core zone and free draining bulk fill typical cross section, incorporating a similar cross section and materials to those at Mawhera Quay. It is unlikely however, that the stopbank incorporates the 6 m cut-off zone of Mawhera Quay, as the stopbank is significantly lower at this location.

6.4.2 Key Considerations

It is considered appropriate to use a similar wall detail to that suggested for Mawhera Quay, with the wall being located at the river-side of the existing stopbank crest, and keying into the existing low-permeability upstream core zone. Design loadings and considerations for the wall are anticipated to be similar to those at Mawhera Quay, although additional consideration of wave impact loading and overtopping effects due to the proximity of the site to the river mouth.

6.5 Cobden

The existing stopbank in the area within around 300 m upstream of the existing Range Creek culvert is very steep, and has a narrow cross section and crest width due to the constraint of the adjacent road. Seepage has been noted around and/or beneath the culvert, and remediation of this structure has been raised as item for consideration in our brief. During the site visit, seepage was observed exiting adjacent to the culvert toward the Grey River. It is therefore likely that the seepage direction will reverse during flooding of the river, and the seepage flows will exit toward Cobden.

It is proposed to raise the entire road embankment to achieve the design stopbank height, rather than attempting to raise the already steep and narrow existing banks adjacent to the road. In the Range Creek culvert location, new culvert sections will be added on either side of the existing structure, and earth fill placed to tie in to the existing stopbank batter.

6.5.1 Investigations

Three test pits and one drill hole were completed in the area. The test pits determined that the river side low permeability facing is present on the stopbank.

The drill hole identified sandy gravel beneath the culvert level (base of stopbank fill). The in situ foundation material is likely to be highly permeable, and it is also considered likely that seepage along the interface of the culverts with natural ground and backfill is occurring. Design details of the wing wall extensions have been sighted, but nothing of the original wing wall and culvert installation which apparently predates the stopbank upgrade of the late 1980’s. No internal inspection of the culverts was undertaken however it is considered likely that settlement of the culverts has occurred to some extent, as the stopbank height has been raised at least once following original construction.

6.5.2 Key Considerations

RILEY supports the idea of raising the road embankment across its full width in this area. The existing road surface should be removed and the upstream core be extended appropriately, as indicated in drawing 09828-5 attached.

At the culvert location, the recommended detail for limiting seepage is a new earth liner layer within the fill surrounding the culvert extension. There is the potential for seepage pressure from either direction (i.e. the Grey River side during flood, and the Cobden side during normal operation/local rainfall events). Therefore the recommended detail incorporates an
internal low permeability core zone on the Grey River side of the culvert, with a supporting shoulder of general stopbank fill material. This arrangement is indicated in drawing 09828-6. It is important that the low permeability core zone is well keyed into the existing low permeability facing layer on the river-side stopbank batter. The previously noted possibility of culvert settlement raises the potential for seepage originating from pipe joints, and it is recommended that an internal inspection of the culverts be completed as part of the structure upgrade.

In the culvert location, the founding level for compacted fill is beneath river level, and occupies the normal drainage path for the Cobden estuary area. Construction will therefore require careful planning and execution, with consideration given to drainage so that fill quality is not adversely affected by water within the excavation. Very high compaction standards are required below and around the pipes in particular.

7.0 Summary of Main Points

1. Investigations have been completed with the purpose of assisting the overall design of the upgrade project. There have been no major issues identified which could detrimentally affect the project, although in some areas challenging ground conditions have been identified requiring specific measures to minimise risk to an acceptably low level.

2. As expected the two Bridges section had the most challenging ground conditions, i.e. soft founding soils requiring undercutting and high groundwater levels.

3. Recommendations are included in this report for each of the areas investigated.

4. Confirmation of assumptions will be required during construction to ensure that the design objectives are fulfilled, and appropriate action taken if conditions differ from those encountered to date. Recommended construction methods and inspection procedures are included in appendix 5: Construction Specification Clauses.

8.0 Limitation

This report has been prepared solely for the benefit of Good Earth Matters as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties’ sole risk.

Recommendations and opinions in this report are based on data from limited test positions. The nature and continuity of subsoil conditions away from the test positions are inferred, and it must be appreciated that actual conditions could vary considerably from the assumed model.

During excavation and construction the site should be examined by an engineer or engineering geologist competent to judge whether the exposed subsoils are compatible with the inferred conditions on which the report has been based. It is possible that the nature of the exposed subsoils may require further investigation and the modification of the design based upon this report.

Riley Consultants Ltd would be pleased to provide this service to Good Earth Matters and believes the project would benefit from such continuity. In any event, it is essential Riley
Consultants Ltd is contacted if there is any variation in subsoil conditions from those described in the report as it may affect the design parameters recommended in the report.

9.0 References

APPENDIX 1
Drawings
**Title:** Greymouth Flood Wall, Greymouth

**Geotechnical Investigation - Cross Sections at 2 Bridges Site**

**Legend:**
- **Sandy Gravel** (Fill)
- **Silt, Local Organics**
- **Sandy Gravel** (Alluvium)
- **Bedrock (Cobden Limestone)**

**Contacts:**
- **Known**
- **Approximate**
- **Inferred**

**Drill Hole Location (150mm dia concentric width not to scale)**

**Notes:**
1. Ground profile produced from tape clinometer survey
2. Elevations approximated from GPS
3. Soil descriptions are simplified, refer to report and bore log for details

**Conceptual - Not for Construction**
CONCEPTUAL RANGE CREEK CULVERT UPGRADE

SCALE 1:50 (APPROX)

EXISTING CONCRETE STRUCTURE (INDICATIVE)

LOW PERMEABILITY FILL

NEW STOPBANK/ROAD FILL LEVEL

FILTER FABRIC AT INTERFACE WITH CONCRETE STRUCTURE

EXISTING CULVERTS

EXISTING STRUCTURE FOUNDATION DETAILS UNKNOWN

EXCAVATE TO DENSE TIGHT FOUNDATION

EXTEND FILTER FABRIC TO FOUNDATION LEVEL

GRANULAR FILL

A FILTER FABRIC AT INTERFACE WITH CONCRETE STRUCTURE

A EXISTING CULVERTS

RIVER LEVEL VARIES

LEVEL VARIES

EXCAVATE TO DENSE TIGHT FOUNDATION

CONCEPTUAL RANGE CREEK CULVERT UPGRADE

GOOD EARTH MATTERS

GREYMOUTH FLOOD WALL, GREYMOUTH

RANGE CREEK CULVERT UPGRADE - CONCEPT DRAWING

CONCEPTUAL - NOT FOR CONSTRUCTION
EAST OF SPORTS CLUB BUILDING

SECTION A
SCALE 1:100

RETAINING WALL

SECTION B
SCALE 1:100

ROAD

24'

44'

31'

46'

FISHERMANS WHARF

CONCEPTUAL - NOT FOR CONSTRUCTION

GOOD EARTH MATTERS
GREYMOUTH FLOOD WALL, GREYMOUTH
GEOTECHNICAL INVESTIGATION - CLINOMETER CROSS SECTIONS
TRACK

MAWHERA QUAY

2'

RETAINING WALL

SECTION C

SCALE 1:100

RIVER

SCALE 1:100

CONCEPTUAL - NOT FOR CONSTRUCTION

GOOD EARTH MATTERS

GREYMOUTH FLOOD WALL, GREYMOUTH

GEOTECHNICAL INVESTIGATION - CLINOMETER CROSS SECTIONS

RILEY CONSULTANTS

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N.Z.M.C.
AUCKLAND
TEL: 09-4897872
FAX: 09-4897873

DATE: / /
APPENDIX 2

Geotechnical Logs
# Test Pit Log

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole position:** Crest of stopbank  
**Job No.:** 09828  
**Start Date:**  
**Ground Level (m):**  
**Co-Ordinates:**  
**No.:** TP1  
**Client:** Good Earth Matters  
**Hole Depth:** 1.00 m  
**Sheet:** 1 of 1

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<tr>
<td></td>
<td></td>
<td>SLT, trace clay, very large angular limestone boulder inclusions up to 350mm</td>
<td></td>
<td></td>
<td>No. 1</td>
<td>1, 2, 1, 2, 1, 3, 2, 3, 4, 20</td>
</tr>
<tr>
<td>0.70</td>
<td></td>
<td>medium to coarse gravelly SAND, minor cobbles, grey, well graded, non plastic, gravels and cobbles are rounded greywacke</td>
<td></td>
<td></td>
<td>No. 2</td>
<td>2, 1, 2, 1, 2, 2, 2, 2, 1, 2, 2, 2</td>
</tr>
<tr>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2, 2</td>
</tr>
</tbody>
</table>

**SKETCH:**
- **SILT CAP**
- **SAND WITH SOME GRAVEL**
- **NORTHERN FACE OF TEST PIT**

**MAP:**
- **Shoring/Support:** Stabilized

**GROUNDWATER:** None

**PIT TERMINATED DUE TO:**
- Target depth

**Remarks:**
- Slow Seep (depth )
- Rapid Inflow (depth )
- Flooding
- Refusal
- Machine limit

All dimensions in metres  
Scale 1:50  
Logged by: MJB  
Checked by:  
Shear Vane No.:
**TEST PIT LOG**

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole position:** stopbank  
**Job No.:** 09828  
**Start Date:** 17-09-09  
**Ground Level (m):**  
**Co-Ordinates:**  
**No.:** TP2  
**Client:** Good Earth Matters  
**Hole Depth:** 1.00 m  
**Sheet:** 1 of 1

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
<th>Weathering</th>
<th>Field Strength</th>
<th>Legend</th>
<th>Defect Description</th>
<th>Samples</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.60</td>
<td></td>
<td>SILT: trace to minor clay, minor large angular gravels up to 100-300mm across</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0, 1, 1</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td></td>
<td>gravelly SAND, rounded greywacke gravels generally up to 100mm, occasionally up to 300mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1, 1, 1</td>
<td></td>
</tr>
</tbody>
</table>

**SKETCH:**
- WEST 600mm TOPSOIL AND SILT-CAP
- EAST
- 100-150mm TOPSOIL
- GRAVELLY SAND

**Shoring/Support:** Stability  

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In situ Vane Shear Strength (kPa)
- P=Peak, R=Residual, UTP=Unable to penetrate
- Scala Penetrometer - blow/50mm

**GROUNDWATER:** None

- Slow Seep (depth )
- Rapid Inflow (depth )

**PIT TERMINATED DUE TO:**
- Target depth
- Flooding
- Refusal
- Machine limit

**Remarks**

**All dimensions in metres**  
**Scale:** 1:50

**Logged by:** MJB  
**Checked by:**

---

RILEY CONSULTANTS LIMITED
4 Fred Thomas Drive  
Takapuna, AUCKLAND
Tel: 09 497 8772  
Fax: 09 497 8773
### TEST PIT LOG

**Project:** Greyouth Flood  
**Location:** Greyouth  
**Hole position:** Western end good shed  
**No.:** TP3

<table>
<thead>
<tr>
<th>Job No.</th>
<th>Start Date</th>
<th>Finish Date</th>
<th>Ground Level (m)</th>
<th>Co-Ordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>09828</td>
<td>17-09-09</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Client:</th>
<th>Geological Description</th>
<th>Hole Depth:</th>
<th>Defect Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Earth Matters</td>
<td>Soil Description: subsoil, profile, MAJOR, minor, colour, structure, strength, moisture condition, grading; bedding, plasticity, sensitivity, major qualifications; weathering of clasts; subsoilton qualifications. minor qualifications; additional structure (GEOLOGIC UNIT).</td>
<td>3.70 m</td>
<td>(type, orientation, spacing, roughness, persistence aspect, setting etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Weathering</th>
<th>Soil</th>
<th>Rock</th>
<th>Defect Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FILL; sandy GRAVELS; mixed with coal gravels up to 300mm (rounded), black</td>
</tr>
<tr>
<td>1.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00; gravel 300mma, light grey</td>
</tr>
<tr>
<td>2.20</td>
<td>1.20</td>
<td></td>
<td></td>
<td></td>
<td>gravel 40mm road chip, angular, dark brown</td>
</tr>
<tr>
<td>2.50</td>
<td>1.70</td>
<td></td>
<td></td>
<td></td>
<td>gravel SAND; trace to minor rounded greywacke gravels, 80mm to &lt;20mm, light brown</td>
</tr>
<tr>
<td>2.90</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
<td>SILT; some clay, trace sand, yellow/orange/brown, moderately plastic, minor - some gravels &amp; boulders up to 500mm across (greatest dimension) gravels very light grey/orange/white</td>
</tr>
<tr>
<td>3.00</td>
<td>3.00</td>
<td></td>
<td></td>
<td></td>
<td>clayey SILT; greenish grey, angular limestone boulders &lt;300mm greatest dimension</td>
</tr>
<tr>
<td>3.70</td>
<td>4.00</td>
<td></td>
<td></td>
<td></td>
<td>EOH @ 3.70 m</td>
</tr>
</tbody>
</table>

**SKETCH:**

**MAP:**

**Shoring/Support:**

**Stability:**

- A  
- B  
- C  
- D

**GROUNDWATER:**

- None

**Remarks:**

- Slow Seep (depth )  
- Rapid Inflow (depth )

**PIT TERMINATED DUE TO:**

- Target depth  
- Flooding  
- Refusal  
- Machine limit

**All dimensions in metres**

**Scale 1:50**

**Logged by:** MJB  
**Checked by:**

---

[Diagram and table details are not transcribed in the text format.]
### Geological Description

- **Elevation (m)**
  - 0.60
  - 0.65
  - 0.95
  - 1.19
  - 2
  - 2.22
  - 2.90
  - 3.60

- **Depth (m)**
  - Trench

- **Soil Description**: sand, gravel, cobbles, grey, non-plastic, gravels and cobbles are rounded greywacke

- **Defect Description**: none

- **Samples**: none

- **Tests**: none

---

### Sketch

- **Shoring/Support**: no shoring required

- **Stability**: none

---

### Map

- **GROUNDWATER**: none

- **Remarks**: none

---

**All dimensions in metres**
- **Scale 1:50**

**Shear Vane No.**: None

**Logged by**: MJB

**Checked by**: None
TEST PIT LOG

Project: Greymouth Flood
Location: Greymouth
Hole position: Crest of stopbank
No.: TP6

Job No.: 09828
Start Date: 17-09-09
Finish Date: Ground Level (m):
Co-Ordinates ()

Client: Good Earth Matters
Hole Depth: 0.75 m
Sheet: 1 of 1

Geological Description

- Soil Description: substrates, profile size, MAJOR, minor: colour, structure, strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; substrate qualifications; minor qualifications; additional structures (GEOLOGIC UNIT).
- Rock Description: weathering, colour, texture, fabric and orientation; NAME; strength, additional description, (GEOLOGIC UNIT).

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Field Strength</th>
<th>Soil</th>
<th>Rock</th>
<th>Defect Description</th>
<th>Samples</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.30</td>
<td>Weathered</td>
<td>SILT</td>
<td>Rock</td>
<td></td>
<td></td>
<td>PSD test</td>
</tr>
<tr>
<td>0.30</td>
<td>0.75</td>
<td>Minor clay, trace to minor sand, minor rounded gravelly gravels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EOM @ 0.75 m

SKETCH:

- NORTH
- TRACK
- GRAVELLY SAND
- 0.3m SILT, MINOR CLAY GAP

MAP:

Shoring/Support Stability:

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In situ Vane Shear Strength (kPa)
- P=Peak, R=Residual
- UTP=Unable to penetrate
- Scala Penetrometer - blows/50mm

GROUNDWATER:

- None

Remarks

- Slow Seep (depth )
- Rapid Inflow (depth )

PIT TERMINATED DUE TO:

- Target depth
- Flooding
- Refusal
- Machine limit

All dimensions in metres
Scale 1:50

Logged by: MJB
Checked by:

Shear Vane No.

RILEY CONSULTANTS
Engineering and Geology
4 Fred Thomas Drive
Takapuna, AKL
Tel: 09 4897872
Fax: 09 4897873
**TEST PIT LOG**

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole position:** Middle of stopbank track  
**No.:** TP7

**Client:** Good Earth Matters  
**Start Date:** 17-09-09  
**Finish Date:**  
**Hole Depth:** 0.85 m  
**Sheet:** 1 of 1

**Geological Description**

- **Elevation (m):**
  - 0.40: Medium to coarse gravelly SAND; minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke
  - 0.65: Dark brown topsoil stained layer with trace organic material, light wood
  - 1.00: Medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke

- **EOH @ 0.85 m**

**SKETCH:**

- Shoring/Support Stability:
  - A
  - B
  - C

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In situ Vane Shear Strength (kPa)
- P-Residual, R-Residual
- UTP=Unable to penetrate
- Scala Penetrometer - blows/50mm

**MAP**

- **GROUNDWATER:** None
- **Remarks:** Shear Vane No. Logged by: MJB Checked by:

All dimensions in metres  
Scale 1:50
Geological Description

- Soil Description: subgrade, particle size, MaksOH, minor, colour, texture, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering, clasts, subgrade qualifications, minor qualifications, additional structure, (GEOLOGIC UNIT).
- Rock Description: weathering, colour texture, fabric and orientation, NAM, strength, additional description, (GEOLOGIC UNIT).

- Depth (m):
  - 0.75 m

- Elevation (m):
  - 0.25 m
  - 0.55 m
  - 0.65 m
  - 0.75 m

- Field Strength:
  - Silty, trace to minor clay, brownish orange, orange and brownish gray staining

- Soil Strength:
  - Medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke

- Rock Strength:
  - Medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke

- Defect Description:
  - (Type, orientation, spacing, roughness, persistence, aperture, splitting etc)

- Samples Tests:
  - No. 1. 1, 2, 3, 4, 5, 10, 20
  - No. 2. 1, 2, 3, 5, 12, 20

- SKETCH:

- MAP:

- Groundwater:
  - None

- Remarks:

- All dimensions in metres
  - Scale 1:50

- Shear Vane No.
  - Logged by: MJB
  - Checked by:
**Geological Description**

- **Soil Description:** Substrate, pebble size, major/ minor colour, structure, strength, moisture condition grading, bedding, plasticity, sensitivity, minor classification of clays, subordinate qualifications, minor qualifications, additional structure, (GEOLOGIC UNIT), strength, additional description, (GEOLOGIC UNIT).
- **Rock Description:** Description and orientation, NAME, strength, additional description, (GEOLOGIC UNIT).

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Legend</th>
<th>Field Strength</th>
<th>Soil</th>
<th>Rock</th>
<th>Defect Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>0.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **ESOIL:** staining, dark brown
- **pockets of topsoil/** clay material, predominantly gravelly sand

**SKETCH:**

- **Shoring/Support:**
  - Small Disturbed Sample
  - Large Disturbed Sample
  - U100 Undisturbed Sample
  - Permeability Test
  - Schmidt Hammer
  - In situ Vane Shear Strength (kPa)
  - PoPeak, PoResidual
  - UTP=Unable to penetrate
  - Scala Penetrometer - blows/50mm

**MAP:**

- **GROUNDWATER:** None
- **Remarks:**
  - Slow Seep (depth )
  - Rapid Inflow (depth )
  - PIT TERMINATED DUE TO:
    - Target depth
    - Flooding
    - Refusal
    - Machine limit

**All dimensions in metres**

**Scale 1:50**

**Shear Vane No.**

**Logged by:** MJB

**Checked by:** MJB
**TEST PIT LOG**

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole position:** Above concrete stopbank wall  
**Job No.:** 09828  
**Start Date:** 17-09-09  
**Finish Date:**  
**Ground Level (m):**  
**Co-Ordinates ():**  
**No.:** TP10  
**Client:** Good Earth Matters  
**Hole Depth:** 0.90 m  
**Sheet:** 1 of 1

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
<th>Weathering</th>
<th>Soil Strength</th>
<th>Rock Strength</th>
<th>Defect Description</th>
<th>Samples</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td></td>
<td>medium to coarse gravelly SAND, minor cobbles, grey, non-plastic, gravels and cobbles are rounded greywacks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.90</td>
<td></td>
<td>SILT, minor clay, minor sand, dark brown topsoil staining</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SHORING/SUPPORT:**
- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- InSitu Vane Shear Strength (kPa) P=Peak, R=Residual
- UTP=Unable to penetrate
- Sclare Penetrometer - blows/50mm

**GROUNDWATER:**
- None
- Slow Seep (depth )
- Rapid Inflow (depth )

**PIT TERMINATED DUE TO:**
- Target depth
- Flooding
- Refusal
- Machine limit

**All dimensions in metres**  
**Scale 1:50**  
**Shear Vane No.**  
**Logged by:** MJB  
**Checked by:**  

**SKETCH:**
- LARGE LIMESTONE ROCKS/BOULDERS
- NORTH

**MAP:**
- GRAVELLY SAND
- SILT, TRACE TO MINOR CLAY
- GRAVELLY SAND
## TEST PIT LOG

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole:** TP12

### Job No.: 09828  
**Start Date:** 18-09-09  
**Finish Date:**  
**Ground Level (m):**  
**Co-Ordinates (°):**  
**No.:**

### Client:

**Good Earth Matters**

### Hole Depth:

- **Hole Depth:** 0.65 m

### Elevation (m) | Depth (m) | Soil Description
--- | --- | ---
0.15 | medium to coarse gravelly SAND; minor cobbles, grey, non-plastic, gravels and cobbles are rounded greywacke
0.65 | SILT; trace to minor clay, trace to minor rounded greywacke gravels and angular limestone gravels-boulders, grey, non-plastic
1.00 | medium to coarse gravelly SAND; minor cobbles, grey, non-plastic, gravels and cobbles are rounded greywacke

### Soil Description
- **Legend**
  - Weathered
  - Field Strength
  - Soil
  - Rock
- **Defect Description**
  - type, orientation, spacing, roughness, persistence, aperture, entraining etc.

### Samples
- **Samples**
  - No. 1
  - 1, 2, 2, 2, 2, 2, 7, 20
  -  No. 2
  - 1, 2, 2, 2, 2, 2, 2
  -  No. 3, 3, 4
  - 10, 6, 11, 6, 8, 8, 6, 5
  - 4, 9, 5
  - 3, 3, 4

### Tests
- **Tests**
  - PSD test

### Sketch

**SKETCH:**
- LARGE LIMESTONE ROCKS/BOULDERS
- NORTH
- GRAVELLY SAND
- SILT; TRACE TO MINOR CLAY
- GRAVELLY SAND

### Map

**MAP**
- GROUNDWATER
  - None
  - Slow Seep (depth)
  - Rapid Inflow (depth)
  - PIT TERMINATED DUE TO:
    - Target depth
    - Flooding
    - Refusal
    - Machine limit

### Shoring/Support
- **Stability:**
  - Small Disturbed Sample
  - Large Disturbed Sample
  - U100 Undisturbed Sample
  - Permeability Test
  - Schmidt Hammer
  - In situ Vane Shear Strength (kPa)
  - P-Pa/p, R-Residual
  - UTP=Unable to penetrate
  - Scala Penetrometer - blows/50mm

### Remarks

**All dimensions in metres**

**Scale:** 1:50

**Shear Vane No.**

**Logged by:** MJB

**Checked by:**
Riley Consultants Ltd
4 Fred Thomas Drive
Takapuna, AKL.
Tel: 09 4497972
Fax: 09 4497973

TEST PIT LOG

Project: Greymouth Flood
Location: Greymouth
Job No.: 09828
Start Date: 18-09-09
Ground Level (m):
Co-Ordinates ():
Hole position: Between two bridges
No.: TP13
Client: Good Earth Matters
Sheet: 1 of 1

<table>
<thead>
<tr>
<th>Elevation (ft)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.80</td>
<td>[FILL] medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke, root and organic debris inclusions.</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td>medium to coarse silty gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke, black carbonaceous organic inclusions</td>
</tr>
<tr>
<td></td>
<td>2.50</td>
<td>organic content, reducing with depth, occasional brick and steal inclusions</td>
</tr>
<tr>
<td></td>
<td>3.30</td>
<td>very large wood fragments inclusions (up to 600mm across), steal and brick inclusions</td>
</tr>
<tr>
<td></td>
<td>3.70</td>
<td>large angular limestone BOULDERS</td>
</tr>
<tr>
<td></td>
<td>4.00</td>
<td>to hard to dig due to large limestone boulders/bedrock</td>
</tr>
</tbody>
</table>

EOH @ 3.70 m

SKETCH:

MAP

Shoring/Support: Stability:

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In-situ Vane Shear Strength (kPa)
P=Peak, R=Residual,
UTP=Unable to penetrate
- Scala Penetrometer - blows/50mm

GROUNDWATER

- None

Remarks

- Slow Seep (depth )
- Rapid Inflow (depth )

PIT TERMINATED DUE TO:

- Target depth
- Flooding
- Refusal
- Machine limit

Shear Vane No.: Logged by: MJB
All dimensions in metres
Scale 1:50

Checked by:
**TEST PIT LOG**

Project: Greymouth Flood  
Location: Greymouth  
Hole position: Between two bridges  
No.: TP14

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>[FILL] medium to coarse gravelly SAND; minor cobbles, grey, non-plastic, gravels and cobbles are rounded greywacke</td>
<td></td>
</tr>
<tr>
<td>1.50</td>
<td>silty gravelly SAND; dark brown, organic pockets, trace wood and inorganic debris</td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>angular limestone boulders inclussions</td>
<td></td>
</tr>
<tr>
<td>3.00</td>
<td>medium to coarse gravelly SAND; minor cobbles, grey, non-plastic, gravels and cobbles are rounded greywacke, angular limestone boulders</td>
<td></td>
</tr>
</tbody>
</table>

EOH @ 3.00 m

**SKETCH:**

**MAP**

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In situ Vane Shear Strength (kPa)
- P=Peak, R=Residual, U=Unlabeled to penetrate
- Scala Penetrometer - blows/50mm

**GROUNDWATER**

- None

**PIT TERMINATED DUE TO:**
- Target depth  
- Flooding
- Refusal  
- Machine limit

**Shoring/Support:**

- Stability:

**All dimensions in metres**

Scale 1:50

Shear Vane No. Logged by: MJB  
Checked by:
### Geotechnical Report

**Hole: TP15**

**Location:** Grey mouth

**Client:** Good Earth Matters

**Start Date:** 18/09/09

**Ground Level (m):**

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.20</td>
<td>[FILL] SAND, some silt and rounded greywacke gravels, brown, non plastic nodules</td>
</tr>
<tr>
<td>1</td>
<td>2.40</td>
<td>gravelly SAND, traces silt, minor cobbles, gravels and cobbles are well graded, rounded greywacke, angular/limestone boulder inclusions, occasional silty sand/pocket</td>
</tr>
<tr>
<td>2</td>
<td>3.50</td>
<td>medium grained SAND, grey, occasional tree/wood inclusions</td>
</tr>
<tr>
<td>3</td>
<td>3.70</td>
<td>seepage</td>
</tr>
<tr>
<td>4</td>
<td>5.00</td>
<td>EOH @ 5.00 m</td>
</tr>
</tbody>
</table>

**SKETCH:**

- **NORTH**
- **SAND, SOME Silt**
- **GRAVELLY SAND**
- **ALLUVIAL SAND**

**MAP:**

- **GROUNDWATER:** None
- **Remarks:**
  - **Shoring/Support:**
    - Small Disturbed Sample
    - Large Disturbed Sample
    - U100 Undisturbed Sample
    - Permeability Test
    - Schmidt Hammer
    - Uniaxial Vane Shear Strength (kPa): P=Peak, R=Residual
    - UTP=Unable to penetrate
    - Scala Penetrometer - blows/50mm

- **Target depth**
- **Flooding**
- **Refusal**
- **Machine limit**

All dimensions in metres

**Scale:** 1:50

Logged by: MJB

Checked by:

Sheet: 1 of 1
<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td></td>
<td>[FILL] medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>trace large subangular limestone boulders inclusions, up to 1m in diameter, occasional wood inclusions</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>sandy SILT, fine gravels, minor rounded gravels, brown, non plastic</td>
</tr>
<tr>
<td>3.60</td>
<td></td>
<td>medium grained SAND, grey, non plastic</td>
</tr>
<tr>
<td>3.80</td>
<td></td>
<td>3.60 m seepage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EOH @ 3.80 m</td>
</tr>
</tbody>
</table>

**SKETCH:**

**MAP:**

**Shoring/Support:**
- A: Small Disturbed Sample
- B: Large Disturbed Sample
- C: U100 Undisturbed Sample
- D: Permeability Test
- E: Schmidt Hammer
- F: In-situ Vane Shear Strength (kPa)
- G: PI/Peaks, R:Residual
- H: UTP=Unable to penetrate
- I: Scala Penetrometer - blows/50mm

**GROUNDWATER:**
- None

**Remarks:**
- Slow Seep (depth )
- Rapid Inflow (depth )
- PIT TERMINATED DUE TO:
  - X: Target depth
  - Flooding
  - Refusal
  - Machine limit

**All dimensions in metres**
- Scale 1:50

**Shear Vane No.:**

**Logged by:**
- MJB

**Checked by:**

**REVISIONS:**
- RILEY, D.B. (L.RILEY TP 094259.GRA) 09/10/2000 12:37 Produced by GRT Professional
TEST PIT LOG

Project: Greymouth Flood  
Location: Greymouth  
Hole position: Adjacent sportsclub  
No.: TP17

Job No.: 09828  
Start Date: 21-09-09  
Finish Date:  
Ground Level (m):  
Co-Ordinates ():  
Client: Good Earth Matters  
Hole Depth: 0.69 m  
Sheet: 1 of 1

Geological Description:

Elevation (m)  Depth (m)
0.25  medium to coarse gravelly SAND; minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke
0.45  SILT; some limestone gravels, light orange/brown, non plastic
0.69  medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke

EOH @ 0.69 m

SKETCH:

MAP:

Shoring/Support:

Stability:

A

B

C

Small Disturbed Sample
Large Disturbed Sample
U100 Undisturbed Sample
Permeability Test
Schmidt Hammer
In situ Vane Shear Strength (kPa)
PIT Terminated due to:
Target depth
Flooding
Refusal
Machine limit

GROUNDWATER:

None

Slow Seep (depth )
Rapid Inflow (depth )

All dimensions in metres
Scale 1:50

Shear Vane No.

Logged by: MJB  
Checked by:
Geological Description

- Elevation (m): Depth (m)
  - Limestone boulders generally <400mm in diameter with SILT, trace fine gravels, trace sand, minor clay, predominantly orangish brown void infill
  - Medium to coarse gravely SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke
  - EOH @ 0.65 m

Shoring/Support: Stability:

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In situ Vane Shear Strength (kPa)
- Pn=Peak, R=Residual
- UTP=Unable to penetrate
- SCA = Penetrometer - blows/50mm

GROUNDWATER: None

- Slow Seep (depth )
- Rapid Inflow (depth )

PIT TERMINATED DUE TO:

- Target depth
- Flooding
- Refusal
- Machine limit

Remarks

All dimensions in metres
Scale 1:50

Sheet: 1 of 1
**TEST PIT LOG**

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole position:** North fisherman's wharf

**Job No.:** 09828  
**Start Date:** 21-09-09  
**Finish Date:**  
**Ground Level (m):**  
**Co-Ordinates:** ()

**Client:** Good Earth Matters  
**Hole Depth:** 0.55 m  
**Sheet:** 1 of 1

---

**Geological Description**

- **0.45 m**
  - medium to coarse silty gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke

- **0.55 m**
  - medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke

- **EOH @ 0.55 m**
  - EOH: End of Hole

---

**Sketch**

- **South-East**

- **Silty Gravelly Sand**

- **Gravelly Sand**

---

**Map**

- **1st Hill**

---

**Plotting and Drafting Details**

- **A**  
  - Small Disturbed Sample  
  - Large Disturbed Sample  
  - U100 Undisturbed Sample  
  - Permeability Test  
  - Schmidt Hammer  
  - In-situ Vane Shear Strength (kPa)  
  - UTP: Unable to penetrate  
  - Penetrometer - blows/50mm

- **GROUNDBWATER**
  - **None**

- **Remarks**

- **PIT TERMINATED DUE TO:**
  - Target depth
  - Flooding
  - Refusal
  - Machine limit

---

**All dimensions in metres**

**Scale 1:50**

**Shear Vane No.:**

**Logged by:** MUB  
**Checked by:**

---
TEST PIT LOG

Project: Greymouth Flood
Location: Greymouth
Hole position: Above Fisherman's wharf
No.: TP20

Job No.: 09828
Start Date: Finish Date: Ground Level (m): Co-Ordinates ():

Client: Good Earth Matters
Hole Depth: 0.70 m

Geological Description

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Soil Description</th>
<th>Rock Description</th>
<th>Defect Description</th>
<th>Samples</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70</td>
<td>gravelly SAND, rounded greywacke gravel generally minor rounded greywacke cobble, dark brown, non plastic</td>
<td>(Topsoil) gravelly silty SAND, rounded greywacke gr</td>
<td></td>
<td></td>
<td></td>
<td>PSD test</td>
</tr>
<tr>
<td>0.50</td>
<td>plastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Samples: Tests

SKETCH:

MAP

Shoring/Support: Stability:

Small Disturbed Sample
Large Disturbed Sample
UL100 Undisturbed Sample
Permeability Test
Schmidt Hammer
Insitu Vane Shear Strength (kPa)
UTP=Unable to penetrate
Scala Penetrometer - blows/50mm

GROUNDWATER

None

Slow Seep (depth )
Rapid Inflow (depth )
PIT TERMINATED DUE TO:
Target depth
Flooding
Refusal
Machine limit

All dimensions in metres
Scale 1:50

Shear Vane No.

Logged by: MJB
Checked by:
**TEST PIT LOG**

**Project:**
Greymouth Flood

**Location:**
Greymouth

**Hole position:**
Crest of stopbank

**Job No.:**
09828

**Start Date:**
21-09-09

**Finish Date:**

**Ground Level (m):**

**Co-Ordinates (°):**

**No.:**
TP21

**Sheet:**
1 of 1

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
<th>Rock Description</th>
<th>Defect Description</th>
<th>Samples</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td></td>
<td>(Topsoil) gravelly silty SAND, rounded greywacke gravels generally minor rounded greywacke cobbles, dark brown, non plastic, roots.</td>
<td>Weathering:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.80</td>
<td></td>
<td>medium to coarse gravelly SAND, minor cobbles, grey, non plastic, gravels and cobbles are rounded greywacke</td>
<td>Rock:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EOH @ 0.80 m**

**SKETCH:**

**MAP:**

**Shoring/Support:**
Stability:

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In-situ Vane Shear Strength (kPa)
- P-Peak, R=Residual
- UTP=Unable to penetrate
- Scala Penetrometer - blows/50mm

**GROUNDWATER:**
None

**Remarks:**

- Slow Seep (depth)
- Rapid Inflow (depth)
- PIT TERMINATED DUE TO:
  - Target depth
  - Flooding
  - Refusal
  - Machine limit

**All dimensions in metres**

**Scale:** 1:50

**Shear Vane No.:**

**Logged by:**
MJB

**Checked by:**

---

RILEY CONSULTANTS

4 Fred Thomas Drive

Takapuna, AUCKLAND

Tel: 09 4897872

Fax: 09 4897873
Project: Greymouth Flood
Location: Greymouth
Hole position: Adjacent culvert
No.: TP22

Job No.: 09828  Start Date: 22-09-09  Finish Date:  
Ground Level (m):  Co-Ordinates ():

Client: Good Earth Matters

Hole Depth: 1.80 m

Sheet: 1 of 1

Geological Description

Elevation (m) | Depth (m) |
-------------|-----------|
0.25         | gravelly SAND, minor silt/topsoil, rounded greywacke gravels generally <30mm in diameter, dark brown, non plastic, rootlets |
1.10         | SILT, minor clay, minor rounded greywacke gravels, trace to minor sand, light grey and orange, non plastic, trace to minor roots, occasional inorganic debris |
1.80         | large limestone BOULDERS, occasional large concrete block, approximately 1.0m |

EOH @ 1.80 m

Tests

PSD test

SKETCH:

MAP

Shoring/Support: Stability:

- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In-situ Vane Shear Strength (kPa)
- Piezo, R-Residual
- UTP=Unable to penetrate
- Scala Penetrometer - blows/50mm

GROUNDWATER

- None

- Slow Seep (depth )
- Rapid Inflow (depth )

PI T TERMINATED DUE TO:

- Target depth
- Flooding
- Refusal
- Machine limit

All dimensions in metres
Scale 1:50

Shear Vane No.
Logged by: MJB
Checked by:
**TEST PIT LOG**

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole position:** Below Road  
**Job No.:** 09828  
**Start Date:** 22-09-09  
**Finish Date:**  
**Ground Level (m):**  
**Co-Ordinates:** ()  
**No.:** TP23b  
**Client:** Good Earth Matters  
**Sheet:** 1 of 1

**Elevation (m)**  
**Depth (m)**  

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Geological Description</th>
<th>Legend</th>
<th>Field Strength</th>
<th>Defect Description</th>
<th>Samples</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td></td>
<td>gravelly silty SAND (boulders); rounded greywacke gravels &lt;150mm in diameter, dark brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.60</td>
<td></td>
<td>coarse grained gravelly SAND; rounded greywacke gravels Fine-mix minor rounded greywacke cobbles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Elevation (m):** 0.60 m  
**Field Strength:** Rock Description

---

**SKETCH:**

**MAP:**

**SHORING/SUPPORT:**

- Small Disturbed Sample  
- Large Disturbed Sample  
- U100 Disturbed Sample  
- Permeability Test  
- Schmidt Hammer  
- In situ Vane Shear Strength (kPa)  
- P好奇, R=Residual, U=Unstable to penetrate  
- Scalp Penetrometer - blows/50mm

**GROUNDWATER:** None

**REMARKS:**

- Slow Seep (depth )
- Rapid Inflow (depth )

**PIT TERMINATED DUE TO:**

- Target depth  
- Flooding  
- Refusal  
- Machine limit

**All dimensions in metres**  
**Scale:** 1:50  
**Shear Vane No.:**  
**Logged by:** MJB  
**Checked by:**
### Test Pit Log

**Project:** Greymouth Flood  
**Location:** Greymouth  
**Hole position:** Crest of stopbank  
**Job No.:** 09828  
**Start Date:**  
**Finish Date:**  
**Ground Level (m):**  
**Co-Ordinates:** ()  
**No.:** TP24a  
**Client:** Good Earth Matters  
**Hole Depth:** 1.00 m  
**Sheet:** 1 of 1

#### Geological Description

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Depth (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>TOPSOIL, sand, mirror silt, rounded gravels, gravelly sand, rounded greywacke gravels generally 50mm in diameter, trace rounded greywacke cobbles, medium grey, non plastic.</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>EOH @ 1.00 m</td>
<td></td>
</tr>
</tbody>
</table>

#### SKETCH:

- **Shoring/Support:** Stability
- **GROUNDWATER:** None
- **Remarks:**
  - **PIT TERMINATED DUE TO:**
    - Target depth  
    - Flooding  
    - Refusal  
    - Machine limit

#### All dimensions in metres

**Scale:** 1:50

---

**Legend:**
- Small Disturbed Sample
- Large Disturbed Sample
- U100 Undisturbed Sample
- Permeability Test
- Schmidt Hammer
- In situ Vane Shear Strength (kPa)
- P=Peak, R=Residual
- UTP=Unable to penetrate
- Scala Penetrometer - blows/50mm

**MAP:**

**Shear Vane No.:**  
**Logged by:** MJB  
**Checked by:**
Geological Description

Soil Description: subordinate, particle size, MAJOR, minor; colour, structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit.

Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit.

Material description is of drilled tailings except for SPT split spoon core samples.

Located on intermediate bench behind dolphin statue, 1.7m from wall supporting top bench.

Remarks

Material description is of drilled tailings except for SPT split spoon core samples.

Located on intermediate bench behind dolphin statue, 1.7m from wall supporting top bench.
<table>
<thead>
<tr>
<th>Run</th>
<th>Fluid &amp; Water</th>
<th>Legend</th>
<th>Depth (m)</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>SPT 2.50 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0</td>
<td>SPT 2.50 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.0</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>5.5</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0</td>
<td>SPT 4.00 m</td>
<td></td>
</tr>
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</table>

**Geological Description**

**Soil Description:** subordinate, particle size; MAJOR, minor; colour; structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit.

**Rock Description:** weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit.

**Material description is of drilled tailings except for SPT split spoon core samples.**

Located on bench 13m downstream of culvert, 3.5m off north edge of vehicle track.

**Remarks**

- Located on bench 13m downstream of culvert, 3.5m off north edge of vehicle track.

**All dimensions in metres**

Scale 1:48

**Checked by:**

CW Drilling & Investigation Ltd

Hitachi Ex60 Multidrill

Barclay Moir
**Geological Description**

Soil Description: subordinate, particle size, MAJOR, minor; colour, structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit.

Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit.

**Grey fine to medium GRAVEL with some sand and minor silt. Moist (FILL)**

**Sandy GRAVEL with minor silt. Moist to wet (ALLUVIUM)**

2.60 m - 2.70 m lens of organic black/yellow organic (fibrous) silt, low plasticity.

2.80 m Becomes moist to wet

4.00 m - 4.45 m (SPT core) Grey gravelly coarse SAND. Wet to saturated

Angular chips of light brown mudstone (COBDEN LIMESTONE)

EOH @ 7.20 m
Material description is of drilled tailings except for SPT split spoon core samples.

Located immediately southwest of culvert on Hill Quay, Cobden (south side of road).
APPENDIX 3

Laboratory Test Results
Material Test Report

Client: Riley Consultants Ltd
PO Box 4355
Christchurch Mail Centre
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details
Sample ID: CAN09S-6040
Client Sample ID: TP10 O/N 09828
Material: Clay
Sample Source: Miscellaneous Source
Site/Sampled From: Greymouth Flood Walls TP10
Date Sampled: 18/09/2009
Specification: No Specification

Sampling By: Advised - See Comments
Sampling Method: As Received - Not Accredited
Date Tested: 30/09/2009
Technician: Max Burford
Sampling Endorsed: No

Other Test Results

<table>
<thead>
<tr>
<th>Description</th>
<th>Method</th>
<th>Result</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Size Distribution</td>
<td>NZS 4407:1991 Test 3.8.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying by: Oven</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>75.0mm</td>
<td>100</td>
<td>0–100</td>
</tr>
<tr>
<td>63.0mm</td>
<td>93</td>
<td>0–100</td>
</tr>
<tr>
<td>37.5mm</td>
<td>87</td>
<td>0–100</td>
</tr>
<tr>
<td>19.0mm</td>
<td>83</td>
<td>0–100</td>
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<td>300µm</td>
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<td>150µm</td>
<td>62</td>
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</tr>
<tr>
<td>75µm</td>
<td>57</td>
<td>0–100</td>
</tr>
</tbody>
</table>

Comments
N/A
Material Test Report

Client: Riley Consultants Ltd
PO Box 4355
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details

<table>
<thead>
<tr>
<th>Sample ID:</th>
<th>CAN09S-6043</th>
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<tbody>
<tr>
<td>Client Sample ID:</td>
<td>TP12 O/N 09828</td>
</tr>
<tr>
<td>Material:</td>
<td>Gravelly Sandy SILT</td>
</tr>
<tr>
<td>Sample Source:</td>
<td>Miscellaneous Source</td>
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<td>Site/Sampled From:</td>
<td>Greymouth Flood Walls TP 12</td>
</tr>
<tr>
<td>Date Sampled:</td>
<td>18/09/2009</td>
</tr>
<tr>
<td>Specification:</td>
<td>No Specification</td>
</tr>
<tr>
<td>Sampled By:</td>
<td>Advised - See Comments</td>
</tr>
<tr>
<td>Sampling Method:</td>
<td>As Received - Not Accredited</td>
</tr>
<tr>
<td>Date Tested:</td>
<td>30/09/2009</td>
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<tr>
<td>Technician:</td>
<td>Max Burford</td>
</tr>
<tr>
<td>Sampling Endorsed:</td>
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Other Test Results

<table>
<thead>
<tr>
<th>Description</th>
<th>Method</th>
<th>Result</th>
<th>Limits</th>
</tr>
</thead>
</table>

Particle Size Distribution

![Particle Size Distribution Diagram]

Method: NZS 4407:1991 Test 3.8.2
Drying by: Oven

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>75.0mm</td>
<td>100</td>
<td>0 - 100</td>
</tr>
<tr>
<td>63.0mm</td>
<td>92</td>
<td>0 - 100</td>
</tr>
<tr>
<td>37.5mm</td>
<td>82</td>
<td>0 - 100</td>
</tr>
<tr>
<td>19.0mm</td>
<td>75</td>
<td>0 - 100</td>
</tr>
<tr>
<td>9.5mm</td>
<td>72</td>
<td>0 - 100</td>
</tr>
<tr>
<td>4.75mm</td>
<td>69</td>
<td>0 - 100</td>
</tr>
<tr>
<td>2.36mm</td>
<td>68</td>
<td>0 - 100</td>
</tr>
<tr>
<td>1.18mm</td>
<td>67</td>
<td>0 - 100</td>
</tr>
<tr>
<td>600μm</td>
<td>65</td>
<td>0 - 100</td>
</tr>
<tr>
<td>300μm</td>
<td>59</td>
<td>0 - 100</td>
</tr>
<tr>
<td>150μm</td>
<td>50</td>
<td>0 - 100</td>
</tr>
<tr>
<td>75μm</td>
<td>46</td>
<td>0 - 100</td>
</tr>
<tr>
<td>63μm</td>
<td>45</td>
<td>0 - 100</td>
</tr>
</tbody>
</table>

Comments

Sampled by Alan Williams
Field Moisture Content = 20.7%
Material Test Report

Client: Riley Consultants Ltd
PO Box 4355
Christchurch Mail Centre
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details
Sample ID: CAN09S-6047
Client Sample ID: TP 22 O/N 90828
Material: Sandy SILT
Sample Source: Miscellaneous Source
Site/Sampled From: Greymouth Flood Walls TP 22
Date Sampled: 21/09/2009
Specification: No Specification
Sampled By: Advised - See Comments
Sampling Method: As Received - Not Accredited
Date Tested: 30/09/2009
Technician: Max Burford
Sampling Endorsed: No

Other Test Results

<table>
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<th>Description</th>
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<th>Limits</th>
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<tr>
<td>Field Moisture Content</td>
<td></td>
<td>37.6%</td>
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Comments
Sampled by Alan Williams
Field Moisture Content = 37.6%

Particle Size Distribution

Method: NZS 4407:1991 Test 3.8.2
Drying by: Oven

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
<th>Limits</th>
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<tr>
<td>9.5mm</td>
<td>100</td>
<td>0 - 100</td>
</tr>
<tr>
<td>4.75mm</td>
<td>100</td>
<td>0 - 100</td>
</tr>
<tr>
<td>2.36mm</td>
<td>99</td>
<td>0 - 100</td>
</tr>
<tr>
<td>1.18mm</td>
<td>99</td>
<td>0 - 100</td>
</tr>
<tr>
<td>600μm</td>
<td>99</td>
<td>0 - 100</td>
</tr>
<tr>
<td>425μm</td>
<td>98</td>
<td>0 - 100</td>
</tr>
<tr>
<td>300μm</td>
<td>97</td>
<td>0 - 100</td>
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<tr>
<td>150μm</td>
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<tr>
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<td>77</td>
<td>0 - 100</td>
</tr>
<tr>
<td>63μm</td>
<td>70</td>
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</table>
Maximum Dry Density Report

Client: Riley Consultants Ltd
PO Box 4395
Christchurch Mail Centre
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details
Sample ID: CAN09S-6040
Client Sample ID: TP10 O/N 09828
Date Sampled: 18/09/09
Sampling Method: As Received - Not Accredited
Date Tested: 30/09/09
Technician: Max Burford

Material: Clay
Material Source: Miscellaneous Source
Sampled By: Advised - See Comments
Sampled From: Greymouth Flood Walls TP10
Specification: No Specification
Endorsed Sample?: No

Dry Density - Moisture Relationship

Test Results

NZS 4402:1986 Test 4.1.1

Maximum Dry Density (t/m³): 1.54
Optimum Moisture Content (%): 26
Assumed Solid Density (t/m³): 2.660
Oversize Sieve (mm): 19.0
Oversize Material (%): 17
Sample History: Natural

Comments
As received moisture content = 33.8%
Sorry about X axis - this computer system is a work in progress
Material Test Report

Client: Riley Consultants Ltd
PO Box 4355
Christchurch Mail Centre
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details
Sample ID: CAN09S-6045
Client Sample ID: TP18 O/N 09828
Material: Sandy Gravel
Sample Source: Miscellaneous Source
Site/Sampled From: Greymouth Flood Walls TP18
Date Sampled: 21/09/2009
Specification: No Specification
Sampled By: Advised - See Comments
Sampling Method: As Received - Not Accredited
Date Tested: 30/09/2009
Technician: Max Burford
Sampling Endorsed: No

Other Test Results

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<th>Limits</th>
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<td>5.1%</td>
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Particle Size Distribution

Method: NZS 4407:1991 Test 3.8.2
Drying by: Oven

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<td>106mm</td>
<td>92</td>
<td>0–100</td>
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<tr>
<td>63.0mm</td>
<td>92</td>
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<tr>
<td>37.5mm</td>
<td>81</td>
<td>0–100</td>
</tr>
<tr>
<td>19.0mm</td>
<td>67</td>
<td>0–100</td>
</tr>
<tr>
<td>13.2mm</td>
<td>57</td>
<td>0–100</td>
</tr>
<tr>
<td>9.5mm</td>
<td>48</td>
<td>0–100</td>
</tr>
<tr>
<td>6.7mm</td>
<td>42</td>
<td>0–100</td>
</tr>
<tr>
<td>4.75mm</td>
<td>38</td>
<td>0–100</td>
</tr>
<tr>
<td>2.36mm</td>
<td>34</td>
<td>0–100</td>
</tr>
<tr>
<td>1.18mm</td>
<td>32</td>
<td>0–100</td>
</tr>
<tr>
<td>600μm</td>
<td>28</td>
<td>0–100</td>
</tr>
<tr>
<td>425μm</td>
<td>24</td>
<td>0–100</td>
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<tr>
<td>300μm</td>
<td>19</td>
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<tr>
<td>150μm</td>
<td>8</td>
<td>0–100</td>
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<tr>
<td>75μm</td>
<td>5</td>
<td>0–100</td>
</tr>
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</table>

Comments
Sampled by Alan Williams
Field Moisture Content = 5.1%
Material Test Report

Client: Riley Consultants Ltd
PO Box 4355
Christchurch Mail Centre
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details
Sample ID: CAN09S-6041
Client Sample ID: TP7 O/N 09828
Material: Sandy Gravel
Sample Source: Miscellaneous Source
Site/Sampled From: Greymouth Flood Walls TP7
Date Sampled: 17/09/2009
Specification: No Specification
Sampled By: Advised - See Comments
Sampling Method: As Received - Not Accredited
Date Tested: 30/09/2009
Technician: Max Burford
Sampling Endorsed: No

Other Test Results

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Particle Size Distribution

Method: NZS 4407:1991 Test 3.8.2
Drying by: Oven

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<tr>
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<tr>
<td>63.0mm</td>
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<tr>
<td>37.5mm</td>
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<td>0 – 100</td>
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<tr>
<td>19.0mm</td>
<td>71</td>
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<tr>
<td>13.2mm</td>
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<tr>
<td>9.5mm</td>
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<tr>
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<tr>
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<td>23</td>
<td>0 – 100</td>
</tr>
<tr>
<td>600µm</td>
<td>20</td>
<td>0 – 100</td>
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</tr>
<tr>
<td>75µm</td>
<td>5</td>
<td>0 – 100</td>
</tr>
</tbody>
</table>

Comments
Sampled by Alan Williams
Field moisture Content = 15.5%
**Material Test Report**

**Client:** Riley Consultants Ltd  
PO Box 4355  
Christchurch 8140  
NZ

**Project:** QA Testing - Aggregates

---

**Sample Details**

- **Sample ID:** CAN09S-6042  
- **Client Sample ID:** TP11 O/N 90828  
- **Material:** Sandy Gravel  
- **Sample Source:** Miscellaneous Source  
- **Site/Sampled From:** Greymouth Flood Walls TP11  
- **Date Sampled:** 18/09/2009  
- **Specification:** No Specification  
- **Sampled By:** Advised - See Comments  
- **Sampling Method:** As Received - Not Accredited  
- **Date Tested:** 30/09/2009  
- **Technician:** Max Burford  
- **Sampling Endorsed:** No

---

**Other Test Results**

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<th>Limits</th>
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<tr>
<td>Drying by:</td>
<td>Oven</td>
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**Particle Size Distribution**

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<tr>
<th>Sieve Size</th>
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<th>Limits</th>
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<tbody>
<tr>
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<td>19.0mm</td>
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<tr>
<td>13.2mm</td>
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</tr>
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<td>2.36mm</td>
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</tr>
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<td>0 – 100</td>
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<td>300µm</td>
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<td>0 – 100</td>
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<td>150µm</td>
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<td>0 – 100</td>
</tr>
<tr>
<td>75µm</td>
<td>4</td>
<td>0 – 100</td>
</tr>
</tbody>
</table>

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**Comments**

- Sampled by Alan Williams  
- Field Moisture Content = 4.5%
Material Test Report

Client: Riley Consultants Ltd
PO Box 4355
Christchurch Mail Centre
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details
Sample ID: CAN09S-6044
Client Sample ID: TP4 O/N 09B28
Material: Sand
Sample Source: Miscellaneous Source
Site/Sampled From: Greymouth Flood Walls TP4
Date Sampled: 17/09/2009
Specification: As Received
Sampled By: Advised - See Comments
Sampling Method: As Received - Not Accredited
Date Tested: 30/09/2009
Technician: Max Burford
Sampling Endorsed: No

Other Test Results

<table>
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<tr>
<th>Description</th>
<th>Method</th>
<th>Result</th>
<th>Limits</th>
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</thead>
<tbody>
<tr>
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<td>NZS 4407:1991 Test 3.8.2</td>
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<tr>
<td>Sieve Size</td>
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<td>Limits</td>
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<tr>
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<td>63.0mm</td>
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<tr>
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<td>65</td>
<td>0 – 100</td>
<td></td>
</tr>
<tr>
<td>13.2mm</td>
<td>57</td>
<td>0 – 100</td>
<td></td>
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<td>0 – 100</td>
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<td>4.75mm</td>
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<td>2.36mm</td>
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</tr>
<tr>
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<td>0 – 100</td>
<td></td>
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<tr>
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<td>32</td>
<td>0 – 100</td>
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<tr>
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Comments
Field moisture content = 4.3%
Material Test Report

Sample Details
Sample ID: CAN09S-6046
Client Sample ID: TP20 O/N 09828
Material: Sandy Gravel
Sample Source: Miscellaneous Source
Site/Sampled From: Greymouth Flood Walls TP20
Date Sampled: 21/09/2009
Specification: No Specification
Sampled By: Advised - See Comments
Sampling Method: As Received - Not Accredited
Date Tested: 30/09/2009
Technician: Max Burford
Sampling Endorsed: No

Other Test Results

Description Method Result Limits

Particle Size Distribution

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.0mm</td>
<td>100</td>
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<tr>
<td>37.5mm</td>
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<td>19.0mm</td>
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<tr>
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</tr>
<tr>
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<td>0–100</td>
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<td>0–100</td>
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<tr>
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Method: NZS 4407:1991 Test 3.8.2
Drying by: Oven

Comments
Sampled by Alan Williams
Field Moisture Content = 15.9%
Material Test Report

Client: Riley Consultants Ltd
PO Box 4355
Christchurch Mail Centre
Christchurch 8140
NZ

Project: QA Testing - Aggregates

Sample Details

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<td>TP 13 O/N 90828</td>
</tr>
<tr>
<td>Material</td>
<td>Sandy Gravel</td>
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<tr>
<td>Sample Source</td>
<td>Miscellaneous Source</td>
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<tr>
<td>Site/Sampled From</td>
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<tr>
<td>Sampling Method</td>
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<tr>
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<tr>
<td>Technician</td>
<td>Max Burford</td>
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Other Test Results

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<tr>
<th>Description</th>
<th>Method</th>
<th>Result</th>
<th>Limits</th>
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Particle Size Distribution

![Particle Size Distribution Graph]

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
<th>Limits</th>
</tr>
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<tbody>
<tr>
<td>63.0mm</td>
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<td>0 - 100</td>
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<tr>
<td>37.5mm</td>
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<tr>
<td>19.0mm</td>
<td>86</td>
<td>0 - 100</td>
</tr>
<tr>
<td>13.2mm</td>
<td>73</td>
<td>0 - 100</td>
</tr>
<tr>
<td>9.5mm</td>
<td>65</td>
<td>0 - 100</td>
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<tr>
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<td>600μm</td>
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<td>300μm</td>
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<td>0 - 100</td>
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<td>0 - 100</td>
</tr>
<tr>
<td>75μm</td>
<td>7</td>
<td>0 - 100</td>
</tr>
</tbody>
</table>

Comments

Sampled by Alan Williams - Field Moisture Content = 18.9%
Estimated Total Coal Content of Sample = 46% (Calculated from 19.0mm - 4.75mm by mass )
(minus 4.75mm fraction by bulk density)
APPENDIX 4

Stability Assessment Printouts
Safety Factor

0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+

Name: 2_bridges_v1
Location: T:\2009 Jobs\09828 - Greymouth Flood Walls\PROJECT TECHNICAL\4.2 Geotechnical\SLIDE analysis\bridges_v1.sli

Material Properties

Material: FILL
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion: 0 kPa
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Existing Fill
Strength Type: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Friction Angle: 35 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Surfacial Alluvium
Strength Type: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Alluvium
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 35 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: ROCK
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 1000 kPa
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1
Material Properties

Material: FILL
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion: 0 kPa
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Existing Fill
Strength Type: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Friction Angle: 35 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Surficial Alluvium
Strength Type: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Friction Angle: 21 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Alluvium
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 35 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: ROCK
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 1000 kPa
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1
Material Properties

Material: FILL
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion: 0 kPa
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Existing Fill
Strength Type: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Friction Angle: 35 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Surficial Alluvium
Strength Type: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Friction Angle: 21 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Alluvium
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Friction Angle: 35 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: ROCK
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 1000 kPa
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1
C.3 STOPBANK CONSTRUCTION – EARTHWORKS

C.3.1 SCOPE

This section of the specification covers:

- All earthworks for the stopbank raising inclusive of fill materials brought from off site.
- Preparation of ground surfaces for filling and concrete structures.
- Temporary drainage.

C.3.2 GROUND CONDITIONS

RILEY has completed a geotechnical investigation in new stopbank foundation areas and existing stopbanks where raising is to take place. The results of the ground investigation are presented in RILEY report 09828-A (attached). The contractor shall familiarise themselves with the contents of this report, which provides background information on soil types, groundwater and constructability aspects of the project.

C.3.3 EXCAVATIONS AND PREPARATION FOR FILL

This work consists of excavation below the stripped surfaces until suitable foundations for placement of fill materials is uncovered and includes:

- removal of materials within the stopbank footprint for areas of new stopbank,
- preparation of existing stopbanks for placement of additional fill,
- preparation of existing stopbanks for construction of concrete flood walls.

C.3.3.1 Clearing

All areas to be occupied by the permanent construction shall be cleared of all vegetation, such as grass, scrub, exposed roots, and any other organic material prior to stripping. Cleared materials shall be disposed of in dump areas to be designated by the Engineer.

C.3.3.2 Stripping

Stripping refers to the removal from all areas subject to excavation or filling, of all organic material remaining after clearing, i.e. topsoil, peat and humus. These materials shall be removed to expose soil or rock containing insignificant amounts of organic material.

All significant volumes of topsoil shall be stockpiled for later re-use. Materials containing insufficient amounts of topsoil for practical separation shall be disposed of in dump areas to be designated by the Engineer.

C.3.3.3 Drainage

All areas to be filled shall have effective surface drainage at all times. Temporary diversions or other suitable methods shall be utilised to keep surface and subsurface water away from the works area. All earthworks shall be carried out in the dry.

Any remedial work or extra excavation that could have been avoided by good drainage and sound earthwork practices shall be completed at no cost to the Principal.
C.3.3.4 New Stopbank Foundations

C.3.3.4 (a) General
New stopbanks will be constructed in the Goods Shed, 2-Bridges and Cobden areas. Geotechnical investigations indicate undercut to varying extents will be required to provide a suitable foundation of stopbank fill. Final undercut profiles will be determined by the Engineer on site. Prior to any filling, the stopbank footprint will be exposed and inspected by the Engineer. The Contractor shall be responsible for maintenance of the approved surface until filling commences.

(b) Goods Shed
The new stopbank section is located within a previously reclaimed goods loading area. Recently the area appears to have been used to stockpile coal. It is anticipated that at least 0.5 m of undercut will be required to remove the disturbed upper layer of fill, which contains coal fragments and other deleterious material.

(c) 2-Bridges
The new stopbank abuts the existing railway fill, and is located in an area of previously reclaimed riverbed. Geotechnical investigations indicate that 1 m to 3 m of fill overlies 1 m to 2 m of soft river sediment, which overlies 0 m to 2 m of dense granular river sediment, over bedrock. Where the new stopbank crest is to be more than 3 m above existing ground level, it is envisaged that the existing fill be removed along with the soft river sediment, and the stopbank founded on the underlying dense gravel. The deeper sub-excavations will be below the groundwater level (as well as the typical Grey River level), and Contractors shall also note extensive seepage occurs from the base of the rock bluff.

(d) Cobden
The new stopbank will be founded on top of the existing stopbank/road embankment. It is anticipated that no undercut will be required to obtain a suitable fill foundation; however the existing road pavement should be removed, along with all grass, topsoil and soft fill materials associated with the existing small stopbank adjacent to the road.

C.3.3.5 Preparation of Existing Stopbanks for Raising
Existing stopbanks to be raised by less than 200 mm shall be cleared of grass and/or vegetation along the crest, exposing topsoil free of grass, scrub, exposed roots, and any other organic material.

Existing stopbanks to be raised by more than 200 mm shall be cleared and stripped along the crest, exposing the underlying granular bank fill and low permeability river-side silty gravel capping layer.

C.3.3.6 Preparation for Concrete Flood Walls
This applies to the proposed concrete flood walls in the Mawhera Quay and Fisherman's Wharf areas. The walls are generally located on the river-side of the stopbank, with their foundation keying into the existing silty gravel zone identified in the geotechnical investigation.
The specified wall foundation cut shall be made to the river-side portion of the stopbank, exposing the silty gravel zone. If the silty gravel zone is not exposed, additional excavation will be directed. Testing shall be completed by the Contractor on the exposed silty gravel zone to confirm material type, consistency, density and moisture content. Scarifying, moisture conditioning, and compaction of the in situ soil may be directed by the Engineer depending on the results of testing.

If the additional excavation is more than 200 mm below the design wall foundation level for a significant length, compacted type 2 earth fill may be used to bring the foundation to design level.

### C.3.4 FILL MATERIALS

#### C.3.4.1 General

The stopbank fill materials shall be obtained from borrow areas off site.

#### C.3.4.3 General Stopbank Fill (Type 1)

General stopbank fill shall be sourced off site. The material shall consist of a well graded sand/gravel mix conforming to the grading limits indicated in Table 1. The envelope is based on the envelope of tests on the existing stopbank material. In addition the d15 value shall be less than 0.7 mm to maintain filter compatibility with Type 1 material.

<table>
<thead>
<tr>
<th>Particle Size (mm)</th>
<th>Percent Passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>9.5</td>
<td>40 - 80</td>
</tr>
<tr>
<td>1.18</td>
<td>20 - 50</td>
</tr>
<tr>
<td>0.075</td>
<td>0 – 15</td>
</tr>
</tbody>
</table>

#### C.3.4.4 Low Permeability Fill (Type 2)

River-side low permeability fill (where specified) shall be sourced off site from an appropriate quarry or borrow area. The material shall consist of well graded silt, sand and gravel mix of low permeability (or a silt/sand mixture ?). The envelope is based on the envelope of tests on the existing stopbank material. The particle size distribution after handling and placement shall conform to Table 2. If the material is produced by mixing two materials the contractor shall demonstrate to the Engineers satisfaction that effective mixing is obtained at all times. In locations where concrete structures will be in direct contact with type 2 fill (i.e. concrete flood walls) the maximum particle size shall be 20mm.

<table>
<thead>
<tr>
<th>Particle Size (mm)</th>
<th>Percent Passing (%) - General type 2 fill</th>
<th>Percent Passing (%) - Type 2 fill in contact with concrete structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>80 - 100</td>
<td>100</td>
</tr>
<tr>
<td>1.18</td>
<td>60 -100</td>
<td>60-100</td>
</tr>
<tr>
<td>0.075</td>
<td>35 - 85</td>
<td>35 - 85</td>
</tr>
</tbody>
</table>
C.3.4.6 Filter Cloth and Riprap

Riprap is specified in a separate section of this specification. However, the following points should be observed where riprap is specified over type 2 fill on new sections of stopbank, and adjacent to new sections of concrete floodwall.

Filter cloth shall be placed between riprap and the underlying soil to protect the stopbank fill and ensure it does not disperse into the riprap. Cloth joints shall be lapped 500 mm minimum. No material shall be permitted between the lapped sections of cloth. The cloth shall be placed without folds or wrinkles.

Where riprap abuts concrete structures, filter fabric shall be affixed to the concrete by battens or similar prior to placement of riprap. The fabric shall be in continuous contact with the underlying soil, requiring the overlying riprap to be sufficiently well graded to effectively hold it in place.

Riprap shall be placed in such a way that the underlying fabric is not damaged.

C.3.5 PLACEMENT AND COMPACTION OF FILL

C.3.5.1 General

Fill shall be placed to the lines and levels indicated on the drawings or otherwise instructed by the Engineer. The requirements for fill quality are specified in Section C.3.6.

Any material not complying with the specified requirements shall be removed at no cost to the Principal.

All bulk earthworks shall be carried out in fully drained conditions with no free water on the working surfaces. Cut and fill areas shall be sloped and graded adequately so that they do not pond stormwater, and drains shall be installed as necessary on a regular basis to deflect run off from the areas of operation or to drain ponded water as soon as ponds are seen to develop.

No fill shall be placed during periods of wet weather. In the event of fill operations ceasing in any area on account of wet weather or for more than two days for any reason, the Contractor shall obtain the Engineer’s approval of the conditions of the fill surface before recommencing fill operations. The engineer may direct removal, conditioning or scarifying of all or part of the exposed sections of fill prior to earthworks resuming.

No new fill shall be placed over previously placed fill that has not achieved the required standard of compaction, has become contaminated, or has deteriorated from the required fill standards. Previously placed fill which does not comply shall be reinstated or removed at no cost to the Principal. Positive and effective drainage shall be maintained during filling operations to minimise deterioration of material exposed in the upper fill layers. Special care shall be taken to avoid hollows which could pond runoff.

The combined operations of spreading and compacting shall be undertaken using very systematic and properly managed procedures to the satisfaction of the Engineer, to ensure that the entire surface of each loose layer receives the specified minimum number of passes of the roller before further loose material is spread.
The specified minimum number of passes shall apply even if tests indicate the compaction requirements are met with fewer passes. Compaction of all material shall be carried out using specialised compacting equipment, separate from that used for transportation.

C.3.5.1 Placement and Compaction of Type 1 Fill

The fill shall be spread out in a uniform thickness layer. Loose layer thickness shall not exceed 200 mm.

Compaction of fill shall be carried out using a 10-tonne (static weight), smooth steel drum vibrating roller. Each fill layer shall be given at least four passes, even if compaction tests are met with fewer passes.

Where stopbank fill abuts sloping ground steeper than 18º (1V:3H), the natural ground or fill being filled against shall be keyed in. The horizontal width of the key shall be equal to the thickness of the compacted layer.

Prior to placement of the next lift, compaction tests in accordance with section 3.7 shall be carried out, and any areas found to be deficient repaired. All areas in which remediation of deficient fill has been necessary shall be re-tested in accordance with section 3.7 prior to additional fill being placed.

C.3.5.5 Acceptance Standards for Fill

General Fill (Type 1)

Deflection of the fill during a proof roll shall be less than 3 mm, and no weaving shall be permitted.

At the 2 Bridges location, type 1 fill shall also be subject to:

- Minimum of 95% of optimum dry density as obtained from a Standard Compaction Test, and
- Maximum of 5% air voids averaged over 10 consecutive tests, and 7% on any one test.

Low Permeability Fill (Type 2)

- Minimum of 95% of optimum dry density as obtained from a Standard Compaction Test, and
- Maximum of 5% air voids averaged over 10 consecutive tests, and 7% on any one test.

C.3.5.6 Unsuitable Material

Unsuitable material shall be placed removed from the site, and disposed of by the contractor.
C.3.5.7 Topsoil and Grassing

Topsoil shall be placed on all stopbank batters and crests that will not be otherwise surfaced (i.e. roads). Topsoil shall be free of stones and vegetation or roots. It shall be placed with a minimum thickness of 200 mm, and be compacted via track rolling. Grassing is covered in a separate section of this specification.

C.3.5.8 Tolerances and Profiles

The construction tolerances for the project are defined elsewhere, however in relation to the type 2 fill zone located on the river-side of the stopbank, the dimensions indicated on the drawings are minimum dimensions. The type 2 fill material is permitted to extend up to half the total stopbank width, with the final thickness to be nominated by the contractor on the basis of material costs and anticipated construction methodologies.

C.3.6 QUALITY CONTROL

The Contractor shall appoint an experienced full time earthworks supervisor, whose duties shall include the control of filling operations in accordance with this specification.

The Contractor shall undertake sufficient tests on site to become thoroughly familiar with fill types and behaviour under compaction, and satisfy himself that the compacted fill meets the specified requirements.

All material control tests shall be carried out and paid for by the Contractor.

The testing shall be carried out by an IANZ registered laboratory or their representative for the tests indicated. This shall include both laboratory and field testing. The results shall be supplied to the Engineer demonstrating compliance with this specification, at no less than every two weeks. Any non compliance shall be reported at the weekly meeting and actions taken. Formal results shall be provided to the Engineer for each monthly progress payment. Up to 10% payment over and above retentions will be withheld if this information is not provided, or is incomplete, accompanying the progress payment application, at the Engineer’s discretion. The scope and frequency of testing can only be altered at the instruction of the Engineer.

If requested by the Engineer, testing shall be carried out in the full time presence of the Engineer or his representative.

At any location the Engineer may carry out his own tests at his discretion. If there is any discrepancy the Engineer’s results shall prevail.

C.3.7 TESTING REQUIREMENTS

C.3.6.1 Compaction Testing

Control tests shall be carried out by the Contractor.

The fill compaction requirements and related tests are defined in Table 3 and the list of qualifying notes.
Table 3: Test methods

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Method and/or Test Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum moisture/density</td>
<td>Standard compaction test as per NZS 4402:1986</td>
</tr>
<tr>
<td>Air voids</td>
<td>As defined in NZS 4402:1986 and involving intermediate tests in situ density, water content and solid density below</td>
</tr>
<tr>
<td>In-situ density</td>
<td>NDM Method</td>
</tr>
<tr>
<td>Water content</td>
<td>NDM Method, with confirmatory laboratory tests as per NZS 4402:1986, Test 2.1</td>
</tr>
<tr>
<td>Solid density</td>
<td>NDM Method</td>
</tr>
<tr>
<td>Sieve analysis</td>
<td>NZS 4402:1986, Test 2.8.1</td>
</tr>
</tbody>
</table>

**Note 1:** In situ Density - The air voids content of the compacted soil at any test location shall be taken as the mean of the air voids results from a set of density tests. A set of density tests shall comprise two or more individual tests made within an area of 0.5 m².

The frequency of testing will depend on the consistency of the fill operations and materials. The testing rate will be generally as follows at the commencement of filling.
Table 4: Fill testing regime

<table>
<thead>
<tr>
<th>Test</th>
<th>Material</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>In situ moisture/ density (NDM method with laboratory moisture content)</td>
<td>Type 1 fill (at new 2 Bridges and Cobden stopbanks only)</td>
<td>1 set per 1000 m³ fill placed</td>
</tr>
<tr>
<td></td>
<td>In situ silty gravel riverside face on existing stopbanks (at new concrete flood wall locations only)</td>
<td>1 set per 50 m length</td>
</tr>
<tr>
<td></td>
<td>Type 2 fill</td>
<td>1 set per lift over 50 m length</td>
</tr>
<tr>
<td>Standard Compaction test (Proctor Test)</td>
<td>Type 1 fill (specifically the material to be used at the 2 Bridges fill)</td>
<td>2 sets prior to start of construction</td>
</tr>
<tr>
<td></td>
<td>Type 2 fill</td>
<td>2 sets prior to start of construction, 1 set per 500 m³ thereafter</td>
</tr>
<tr>
<td>Sieve Analysis</td>
<td>Type 1 fill</td>
<td>3 sets prior to start of construction, 1 set per 2,000 m³ thereafter.</td>
</tr>
<tr>
<td></td>
<td>Type 2 fill</td>
<td>3 sets prior to start of construction, 1 set per 500 m³ thereafter.</td>
</tr>
</tbody>
</table>

The Engineer may reduce or increase the frequency of testing as he judges appropriate, depending on the consistency of the results.

C.3.6.2 Inspections and Approvals

The following critical points during construction must be inspected by the Engineer prior to further work being carried out in the area. No filling, concrete work, or quarry excavation for fill purposes shall commence without the Engineer’s approval. All surfaces are to be surveyed for quantity measurement purposes. The Engineer must be informed at least 48 hours prior to the following hold points being reached, to ensure construction is not delayed.

Hold Points

- Inspection of each section of stripped, excavated and trimmed concrete floodwall foundation, prior to placement of concrete.
- For all sections of stopbank to be raised by more than 200 mm, inspection of each section of stripped, excavated and trimmed stopbank prior to placement of fill.
- Inspection of the prepared subgrade prior to placement of any fill at each of the Goods Shed, 2-Bridges and Cobden areas.
- At the 2-Bridges site, inspection of the installed culverts and their interfaces with the in situ rock and associated drainage works prior to backfilling.