OPUS

Buller District Council

Westport No.1 Water Tunnel Repairs Option 2d (Stabilising + Piping)

Feasibility Study

October 2017

Buller District Council

Westport No.1 Water Tunnel

Option 2d (Stabilising + Piping)

Feasibility Study

October 2017

Prepared By

Greg Birdling
Principal Environmental Engineer

Michael Duff
Council Group Manager, Assets & Infrastructure

Reviewed By

John Black
Technical Principal, Environmental Engineering

Approved for Release By

Christopher Bergin
Project Manager

Opus International Consultants Ltd
Christchurch Environmental Office
12 Moorhouse Avenue
PO Box 1482, Christchurch Mail Centre,
Christchurch 8140
New Zealand

Telephone: +64 3 363 5400
Facsimile: +64 3 365 7858

Date: 18 October 2017
Reference: 6-wblu0.33
Status: Final

© Opus International Consultants Ltd 2017

Contents

1 Executive Summary ... 1

2 Introduction ... 3
- 2.1 Background ... 3
- 2.2 References ... 4

3 Project Definition ... 5
- 3.1 Project Charter ... 5
- 3.2 Objectives ... 5
- 3.3 Scope of Work ... 5
- 3.4 Key Performance Indicators ... 6
- 3.5 Stakeholders' Expectations ... 6
- 3.6 Project Work Breakdown Structure ... 6
- 3.7 Project Delivery Model ... 7
- 3.8 Budget ... 7
- 3.9 Project Programme ... 7

4 Strategy ... 8
- 4.1 Long Term Plan Alignment ... 8
- 4.2 Strategic Alternatives ... 8
- 4.3 Options Analysis ... 9
- 4.4 Future Work ... 10

5 Planning ... 11
- 5.1 Statutory Requirements ... 11
- 5.2 District Plan Assessment ... 11
- 5.3 Regional Plan Assessment ... 12
- 5.4 Assessment of Effects ... 16
- 5.5 Consultation ... 18
- 5.6 Other Statutory Considerations ... 18
- 5.7 Archaeology ... 18
- 5.8 Tangata Whenau & Iwi ... 18

6 Project Execution Strategy ... 19
- 6.1 Overall Approach ... 19
- 6.2 Engineering ... 19
- 6.3 Procurement ... 19
- 6.4 Construction ... 20
- 6.5 Commissioning ... 20
- 6.6 Project Funding ... 20
- 6.7 Owner's Role ... 21
- 6.8 Project Management Plan ... 21

7 Project Organisation ... 22
- 7.1 Project Team Overview ... 22
- 7.1 Integrated Owner's Team ... 23

7.2 Contractor 24
7.3 Roles & Responsibilities 24
7.4 Authorities & Signatories 24

8 Health, Safety, Environmental & Community 25
8.1 Health & Safety 25
8.2 Environment 25
8.3 Community & Social 25
8.4 Security 26
8.5 Communications 26

9 Risk 27
9.1 Overview 27
9.2 Risk Management 28
9.3 Risk Assessments 28
9.4 Key Risks 28

10 Engineering 29
10.1 Design Criteria 29
10.2 Engineering Management 29
10.3 Civil Works 29
10.4 Piping 30

11 Procurement 33
11.1 Overview 33
11.1 Procurement Strategy 33
11.2 Procurement Process 34
11.3 Contracting Model 35

12 Construction 37
12.1 Construction Management 37
12.2 Access 37
12.3 Tie-in Plans 37
12.4 Heavy & Special Lifts 38
12.5 Constructability 38
12.6 Work Package Management 38
12.7 Site Administration 38
12.8 Testing 38
12.9 Commissioning Management 39
12.10 Handover 39

13 Project Services 40
13.1 Project Controls 40
13.2 Baseline Establishment 40
13.3 Work Breakdown Structure 40
13.4 Change Management 40
13.5 Earned Value & Forecasting 41
13.6 Project Support Functions 42

14 Operations 43
14.1 Operational Readiness 43
14.2 Pre-commissioning, Commissioning & Handover 43

15 Capital Cost Estimate 44
15.1 Basis & Accuracy of Estimate 44
15.2 Owner's Costs 44
15.3 Escalation & FOREX 44
15.4 Contingency 44
15.5 Cash Flow Forecasts 45
15.6 Range Analysis 45
15.7 Estimates for Future Work 45
15.8 Cost Breakdown Structure 45

16 Operating Cost Estimate 46
16.1 Basis & Accuracy of Estimate 46
16.2 Start-Up Costs 46
16.3 Escalation & FOREX 46
16.4 Contingency 46

17 Conclusions 47
17.1 General 47
17.2 Feasibility and Risks 47
17.3 Residual Systemic Risks 48

18 Appendix A1 – Risk Register 49

19 Appendix A2 – Geotech Ground Engineering Proposed Methodology 50

20 Appendix A3 – Capital Cost Estimate 51

21 Appendix A4 – Project Program 52

22 Appendix A5 – Archaeological Assessment 53

23 Appendix A6 – Opus Supplementary Options' Report 54

24 Appendix A7 – Options Workshop Report 55

25 Appendix B1 – Project Charter 56

26 Appendix B2 – Project Management Plan (Example) 58

27 Appendix B3 – Project Status Report Template 59

28 Appendix B4 – Change Management Flowchart 60

1 Executive Summary

This report assesses the feasibility of the proposed repairs to Buller District Council's (Council) Westport No.1 water tunnel which supplies raw water to the Westport Water Treatment Plant for potable supply to the town of Westport and Carters Beach. This tunnel has suffered a rockfall approximately 350-450m upstream from the downstream portal which has completely stemmed the water flow through the tunnel since late 2016.

A proposed repair methodology has been developed since the previous report in conjunction with a geotechnical contractor, who has in turn discussed the proposed methodology with Worksafe NZ. It is now proposed to progressively enter the tunnel, assessing and stabilising as necessary to make the tunnel safe until the collapse area is encountered. The fallen material and timbering will then be removed using similar techniques to those used in the past, using a tramway and wagons to transport the material to the downstream portal for disposal. The area where the fall had occurred will then be assessed and stabilised to reduce the risk of further collapse.

A pipe will then be installed from upstream of the active collapse area back to the connection to No. 2 Tunnel (a total length of approximately 500m). This will have some low-strength dry-mix concrete blown in on top and the sides to provide some additional protection and strength in the event of future collapses. A bulkhead will be installed at the upstream end to direct water into the pipeline, and an elbow at the intersection with No. 2 Tunnel to direct flow into that tunnel.

A key factor in the viability of this project is selecting a suitable contractor to undertake the physical works. They must be suitably experienced and qualified, able to satisfy Worksafe of their competence and proposed methodology, as well as having the necessary practical skills to provide a high quality and durable outcome.

We have made an assessment of the feasibility, risks and costs associated with undertaking this work. The key outcomes from this study are:

1. The estimated cost of the work is $2M (median value) with an assessed range of $1.4-2.5M.

2. It is expected that the proposed underground works will be acceptable to Worksafe, and that the works can be effected in accordance with accepted safety standards. The specific nature of the work proposed for stabilisation is not unusual in the context of tunnelling work.

3. Previous assessments have identified a number of other systemic risks to the tunnel system which conveys water from Giles Creek, particularly from an existing landslide, a possible fault and the general seismicity of the area. There is a distinct possibility that substantial monies could be spent on this repair, only to find that another event will require additional expenditure on other at-risk sections of the supply, e.g. Nos. 2 and 3 Tunnels. The residual risk of this will not be reduced by this project.

4. Council's stated preference is to run a conventional public tender process. There is a risk that tenders may not be forthcoming or may not be acceptable as the risk profile may make the project commercially unattractive. A more collaborative process may be required which will have the effect of openly sharing the risk between the parties. Such a process is likely to be more time-consuming and will require Council to identify and shortlist potential contractors, but may be the only way to affordably progress the works.

In summary, the proposed work appears to be feasible, i.e. it should be physically possible to make repairs as intended which will give the desired result, and to undertake these works within the prescribed safety margins for this type of work. Worksafe are not able to give 'pre-approvals' for the methodology, but discussions with them to date have been favourable, and no fatal impediments to the proposed underground methodology have been identified.

There remains uncertainty relating to the extent of the collapse and the final cost of repairs, allowing for reasonable contract variations.

2 Introduction

2.1 Background

The town of Westport is normally supplied with water sourced from Giles Creek, a tributary of the Orowaiti River, about 6 km south-east of Westport. Buller District Council (Council) own and operate this water supply system. The estimated peak water demand is 7,685 m^3/day and the average daily demand is 4,858 m^3/day.

Water is abstracted by gravity from Giles Creek, and enters a series of four tunnels before discharging into a series of storage ponds near the water treatment plant (WTP). These tunnels were constructed at the beginning of the 20^{th} century and were hand-hewn through the sandstone hillsides, with timber shoring installed at sections where the tunnels were not self-supporting.

At various times, particularly since the year 2000, there have been minor collapses which reduced or cut off the water supply to Westport. These were previously made good by a repair crew entering the tunnel, removing the fallen material, and installing additional or repaired timber shoring as required.

In 2014, a significant collapse occurred approximately 400m from the downstream portal of No. 1 Tunnel, which initially reduced the water flow and increased its turbidity. The flow of water then stopped completely in late 2016, which may be due to further collapses or movement of material.

An alternative pumped supply from the lower Orowaiti River with a capacity of 80-90 L/s has been used to supply water for Westport since the tunnel failure. This system is expensive to operate (circa $20k per month in energy and maintenance costs). In addition, a temporary supply has been effected from Ballarat Creek using a generator and pump which is providing an additional 15-20 L/s raw water supply into the ponds. The cost of this is also significant (in the order of $10-12k per month).

A number of alternative options to repair No. 1 Tunnel have been considered at length. Council were initially not prepared to allow people to enter the tunnel for repairs as was done in the past due to safety concerns, and an alternative repair methodology using pipe-jacking was developed and costed. However, the estimated cost of this was very high and Council have acknowledged that tunnel entry may be the only economic means of repair and that the associated safety risks will need to be managed and accepted. The option considered in this report, Option 2d, has been developed from the various Option 2 solutions previously considered. The main difference is that Option 2d includes installing some pipe following stabilisation of the tunnel and removal of the collapse.

The purpose of this report is to present a feasibility assessment of the enter and repair methodology, focussing on the following matters in particular:

- Technical feasibility
- Health and Safety
- Costs
- Risks
- Programme

To assist with the development of the methodology and cost estimates, Geotech Ground Engineering (Geotech) have been engaged, with Terra Firma Mining Ltd. (TFM) providing peer review.

2.2 References

We note that there is a significant amount of relevant material available from previous site investigations, engineering assessments, reports, cost estimates and the like. In particular, these include:

1. Geotech Ground Engineering Ltd (Oct 2017): *Westport water tunnels – Risk assessment and construction methodology – Proposed tunnel remediation works*
2. Opus, (Jul 2017): *Westport No.1 Water Tunnel – Option 3a (extended) Feasibility Study*
3. Open Earth Consulting (Dec 2016): *Geotechnical Assessment and Fall Recovery Options for Tunnel No.1, Westport Water Supply*
4. Opus (Mar 2016): *Westport Water Tunnel No 1 Refurbishment Options – Supplementary Report*
5. Opus (Dec 2015): *Westport Water Tunnel No 1 Refurbishment Options*
6. Opus (Feb 2015): *No. 1 Tunnel – Partial Collapse Repair – Preliminary Design Report*
7. Opus (Mar 2010): *Westport Water Supply Selection & Treatment Assessment – Tunnel Condition Risk, Natural Hazard Analysis*
8. CJ Coil (Sep 2000): *Waterworks Plans & Elevation Drawings*

Contained within many of these references are drawings, surveys, sketches and diagrams that will be of value to a potential contractor. There are also relevant photographic and video records from within and around the tunnels. Much of this information was collected by entry into the tunnel with camera equipment, and further deterioration or rockfalls may have occurred since.

3 Project Definition

3.1 Project Charter

The Project Charter formally recognises the project and provides a reference of authority for its viability and purpose. The project goals and objectives are summarised into a written agreement between the Project Manager and the Project Control Group.

The Project Charter also delineates between the roles and responsibilities of each position, which is reflected in the Project Governance Model.

A draft Project Charter is appended, and will be finalised by the Project Manager at the commencement of the implementation phase.

3.2 Objectives

The objectives of this project are to:

1. Restore the water supply capacity of the tunnel to at least 140 L/s under typical conditions (this is 150% of the existing peak-day demand).

2. Provide a durable solution that minimises the risk of future failure in the repaired tunnel section. A design life of 100 years for the installed pipe is required.

3. Minimise or eliminate maintenance requirements to the repaired section.

4. Minimise or avoid the need for any future man-entry to the tunnel.

5. Effect the repairs in a way that minimises the risk to workers. In particular, the repair methodology shall avoid working in any sections of the tunnel that have not been assessed and (where necessary) strengthened.

6. Provide a cost-effective and timely solution consistent with meeting the above objectives.

3.3 Scope of Work

The proposed scope of work is as follows:

1. Enabling works as required to provide access and working space. This may optionally include daylighting from the downstream portal of No. 1 Tunnel to the connection to No. 2 Tunnel if the contractor considers this to be to their advantage.

2. Progressive assessment and stabilisation of the existing No. 1 Tunnel as required from the downstream portal to the area of collapse.

3. Removal of the collapsed material and stabilisation of the remaining tunnel sections. It is not expected that much, if any, work will be required in the top 600m or so from the tunnel entrance portal.

4. Installation of a pipe into No. 1 Tunnel for approximately 500m upstream from the junction with No. 2 Tunnel in order to extend beyond the collapsed area of the tunnel into an area that is more stable (in conjunction with targeted stability improvements).

5. Merging the inlet of the piped section with the upstream tunnel in order to capture all of the abstracted water, and providing a connecting bend into No. 2 Tunnel.

3.4 Key Performance Indicators

Key performance indicators for this project include:

1. The repaired tunnel provides the design flow rate with high reliability.

2. There are no harm accidents during the project.

3. All legal requirements are demonstrably met – particularly relating to health and safety, resource management, and construction.

4. There is satisfaction within the community that the project provides a cost-effective, long-term outcome.

5. No complaints are received from iwi in respect of the project implementation.

6. The environmental impact of the work is minimised.

3.5 Stakeholders' Expectations

The stakeholders' expectations are considered to be:

1. The project safely delivers the key performance indicators.

2. The residual risks to the supply are minimised.

3. No incidents occur during the project that reduce the prestige or mana of the stakeholders.

3.6 Project Work Breakdown Structure

The work will be broken into a number of distinct phases. These are:

1. Preliminary design

2. Preparation of Contract Documentation

3. Tendering, Evaluation, negotiation (if required) and Award.

4. Design submissions and notification of proposed works and methodology to Worksafe NZ at least 2 months prior to commencement. (Worksafe will advise if the work may not proceed due for health and safety reasons, but do not issue a formal approval).

5. Establishment on site.

6. Enabling works' construction

7. Main works construction.
8. Commissioning.
9. Reinstatement & disestablishment.
10. Completion.

These phases are discussed further in subsequent sections.

3.7 Project Delivery Model

Refer to the Project Organisation and Procurement sections for details of the proposed project delivery model.

3.8 Budget

The minimum recommended budget that should be made available for the project is $2M. We note that this includes a 20% contingency, and that there is a possibility that the project will cost more than this. Additional funding may be required if tender prices are higher than estimated, or if tunnel conditions require more extensive stabilisation work than expected.

3.9 Project Programme

We have prepared an indicative programme for the project with assistance from Geotech and TFM. This programme is appended and suggests that at least 60 weeks should be allowed from commencing preliminary design work and the preparation of Contract Documents through to completion. This assumes that there are no significant delays, and also assumes that some enabling works will proceed during the 2 month Worksafe notification period.

4 Strategy

4.1 Long Term Plan Alignment

The Westport No.1 Water Tunnel project aligns with Council's Long Term Plan (LTP) and commitment to provide safe, adequate and reliable drinking water for the supplies BDC are responsible for. This supports the overall health and well-being of the community as safe, potable water is an essential need for both private use and commercial operations.

Council is the registered drinking water supplier for the Westport & Carters Beach network, as per the register maintained by the Director General of Health under Section 69J of the Health Act 1956. Drinking water suppliers must comply with the Health (Drinking Water) Amendment Act 2007, including duties and responsibilities specified under Drinking Water Standards NZ rev 2008. In order to provide adequate and reliable drinking water, the raw water supply to the treatment plant must be guaranteed.

4.2 Strategic Alternatives

The raw water reservoirs for the Westport & Carters Beach network are normally supplied through a gravity-flow tunnel system upstream of the treatment plant. The system consists of races and four tunnels (numbered 1 through to 4), which supply the reservoir ponds. The No.1 Tunnel is the longest and closest to the abstraction (intake) point in Giles Creek.

After the partial collapse of No.1 Tunnel in 2014, Council commissioned an options study to identify the best alternatives for guaranteed supply. Several options were proposed (refer Table 4 of the Opus Supplementary Report March 2016 which is appended). These options included tunnel repair (stabilisation), microtunneling (pipe-jacking) and directional drilling.

At the time, the tunnel repair Option 2a was selected on the basis of affordability, whilst acknowledging this was a medium-term solution that would still leave Council with a moderate level of risk.

Further collapse and obstruction within the No.1 Tunnel occurred late 2016, resulting in complete blockage of water flow through the No.1 Tunnel. Raw water is currently being supplied to the reservoirs from the alternative pumped system which must operate near-continuously to meet demand.

In addition, recent changes to Health & Safety and legislative requirements means that tunnel repairs must satisfy mining and quarrying regulations, causing an escalation in risk control measures and costs when compared to the original options study assessment.

As a result, Council initially resolved to eliminate all tunnel repair solutions from consideration (including Option 2a), on the basis that a longer-term solution with lower residual risk would be more aligned with the LTP. With tunnel repairs eliminated, the focus for the feasibility study changed to selecting another option from those remaining in Table 4 of the Opus Supplementary Report March 2016. The selection process was managed through an Options Workshop.

4.3 Options Analysis

After clarifying the desired outcome of affordable, adequate and reliable water supply, the Options Workshop process identified key objectives and corresponding criteria from which to assess the options.

Following a bottom-up evaluation and top-down review, Option 3a (Extended) was unanimously selected as the go-forward option on which to complete the previous feasibility study. Option 3a was a Pipe-Jacking solution through the existing tunnel.

The (Extended) suffix denotes an increase in length from the originally scoped 450m for Option 3a, up to approximately 660m in order to clear the worst tunnel sections (refer Figure 4-1 below). This improves the reliability of the option significantly, as the remaining 500m of tunnel is in relatively sound condition, i.e. virtually unchanged since 1903. Refer to the appendices for a full report of the Options Workshop.

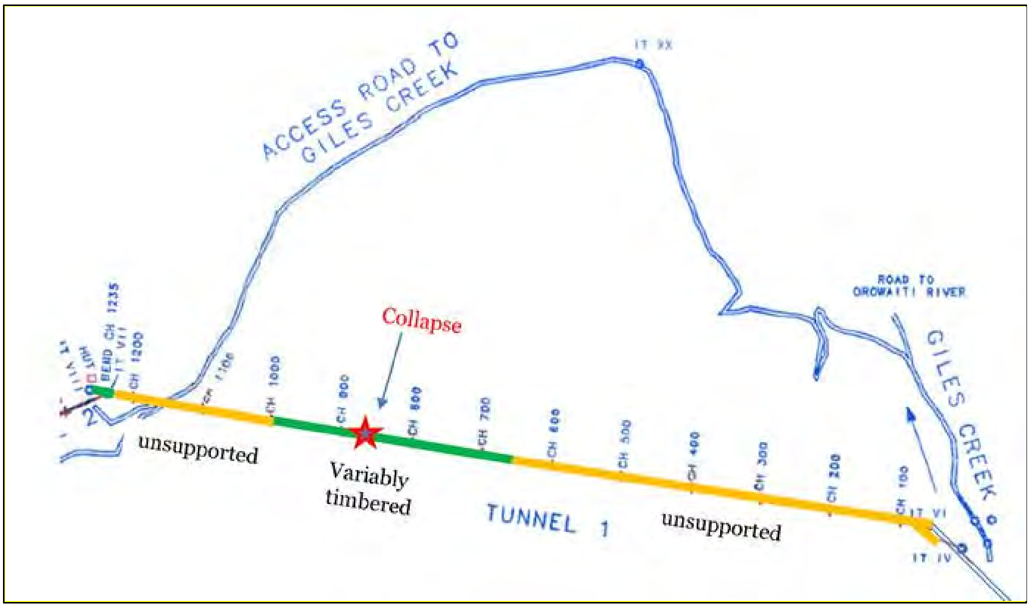


Figure 4-1: No. 1 Tunnel Schematic

The feasibility study identified that the likely cost for Option 3a was high, in the order of $5M, and also had a number of significant risks. Based on this, Council decided that the options involving tunnel entry and stabilisation would need to be reconsidered (i.e. the Option 2 theme).

Geotech and TFM were selected by Council to provide advice based on their practical experience with these tunnels, undertaking repairs previously. Their recommendation was to stabilise the tunnel and clear the collapse, which they considered to be feasible, and install a pipe in the less-stable part of the tunnel (the 500m upstream from the junction with No. 2 Tunnel). In their view, the previous tunnel stabilisation work using timber sets and shoring was not very effective due to the gap between the shoring and the tunnel walls. They proposed that stabilising could be effectively undertaken by installing rockbolts, mesh, and W links between the bolts which had previously been carried out in a trial section of the tunnel.

A new option, Option 2d, was developed from this in collaboration with Opus who advised on pipe options, hydraulics and pipe installation. It is proposed that the pipe is covered with lean, dry-mix concrete to provide additional strength, resilience and reliability.

4.4 Future Work

Option 2d would mean that future entry from the lower portal of the tunnel is effectively unavailable, although it would leave a crawl space that could be used as an emergency exit and for ventilation purposes.

The upstream section of the tunnel from Giles Creek for approximately 600m is considered to be relatively stable, and access could be effected from this end in future if required to assess and stabilise this section. It would also be possible to install piping in this section as well in a similar fashion when and if required.

5 Planning

5.1 Statutory Requirements

The Buller District Plan and the Regional Land and Water Plan are the relevant documents in this instance. We have undertaken a high-level review of these Plans but have not examined the objectives and policies of these documents in detail.

Please note, the land is held for 'Water Conservation purposes' having been gazetted under the Land Act 1948. This suggests that the Reserves Act may be relevant.

5.2 District Plan Assessment

The site of the proposed works is zoned *Rural* in the Buller District Planning Maps.

A preliminary assessment of the Buller District Plan has identified the following possible resource consent requirements:

Table 5-1: District Plan Assessment

Rule number	Rule description	Assessment
Rural Zone- Permitted activity-5.3.2.1.2	Network utilities are permitted activities in the Rural Zone subject to compliance with Part 6 (Infrastructure).	Likely to comply.
Rural Zone- Permitted activity- 5.3.2.1.3	Indigenous vegetation clearance (excluding natural wetlands) up to 0.5ha per site, in total, over any continuous three year period.	Further assessment will be required to determine extent of vegetation clearance required to provide heavy vehicle access to the site.
Rural Zone – Permitted activity- Table 5.7	To be permitted the activity must involve no modification within 25m of a natural wetland larger than 0.5ha, 20m of a lake and 10m of a river or streambank where the river or stream has an average bed width greater than 3m	N/A- At this stage of the project no work is proposed within any riparian margin. Please refer to this rule if during detailed design any earthworks are proposed within any riparian margin.
Rural Zone- Controlled activity- 5.3.2.2.1	Indigenous vegetation clearance and incidental earthworks (excluding natural wetlands) from 0.5ha up to 5.0ha per site, in total, over any continuous three year period. The matters over which control are reserved are: -5.3.2.2.1.1. Location and dimensions of areas to be cleared and vegetation type. -5.3.2.2.1.2. Effects on archaeological, cultural or historic sites. -5.3.2.2.1.3. Effects on habitat of any threatened or protected species. -5.3.2.2.1.4. Effects on waterbodies and riparian margins. -5.3.2.2.1.5. Clearance methods. -5.3.2.2.1.6. Protection of areas of significant indigenous vegetation or significant habitats of indigenous fauna identified using the criteria in Policy 4.8.7.4 as a guideline.	Further assessment will be required to determine the extent of vegetation clearance required to improve heavy vehicle access to the site. Should vegetation clearance exceed 0.5ha, resource consent will be required as a controlled activity.

Table 5-1: District Plan Assessment		
Rule number	**Rule description**	**Assessment**
Infrastructure, Services & other Activities District Wide- Permitted activity- 6.2.18.1 and/or 6.2.18.3	Temporary activities which are incidental to building and construction and temporary storage and buildings are permitted subject to the relevant conditions.	Likely to comply.
Infrastructure, Services & other Activities District Wide- Discretionary activity- 6.4.2.6	New roads and associated facilities including retaining walls, culverts, bridges and traffic signs and control devices on legal road.	N/A- at this stage of the project this rule is not relevant. However, during detailed design should it be identified that a new road, retaining wall, culvert or bridge is required, resource consent will most likely be required as a discretionary activity.
District Wide Rules- Noise Standards- 7.8.3.4	Construction noise emanating from any site shall not exceed the limits recommended in, and be measured and assessed in accordance with the provisions of New Zealand Standard 6803P:1984 "The Measurement and Assessment of Noise from Construction, Maintenance, and Demolition Work".	Likely to comply provided the standards of this Rule are abided by.

5.3 Regional Plan Assessment

A preliminary assessment of the Regional Land and Water Plan has identified the following possible resource consent requirements:

Table 5-2: Regional Plan Assessment		
Rule number	**Rule description**	**Assessment**
Rule 2- Earthworks in riparian margins	Earthworks within riparian margins, and any associated discharge of sediment are a **permitted activity** if all of the following conditions are met: (a) The volume of earthworks in the riparian margin must not exceed 25m^3 and must not involve the cumulative disturbance of more than 20 linear metres in any 200 metre length of riparian margin; and (b) Sufficient sediment control is constructed so that the activity does not cause the visual clarity of any receiving water to decrease by more than 40%, as measured by black disc beyond 12 times the river's width or 200 metres of the activity, whichever is the lesser; and (c) No soil or debris is placed directly in any river or lake bed; and (d) There is no conspicuous deposition of sediment on the bed of any water body; and (e) The activity does not affect any surface water take; and (f) There is no disturbance to inanga (whitebait) and other native fish spawning habitat at any site listed in Schedule 11 during the months of December to May inclusive; and (g) Earthworks are carried out such that: i) Formed surfaces with an inward cross fall must have a constructed form of drainage control such as a water table, kerb and channel, swale, channel/ditch, or sumps and pipes, to avoid causing erosion; and ii) Any culverts or cut and fill batters are designed and constructed or installed to prevent their failure and avoid causing erosion; and iii) Trenches for the purpose of installing pipes, lines, or cables are backfilled and compacted as soon as practicable; and (h) No refuelling of equipment takes place on any area of a riverbed; and (i) The activity does not cause or contribute to any slope or land instability, including subsidence or other erosion; and (j) All areas of bare ground created by the activity are protected from soil erosion as soon as practicable; and (k) No earthworks occur within any wetland identified in Schedule 1; and (l) No earthworks occur within any wetland identified in Schedule 2 unless it meets the requirements of Rule 7.	N/A- At this stage of the project no work is proposed within any riparian margin. Please refer to this rule if during detailed design any earthworks are proposed within any riparian margin. Please note, Giles Creek (the closest waterbody to the site of the proposed works) is not listed in Schedule 11 and the area is not listed as a wetland in Schedule 1.

Table 5-2: Regional Plan Assessment		
Rule number	**Rule description**	**Assessment**
Rule 6- Earthworks for the purpose of maintenance or repair	Earthworks for the purpose of maintaining or repairing a road, track, railway line, landing, drilling pad, stand-off pad, firebreak, structures and infrastructure associated with a hydroelectric generation scheme, or network utility line, pipe, or cable, and any associated discharge of sediment is a **permitted activity** if all of the following conditions are met: (a) Formed surfaces with an inward cross fall must have a constructed form of drainage control such as a water table, kerb and channel, swale, channel/ditch, or sumps and pipes to avoid causing erosion; and (b) Sufficient sediment control must be constructed so that the activity does not cause the visual clarity of any receiving water to decrease by more than 40%, as measured by black disc beyond 12 times the river's width or 200 metres from the activity, whichever is the lesser; and (c) No soil or debris is placed directly in any river or lake bed, or wetland identified in Schedule 1 or 2; and (d) There is no conspicuous deposition of sediment on the bed of any water body, or on land beyond the boundary of the subject property; and (e) The activity does not affect any surface water take; and (f) Any culverts or cut and fill batters are maintained so as to prevent their failure and avoid causing erosion; and (g) Trenches for the purpose of maintaining lines, pipes, or cables are backfilled and compacted as soon as practicable; and (h) Any activity does not cause or contribute to any slope or land surface instability, including subsidence or other erosion; and (i) No refuelling of equipment takes place on any area of a riverbed; and (j) All areas of bare ground created by the activity and any stockpiles of material are protected from soil erosion as soon as practicable; and (k) The activity is not within any wetland identified in Schedule 1; and (l) The activity is not within any wetland identified in Schedule 2 unless it meets the requirements of Rule 7.	The proposed activity is likely to meet the conditions of this rule. However, further assessment will be required during the detailed design phase of the project. Please note, Giles Creek (the closest waterway) is not listed in Schedule 11 and the area is not listed as a wetland in Schedule 1.

Table 5-2: Regional Plan Assessment

Rule number	Rule description	Assessment
Rule 8- Vegetation disturbance in riparian margins	Vegetation Disturbance within riparian margins is a **permitted activity** if all of the following conditions are met: (a) Native Vegetation is only removed where: i) It is causing bank erosion; or ii) It is toxic to livestock; or iii) The activity is undertaken in conjunction with permitted activity Rule 2 or 7; and (b) There is no disturbance to inanga (whitebait) and other native fish spawning habitat at any site listed in Schedule 11 during the months of December to May inclusive; and (c) The activity does not cause or contribute to land instability or erosion; and (d) All areas of bare ground created by the activity are protected from soil erosion as soon as practicable; and (e) No debris is placed directly in any river or lake bed, or in any wetland identified in Schedule 1 or 2.	N/A- At this stage of the project no work is proposed within any riparian margin. Please refer to this rule if during detailed design any vegetation disturbance is proposed within any riparian margin.
Rule 9- Vegetation disturbance in Erosion Prone Area One, Two, or the Greymouth Earthworks Control Area and outside any riparian margin	Vegetation Disturbance in Erosion Prone Area One, Erosion Prone Area Two, or the Greymouth Earthworks Control Area, and outside any riparian margin, and any associated discharge of sediment, is a **permitted activity** if all of the following conditions are met: (a) The area disturbed is less than 20m^2 if undertaken within Erosion Prone Area Two or the Greymouth Earthworks Control Area; and (b) Sufficient sediment control is constructed so that the activity does not cause the visual clarity of any receiving water to decrease by more than 40%, as measured by black disc beyond 12 times the river's width or 200 metres from the activity, whichever is the lesser; and (c) No soil or debris is placed directly in any river or lake bed; and (d) There is no conspicuous deposition of sediment on the bed of any water body, or on land beyond the boundary of the subject property; and (e) The activity does not affect any surface water take; and (f) All areas of bare ground created by the activity are protected from soil erosion as soon as practicable; and (g) The activity does not cause or contribute toward any slope or land surface instability, including subsidence or other erosion; and (h) The activity is not within any wetland identified in Schedule1; and (i) The activity is not within any wetland identified in Schedule 2 unless it meets the requirements of Rule 7.	The proposed activity will need to be assessed against this rule once it has been established how much vegetation removal is required and where.

Table 5-2: Regional Plan Assessment		
Rule number	**Rule description**	**Assessment**
Rule 22- Placement of any pipe, line, or cable on or under the bed of a lake or river	The placement of any pipe, line, or cable on or under the bed of a lake or river, is a **permitted activity**, provided the following conditions are met: (a) The pipe, line, or cable does not impede the flow of water or debris, or is installed and maintained so it results in no flooding, erosion or sedimentation; and (b) The location of the pipe, line, or cable is identified by markers on the banks of the river or lake; and (c) The pipe, line, or cable is maintained in good repair; and (d) Where the pipe is located within any wetland identified in Schedule 1 or 2 its maximum diameter is 150mm; and (e) Where the activity is undertaken in any wetland identified in Schedule 1 or 2: i) There is no native vegetation clearance in excess of 0.6 metres in width per 1 metre in length; and ii) There is no change to the natural flow, path or fluctuation in water level; and iii) There is no disturbance to inanga (whitebait) and other native fish spawning habitat at any site listed in Schedule 11 during the months of December to May inclusive; and iv) No bird nests are disturbed.	Should the proposed pipe be on or under the bed of any river provided the conditions are meet is likely to be permitted.
Rule 71- Discharge of any contaminant, or water to water, not complying with Rules 63 to 70	Unless permitted by Rules 63, 64, 65, 66, 67, 68, 69 or 70 the discharge of any contaminant or water to water is a **discretionary activity**	N/A- At this stage it is assumed that no sediment will be discharged into any water. This rule will apply if during detailed design of the project it is identified that the proposed works will result in any sediment being discharged into any water, its likely resource consent will be required as a discretionary activity.

Please note: Giles Creek is identified in Schedule 7B of the Regional Land and Water Plan. This Schedule identifies existing water takes from lakes, rivers, and groundwater where the water taken is used for public water supply purposes. The potential impact of activities on these takes will be taken into account when considering applications for resource consents.

5.4 Assessment of Effects

The following environmental effects arising from the proposed activity will need to be assessed and any methods proposed to avoid, remedy or mitigate the environmental effects noted in Table 5-3.

Table 5-3: Potential Environmental Effects	
Effect	**Comment**
Noise	Some changes to the local noise environment. However, given the remote location of the site it is unlikely to be a significant issue.
Air Quality	Some very minor localised changes. However, given the remote location of this site it is unlikely to be a significant issue.
Water Resources	At this stage no work is proposed within any riparian zone or riverbed. Should during detailed design of the project it be established that works are required within any riparian zone or river bed the effects on water quality will need to be assessed. The proposed work seeks to improve long term access to water for the residents of Westport.
Ecological	Further assessment required once the extent of disturbance is confirmed. The site is likely to hold ecological value given its location and surrounding indigenous forest.
Culture & Heritage	The proposed site is not identified in the Buller District Plan or listed as a Historic Site by Heritage New Zealand but does have heritage value. The site is not identified in Schedule 16 of the Regional Land and Water Plan, nor in Part 16 of the Buller District Plan, as a Statutory Acknowledgment Area.
Construction Effects	Given the remote location of the site it is unlikely that anyone will be directly affected by the proposal during construction. Erosion and sediment control measures will need to be in place when earthworks are undertaken. Further assessment will be required to assess the effects of additional traffic going to and from the site during construction.
Visual / Landscape	The proposed activity is unlikely to significantly affect the existing landscape. Majority of the works will be within the tunnel itself and therefore underground. Works will be required to the existing access track to make it suitable for heavy machinery. This is likely to require minor earthworks and vegetation removal. This will change the existing landscape moderately and will require further consideration.

Based on our review of the relevant plans, and the likely effects arising from the proposal we consider the following technical assessments will be required to inform an assessment of environmental effects:

- Ecological advice – Should any works be required in the riparian margin or waterbody we recommend advice is sought from a freshwater ecologist on minimising and mitigating effects during construction in the riverbed.

- Advice should also be sought with respect to any vegetation clearance required.

The above should be discussed with the relevant Councils at an early opportunity to understand the scope of the information they see as necessary for an AEE, if resource consent is required.

5.5 Consultation

We have obtained a copy of the Certificate of Title (CT) for the site. As well as being registered as a Water Conservation Reserve, Rangitira Developments Limited and Buller Minerals Limited hold Mining Permits under s81 of the Crown Minerals Act 1991 for the site. However, these parties are unlikely to be considered as affected for the purposes of the work proposed.

5.6 Other Statutory Considerations

National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NESCS) is relevant if the land affected by the recommended option currently has or had HAIL activities undertaken on it. This is considered as unlikely.

5.7 Archaeology

Opus have undertaken an archaeological assessment of the proposed project, and this is appended. This notes that there appears to be no archaeological issues that require regulatory approvals, but that the site does present some heritage values that BDC may wish to consider preserving or documenting. An on-site heritage assessment is recommended prior to commencing work.

5.8 Tangata Whenau & Iwi

Ngai Tahu own all pounamu (greenstone) previously bested in the Crown. Schedule 10 of the Regional Land and Water Plan contains the accidental discovery protocols for the pounamu management plan and they should be taken into account when undertaking any earthworks.

6 Project Execution Strategy

6.1 Overall Approach

The project will be executed by the following general processes:

- Development of a Contract Document including tendering, legal, and technical requirements suitable for public tendering.
- Tendering the work to either selected tenderers or openly.
- Evaluating, negotiating (if required) and awarding a Contract subject to approval of Council, and assuming that a satisfactory agreement can be reached.
- Execution and completion of the contract works.

6.2 Engineering

Due to the nature of the work, not all detailed design can be undertaken prior to entering the tunnel. What can be designed is the general pipe and backfill arrangement and extent, and key elements such as the upstream bulkhead and connection into No. 2 Tunnel. Other information and drawings will be provided in order to make Council's expectations as clear as possible to potential contractors. This would include drawings showing areas potentially available for laydown and access, and any other particular constraints which might be identified.

The successful contractor will need to design temporary and/or enabling works such as an access track, laydown area and excavations and shoring as required for their specific equipment and methodology. They will also need to undertake detailed design for their chosen stabilisation techniques and equipment such as rock bolt types, depths and spacing along with design of their ventilation systems, safety arrangements, and muckout system.

Notification will need to made to Worksafe for the underground works at least 2 months prior to commencement. Some preliminary discussion has occurred between Geotech and Worksafe in respect of the general methodology proposed, and it is expected that Worksafe will find this methodology generally acceptable. However, this will not be known until a detailed methodology, including design for associated temporary works, is fully developed by the contractor, and has been reviewed by Worksafe.

The Contract will require that the contractor submit any detailed design work they undertake for approval to the Engineer. It may be appropriate to obtain peer review of key engineering aspects to ensure that the proposed works are fit for purpose and will meet the project objectives.

6.3 Procurement

Council require that the work is procured in accordance with their policies. Refer to Section 11 for further details of this.

We note that the novelty and risk aspects of this project are significant, and this is deserving of particular consideration of the following aspects:

1. Tender Period: It would be essential for tenderers to visit the site in order to properly assess the context and nature of the project. A guided visit on a designated day would probably be required. The tender period would need to be confirmed, but the usual period of three weeks is likely to be too short and four weeks may be more appropriate.

2. Type of Contract: An NZS3910 contract would normally be used for this type of work and is well understood by NZ contractors. The contract would likely be a lump sump contract, with provisional items and rates for additional work that might be identified (e.g. stability works in other parts of the tunnel system). Alternatively, there are other standard contract conditions (e.g. NZS3916 or FIDIC for Design and Construct contracts) which could be used but we do not believe that the value and likely construction methodology for this project is suited to this approach.

6.4 Construction

The construction approach will need to be confirmed by the successful contractor. We expect that the following general approach will be required:

1. Pre-construction: There are a number of legal approvals that are required for the work, and some of these have prescribed timeframes (e.g. 2 months for Worksafe approval for tunnelling). Design approvals will also need to be obtained during this period, and the contractor will need to mobilise plant to the site and may need to get other items fabricated.

2. Preliminary works: Work on the access, laydown and other operational areas can proceed once any relevant approvals, consents or permits are obtained. This work may be carried out by a local general civil subcontractor. It may also be necessary to undertake some work at the upstream und of the tunnel to prevent water from being able to enter and flood the works.

3. Underground works: Work in the tunnel will consume the largest proportion of the contract period. Most of this time is likely to be involved with the removal and stabilising of the collapsed area.

4. Completion: Once the mains works are completed, the site will be tidied and reinstated.

6.5 Commissioning

Commissioning of the works will occur once the pipe is in position and the end connecting details are in place. Water will be re-directed into the tunnel and flushed through to the WTP storage ponds. This water may take some time to clear, and it may need to be discharged to waste initially if it is particularly turbid.

6.6 Project Funding

The Westport No.1 Water Tunnel project will be funded from Council's asset upgrade Capital Expenditure budget.

The 2017/18 Annual Plan has set aside $3.0M for tunnel stabilisation works. The option considered in this report (Option 2d), combining stabilisation and partial piping, is expected to cost approximately $2M.

6.7 Owner's Role

As the asset owner representing the community, Council's role is to ensure the project is properly and adequately supported to ensure the overall objective is successfully achieved.

Through the Project Control Group (including key Council staff members and stakeholders), the Project Manager will be delegated responsibilities and accountabilities as defined in the Project Charter.

The Project Governance Model reflects the organisation structure which ensures that critical project decisions, change management and status reporting are always communicated through the appropriate and authorised channels.

6.8 Project Management Plan

A Project Manager will be appointed to oversee all of the various parties involved in the project, and to ensure that their inputs are defined and delivered in a timely manner. The project manager may be a Council employee or an external resource. They will also be responsible for ensuring that lines of communication are effective and that project records are being maintained.

The project manager will prepare a detailed Project Management Plan (PMP) based on the appended template.

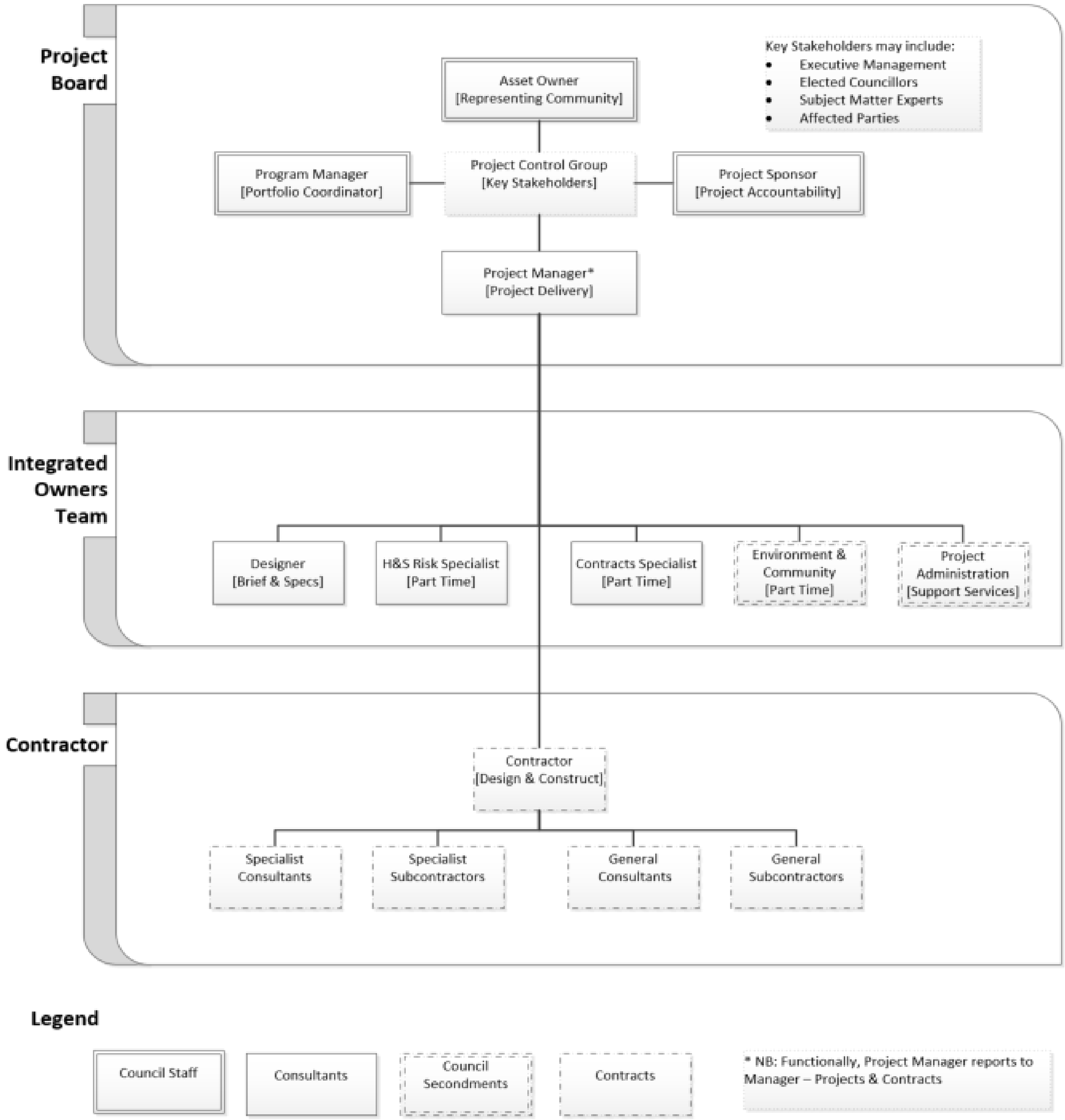
7 Project Organisation

7.1 Project Team Overview

The Westport No.1 Water Tunnel project team will be organised according to the approved Project Governance Model. Representing the community will be a Project Board comprised of key Council staff members and stakeholders.

As a minimum, the Project Board will include the Asset Owner/Program Manager (Three Waters Coordinator), the Project Sponsor (Group Managers Assets & Infrastructure) and the appointed Project Manager. The Project Sponsor is ultimately accountable for the success of the project and is required to provide influence, leadership and ultimately make decisions in the best interests of the project objectives.

From time to time, other key stakeholders may join the board representing executive management, elected members, subject matter experts and affected parties. Refer to the diagram below which illustrates the overall structure.



7.1 Integrated Owner's Team

The Integrated Owner's Team (IOT) is led by the Project Manager, who is responsible for the successful delivery of the project as defined by the Project Charter. Assisting the Project Manager will be an administration resource providing project support services.

The IOT also includes part-time specialist functions including Health & Safety, Risk Management, Contracts Administration, Environment and Community.

These roles will be brought into the project at the relevant times for the required durations. The overall purpose of the IOT is to ensure that management of the implementation phase is properly executed on behalf of Council. The IOT will be generally self-sufficient and not detrimental to the

day-to-day operations of Council business. The IOT will function from a separate Capital Projects Office and will be fully funded from the capital budget.

7.2 Contractor

Through a formal Request for Tender process, Council will appoint a Contractor to deliver the scope of works for the project. Refer to the Contract Model outlined in the Procurement section for further details of the process.

7.3 Roles & Responsibilities

Project roles and responsibilities will be outlined in the Project Management Plan (PMP). The Project Manager role will be defined formally in a Council position description. Other individual roles including administration and the functional specialists will be developed by the Project Manager at the commencement of implementation phase.

7.4 Authorities & Signatories

A project-specific approvals framework will be outlined in the Project Management Plan (PMP). It will be developed according to the level of risk and exposure for Council. Based on the significant capital value, fast-track requirements and high-profile nature of the project, a detailed approval authority matrix is required. This will set out the project delegations of authority by key project roles, for functions including tender approvals, authority to commit, authority to pay, execution of contracts and purchase orders and approval of expenses.

8 Health, Safety, Environmental & Community

8.1 Health & Safety

This project presents a number of Health and Safety hazards which will need to be addressed through the appropriate regulations and in compliance with the law.

Particular H&S hazards include the following:

1. General construction hazards (construction machinery, noise, dust etc.).
2. Slope stability – the construction of tracks and enabling areas for stockpiling and plant will require excavation of steep batter slopes.
3. Flood protection – the area is known for high rainfall rates and temporary and permanent works will need to be designed to accommodate this.
4. Underground work – there are specific hazards associated with this activity which need to be managed in accordance with the Mining Operations and Quarrying Operations Regulations.

8.2 Environment

The proposed project has some potential for adverse environmental effects, although these are not expected to be significant due to the nature of the work required. These will be managed through the Resource Consent process, and through the design and construction methodologies which will minimise the environmental impacts.

8.3 Community & Social

Council has a duty of care to all residents and visitors within the Buller district. The Westport No.1 Water Tunnel project will give paramount consideration to those duties, specifically the health and well-being of those involved and affected by the implementation phase works.

Council acknowledges the importance of building positive relationships with the community and to embrace ongoing dialogue and feedback to improve decision making processes. This is achieved through timely, transparent, honest, inclusive, accessible and responsive community participation.

Receiving diverse perspectives and potential solutions enables more informed decisions. It does not replace the decision-making functions and duties of Council but informs it. Furthermore, it is not always practical or appropriate to engage the community on all decisions.

It is crucial that community members are sufficiently informed on major issues, plans and projects and all matters likely to affect them and have opportunities to participate meaningfully in community engagement to enhance final decision-making process.

These community and social principles will be developed into a Community Engagement plan which will thereby reduce potential misinformation and miscommunication regarding the project.

8.4 Security

During implementation phase, the control and security of the project site (including access to and from) will be delegated by Council (asset owner) to the Contractor for the duration of the project.

The contract will clearly specify delineation, roles and responsibilities to ensure that access to the site is controlled and all project facilities and areas are appropriately protected and secured. This will also ensure members of the public are not exposed to risk or safety hazards.

8.5 Communications

As part of the Community Engagement plan, a communications protocol will ensure that relevant project news and information is provided to key stakeholders in a timely and organised manner. This will cover aspects such as media releases, website information and community newsletters which will be coordinated by the Project Manager through Council's communications team.

Project Status Reports (PSR's) will be prepared by the Project Manager and provided to the Project Control Group on a monthly basis. The reports will contain an overall summary of progress in report card format, as well as achievements completed and planned, key milestones, budget forecasts, critical issues, risks and change management. Refer to the appended example template.

Reports to Council will also be provided on a monthly basis at the scheduled meetings, so that elected members representing the community are kept informed on project status.

The Project Manager will organise and chair monthly progress meetings with the Project Control Group, with meeting minutes included in the monthly PSR.

The Project Manager will also run weekly progress meetings with the Contractor, subcontractors, designers, trades and other parties as appropriate in the general role of managing the project effectively.

9 Risk

9.1 Overview

Risk is the effect of uncertainty on achieving objectives. Risk Management is the identification, assessment and prioritisation of risk factors. The typical process involves:

- Define the objective
- Identify the threats
- Assess the risk
- Control the risk
- Monitor the process

Strategies, methods and tools including risk workshops, risk registers, risk matrix and hierarchy of controls can then be applied to manage risk. The key risk factors for major projects can generally be categorised as follows:

- Planning Risks
    - Statutory, Environmental, Public Consultation, Site Establishment, Variations, Legal Compliance, Consents & Licences, Time & Cost Overruns
- Design Risks
    - Information Quality, Redesign, Performance, Variations, Resources, Flexibility, Design Standards, Inflation, Time & Cost Overruns
- Construction Risks
    - Site Conditions, Weather Conditions, Site Access, Public Protest, Labour Resources, Material Resources, Commissioning, Cost Control, Construction Methods, Workmanship, Related Facilities/Services, Variations, Extensions of Time, Interfaces, Contractor Works, Site Health & Safety, Utilities, Industrial Action, Interruptions, Inflation, Existing Liabilities, Time & Cost Overruns, Force Majeure
- Operating Risk
    - Latent Defects, Service Availability, Service Performance, Estimation Errors, Materials, Utilities, Resource Plans, Industrial Action, Residual Equipment, Variations, Environmental Compliance, Third Party Claims, Cost Control, Future Proof, Maintenance, Health & Safety, Design Deficiencies, Infrastructure Damage (Insurable & Uninsurable), Inflation, Subcontractor Performance, Force Majeure
- Financial Risk
    - Affordability, Interest Rates (pre/post Financial Close), FOREX (if applicable), Taxation, Residual Value, Insurance Scope & Cost, Patronage, Cost Changes
- Legislative Risk
    - Law Changes, Voluntary Termination, Contractor Default

9.2 Risk Management

This project requires a robust risk management system that is tailored to the varied risk profile that the project presents. The risk assessments will need to be developed and evolve during the project to account for improving knowledge, and the selected contractor's methods and capabilities.

9.3 Risk Assessments

There have been various assessments of risk made relevant to the project in previous reports and studies. These have been drawn on to prepare the risk assessment contained within this report which is focussed on managing the risks.

Some of the critical risks' assessments and mitigations will need to be developed by the contractor as they will be responsible for following regulatory processes to undertake the works, particularly the underground works. Some preliminary risk assessment in this respect has been undertaken by Geotech which is contained in their appended report.

Risks have been assessed in accordance with the principles of AS/NZS 4360. An initial risk register has been developed and is appended (refer Appendix A1).

9.4 Key Risks

There are a number of key risks that have been identified that could potentially affect the ability to effect the works. These are:

1. No satisfactory Tender received.
2. Capital cost too high.
3. Health and safety risks during construction.
4. Residual risks from other parts of the water supply system.

These risks and possible control measures will need to be assessed further by Council.

10 Engineering

10.1 Design Criteria

The key design criteria for this project are:

- Capacity of refurbished tunnel and pipe to be at least 140 L/s
- Design life of the installed pipe: 100 years
- Target length of pipe installation: 500m upstream from No. 2 Tunnel branch.
- Minimum ongoing maintenance inputs

10.2 Engineering Management

The engineering design for the project will be developed from a preliminary design provided with the Contract Documents to a detailed design that will be constructed. It will not be feasible to provide a fully detailed design from the outset as this will need to be developed in-place by the contractor as they proceed with the tunnel stabilisation and respond to the geotechnical situation as it presents itself.

There will need to be an interactive process between all parties to ensure that the engineering solutions will achieve the required standards and that the safety in design aspects are satisfactorily resolved and any certifications are obtained. The safety in design process will require all parties contributing to the design to participate to ensure that the design interfaces are well covered.

10.3 Civil Works

It is proposed to install a new pipe in the existing tunnel from the downstream portal through to beyond the collapsed area. It is expected that this will require the following general sequence of work:

1. Construct access, laydown and working areas. This may include daylighting No. 1 Tunnel from the downstream portal to the intersection with No. 2 Tunnel.
2. Progressively enter the tunnel, continually assessing the stability and safety of the tunnel and installing rock bolts, mesh, tensioned 'W' straps, shotcrete, refuge bays and supports as required to provide a safe and stable thoroughfare. Remove the existing wooden supports as required to provide working room until the collapse area is encountered.
3. Construct a temporary tramway up the tunnel from the exit portal to the collapse site. Break up and remove collapse material by loading into wagons and winching them back out the downstream portal for disposal. Repair and stabilise the collapsed area as it is uncovered through to the open tunnel beyond the collapse.
4. Continue through the tunnel and make repairs as required until the stable upstream end of the tunnel is encountered. Inspect the entire tunnel and undertake additional repairs as required that have become apparent since the last entry.

5. Install a pipeline from above the collapse area (approx. 700m from the upstream portal) to the downstream portal. This will be installed in sections and a concrete bulkhead constructed at the top end. Blow a dry-mix low-strength (approx. 10 MPa) cement-backfill mix to 200mm over the pipe crown to provide impact protection from future collapse.

This core activity will need to be supported by general construction to provide temporary and enabling works to allow plant and material to be brought to the site, and to dispose of surplus materials (e.g. collapsed materials and redundant shoring).

This revised option utilises common tunnel stabilisation techniques that are frequently used to effect repairs and enable other works to occur. The installation of a pipe in the tunnel is also a generally similar technique to those used elsewhere, including the 2009 repairs to No. 4 Tunnel.

10.3.1 Hydraulics

The gradient of No. 1 Tunnel is approximately 1:1,500. To convey the required flow rate of 140 L/s would require a pipe with an internal diameter of about 575 mm (assuming a nominal roughness value of 1.5mm). This is the minimum pipe size that would be acceptable from a hydraulic capacity viewpoint.

10.4 Piping

10.4.1 General

It is proposed to install a pipe up the existing No. 1 Tunnel by bringing sections in using the tramway and jointing them in place. At the upstream end, a concrete bulkhead will be constructed to provide a seal to the tunnel and ensure that the abstracted water flows down the pipe. At the junction with No. 2 Tunnel, an elbow will be installed to direct flow into No. 2 Tunnel.

10.4.2 Pipe Material

We have considered in depth a number of pipe material options to identify those that would be most suitable for this project, taking into account the unique characteristics of the proposed works. The ideal qualities that are required of this pipe are:

- Minimal outside diameter with an absolute maximum of 750mm (including sockets at joints) to make it easier to manoeuvre and joint the pipe in the confined tunnel space, but still with an internal diameter of at least 575mm.
- High impact strength to provide protection against unavoidable rough handling during transport and installation and to cope with future minor collapses onto the pipe.
- Durability to corrosion and abrasion to ensure that the pipeline will meet the required 100-year design life.
- Light weight to make handling easier and safer.
- Suitability to convey raw water for use in a potable water supply.
- Cost-effectiveness.

Materials that are available in the sizes required and that have been considered but which are not preferred include:

- Reinforced concrete: Although generally suitable, it is very heavy and a standard DN600 flush-joint pipe weighs approximately 220 kg/m. It is usually supplied in 2.44m lengths which requires more joints.
- Glass Reinforced Plastic (GRP): This meets most criteria but has comparatively poor impact resistance and is sensitive to rough handling.
- Steel: The durability of steel is not considered adequate for this application, particularly since coatings will be easily damage during installation and will be subject to wear from sediment/gravel in the water.

We believe that the best material for this application is polyethylene (PE100). This is available in a number of variants:

- Solid wall extruded pipe: This is the most common but also the most costly product. It is usually jointed by electrofusion or butt-fusion welding, although mechanical couplers are also available in the small-medium sizes. This type of pipe (DN800) was used in No. 4 Tunnel, and was welded into a string and pulled through in one operation (although this was only just achieved). A DN710 (710mm OD) pipe would be the most suitable, as the internal diameter of a DN630 (approximately 550mm ID) pipe would be too small to convey the design flow.
- Solid wall wrapped pipe: This is manufactured by wrapping PE strips around a mandrel and is generally less expensive than extruded pipe. It is manufactured in Christchurch by Frank - PKS NZ Ltd and available in DN600 (600mm ID) with a SN16 rating and OD of 680mm. These pipes are available with either a built-in electrofusion joint or with rubber ring joints (single or twin ring). There is no socket bell, as each end of the pipe is machined to provide what is effectively a flush joint.
- Profile wall pipe: There are several of these products available. Euroflo produce a smooth-bore profiled-wall pipe; Frank-PKS produce a thin wall PE pipe with a helical outside rib; and Waters & Farr produce a profile-wall smooth-bore PE (as well as polypropylene variants) pipe (Bosspipe). The Frank-PKS pipe has the same jointing options as described above for the solid wall wrapped pipe, and the other pipes have a bell or slip coupler which increases the outside diameter of the pipe at the joints.

All of these options could potentially be used, but once consideration is given to the fairly narrow installation space and required internal diameters, the Euroflo and Bosspipe are not available in the required diameter. Electrofusion jointing is not favoured for this application as it will increase the fire risk in the tunnel, so rubber ring joints will be needed.

The most suitable, readily available, products that we have identified are the DN600 Frank-PKS pipes, with a 600mm internal diameter. The profile wall pipe is available in a SN12 rating and has an outside diameter of 696mm. The solid wall wrapped pipe is SN16 and has an outside diameter of 680mm. The solid wall pipe weighs about 77 kg/m. The profile wall pipe weighs about 37 kg/m, is much less expensive, and easier to handle. The pipe lengths can be selected to suit up to a maximum of 6m (noting that shorter lengths incur higher purchase costs due to the additional joints).

We believe that the profile wall pipe would be suitable, but note that it has an inner wall thickness of only 5mm, compared to 40mm for the solid wall pipe. This means that it will not be as resistant to impact damage and puncturing, and if there is significant bedload (sand and gravel) the invert could eventually wear through, although PE is generally very resistant to abrasion. The profile wall pipe may also be more difficult to manoeuvre and install as the external ribs may catch on protrusions within the tunnel.

The calculated flow depth for 140 L/s in the 600mm ID pipe is 443mm for a 1:1500 grade and k value of 1.5mm.

10.4.3 Pipe Installation

We expect that the pipe will be installed by moving lengths of pipe into the tunnel on a tramway system. Once in place, it will be joined to the upstream pipe by a combination of pulling/aligning/lubricating at the upstream end and pushing the pipe using a bar or lever from the downstream end.

We believe that the risk of future damage and deformation of the pipeline can be mitigated by backfilling the pipe to a level of approximately 200mm above the crown of the pipe. This can be effected by blowing dry material in using a shotcrete technique, provided the aggregate size does not exceed about 8mm. It would also be worth adding cement to the mixture to give a low-strength (*ca.* 5-10 MPa) dry mix concrete that will give additional security against collapse and damage. The dry mix will slowly set with atmospheric moisture which avoids creating significant heat of hydration which may weaken the pipe.

This backfill will protect the pipe from puncture damage, and reduce the risk of crushing/deformation failure as the sidewalls will be supported. It will still leave sufficient room for a person to crawl along the space above the pipe if this were ever necessary in future to undertake further repairs. An indicative section for the solid-wall pipe option is shown below.

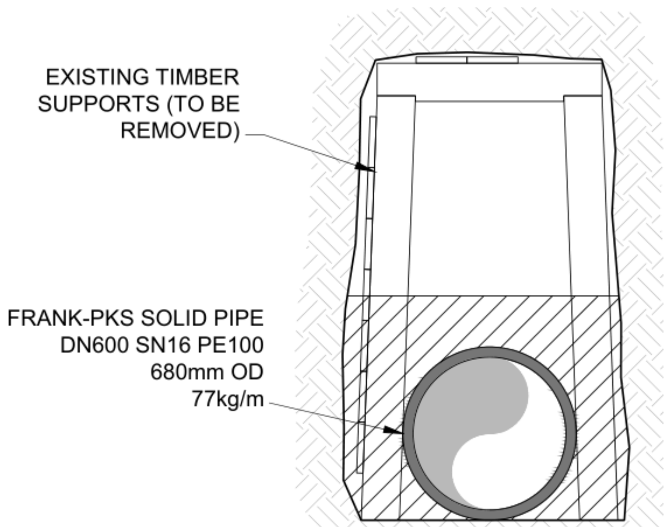


Figure 10-1: Indicative Piped Cross Section

11 Procurement

11.1 Overview

Council is responsible for acquiring or procuring goods, services and works for the benefit of the community. Council is also required to act within the provisions of the Local Government Act with the aim of achieving value for money. Value for money is defined as '*…using resources effectively, economically, and without waste, with due regard for the total costs and benefits of an arrangement, and its contribution to the outcomes the entity is trying to achieve*'.

In addition, the principle of value for money when procuring goods and services does not necessarily mean selecting the lowest price but rather the best possible outcome for the total cost of ownership (or whole of life cost). Value for money is achieved by selecting the most appropriate procurement method for the risk and value of the procurement, and is not necessarily by using a competitive tender". Council's strategy provides for a range of delivery models and procurement procedures that are determined by risk, complexity of tasks and predictability.

Council aims to ensure that competition is maintained in the market without creating costly inefficiencies through having one system for all procurement.

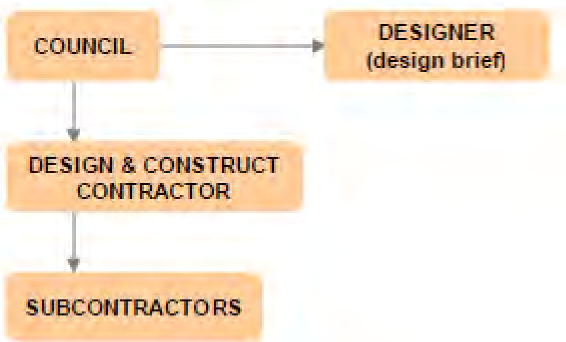
11.1 Procurement Strategy

The purpose of the procurement strategy is to assess all available options and select the one most suitable for the project requirements. Where possible, the preferred option is validated through market sounding. This can provide a crucial means of testing the assumptions and conclusions from a deliverability perspective.

This was achieved during the feasibility study by engaging practitioners as subject matter experts to provide input in specialised areas. Conventional procurement strategies were considered, including design and construct, construction management as well as more advanced models including EPCM, alliance and ECI.

The selected procurement strategy for the Westport No.1 Water Tunnel is the Design & Construct model shown below, which has the following key features:

- Council prepares a detailed design brief
- Council engages one party for both the design and construction of the project under a single contract
- Contractor is primarily responsible for the design and construction risks



11.2 Procurement Process

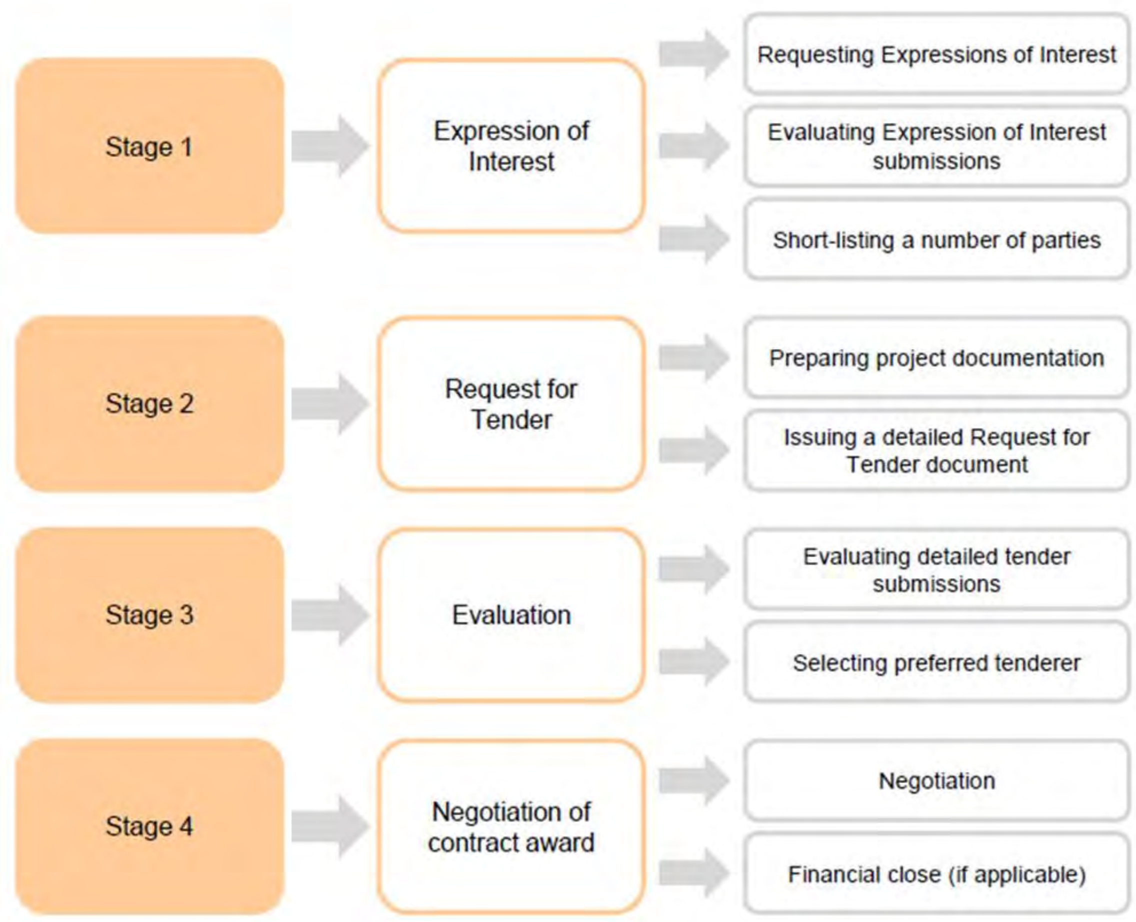
An effective and transparent procurement process that achieves value for money is in the interest of all project stakeholders. The process must comply with the procurement framework for local government. This framework imposes a number of controls within which Council's own Procurement Policy are undertaken, in addition to:

- Legislation
- Regulations
- Best practice

These controls are designed to ensure that the process is carried out in accordance with probity principles, and in a competitive environment conducive to Council achieving best value and certainty in the award of public contracts for major project works. The key objectives when developing an effective, staged procurement process include:

- Structured to facilitate competitive tendering
- Transparent in order to withstand public and private scrutiny
- Clearly defined with specified timeframes
- Developed planning to increase certainty and value for money
- Effectively manage risks
- Compliant with statutory requirements
- In accordance with best practice and probity principles
- Appointment to the tenderer most capable of delivering the works and/or services
- Produce a binding contract

A diagram of the process is shown below.



11.3 Contracting Model

Under the selected procurement model, Council will arrange for preparation of Tender Documents which describe the works to be completed, provide a partial design, and advise commercial terms and technical specifications. It will then seek tenders for the completion of the detailed design and construction of the works in accordance with these Tender Documents and relevant regulations.

Council will engage a suitable Contractor to deliver the contract works, divided into appropriate trade packages. The contract will be based on a lump-sum price (subject to contractually permitted adjustments) and will be inclusive of detailed design, trade contracts and management services. Council is responsible for approval/acceptance and payment of work done.

The Contractor must possess appropriate expertise such that it can manage the remaining detailed design and regulatory processes, and the construction phase. The risk of fitness for the described purpose of the design by the Contractor is borne by the Contractor. However, Council will retain responsibility for the performance objectives and user requirements included in its design brief, and will therefore be required to accept the final design prior to construction proceeding.

The Contractor will seek tenders and enter into trade contracts in its own capacity and not as an agent of Council. The Contractor will pay trade contractors directly and is ultimately responsible for safety, risk, quality, scope, costs, and schedule for the contractors it engages, and will warrant the overall project completion date. Included in the contract price will be a lump sum fee for

management services including project planning, co-ordination and monitoring, preliminaries, security, insurance, tendering and managing of external consultants and trade contractors.

12 Construction

12.1 Construction Management

Construction management will follow a typical NZS3910 arrangement where the contractor is primarily responsible for managing the site, quality, resources and the construction programme to meet the due date for completion. Construction observation will be provided by the Integrated Owner's Team to monitor progress and issues.

An Engineer to Contract will be appointed, along with a representative who will have delegated authority undertake the general administration duties such as assessing payment and variation claims. The Engineer will generally not be involved in the project in order to maintain impartiality in the event of a dispute that requires the Engineer's involvement.

The Principal will make payments as certified by the Engineer, and provide operational resources as might be required (e.g. during the commissioning phase).

The Contractor's responsibilities will include:

- Providing Plant and Labour resources.
- Providing training as required.
- Managing logistics.
- Designing and constructing temporary and enabling works including site offices and ablutions' facilities.

12.2 Access

At present, there is inadequate access to the site to enable construction. A metalled track from the WTP provides access for a small truck, but there is only a steep 4WD track from this point to the No. 1 Tunnel downstream portal.

It is expected that the 4WD track would be graded and surfaced to improve its usability, but its grade cannot be easily corrected without substantial works. It would still be usable for heavy vehicles with tow assistance.

A laydown area would need to be created near the portal area. The size of this is limited by the local topography, and materials may need to be shuttled from another laydown area located further away.

12.3 Tie-in Plans

The upstream end of the piped section will need to be connected to the existing tunnel in a way that captures all of the water flowing down from the upstream portal. This would be achieved by constructing a concrete bulkhead that will extend to a high enough level to capture the water.

The detail relating to the tie in to No. 2 Tunnel will need to be confirmed with the contractor to suit their construction methodology and materials. For example, it has been suggested that

approximately 30m of No. 1 Tunnel could be daylighted from the existing portal to the No. 2 Tunnel inlet as part of the works. This would provide some advantages, but would require a substantial amount of material to be removed along with slope stabilisation works etc., still leaving a risk of land slips.

12.4 Heavy & Special Lifts

It is not expected that any particularly heavy lifts will be required, but all of the pipes and any portal reinforcement frames or ducts will need to be lifted into position, as well as unloaded and placed ready for installation. These are likely to be light enough to be moved by using a hiab or small all-terrain crane. The arrangement of cranage will need to be confirmed by the contractor, but they may require a large crane to provide sufficient reach.

12.5 Constructability

Constructability issues will need to be worked through with the selected Contractor. This must be sufficiently addressed during the tender evaluation and negotiation phases to give all parties confidence that the works can be constructed as expected.

For the purposes of this report, our discussions with Geotech support the constructability of the proposed work, noting that the current condition of the tunnel will not be fully revealed until it is entered and the collapsed section exposed.

Further details relating to constructability will be dependent on the design submissions from the contractor, and any specific requirements or agreements in respect of the regulatory review by Worksafe to undertake the works.

12.6 Work Package Management

The Contractor will be responsible for determining and managing all the packages of work required to complete the contract.

12.7 Site Administration

The Contractor will be responsible for administering the site. Due to the limited room available at the work area, they may need to set up their administrative facilities at a nearby location (e.g. nearer to the WTP).

12.8 Testing

It is normal practice to test a new pipeline to ensure that it is not leaking. A gravity main such as that proposed would normally be subjected to a low pressure (30 kPa) air test to prove that the joints have been effectively made. In this case, any water that leaked out of the joints would flow down the tunnel to the downstream portal in any case.

Undertaking a test such as this requires installing a bung at each end of the pipe. This would require that a bung is taken to the upstream end and inflated. It may be decided that testing in this case is not important enough to justify the additional risks of installing the testing equipment.

12.9 Commissioning Management

The Contractor will be primarily responsible for commissioning the works, with assistance from Council. In particular, this would include Council staff and contractors preparing the intake for use – removing gravel build-up, flushing etc., as well as making checks on the downstream conveyance system to ensure all is ready to operate again.

The initial water flow may need to be flushed for a period of time until it clears and is suitable for use at the WTP. Some water quality testing may also be required to confirm that there are no unexpected construction residues or effects which may make the water unsuitable for use.

The weather has potential to disrupt the commissioning activities. If the water in Giles Creek is too turbid or the flow too high, commissioning may be delayed until suitable conditions are present.

12.10 Handover

Once Council is satisfied that the water flow and quality has been acceptable for a reasonable period of time (acceptance criteria will need to be determined prior to finalising the Contact Documents), then they will take over the operation of the works, and the contractor will have fulfilled their primary requirements to achieve practical completion, and can disestablish from the site. They will also be required to provide as-built information to Council for the works they have constructed.

13 Project Services

13.1 Project Controls

Project Controls is the routine monitoring of project status, resources, tasks and schedule. The key purpose is to ensure that project performance is observed and measured regularly and consistently to identify variances from the Project Management Plan (PMP). It is a vital component of tracking and managing progress, and supports the Project Manager to control the triple constraints of scope (work), cost (budget) and time (schedule) as shown below:

13.2 Baseline Establishment

The project baseline will be established by the Project Manager at the beginning of implementation phase and documented in the Project Management Plan (PMP). The original approved PMP incorporating scope, budget and schedule will be approved by the Project Control Group. Scope management is critical to ensure that the project includes all the work required, and only the work required, to complete the project successfully. The approved scope will be organised into a work breakdown structure (WBS).

13.3 Work Breakdown Structure

The work breakdown structure (WBS) provides a hierarchically-organised grouping of project elements that orders and defines the total scope of the project. Each descending level is an increasingly detailed definition of a project component, and is the structure from which key project deliverables are organised, including the project budget, work packages and schedule. The capital cost estimate is also compiled as a WBS for mapping across to the project budget control accounts at the beginning of implementation phase.

13.4 Change Management

Once the baseline has been defined and approved, change management process will be applied to capture trends and changes. Change management is critical to ensure project risks are managed and provides lead indicators to ensure no surprises. It also helps to manage stakeholders, and maximise benefits and opportunities for the project. The process for change management is shown in the appended flowchart and will be supported by appropriate procedures, forms, templates and a project trend/change register.

Trends will be defined as any actual or forecast deviations to the baseline approved by the Project Manager. Changes will be those trends identified as scope changes and approved by the Project Control Group acting on behalf of stakeholders (client). Approved changes will be incorporated with the baseline to become the "current" status. Approved trends will be added to current, to provide the project "forecast" as illustrated in the Figure 13-1 below:

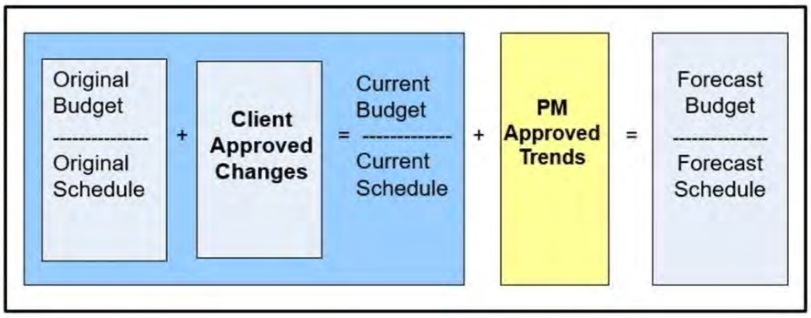


Figure 13-1: Project Forecasting

13.5 Earned Value & Forecasting

Earned value performance measurement will be applied for this project. Earned value is the measure of physical work completed expressed in terms of current budget (i.e. stakeholder approved scope). Agreed rules of credit will be developed with the Contractor to ensure the progress measurement strategy is relevant and fit for purpose, including demonstrable acceptance criteria for key milestones to provide validation of progress claims.

Earned value will measure how work is performing to current plan (i.e. a health check-up), as well as providing a method-based forecast basis for estimate to complete (ETC) and estimate at completion (EAC) projections. Through timely status updates and incorporation of change management, accurate reporting will be provided by the Project Manager. Reporting of progress and performance is critical for effective governance and keeping the Project Control Group and stakeholders informed.

Forecasts identifying deviations (trends and changes) from the approved baseline enables intervention for recovery and opportunities for problem-solving. This approach will support the Project Manager to successfully deliver the project within agreed scope, cost and time. The key relationships demonstrating how earned value will be used to drive project forecasts (EAC and ETC) are shown in Figure 13-2 below:

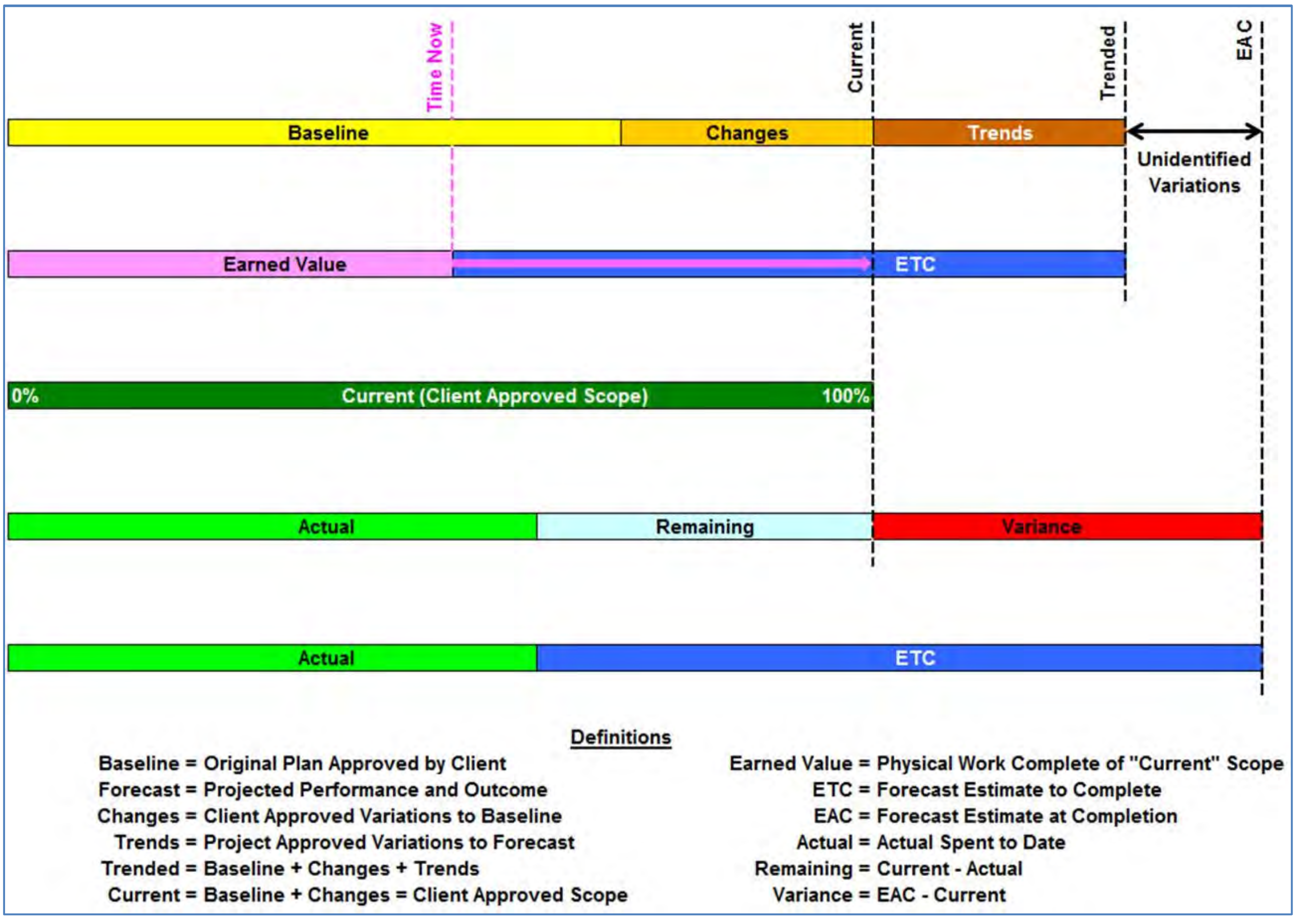


Figure 13-2: Forecasting Process

13.6 Project Support Functions

Associated project support functions including schedule management, cost management, quality management, document management, project accounting and administration will be developed as part of the Project Management Plan (PMP) at the beginning of implementation phase. These aspects will be covered in their own separate plans appended to the PMP.

14 Operations

14.1 Operational Readiness

Council, along with their operations' contractor, will remain responsible throughout the project for maintaining operation of the Westport WTP. As the time approaches to bring the new works into commission, there will need to be effective communication between all parties so that the transition onto the tunnel supply can be effectively managed.

14.2 Pre-commissioning, Commissioning & Handover

Prior to commissioning, a number of tasks will need to be undertaken by Council and/or its operations' contractor:

1. Inspection, maintenance, and cleaning out of the Giles Creek intake structure and control mechanisms.
2. Inspection and maintenance as required on downstream sections of tunnel, pipeline and race to ensure that they are clear of trash, debris and other potential obstructions.
3. Opening of drain or scour valves or gates downstream of No. 1 Tunnel to allow the initial flow of water, which is likely to be discoloured, to be discharged in accordance with resource consent requirements. If required, a temporary silt trap may need to be put in place.
4. Managing of the raw water storage reservoir levels and/or supply pipework and valves to ensure that there is provision to accept full flow from the Giles Creek intake.

During commissioning, the following operational inputs will be required:

1. Monitoring of the Giles Creek intake to check that it is providing the required flow into the Tunnel.
2. Checking of water quality to ensure that it is suitable for use at the WTP.
3. Closing scours and drains once the water quality is suitable for use, and directing it into either the storage reservoirs or the WTP.
4. Removing any temporary silt traps or other temporary measures put in place to assist with the commissioning process.

Once the commissioning phase has been successfully completed, normal operational activities can resume.

15 Capital Cost Estimate

15.1 Basis & Accuracy of Estimate

We have built up a capital cost estimate and the full detail of this is appended. This has been built up using:

- Information provided from Geotech for the core work (i.e. tunnel stabilisation and pipe installation), rounded up to reflect the preliminary nature of the pricing. We consider this to be as accurate as reasonably possible at this stage.

- Estimated costs for some of the enabling works. The scope of these is not very well defined and will depend on the contractor's preferences; however, it is a relatively minor aspect of the total cost.

- An allowance for additional spot bolting that is likely to be required in the tunnel upstream of the collapse area to maximise long-term reliability of that section.

- Estimated costs for the support, project management, engineering and similar items. These are also relatively small costs in comparison with the core work.

- A contingency to allow for the uncertainty associated with the project. We have allowed 20% at this stage to reflect the risk profile of the work.

We note that a large proportion of the cost is for labour associated with repairs and stabilisation. The labour costs will be highly dependent on the as-found condition of the tunnel and extent of the collapse which will dictate how much time is required to effect the repairs and pipe installation.

15.2 Owner's Costs

Council will meet the owner's costs associated with the project including the initial design brief and the Integrated Owner's Team for project delivery. All other costs (including the cost of project management, subcontractors, materials, approvals, consents, licences etc.) will be included in the Contractor's contract price.

15.3 Escalation & FOREX

The timeframe for the project is approximately 12 months. No provisions are anticipated to be required to compensate for escalation costs during the project.

Likewise, there are not expected to be significant FOREX risks as most of the cost associated with the job will be spent locally. It would be typical for FOREX risks to be assigned to the Contractor in the contract for a project of this nature and scale.

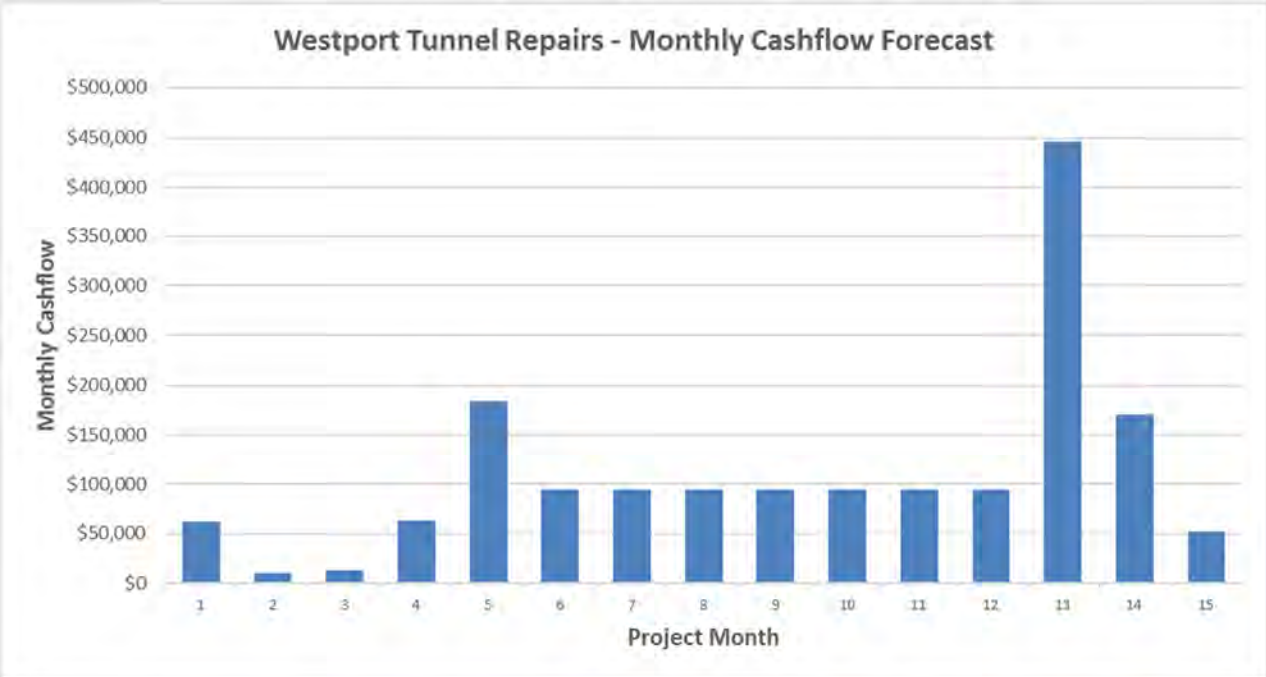
15.4 Contingency

We recommend that a generous contingency is provided for this project in recognition of the novelty and risk factors that apply to it. For this project we have assigned a 20% total contingency, made up of the following components:

- Estimate Contingency: 10%
- Event Contingency: 5%
- Management Reserve: 5%

15.5 Cash Flow Forecasts

The expected cash flow over the project is shown in the graph below. This is based on monthly claims for work occurring, with higher monthly costs incurred at establishment on site, and upon completion. It is based on the median capital cost estimate, without contingency and assumes that the work will proceed at a fairly uniform rate, and that the contractor will be paid monthly based on progress.



15.6 Range Analysis

We have made an assessment of the potential range of each component in the capital cost estimate. This results in a range of capital costs from about $1.4M to $2.5M, with a median of $1.99M.

15.7 Estimates for Future Work

At this stage we have not made estimates for future work. We note that there are approximately 1,100m of tunnel that are outside the scope of this project; significant failures in any of these could incur similar or greater costs to effect repairs. We note that No. 4 Tunnel has previously had a PE pipe laid through it which will provide protection from minor rockfall and fretting, but does not necessarily have sufficient structural strength to resist a significant collapse.

15.8 Cost Breakdown Structure

A breakdown of the costs is provided in the appended capital cost estimate.

16 Operating Cost Estimate

16.1 Basis & Accuracy of Estimate

The operating costs of the project are difficult to assess in respect of the new works. Certainly, the return to service of the gravity tunnel supply will reduce the ongoing operating costs for the water supply significantly (largely through reduction in energy and wear and tear at the pumping station, as well as the costs associated with the temporary Ballarat Creek supply).

We do not expect the repaired section of tunnel to have any foreseeable operating costs *per se*. The operating costs for the tunnel system are likely to be similar to those prior to the project, with perhaps a slight reduction in repairs to the rockfall-prone section of the tunnel.

16.2 Start-Up Costs

There will be some modest start-up costs associated with the commissioning of the repaired tunnel. These will be incurred as a result of increased labour inputs and water quality testing, and deferred maintenance on other parts of the intake system (such as the intake, channels and flumes) may also need to be undertaken in preparation for a return to normal operational service.

16.3 Escalation & FOREX

Escalation of the operating costs will be covered separately in the Council maintenance contract for the Westport water supply.

16.4 Contingency

Some contingency should be allowed to cover unexpected inputs required to return the system to operational service. We recommend that an additional two days of operator time is allowed.

17 Conclusions

17.1 General

The primary purpose of this report is to assess the feasibility of the proposed project. This section summarises the key aspects relevant to this.

17.2 Feasibility and Risks

There are a number of aspects to feasibility, and these are intertwined with risks. These aspects are considered in the sections below.

17.2.1 Technical & Construction

Based on the information available, we believe that it will be technically feasible to stabilise the tunnel to allow entry to remove the collapsed material:

- There is a relatively large amount of information available on the existing tunnel including photographic/video records, as well as local knowledge from previous repairs and inspections.
- Work has been undertaken in the past using very similar techniques to those proposed (e.g. No. 4 Tunnel repairs and piping).

There are also some risks that cannot be entirely assessed or mitigated, leaving some residual risk. These residual risks to the project must be accepted if it is to proceed. The most significant of these are:

- Risk of not being able to sufficiently stabilise part of the tunnel to enable safe installation of the pipeline. A bypass tunnel or other alternative option would be required to continue to use the Giles Creek source.
- Risk that the collapse is more extensive than expected, resulting in longer construction times and greater project costs.

17.2.2 Programme

This project will require a significant amount of time to complete, and is dependent on getting approvals from a number of other parties prior to commencement which is a risk to timely completion.

17.2.3 Financial

Council are aware that this project will have a significant cost. Due to the nature of the work and uncertainties about extent or repairs, it is difficult to reliably predict the final capital cost of the project, considering potential for reasonable contract variations.

17.3 Residual Systemic Risks

We believe that, even if this project is successful to repair the damaged tunnel, there are significant residual risks to the water supply from Giles Creek. These risks are primarily due to the landslide in the vicinity of No. 2 Tunnel, and the potential for ongoing deterioration and collapses in the other tunnels. The area has known potential for strong seismic shaking which could cause more widespread failures or collapses in the tunnels which would be challenging to repair, or may not be feasible to repair at all.

These risks present a significant risk of total failure of the tunnel supply system. Maintaining and developing alternative supply options with different risk profiles is likely to be the best way to enhance the resilience of the Westport water supply.

18 Appendix A1 – Risk Register

PROJECT: Westport No.1 Water Tunnel - Option 2d | **Revision: A** | LAST UPDATED: 18/10/2017

Category	ID	Status	Cause / Risk / Hazard	Description of Risk	Identify consequences	Likelihood	Consequence	Risk	Mitigation	Primary Management Responsibility	Resolved Date	Resolution
Subject area	Risk ID #			***Brief description of the risks, or any significant changes in grading, and new risks identified***	***What will occur if the risk is left untreated?***	***High/ Medium/ Low***	***Severe/ Major/ Moderate/ Minor***	***Extreme/ High/ Medium/ low***	***List actions being undertaken to mitigate the risk***	***Who is responsible for managing this risk***	***When was it resolved***	***How was it resolved***
Design and Technical	1	**Open**	Extent of repair	Extent of collapse not known and may have progressed beyond 2015 inspection extents	Repair section may not go far enough and supply be either limited or fails again	Medium	Moderate	Medium	Make reasonable provision for additional stabilisation distance and removal quantities.	BDC		
	2	**Open**	Flow rate	Design flow rate is inadequate for future needs	Installed pipe is too small and supplementary pumped supply is needed	Low	Moderate	Low	Use pumped supply to augment if required, reduce losses	BDC		
	3	**Open**	Flow not effectively captured	Actual flow rate less then designed due to losses at transitions	Supplementary pumped supply is needed; remedial works	Low	Moderate	Low	Provide example detail for tenderers including grouting or sealing	Opus		
	4	**Open**	Works cannot be safely constructed	There is no way that the adopted solution can be safely constructed by a contractor	Alternative design solution needed. Pumped system to remain in service	Low	Major	Medium	Engagement with contractor and worksafe	Opus		
	5	**Open**	Future maintenance or extension	Inability or difficulty to repair or replace collapses that occure beyond the repaired section	Loss or reduction of supply for extended period. Pumped system needed.	Low	Major	Medium	Proposed solution will leave crawl space above pipe.	BDC		
	6	**Open**	Operational issues	Design results in operational issues, inconvenience or difficulty.	Additional ongoing costs.	Low	Moderate	Low	Retain operational oversight/comment on design.	BDC		
	7	**Open**	Cost too high	Tenders are much higher than expected and Council do not have sufficient funding available.	Unable to proceed with works or work extent reduced increasing residual risk. Pumped system required to remain.	Medium	Moderate	Medium	Have contingency funding available. Be prepared to re-evaluate benefit: cost of other options	BDC		
	8	**Open**	H&S	Design creates avoidable risks and/or hazards	Ongoing H&S risk	Low	Moderate	Low	Safety in design and HAZOP workshops.	Opus & BDC		
	9											
Programme	1	**Open**	Landowner issues	Legal issues with land access/usage. Land is held as a Water Conservation Reserve administered by DoC.	Possible legal challenge and judicial review. Potential delays, costs and unfavourable outcome.	Low	Major	Medium	Consultation with DOC.	BDC		
	2	**Open**	Resource Consents	Delay in obtaining consent or unexpected requirements/conditions	Delays, additional costs, ongoing operational constraints	Medium	Moderate	Medium	Proactive consultation with regulatory authorities	Opus		
	3	**Open**	Underground regulations	Unable to satisfy regulator (Worksafe) that works can be done to required safety standards	Delays, additional costs	Medium	Moderate	Medium	Proactive consultation with regulatory authorities	Opus & Contractor		
	4	**Open**	Slow progress	Construction much slower than expected	Delays, additional costs, variation claims	Medium	Moderate	Medium	Structure Contract to clearly assign risk and costs for delays.	Opus		
	5	**Open**	Council Approval	Delay or failure of Council to award Contract	Delays, additional costs, retendering, work is not undertaken.	Low	Major	Medium	Communication with elected members to avoid surprises	BDC		
	6	**Open**	Contract Dispute	Dispute during contract period	Delays, costs, retendering, inability to complete work	Medium	Moderate	Medium	Clear contract document; robust tender evaluation to weed out potentially troublesome contractors.	Opus & BDC		
	7	**Open**	Inadequate Tenders	No satisfactory tenders are received	Negotiations required, delayed evaluation, retendering, no-one prepared to undertake work	Medium	Major	High	Contract must be palatable to industry, BDC prepared to negotiate terms.	BDC		
	8	**Open**	Objections	Objections from Iwi, or other stakeholders to the work occurring	Delays, design changes, vandalism, obstruction, increased costs, loss of project support	Medium	Moderate	Medium	Proactively identify and engage with various stakeholders at early stage to avoid presenting ***fait accompli***	Opus & BDC		
	9											
Construction	1	**Open**	H&S Incident	Harm incident to person(s) working on or associated with the project	Delay, costs, legal consequences (fines, prosecution)	Low	Severe	High	All parties to proactively support H&S management. Contractor to comply with all regulatory requirements, and Principal to ensure that this occurs.	Opus, BDC, Contractor		
	2	**Open**	Collapse	Work triggers additional cascading collapse as supports are removed and stresses reallocated.	Delay, H&S risk, damage to pipe, variation claims, unable to complete works	Low	Major	Medium	Proposed methodology is well proven in this tunnel.	Contractor		
	3	**Open**	Cannot clear tunnel	Too much material or area cannot be sufficiently stabilised	Bypass tunnelling or similar required to link sound sections	Low	Major	Medium	Require contractor to be capable of undertaking bypass tunnelling if required.	Opus		
	4	**Open**	Unforeseen ground conditions	Ground conditions are not as expected (including for enabling/temporary works)	Variation claims, delays.	Low	Moderate	Low	Present all available information to contractor and require they are familiar with likely site conditions in order to tender.	Opus		
	5	**Open**	Inadequate design	Works prove to be not constructable as expected	Resdesign, delays, variation claims	Low	Moderate	Low	Workshop design with preferred contractor prior to award (ECI)	Opus & BDC		
	6	**Open**	Extreme event	Flood, fire, landslide, snow, earthquake or other significant event	Damage to works and equipment, fatal blow to feasibility, personal harm.	Low	Major	Medium	Identify and categorise individual risks and assign individual mitigation,warning triggers and actions. Ensure BDC and contractor's insurances aligned and provide wide coverage.	Opus, BDC & Contractor		
	7	**Open**	Equipment or material failure	Failure of critical equipment or materials during construction	Delays, variation claims	Low	Moderate	Low	Identify critical equipment items and materials and scrutinise accordingly.	Contractor		
	8	**Open**	Environmental Impact	Spillage, discharge or other event that causes environmental damage.	Delays, variation claims, regulatory action (fines, prosecution).	Low	Moderate	Low	Contractor to provide methodologies to minimise risk and response plans	Contractor		
	9	**Open**	Inexperienced Contractor	Contractor not familiar with local underground working conditions or techniques	Greater risk of incidents, delays, variation claims. Do not meet Worksafe requirements.	Medium	Severe	Extreme	Eliminate tenders from contractors who do not have relevant experience and proven competence	Opus & BDC		
	10											
Operation & Maintneance	1	**Open**	Future collapse	Tunnel collapses in area that was not repaired or damages pipe	Reduction or loss of flow. Unable to easily repair.	Medium	Moderate	Medium	Keep pumped system available for use at short notice. Monitor flow from tunnels. Provide backfill over most vulnerable sections	BDC		
	2	**Open**	Systemic tunnel residual risk	Substantial or total loss of part or all of tunnel system due to major collapse, seismic event or landslide	Loss of supply. Pumped system needed.	Medium	Major	High	Retain alternative supply; upgrade if necessary. Proactive stabilisation works in other parts of the tunnel system	BDC		
	3	**Open**	Gravel accumulation	Gravel builds up in pipe or upstream tunnel section.	Reduction or loss of flow.	Low	Moderate	Low	Ensure pipe is laid on even grade. Flush with high water volumes.	BDC		
	4	**Open**	Leaking joints	Pipe joints leak	Reduction in flow rate, scouring of support	Low	Minor	Low	Substantial margin allowed in design flow for leakage. Potential to enter for repair. Leakage will travel to bottom of tunnel in any case.	BDC		
	5	**Open**	Water Quality	Water quality from source deteriorates	Additional treatment required	Low	Moderate	Low	Catchment is generally bush, although out of BDC control.	BDC		
	6	**Open**	Regulations	Future law changes make maintenance more difficult or impractical	Alternative supply required.	Medium	Moderate	Medium	Future technology advances. Retain pumped system as standby.	BDC		
	7	**Open**	Durability	Pipe deteriorates more rapidly than expected.	Does not meet design life and replacement or rehabilitation is required.	Low	Moderate	Low	Ensure good quality pipe specified and used	Opus		
	8											

In relation to consequences or impact on the project, these are defined in the Table on the 'consequence' tab

From this assessment, the Priority of risks will be categorised into:
Extreme = Immediate attention required. Risk to be pro-actively managed with strategy to either eliminate risk, transfer risk or mitigate the risk. Responsibilities to be assigned immediately
High = Mitigation actions to reduce likelihood and consequence to be identified and reactively managed as part of the project management process
Medium = Mitigation actions to reduce likelihood and consequence to be identified and costed for possible implementation.
Low = to be noted, no action is needed unless grading increases over time

Risk Assessment Matrix

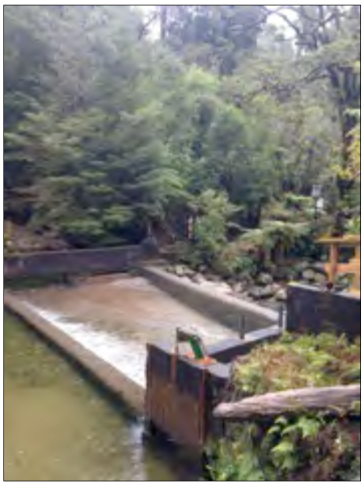
Likelihood	Consequence			
	Severe	Major	Moderate	Minor
High	Extreme	Extreme	High	Medium
Medium	Extreme	High	Medium	Low
Low	High	Medium	Low	Low

Ref: Risk Management Guidelines; Companion to AS/NZS 4360:2004

19 Appendix A2 – Geotech Ground Engineering Proposed Methodology

Westport water tunnels

Risk assessment and construction methodology
Proposed tunnel remediation works

Prepared by:

GEOTECH GROUND ENGINEERING
7370 State Highway 6
Charleston, Buller
West Coast, New Zealand
www.geotech.net.nz

GEOTECH
GROUND ENGINEERING

This document has been produced referencing the following documents:

- Health and Safety at Work Act 2015 (HSWA)
- Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016
- Guidance for a Hazard Management System for Mines, MBIE, June 2013
- AS/NZS 9001:2016, Risk based thinking
- General Risk and Workplace Management, WorkSafe, 2017
- Extractives: Developing a ground or strata instability principal hazard management plan, WorkSafe, August 2015
- ACOP: Ventilation in Underground Mines and Tunnels, WorkSafe February 2014
- ACOP: Ground or Strata Instability in Underground Mines and Tunnels, WorkSafe September 2016
- ACOP: Air quality in the Extractives Industry, WorkSafe September 2016
- ACOP: Emergency Preparedness in Mining and Tunnelling Operations, WorkSafe August 2016

Prepared by:

Lisa Dickson
Quality Manager - Geotech

Signed: L. Dickson Date: 11 October 2017

Reviewed by:

Ant Black
Managing Director – Geotech

Signed: Ant.B Date: 11 October 2017

Craig Smith
Mining Executive – TerraFirma Mining Limited

Signed: ____________ Date: **** October 2017

Figure 1. (Above and below). Opening of Westport town water supply, 1903. Historic photos courtesy of Dan Maloney, Westport.

Contents

1. Introduction page 5

2. Water tunnels overview page 6

3. Geological setting and assessment page 9

4. Risk assessment page 13

- Ground/strata instability
- Ventilation/air quality (including fire risk)
- Winding machinery/winch

5. Construction methodology page 16

- Development of a safety management system
- Portal establishment and ventilation
- Spot bolting and drilling
- Stabilisation and excavation
- Piping
- Additional recommendation

6. Control measures page 19

Appendices page 24

1. Introduction

Purpose of the document

Geotech have been engaged by Buller District Council, to document a construction methodology to repair/reinstate the Westport water tunnel collapse, with supporting estimates of time and cost.

Terra Firma Mining Limited have also been engaged by Council to provide peer review services of the methodology prior to it being submitted to WorkSafe.

The construction methodology is to:
Reinstate the tunnel in a safe manner for Worksafe consideration and comment, demonstrating how risks will be managed. The methodology will need to demonstrate that the tunnel can be reinstated in an efficient and cost effective manner, but primarily it is to deliver the quantity of water to maintain reservoir levels at the Westport Water Treatment Plant.

The Westport water tunnels have a long and successful history, but in the last 30 years have suffered from underinvestment and sub-optimal ground support. This does not preclude refurbishment with modern methods, and nor does it detract from the excellent source water.

Costing, proposed methodology and timing have been designed around full compliance in the present regulatory/safety environment. Should BDC decide to go with a tunnel reinstatement option the successful tenderer will be required to satisfy the regulatory requirements of WorkSafe. This document should be submitted to WorkSafe to formally initiate their early involvement in project planning. Positive discussions with Bryn Harrington of WorkSafe in Greymouth have been started.

Summary

We believe that with the methodology outlined, the Number 1 Westport water tunnel can be refurbished for a budget figure of NZ$1.5M. This figure includes the installation of a robust polyethylene pipe over a distance of 500m, this is a compromise between 450m (that takes in the recent fall but would finish in poor quality ground) and 660m. If budget permitted, extending the pipe some 660m would be optimum and would significantly reduce the risk. Installing 500m of pipe, supplemented by the additional spot bolting that we have recommended, would achieve a good outcome.
It is recommended an additional $200k be spent spot bolting the remaining un-piped tunnel (refer page 18).

2. Water tunnels overview

History of the Westport water supply:

The original Westport water supply is essentially the same supply that feeds the township today. A gravity-feed system consisting of four earth tunnels (around 1,900m in total length) and timber races were constructed establishing water supply from the south branch of Giles Creek (headwaters of the Orowatiti River) to three raw water reservoirs/storage ponds. The water was piped from there to the township via a single eight inch (200mm) diameter cast iron pipeline (refer to water supply maps in Appendix A). The water scheme was opened in 1903, after a lengthy construction period.

Around 1920, a second 14 inch (355mm) diameter steel delivery pipeline was installed to provide additional water to cope with and increase in population in the township.

Figure 2. Westport waterworks dam, Giles Creek, early 1900s

This system is still relied on to supply Westport with water to the current day. Some modifications have been made since 1920. A delivery pipeline (between Westport and Carters Beach) was installed by Carters Beach residents in 1967. This enabled Carters Beach to join the town water supply. In 1986, the Westport Borough Council constructed a water treatment plant, with assistance from a Government subsidy. At the time, this plant was state of the art, and the water supply was graded AA (the highest grading possible). In 2000, New Zealand's drinking water standards changed. The Westport water supply remained un-graded from this time, as the system did not meet the new water standards.
The water treatment plant was extensively upgraded by Buller District Council (BDC) in 2014. The upgrade consisted of the installation of a flocculation tank, UV plant and a concrete

reservoir, along with other minor improvements. According to the ESR Drinking Water website (http://www.drinkingwater.esr.cri.nz), the Westport water supply remains un-graded.

Figure 3. Diagram showing layout of Westport water supply

Tunnel collapse history:

Over the years, there have been several partial collapses in the tunnels that have affected the delivery of water to the township.

- 2000: First significant tunnel collapse (Tunnel No. 4) occurred.
- 2009: A second significant collapse (Tunnel No. 4) occurred in 2009. This tunnel had by now caused issues on several occasions prior, and was subsequently piped the full 400m length.
- 2014: Partial collapse in Tunnel No. 1. Fall is impassable to personnel, but water supply passes through the collapsed area unrestricted.
- 2016: Full collapse in Tunnel No. 1. This collapse in late 2016 blocked the tunnel and halted water flow. The fall is thought to have been as a result of the Kaikoura earthquake (BDC Engineering Department, personal communications, September 2017) but this is not known for sure, and the exact date of the collapse is not known.

Reason for proposed remediation works of Tunnel 1:

The full collapse in Tunnel No. 1 in late 2016 blocked the tunnel and halted water flow. At 1.2km long, this tunnel is the longest of the four tunnels. The collapse, at 885 meters in from the Giles Creek intake end (same site as earlier 2014 collapse), has resulted in the tunnel system being unusable, due to no water being able to pass through the tunnel system. Water is currently being pumped from another source (alternative water supply pump station) back up to the reservoirs, essentially by-passing the tunnel system.

The tunnel network (when operational) supplies 150-200 litres per second (normal daily supply). The alternative water supply produces around 85 litres per second. The alternate supply cannot be operated in flood conditions, or when heavy rain increases debris in the water at a level that impacts on pump efficiency. The alternate supply effectively provides at best, half what the tunnel system can provide.

Buller District Council are investigating means by which to reinstate the water supply. Works may include strengthening works, excavation/clearance of the collapse and stabilisation or strengthening works and installation of a pipe through the existing tunnel system. This document outlines our preferred construction methodology, which addresses risks related to ground/strata instability, air quality, fire and emergency egress, when working in the tunnel. These risks will need to be managed by any contractor engaged to undertake remediation or reinstatement works. Further detail on these requirements is included in section 5 of this document.

3. Geological setting and assessment

Background

The Westport water tunnels and treatment plant is located at Sergeant's Hill, a rural setting on the eastern outskirts of Westport (approximately 6.5km from Westport township). The site lies at an elevation of around 130 above sea level. Sergeants Hill was originally a gold mining district, with a large amount of gold taken from the terraces in the late 1800s.

Site characterisation and geological properties

The Westport water supply tunnels are driven in O'Keefe formation, which is a yellow, muddy, micaceous fine sandstone. Minor hard cemented layers are present, these layers are difficult to see, but are encountered when drilling. Generally the ground is homogeneous with few structural defects. The lack of defects is probably related to plastic deformation due to a rock strength that is estimated to be below 500kpa if damp, and increases to a nominal maximum of 10mpa when locally indurated. Strength in the order of 1-2mpa should be expected. With an unsupported stand-up time in excess of 100 years in many places the RMR is high (Figure 4) although this is distorted by a modest primary design width of 0.75m.

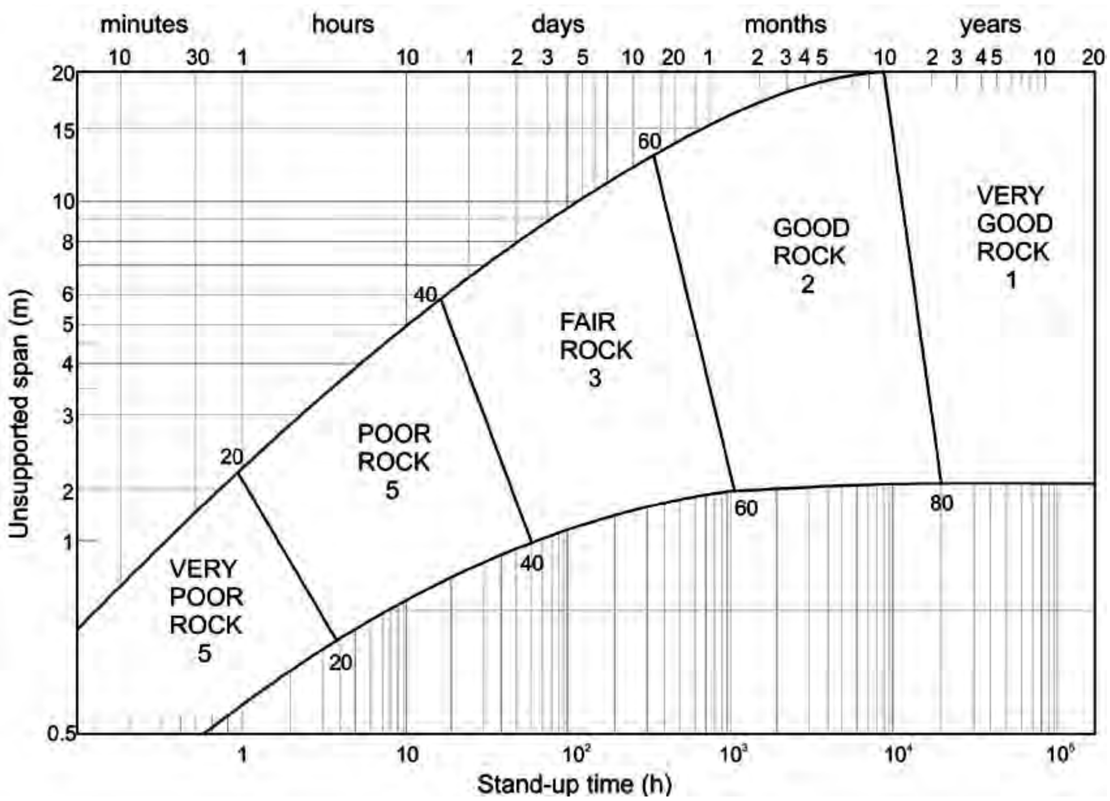


Figure 4. Relationship between the stand-up time and span for various rock mass classes according to the RMR system (Bieniawski, 1993).

Water ingress is not common, but where it occurs, tunnel collapse happens. Due to depth of cover (Figure 5) there is no water ingress into Tunnel No. 1 and the collapse mechanism is initiated by fretting of the tunnel walls causing width to increase, and roof failure to follow. Failure blocks are generally below 100 litres volume but larger blocks occur when defects are present or as the roof span exceeds 1.5m. While the tunnel dimension stays at its driven width (0.75-0.8m) the tunnel is very stable.

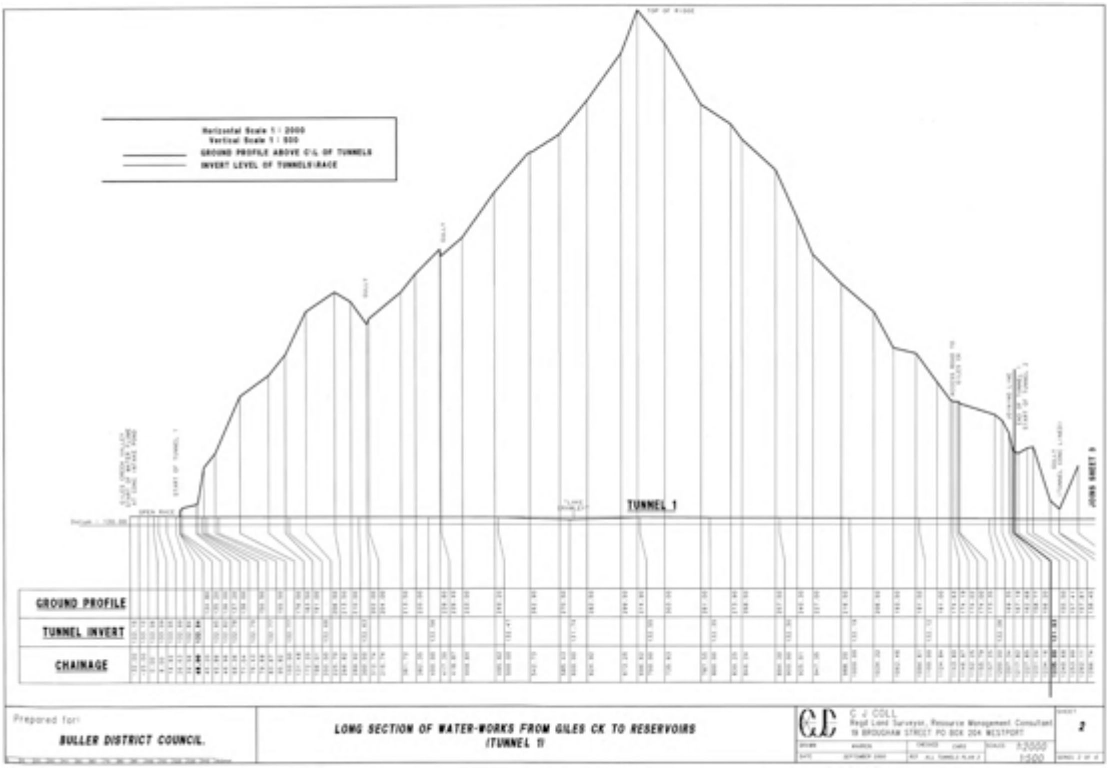


Figure 5. Survey map showing ground cover levels above Tunnel No. 1 (full size version in appendices).

Over time collapses and fretting has blocked water flow and indeed the entire tunnel. BDC used to have a programme of building wooden water conduits that superficially appeared to be propping and ground support. On closer examination it becomes apparent that the timberwork produced rectilinear pipes and added little ground support. Timber packing to provide ground confinement was lacking and the ground would keep failing around and onto the timberwork.

Due to timbering collapses, Geotech Limited were called in to add muscle to a collapse that BDC did not have the manning to cope with. The collapse was “spiled” through and water flow re-established with town water supply down to seven days. After discussions between BDC District Engineer Gary Murphy and Geotech Limited, a modern ground support trial over 20 metres of wet collapsing ground was initiated.
Resin encapsulated rock bolts, mesh and “W” straps were installed (Figure 6). 1.8 metre by 20mm bolts were installed in the roof with resin anchors in 27mm diameter holes at one metre spacing. Due to width/space considerations 1.2m bolts were installed in the rib at 1m centres. These bolts held “W” straps to the rib and provided immediate and effective confinement, which is a key to ground stabilization in the O’Keefe lithology.

Figure 6. Geotech Ltd removing timber using modern bolts, mesh and 'W' strap in Westport water tunnel - Tunnel No. 4.

Experience has demonstrated modern ground support works well but bolts must not be isolated but joined by tensioned “W” straps that add confinement.

A historic geotechnical assessment report was completed by Anthony Black of Geotech Limited, for Buller District Council in 2008/09. This report resulted in the trials to install resin anchor bolts and w-strap supports discussed above.
A geotechnical assessment was completed by Open Earth Consulting (for WestReef Services Ltd) in 2016. A copy is included in Appendix B.

A site visit was undertaken by Ant Black of Geotech Limited on 18 September 2017, and again (accompanied by Craig Smith – TerraFirma) on 21 September 2017. These visits confirmed that there has been no change to the nature or status of the tunnels (bar the structural collapse), and the site characteristics, ground conditions and natural and geotechnical features remain the same.

Seismic hazards

Sergeant’s Hill lies within a seismically active part of New Zealand, being located roughly 100km west of the Alpine Fault plate boundary. The site (and the water tunnels) have been subjected to multiple instance of strong ground shaking in recent history, with the Inangahua Earthquake (1968) and the Murchison Earthquake (1929). No active faults are known in the

immediate vicinity of the site and surrounds, however general seismic risk exists in the region from potentially strong ground shaking associated with any movement or rupture of the Alpine Fault. The construction methodology controls intended to manage risks related to ground/strata instability will apply to seismic risk.

4. Risk assessment

Known site risks:

Following the site visit and discussions held on 18 September 2017, a broad-brushstroke risk assessment (BBRA) was completed for the site, looking at general risks to be considered when undertaking any remediation works. A copy of the BBRA is included in Appendix C.

The BBRA identified two principal hazards (ground/strata instability and ventilation/fire). There are also risks/hazards associated with the use of a winch to assist with tunnel muck out. The following table summarises the results of the risk assessment in relation to these risks:

Ground or strata instability – hazards and risks assessed	Control measures that address the risks
Risk of rock fall from the slope above the portal	• Daylight area above portal (including large rocks) prior to work commencing • Establish appropriate rockfall protections measures/culverts • Day light portal to remove stressed sets • Establish new portal • Monitor ground conditions around portal on a regular basis • Portal watch at all times when staff are working in tunnels
Risk of rockfall or collapse inside the tunnels – injury or temporary confinement	• Initial stabilisation and support (design life equal or greater to the construction period) to be installed prior to works commencing (as per documented PHMP) • Report any signs of slumping, instability (of ground or supports) or geological changes • Geological assessments as required • Refuge station to be established, suitable for maintaining staff in the event of confinement, during excavation of single entry
Risk of collapse when removing existing timber works*	• Increase bolt density on entering the timbered areas • Undertake tapping (with pick or hammer) to hear whether there is load prior to commencing sections of work • Extra vigilance and experienced staff will be required when removing timbered areas of tunnels
Risk of further collapse as a result of excavation/remediation works	• Initial stabilisation and support (design life equal or greater to the construction period) to be installed prior to works commencing (as per documented PHMP) • Report any signs of slumping, instability (of ground or supports) or geological changes • Geological assessments as required
Risk of rock fall or collapse as a result of seismic activity	• Initial stabilisation and support (design life equal or greater to the construction period) to be installed prior to works commencing (as per documented PHMP)

	• Emergency plan to be in place prior to works commencing. • No work subsequent to any noticeable earthquake until a geological assessment has been completed.

* Above the timber supports/tunnel pipe, it is difficult to assess the volume of fall material currently being supported by the timber works. When removing timber, this loose material can cascade down reasonably rapidly. To recover the fall, there must be enough space between the fill and the roof to enable entry and rock bolting to effect recovery. It is difficult to ascertain the amount of load on the timber (unless it is bowed under load), but there is always the risk of catastrophic failure when knots are in the props.

Ventilation and air quality – hazards and risks assessed	Control measures that address the risks
Air quality in tunnels becomes hazardous to workers due to build up of fumes/gases in the tunnel	• Ventilation control plan to be in place (a documented PHMP) • Excavator working in tunnel to be pneumatically powered to eliminate risk of fumes and reduce risk of smoke/fire • Muck out wagon to be on a continuous rope (rail/winch) to remove risks posed by diesel fumes and significantly reduce fire risk • Winch and other equipment to be sited outside of tunnel environs, where it can have no impact on tunnel air quality • Monitor air quality and air humidity to manage risk of heat stress
Fire/smoke risk in tunnels affects air quality	• All machinery operating in the tunnel must be fitted with fire suppression and extinguishers • Remove all sources of ignition where possible • No workers to be in-bye of any ignition source when working in tunnels – workers MUST have direct access to portal (not blocked by machinery) at all times when machinery is operational • Refuge bay to be established within stretch of tunnel near excavation works • Staff to carry self rescuers
Dust levels makes air quality in tunnel hazardous to workers	• Geological assessment to confirm soil/rock mineralogy • Monitor dust generated by works • Monitor air quality to ensure adequate fresh air is being received • RPE to protect workers from respirable dusts when drilling etc

Winding machinery – hazards and risks assessed	Control measures that address the risks (see Section 6 Control measures for detail)
Injury from moving parts	• Winching protocols to be established, including visual or audible signals • Winch to be established outside portal, monitored by portal watch at all times • All workers to stand clear of wire rope and load

	during operation • Wear heavy leather gloves when handling the wire rope
Stored energy	• Winch to be rated for load capacity • Complete commissioning and pre-start checks prior to operation • Particular attention to wire rope condition
Trip and fall	• Keep winch operation area clean, tidy and free from obstructions • Winch is not to be operational when people are traversing the length of the tunnel
Overheating/fire	• Winch to be located clear of tunnel, where it cannot impede egress • Winch to be monitored by portal at watch at all times during operation • Fire extinguisher to be on site

The risk appraisal and assessment has taken into consideration the views of Geotech Limited (as consulting geotechnical and tunnelling expertise), WestReef Services staff (contracted to run the Westport water system, undertake general maintenance on the system and run the treatment plant, good knowledge of the water system operation) and Buller District Council's Asset Engineer. It is expected that any company who may undertake the remediation works will incorporate the identified risks into their on-site health and safety management system prior to works commencing. This may require controls to be adjusted to account for machinery selection, existing guards, safety devices etc.

5. Construction methodology

Due to the modern regulatory environment, we now favour stabilising the tunnel and removing the fall to enable pipe installation as this eliminates the need to go back into the tunnel.
The construction methodology below is based on providing sufficient strata control (through rock bolting) to enable safe installation of HDPE socketed pipes. These pipes have high resilience to load from falls, and this resilience will be enhanced by pneumatically placing cementitious fill over the pipe to give cover that will ultimately set to 10mpa.

The proposed construction methodology programme is shown in figure 7 below.

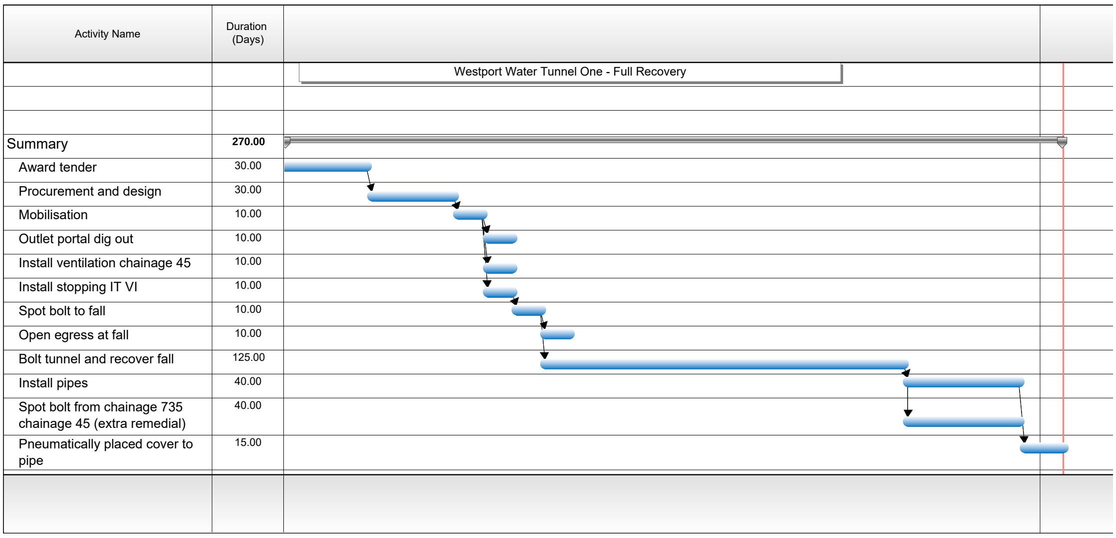


Figure 7. Draft construction programme showing 270 day estimate. Full size version included in Appendices.

Development of a safety management system

Following any award of tender or contract, the identified contractor will be required to confirm the construction methodology and develop a safety management system (SMS) to be used as the primary means of ensuring the safe operation of the tunnel during reinstatement works. The SMS must be comprehensive enough to suit the risks and complexity of the tunnel operations. At a minimum, the SMS should include:

- Safety policy
- Organisational structure and contacts for those involved in the tunnel works
- Confirmation of training
- Procedures to control hazards in normal operations (SWPs/SOPs)
- Principal Hazard Management Plans (PHMPs) for key identified hazards:
  - Ground/strata instability
  - Air quality/Ventilation
  - Fire
- Emergency response plan, including plans to address risk of collapse causing temporary confinement

- Process for incident management
- Process for worker participation in the SMS

All PHMPs must be available for examination by an inspector at least three months before the commencement of the tunnel operation. WorkSafe have indicated that they are open to conversation around the notification periods, recognising the importance of the provision of potable water supply to the Westport township (Mark Pizey, WorkSafe, via email 2 October 2017).

Portal establishment and ventilation
Once mobilised and established on site, the first priority is to dig out the downstream portal, which is under load and imminent danger of collapse. We recommend that the existing portal is daylighted, removing the stressed sets along the first 12m of Tunnel No.1. A new portal will need to be established, we recommend installing 2.5m diameter steel culvert pipes. Along with the portal establishment, ventilation is to be established at the entry to the water intake, on the far side of the tunnel collapse, at chainage 45. Previously we have used a remote, hydraulically powered fan that enabled us to have variable speed. The fan also had a door for egress. As Tunnel No. 1 effectively has two entrances, IT VI will require a brattice stopping to enable pressurisation of the tunnel.

Spot bolting and drilling
Initial spot bolting needs to be undertaken in the worst areas to enable safe access to the fall. We have allowed ten days to improve ventilation at the fall and hopefully establish a second egress. If this was not achieved after 10 days, the attempt should be abandoned, and the health and safety system would need to address the single entry tunnel situation and the additional additional standards that this imposes. Drilling for spot bolting will be dry. This produces some (very minor) dust, which can be controlled by a combination of ventilation and respiratory protection (RPE). There should be little dust generated due to drilling through poorly consolidated sandstones that readily cut. Wet drilling is not acceptable as if the insitu clay is wetted, a good resin rock bond is not achieved and the efficacy of the bolts will drop. All of the bolting (initial spot bolting and stabilisation works) will be dry drilling.

Stabilisation and excavation
Once the initial spot bolting has been completed (and second egress has or has not been established), work will commence from the portal working in, installing stabilisation and support consisting of rock bolts, w-strap and mesh (estimate 8 bolts per every 2.5m. There will be minor stripping of the ribs, particularly when they are showing signs of stress. Stripping both the ribs and the wood out of the tunnels is very physical, and ventilation is required to keep the men cool as progress will only be achieved with "hard labour". The work and the rock type is non-oxygen consumptive, but keeping cool, low humidity working conditions requires a reasonable air flow. This air flow is also related to the outside external conditions, and on a hot day, fan speed needs to be increased but air movement needs to be kept below dust lift-off velocities.
To reduce fire risk, and to keep the tunnel width as narrow as possible, a rail and winch system will be used for muck removal. A double drum winch system will be set up outside and

controlled by the portal watch through either audible or visible signals (as per standard winching protocols). Although the tunnels have had a long stand up time, this is heavily a function of width and any stripping out must be minimised.
An excavator will be positioned at the face of the collapse. Due to the initial single egress status (no passage over the collapse for workers), it is vital that workers are always positioned out-bye of any ignition source when working in the tunnels, where possible. Workers must at all times have direct access to the portal, with exit not blocked by machinery.
The remediation works is planned for low-level manning, with two experienced tunnel crew sited inside the tunnel, and another 1-2 staff outside the portal.

Piping
Once the tunnel is fully re-established, some 500 meters of socketed pipe in 5.8m lengths will be installed under retreat conditions. The pipe will be bought in on the light rail system. As it is laid, the rail will be retreated to the portal. Once the pipe is installed, it will be pneumatically covered with very low strength (nominally 10mpa) dry shotcrete mix, which will set over time with natural humidity in the air. This layer will ensure pipe integrity from roof fall loading and resist any puncturing from a rock bolt that may come down. Once the pipe is installed and the pneumatically installed cover is in place, no further entry is envisioned for the tunnel. You will note from the construction programme (Figure 7), that work in the tunnel is very labour intensive and that the total job takes some 270 days, of which 125 days involve tunnel bolting and fall recovery.

Advice has been reviewed from Dan Johnson et al (Opus New Zealand), and this is appended (Appendix E). The Opus advice is costed and planning is based on their recommendation.

Additional recommendation
It is recommended that localised spot bolting be conducted in the tunnel that is not piped (from Intake IV to chainage 735), a figure of $200,000 is estimated as an additional sum to complete this work and it would bring about a significant risk reduction for the Council.

6. Control measures

This section discusses in more detail the controls required to manage hazards identified in the risk assessment.

Geological assessment

Likely geological conditions have been identified using data from the following sources:

- Site inspections, including previous tunnel inspections and remediation works undertaken by Geotech Limited
- Plans and survey maps of the water tunnels, including surveys showing ground profiles, previous tunnel collapses, and locations of historic mine shafts (included in Appendix A)
- Geotechnical characterisation and geological maps (*Geology of the Greymouth Area, Institute of Geological and Nuclear Sciences*, Lowe Hutt, 2002).

A copy of the most recent documented geotechnical assessment is included in Appendix B, with updates from site visits completed by Geotech Limited in September 2017 included in this document.

Ground/strata monitoring

Ground or strata instability must be monitored over the duration of the remediation works. Monitoring controls are aimed at:

- Identifying changes in the ground condition or roof loading
- Ensure controls (such as stabilisation and supports) continue to be effective
- Early detection of any changes to ground or strata stability
- Monitor rock mass characteristic for any change during work operations

A monitoring plan must be in place, with daily checks whenever works are being undertaken. A competent person must undertake a physical check, taking note of any changes, abnormalities, rock fall, sags, faults or changes in support loadings. The status of supports is to be checked.

Inspections must be documented and signed, and records retained. Periodic photographs of walls, roof/backs, pillars etc should be taken, and dates recorded.

In the event of any actual or suspected ground or strata change or failure, the Tunnel Manager must be notified.

Any unplanned rockfall must be assessed and investigated by the Tunnel Manager. If the investigation finds the cause of the fall was due to a ground or strata support fault, the Tunnel Manager must ensure that the support controls are reviewed by a competent person.

Ventilation:

If it is possible to successfully force air through the main collapse (which is permeable due to the amount of timber in the fall), ventilation ducting will not be required. Presently there is modest natural ventilation in the tunnel, and this will be sufficient until heavier works are started.

Air flow would be achieved by the installation of a fan at chainage 45, and brattice stopping at IT VI. Brattice stoppings will be established each 200m to be deployed should there be an out-bye fire. The brattice would be rolled out and secured, and compressed air lines turned on in-bye of the stopping to assist with pressurising the area where the men are located. In effect, in-bye of the stopping would become a refuge chamber. Caches in sealed 20litre buckets will be out in the tunnel for use should the men be trapped in the unlikely event of a catastrophic roof fall. Caches will contain clean water, food, space blankets and additional lighting. They will be installed on first entry into the tunnels at two locations, nominally 200m and 400m in from the outlet portal.

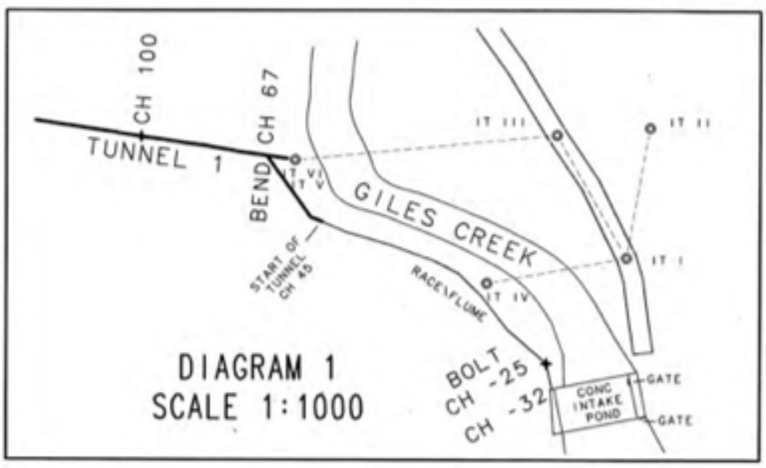


Figure 8. Diagram showing location of ventilation fan and brattice stopping.

Machinery, excavation and drilling method controls:

All equipment is to be selected with air quality and fire risk considerations in mind. Pneumatic excavator operation (rather than diesel) will remove the risk of diesel particulate matter (DPM) in the tunnel working environment and will reduce fire risks.

The muck out bin will be mounted on rails and will be operated by a winch located outside the tunnel, away from the portal, where fumes can properly disperse.

Air quality will be monitored. In the event that dust becomes a concern, muck-out piles can be dampened down. Experience has been that the water tunnels are reasonably high humidity with low dust generation. Workers should remain out of the dust generating areas, and should be working upstream of any dust generated, and in an area clear of dust hazards.

Respiratory protective equipment (RPE) is to be worn for protection as required, but should only be used in conjunction with other controls. Every effort is to be made to reduce airborne contaminants to levels that do not require the mandatory use of respiratory protections as far as reasonably practicable.

Contractors must ensure a rigorous maintenance regime is in place for all machinery, drills etc, to optimise efficient operation and minimise dust generation at the source.

No diesel emissions are to be generated within the tunnel environs. Be aware that some diesel filtration systems will produce high levels of heat and pose a significant fire risk in underground work situations.

Workers within the tunnel must remain in-bye of any machinery/ignition source. Workers must have direct access to the portal, and their exit must not be impeded by any machinery or potential ignition source at any time. Suitable and sufficient fire extinguishers must be on hand at all times when work is operational.

The proposed methodology involves no blasting and no use of hazardous substances within the tunnel environs.

Air quality monitoring:

Air quality must be monitored over the duration of the remediation works. Monitoring controls are aimed at:

- Ensuring that the working environment is suitable for work
- Identifying changes in the air quality
- Ensure controls (such as dust suppression and fume elimination) continue to be effective
- Early detection of any changes to air quality

A "fresh air" environment must be maintained at all times when workers are in the tunnel. "Fresh air" means that the air;

> "*Contains not less than 19% by volume of oxygen, and contains no more than 0.25% methane, 25ppm of carbon monoxide and no more than 5,000 ppm of carbon dioxide. It must also contain no other substance at a level that is likely to cause harm to a mine worker over the period that the worker is exposed to the substance at the mining operation*."

The atmosphere underground is limited and confined. Other than fire and dust generation (potentially from rockbolting) none of the planned activities can lead to oxygen depletion. The tunnels naturally have very good air and support good underground populations of wetas, glow worms etc. As previously laboured in the document, fire is the biggest risk to the ventilation system. There are no oxygen depleting minerals in the system. In terms of ventilation requirements, it is quite a benign job, with the ground being extremely inert and non reactive. Drager X-am 5000 (or similar personal monitors) will be present within the tunnels. These monitors will measure environmental changes, including detecting the presence of combustible gases and vapours as well as monitoring any changes to O2 levels.

Temperatures (heat and humidity) must be monitored to ensure that there is no risk of heat stress to workers. Intervention methods will be required if effective temperatures increase

above 25^{o}C. General tunnel temperatures are good, but at the crown of the fall there is a risk of semi-stalled air, and temperatures will need to be monitored,

In the event of any actual or suspected air quality changes, the Tunnel Manager must be notified.

Regular inspections of work areas should be carried out to identify any sub-standard work practices or conditions.

Training:

Workers involved in the tunnel remediation works must be competent to perform their roles. They must have an understanding of:

- The contents of any ground/strata instability PHMP
- Effectiveness of ground support and how it works
- Ground instability hazards at the site
- Scaling and barring down
- Support and installation methods and procedure outlined in the construction methodology or PHMP
- Handling, storage, and application of the chemicals to be used, and the personal protective equipment (PPE) required
- Monitoring arrangements and testing procedures
- The contents of any ventilation and air quality PHMP
- The works and how they may effect the air quality
- Air quality hazards at the site
- Controls in place to eliminate or minimise the effects of airborne contaminants and dust
- Correct operation of equipment and mobile plant to manage risks associated with fumes, emissions, dust, heat and fire
- Correct use of respiratory and personal protective equipment (RPE and PPE) required (including self rescuers)
- Extra vigilance required for single entry work

Emergency preparedness:

The contractor responsible for any tunnel collapse remediation works will be required to provide an emergency preparedness response plan for the works. The plan should be proportionate to the operation, and should comply with the Approved Code of Practice for Emergency Preparedness in Mining and Tunnelling Operations. At a minimum, the plan should;

- Identify the potential emergencies, including tunnel collapse, fire, evacuation, and entrapment
- Identify availability of equipment and resources for rescue and recovery
- Treatment and transport of injured workers
- Emergency communications

The plan must be documented and approved prior to works commencing, and must be accessible to all workers on site.

Appendices

- Appendix A: Westport water supply maps
- Appendix B: Geotechnical assessment and Fall Recover Options report for Tunnel No. 1, Westport Water Supply
- Appendix C: Broad brush-stroke risk assessment
- Appendix D: Estimate construction programme
- Appendix E: Advice from Opus New Zealand re piping
- Appendix F: Draft costings

Figure 9. Men working on construction of Westport water tunnels and supply, circa 1901.

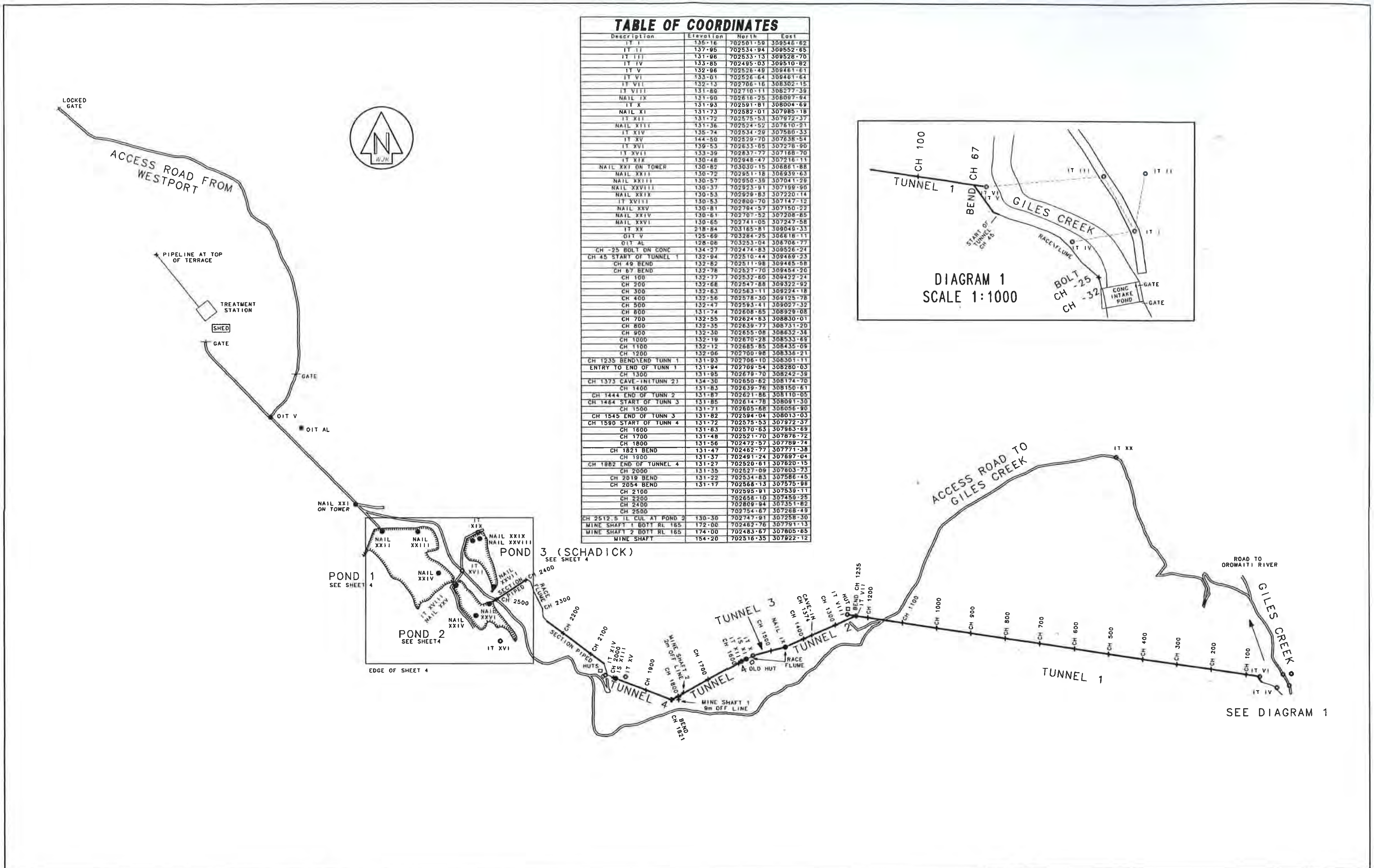


TABLE OF COORDINATES

Description	Elevation	North	East
IT I	135·16	702501·59	309546·62
IT II	137·95	702534·94	309552·65
IT III	131·96	702533·13	309528·70
IT IV	133·85	702495·03	309510·82
IT V	132·96	702526·49	309461·61
IT VI	133·01	702526·64	309461·64
IT VII	132·13	702706·16	308302·15
IT VIII	131·89	702710·11	308277·39
NAIL IX	131·90	702616·25	308097·94
IT X	131·93	702591·81	308004·69
NAIL XI	131·73	702582·01	307985·18
IT XII	131·72	702575·53	307972·37
NAIL XIII	131·36	702524·52	307610·21
IT XIV	135·74	702534·29	307580·33
IT XV	144·50	702529·70	307638·54
IT XVI	139·53	702633·65	307278·90
IT XVII	133·39	702837·77	307168·70
IT XIX	130·48	702948·47	307216·11
NAIL XXI ON TOWER	130·82	703030·15	306861·88
NAIL XXII	130·72	702951·18	306939·63
NAIL XXIII	130·57	702950·39	307041·29
NAIL XXVIII	130·37	702923·91	307199·90
NAIL XXIX	130·53	702929·83	307220·14
IT XVIII	130·53	702800·70	307147·12
NAIL XXV	130·81	702794·57	307150·22
NAIL XXIV	130·61	702707·52	307208·85
NAIL XXVI	130·65	702741·05	307247·58
IT XX	218·84	703165·81	309049·33
OIT V	125·69	703284·25	306616·11
OIT AL	128·06	703253·04	306706·77
CH -25 BOLT ON CONC	134·27	702474·83	309526·24
CH 45 START OF TUNNEL 1	132·94	702510·44	309469·23
CH 49 BEND	132·82	702511·98	309465·58
CH 67 BEND	132·78	702527·70	309454·20
CH 100	132·77	702532·60	309422·24
CH 200	132·68	702547·88	309322·92
CH 300	132·63	702563·11	309224·18
CH 400	132·56	702578·30	309125·78
CH 500	132·47	702593·41	309027·32
CH 600	131·74	702608·65	308929·08
CH 700	132·55	702624·63	308830·01
CH 800	132·35	702639·77	308731·20
CH 900	132·30	702655·08	308632·36
CH 1000	132·19	702670·28	308533·69
CH 1100	132·12	702685·85	308435·09
CH 1200	132·06	702700·98	308336·21
CH 1235 BEND\END TUNN 1	131·93	702706·10	308301·11
ENTRY TO END OF TUNN 1	131·94	702709·54	308280·03
CH 1300	131·95	702679·70	308242·39
CH 1373 CAVE-IN(TUNN 2)	134·30	702650·62	308174·70
CH 1400	131·83	702639·76	308150·61
CH 1444 END OF TUNN 2	131·87	702621·86	308110·05
CH 1464 START OF TUNN 3	131·85	702614·78	308091·30
CH 1500	131·71	702605·68	308056·90
CH 1545 END OF TUNN 3	131·82	702594·04	308013·03
CH 1590 START OF TUNN 4	131·72	702575·53	307972·37
CH 1600	131·63	702570·63	307963·69
CH 1700	131·48	702521·70	307876·72
CH 1800	131·56	702472·57	307789·74
CH 1821 BEND	131·47	702462·77	307771·38
CH 1900	131·37	702491·24	307697·04
CH 1882 END OF TUNNEL 4	131·27	702520·61	307620·15
CH 2000	131·35	702527·09	307603·73
CH 2019 BEND	131·22	702534·83	307586·45
CH 2054 BEND	131·17	702568·13	307575·98
CH 2100		702595·91	307539·11
CH 2200		702656·10	307459·25
CH 2400		702809·94	307351·82
CH 2500		702754·67	307268·49
CH 2512.5 IL CUL AT POND 2	130·30	702747·91	307258·30
MINE SHAFT 1 BOTT RL 165	172·00	702462·76	307791·13
MINE SHAFT 2 BOTT RL 165	174·00	702483·67	307605·65
MINE SHAFT	154·20	702516·35	307822·12

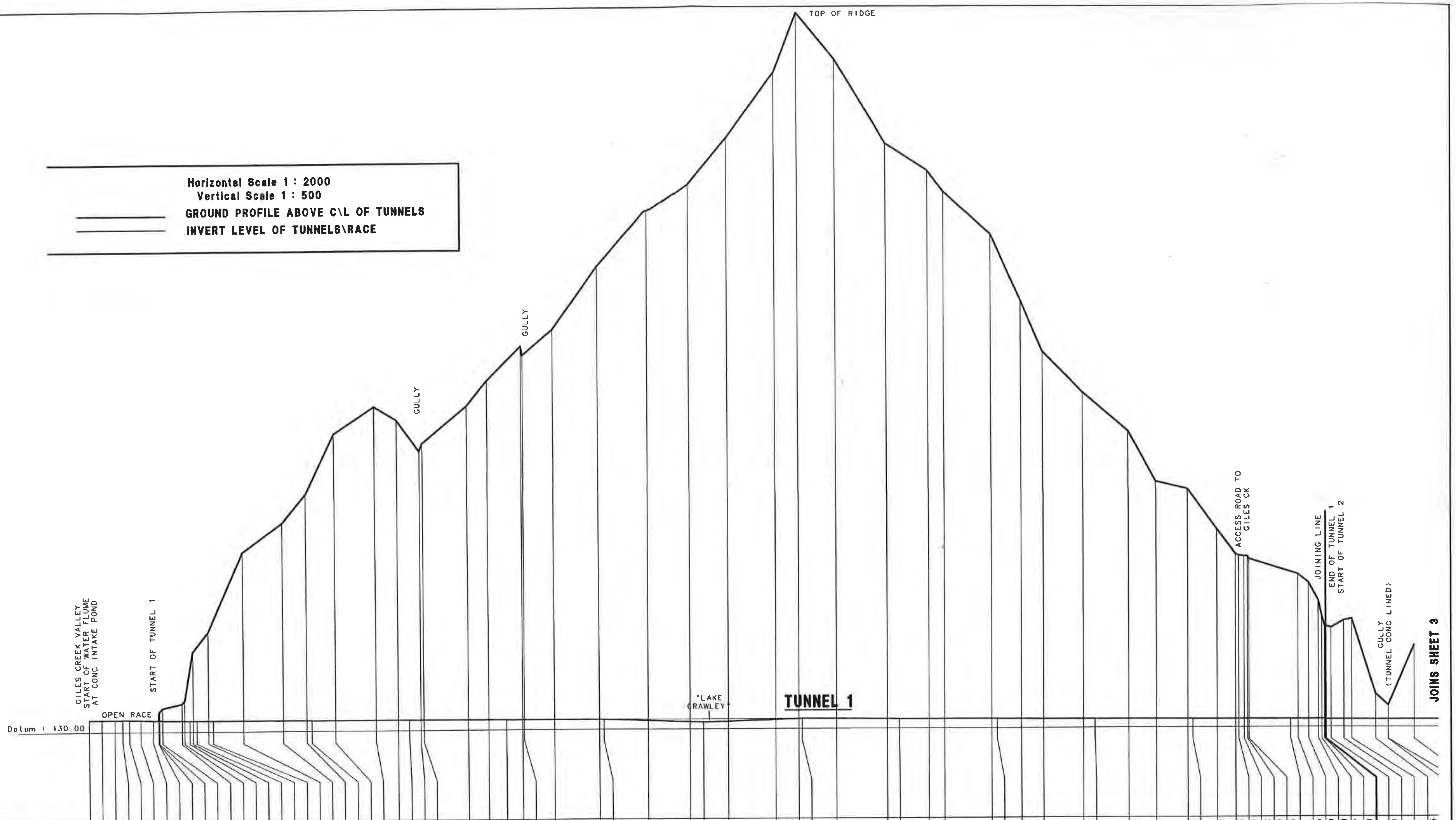
Prepared for:

BULLER DISTRICT COUNCIL.

PLAN OF WATER-WORKS FROM GILES CK TO RESERVOIRS

C J COLL
Regd Land Surveyor, Resource Management Consultant
19 BROUGHAM STREET PO BOX 204 WESTPORT

DRAWN	WARREN.	CHECKED CHRIS	SCALES 1:5000	SHEET 1
DATE	SEPTEMBER 2000	REF ALL TUNNELS PLAN 1		SERIES 1 OF 4



GROUND PROFILE	TUNNEL INVERT	CHAINAGE
	133.15	-32.00
	133.12	-25.00
	133.06	0.00
	133.09	8.00
	133.05	14.92
	132.99	26.63
	132.84	39.56
	132.94	**48.00**
134.80		45.20
135.20	132.95	45.86
136.00	132.82	48.96
137.20	132.78	68.36
138.00		71.04
	132.79	76.43
150.50		79.69
	132.77	83.67
155.50		95.82
	132.77	100.00
176.00		131.48
183.50		172.20
191.00		196.01
	132.68	200.00
206.50		225.70
213.50		266.82
210.00		289.92
	132.63	300.00
202.00		312.74
204.00		315.74
213.50		361.72
220.00		382.35
	132.56	400.00
228.80		417.30
226.40		418.87
233.00		449.64
249.20		495.62
	132.47	500.00
262.90		542.73
270.50		585.43
	131.74	600.00
282.50		624.92
299.50		673.25
314.90		696.62
	132.55	700.00
303.00		735.63
281.00		787.55
	132.35	800.00
273.90		830.25
268.50		846.24
257.50		894.30
	132.30	900.00
240.30		925.01
227.00		947.35
216.50		988.20
	132.19	1000.00
206.50		1034.32
193.50		1062.46
191.50		1094.61
	132.12	1100.00
181.00		1124.84
174.63		1143.60
174.19		1146.97
174.02		1152.25
174.00		1155.79
173.35		1157.25
	132.06	1200.00
169.35		1207.34
167.19		1217.82
162.68		1227.85
158.77		1231.24
156.20		1234.16
	131.93	**1235.00**
155.50		1240.68
157.41		1253.99
157.81		1262.11
138.45		1286.74

Prepared for:

BULLER DISTRICT COUNCIL.

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150mm

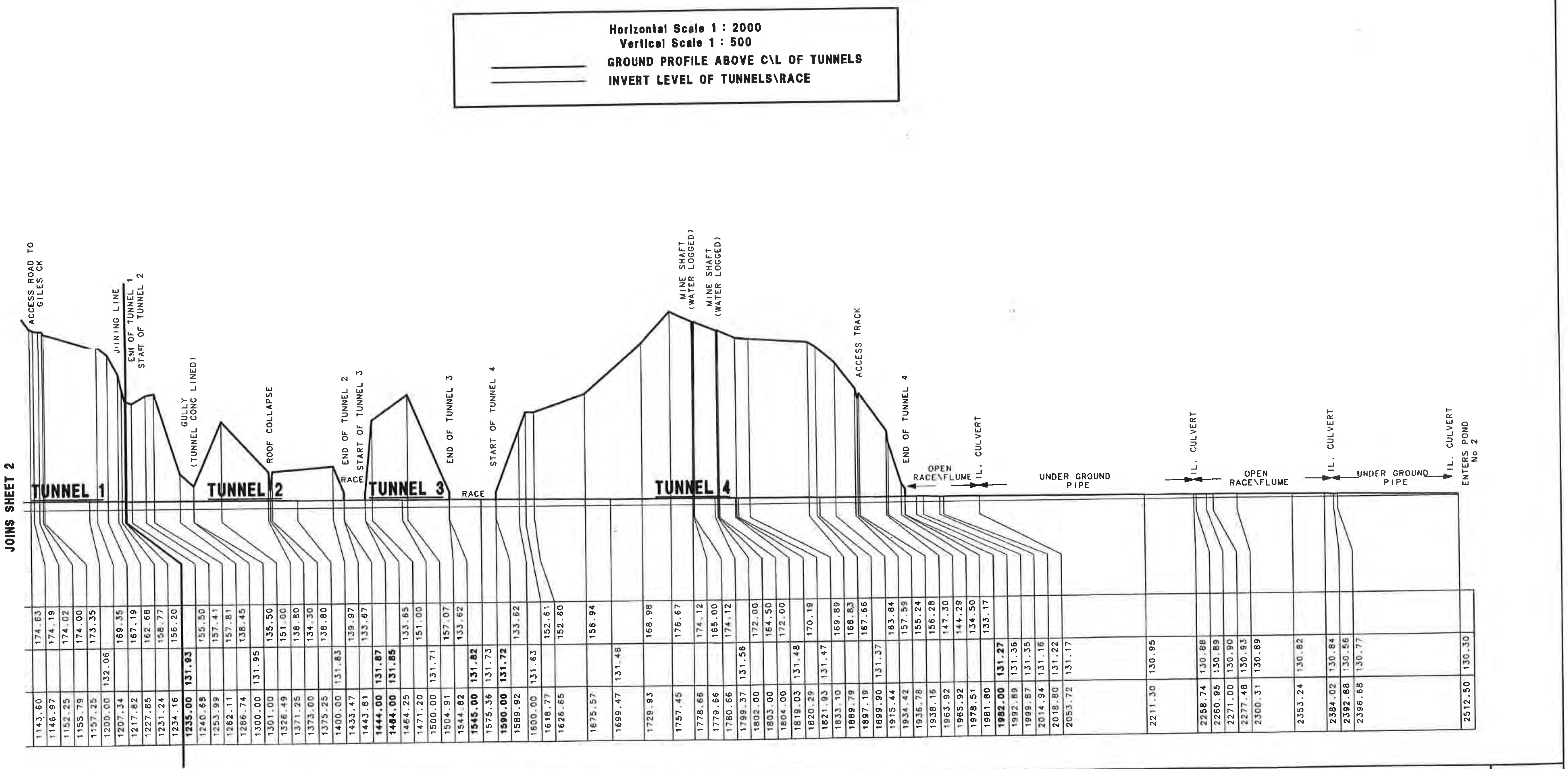
LONG SECTION OF WATER-WORKS FROM GILES CK TO RESERVOIRS (TUNNEL 1)

C J COLL
Regd Land Surveyor, Resource Management Consultant
19 BROUGHAM STREET PO BOX 204 WESTPORT

DRAWN	WARREN.	CHECKED	CHRIS	SCALES	1:2000
DATE	SEPTEMBER 2000	REF	ALL TUNNELS PLAN 2		1:500

SHEET 2

SERIES 2 OF 4



Prepared for:

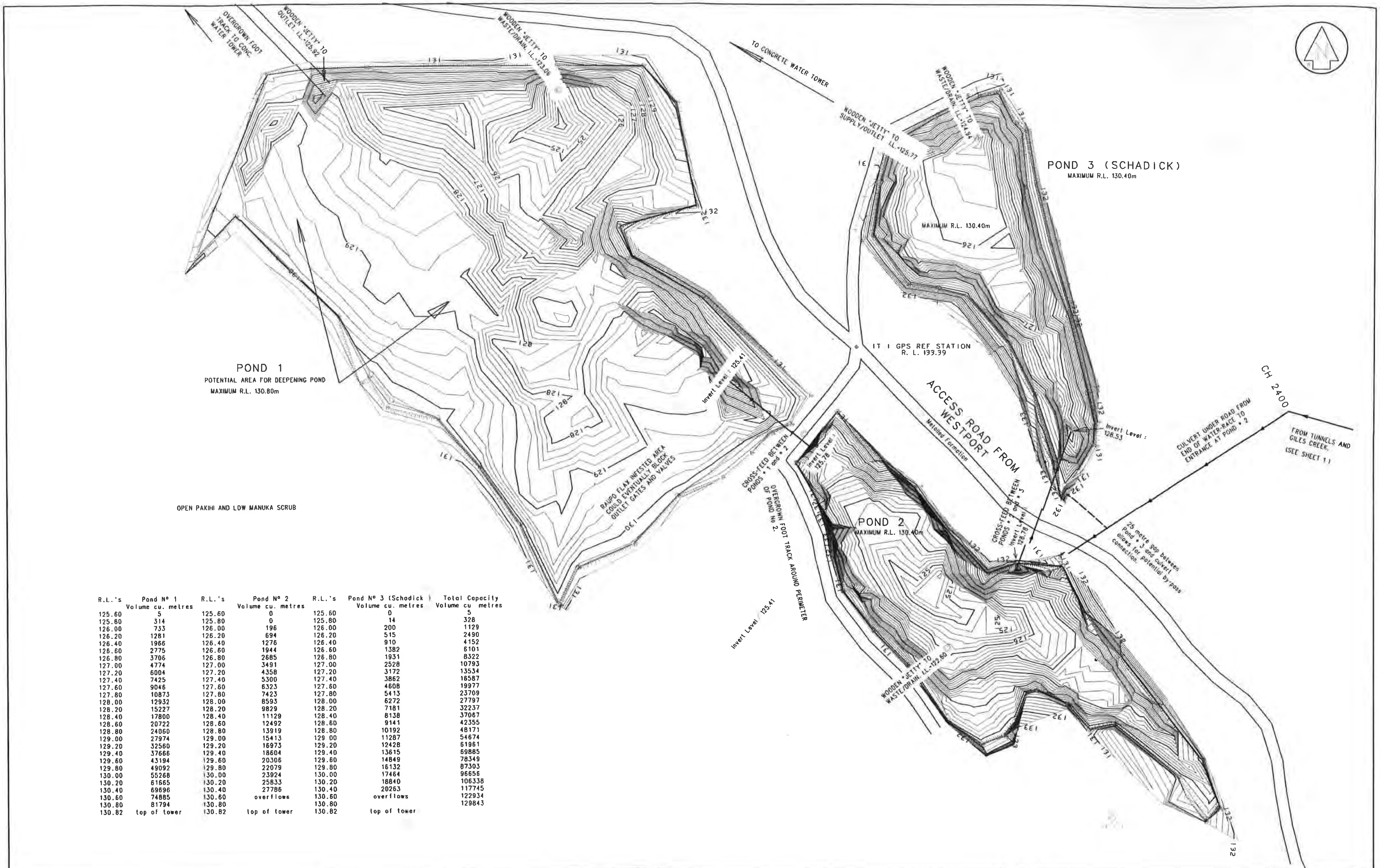
BULLER DISTRICT COUNCIL.

LONG SECTION OF WATER-WORKS FROM GILES CK TO RESERVOIRS (TUNNELS 2,3 AND 4)

C J COLL
Regd Land Surveyor, Resource Management Consultant
19 BROUGHAM STREET PO BOX 204 WESTPORT

DRAWN	WARREN.	CHECKED CHRIS	SCALES 1:2000	SHEET 3
DATE	SEPTEMBER 2000	REF ALL TUNNELS PLAN 3	1:500	SERIES 3 OF 4

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150mm



R.L.'s	Pond Nº 1 Volume cu. metres	R.L.'s	Pond Nº 2 Volume cu. metres	R.L.'s	Pond Nº 3 (Schadick) Volume cu. metres	Total Capacity Volume cu metres
125.60	5	125.60	0	125.60	0	5
125.80	314	125.80	0	125.80	14	328
126.00	733	126.00	196	126.00	200	1129
126.20	1281	126.20	694	126.20	515	2490
126.40	1966	126.40	1276	126.40	910	4152
126.60	2775	126.60	1944	126.60	1382	6101
126.80	3706	126.80	2685	126.80	1931	8322
127.00	4774	127.00	3491	127.00	2528	10793
127.20	6004	127.20	4358	127.20	3172	13534
127.40	7425	127.40	5300	127.40	3862	16587
127.60	9046	127.60	6323	127.60	4608	19977
127.80	10873	127.80	7423	127.80	5413	23709
128.00	12932	128.00	8593	128.00	6272	27797
128.20	15227	128.20	9829	128.20	7181	32237
128.40	17800	128.40	11129	128.40	8138	37067
128.60	20722	128.60	12492	128.60	9141	42355
128.80	24060	128.80	13919	128.80	10192	48171
129.00	27974	129.00	15413	129 00	11287	54674
129.20	32560	129.20	16973	129.20	12428	61961
129.40	37666	129.40	18604	129.40	13615	69885
129.60	43194	129.60	20306	129.60	14849	78349
129.80	49092	129.80	22079	129.80	16132	87303
130.00	55268	130.00	23924	130.00	17464	96656
130.20	61665	130.20	25833	130.20	18840	106338
130.40	69696	130.40	27786	130.40	20263	117745
130.60	74885	130.60	overflows	130.60	overflows	122934
130.80	81794	130.80		130.80		129843
130.82	top of tower	130.82	top of tower	130.82	top of tower	

Prepared for:

BULLER DISTRICT COUNCIL.

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150mm

PLAN OF WATER-WORKS FROM GILES CK TO RESERVOIRS
PONDS 1 to 3

C J COLL
Regd Land Surveyor, Resource Management Consultant
19 BROUGHAM STREET PO BOX 204 WESTPORT

DRAWN	C.J.C	CHECKED	SCALES 1 to 750	SERIES 4 OF 4
DATE	SEPTEMBER 2000	REV.		REF 1190all-ponds2

SHEET 4

OPEN
EARTH
CONSULTING

Geological, Geotechnical,
Mining Engineering &
Risk Management

GEOTECHNICAL ASSESSMENT AND FALL RECOVERY OPTIONS FOR TUNNEL NO.1 WESTPORT WATER SUPPLY

CLIENT	WESTREEF
REPORT No.	16001-A
DATE	22/12/2016

COMPILED BY Chris Lee – Principal Geotechnical Engineer
&
Paul Herbert – Principal Geologist

Table of Contents

Executive Summary 4

1 Introduction 7

2 Site Location & Description 8

3 Geology 10

4 Project History 11

5 Previous Investigations 11

6 Geotechnical Characterisation of Tunnel 13
6.1 Estimated rock strength 13
6.2 Tunnel Conditions 14
6.2.1 Portals 14
6.2.3 Tunnel No.1 15
6.3 Summary of mapping information 19

7 Tunnel No.1 Characteristics and Risk 19
7.1 Key tunnel characteristics and risks 19
7.2 Length of tunnel to be remediated 20
7.3 Tunnelling Regulations 20

8 Fall Recovery & Tunnel Refurbishment Options 21
8.1 Conventional mechanised methods 21
8.2 Pipe jacking 22

9 Alternative Options for Gravity Water Supply 23

10 Geotechnical Investigations Required to Support Tunnel Options 23

11 Recommendations 24

12 References 25

Appendix A – Summary of Mapping Information 26

Appendix B – Tunnel Photographs Highlighting Range of Conditions 27

Table of Figures

Figure 1 – Westport gravity feed water supply system 7

Figure 2 – Westport water supply intake and gravity feed tunnel and race network 9

Figure 3 – Chris Coll survey plan of the upstream water supply network 9

Figure 4 – Geology of the project area 10

Figure 5 - Tunnel No. 1 downstream portal showing significant deformation of wooden sets 15

Figure 6 - Depth of Cover along the Tunnel No. 1 alignment 16

Figure 7 - Range of conditions from very good (100m), moderate (550m) to poor (800m) 17

Figure 8 - Example of guttering mapped in the tunnel roof around 350m and collapse at 885m showing significant deformation on timber sets. Recent failure at 815m demonstrates ongoing deformation and instability of the tunnel. 18

Figure 9 – Plan showing relative geotechnical risk and proposed bypass of fall and areas of high instability 22

Executive Summary

Open Earth Consulting (OEC) was engaged by WestReef Services Ltd to conduct an inspection of the Westport Water Tunnel No. 1 and make recommendations for safe fall recovery and tunnel refurbishment methods. The inspection was carried out over two days in December 2016 and has revealed a range of ground conditions within the tunnel ranging from very good to poor. A fall of ground, which is impassable to personnel, occurred within the tunnel at 885m sometime during 2014. The water supply currently passes through this collapsed area unrestricted. A recent tunnel sidewall failure was identified during our inspection at 815m which has caused localised water ponding and sedimentation in the tunnel. The tunnel appears to exhibit on-going signs of deterioration in deeper sections.

The key driver of stability within the tunnel appears to be failure of the sidewalls due to overstressing in the deeper areas which result in tunnel "widening" and subsequent tunnel instability and collapse.

Existing ground support in the tunnel consists of wooden sets which have been installed at various times over the tunnels approximate 100yr history typically in response to zones of visually deteriorating and poor ground. The ground supports vary in quality and in places display signs of significant load and are at risk of failure. The deeper sections of tunnel appear to be deteriorating over time and the installed ground support has proven less than adequate in some areas which has resulted in zones of localised instability. Many of the shallower sections of Tunnel No. 1 are generally in very good condition, particularly the upstream end, where the original pick marks still visible.

Based on initial inspections and assessment of ground conditions OEC recommends that the minimum length of tunnel that would need to be repaired to reduce further instability risk over the short to medium term is an estimated 630m length comprising from the downstream portal (1250m) to approximately 600m chainage. This represents approximately 50% of Tunnel No.1s entire length.

To safely recover the fall and refurbish the tunnel the tunnel will require widening. Widening the tunnel will:

- Provide room for some form of small conventional mechanised cutting / scaling and/or bolting machine to be used.
- Allow for effective levels of ground support to be designed and installed in the tunnel.
- Allow for a safe system of work including provision of a fit for purpose temporary support system for workers to be employed in the tunnel as it is widened and stabilised.

The recently introduced Health and Safety in Employment (Mining Operations and Quarrying Operations) Regulations 2013 also sets out the new regulatory framework for hazard identification and risk management in tunnelling operations. The regulations would be activated by the tunnel refurbishment methodologies described above. Worksafe NZ would be required to review and approve a comprehensive Health and Safety Management System relating to tunnel remediation. Such Health and Safety Management Systems are now common place in mining and tunnelling operations throughout New Zealand.

Subject to Worksafe confirmation the tunnelling regulations intention is to also exclude small diameter tunnels 'usually non-manned' (where entry will come under regulations covering working in confined spaces) and 'non-manned' micro tunnelling, pipe jacking and directional drilling.

In 2014 as a response to the tunnel collapse Buller District Council obtained expressions of interest from three tunnelling contractors to provide solutions which included; conventional tunnel stabilisation, pipe jacking and directional drilling options.

Conventional stabilisation methods of Tunnel No. 4 were carried out in 2009/2010 prior to the introduction of the 2013 Regulations. The new regulations require significantly more Health and Safety Management processes than would have been required for the stabilisation works carried out in 2009/2010. This method is considered safe when all risks are identified and robustly managed.

Based on an assessment of the tunnel conditions and review of previous investigations relating to tunnel refurbishment options there appear to be a range of options for either repairing or replacing the existing tunnel(s). Preferred methods to reinstate gravity water supply from Giles Creek are:

1. Tunnel widening using mechanised methods which bypass the higher risk sections of the existing tunnel thereby eliminating geotechnical risk (and reducing project uncertainty) associated with a large portion of the existing tunnel.
2. Installation of a new pipeline utilising directional drilling or micro-tunnelling technologies to bypass Tunnel No.1, Tunnel No.2 and Tunnel No. 3 as identified by Opus.
3. Installing a pipe via pipe jacking and associated widening of the existing tunnel.

The options are summarised in the table below.

Water Supply Option	Summary	Rough Cost Estimate	Project Risk
Tunnel stabilisation using conventional mechanised methods	• Tunnel would be designed to link in at each end of existing tunnel & bypass poor ground eliminating risk with poorer sections of tunnel • New 2013 Mining Regulations would apply • Portal stabilisation and access works required • Pumping of water during tunnel construction	$3.5 – 4.5M	Medium
Installation of a new pipeline to bypass Tunnels 1, 2 and 3	• Installation of new pipeline to bypass existing tunnels • Constructed using direction drilling or micro tunnelling methods • New 2013 Mining Regulations would not apply where tunnel is unmanned	$3.5 – 6M	Low
Installing a pipe via jacking	• Pipe would be jacked through collapsed ground & potentially right through Tunnel No. 1 • New 2013 Mining Regulations would apply where tunnel is widened and personnel are underground • Portal stabilisation and access works required • Pumping of water during tunnel construction	$3 – 4.5M	Medium

Further assessment and cost estimation of the preferred options is required prior to determining the most acceptable solution. OEC would be happy to assist WestReef with this process.

1 Introduction

The Westport town water supply is collected from the headwaters of the Orowaiti River. Water is diverted at Giles Creek and gravity flumed into a series of races and four sections of tunnel to holding ponds on Caledonian Terrace from where it is piped into the Water Treatment plant located on Sergeants Hill and distributed to the town via the downstream water supply network. Figure 1 shows the location of the water treatment plant, water storage ponds and upstream gravity supply network.

Figure 1 – Westport gravity feed water supply system

The contractor responsible for maintenance of the Tunnel network, WestReef Services Ltd, engaged Open Earth Consulting (OEC) to conduct an inspection of the No. 1 Water Tunnel. The primary objective of the inspection was to assess the ground conditions and associated strata control issues and provide recommendations relating to a suitable methodology & safe system of work to enable fall recovery and tunnel refurbishment. The work forms part of Buller District Councils (BDC) overall assessment to secure ongoing water supply to the Westport Township using the existing supply network and is part of a range of options being considered to reinstate the tunnel or identify and confirm other viable options.

Sometime during 2014 a collapse in Tunnel No.1 occurred. The tunnel collapse is located at chainage 885m in an area that had been previously supported with standing timber supports in response to poor tunnel conditions. Inspection of the fall confirms it to be approximately 1.5m to 2m in height and 4m – 8m in length. Water is currently freely passing through the fallen material which is relatively large and blocky in nature but the fall cannot be safely passed by personnel. Chris Lee and Paul Herbert of OEC undertook an initial underground site inspection and discussion with WestReef staff on the 5th of December 2016 with a detailed inspection comprising geotechnical mapping on December 12. A complete inspection of the tunnel from the upstream portal end to the upstream side of the 885m rockfall was not possible as further unstable and fallen ground was identified at chainage 815m which was considered impassable due to instability risk. Inspection was therefore limited to areas starting from the upstream portal to 815m, and the downstream portal to the collapsed tunnel section located at 885.

This report provides information relating to geotechnical characterisation of the tunnel, makes comment on mechanisms for instability observed within the tunnel and discusses potential methodologies and safe systems of work to assist with feasibility planning for fall recovery and tunnel refurbishment based on the ground conditions observed. The report also comments on alternative lower risk options previously identified for gravity fed water supply.

2 Site Location & Description

The layout of the Tunnels and access road is shown in Figures 2 and 3, along with reference chainage (Figure 3). Tunnel No.1 extends 1250m from Giles Creek under a ridge with a maximum depth of cover of 180m.

The upstream portal to Tunnel No.1 is situated in a ~30m high bluff of sandstone on the southeast side of Giles Creek, immediately above a small tributary. A ~40m wooden and concrete race diverts water from an intake structure in Giles Creek into the upstream portal of Tunnel No.1. The downstream portal of Tunnel No.1 breaks into a steep sided gully approximately 10m below the contact between the sandstone it is constructed in and the overlying alluvial gravels. Tunnel No.2 intersects Tunnel No.1 at the 1233m mark.

Tunnels No.2 & No.3 are much shorter, at each end of Tunnel No.3 short open races link to the portals of tunnels No.2 & No.4. Tunnel No.4 has an 800mm diameter High Density Polyethylene (HDPE) pipe extending through it and is no longer accessible.

Access to the upstream portal of Tunnel No.1 is via a 4WD track that in places is narrow and steep with several hairpin corners and a ford over Giles Creek. Access to the portal is made on foot by crossing the intake structure and walking approximately 40m along the water race to the tunnel entrance. Access to the downstream portal is via the same access road and a short walk down an excavated track benched into the alluvial gravels. Figure 2 shows the layout of the upstream water supply network and access road.

Access to the tunnels is restricted only by the gate on Water Works Road leading to the Water Treatment Plant.

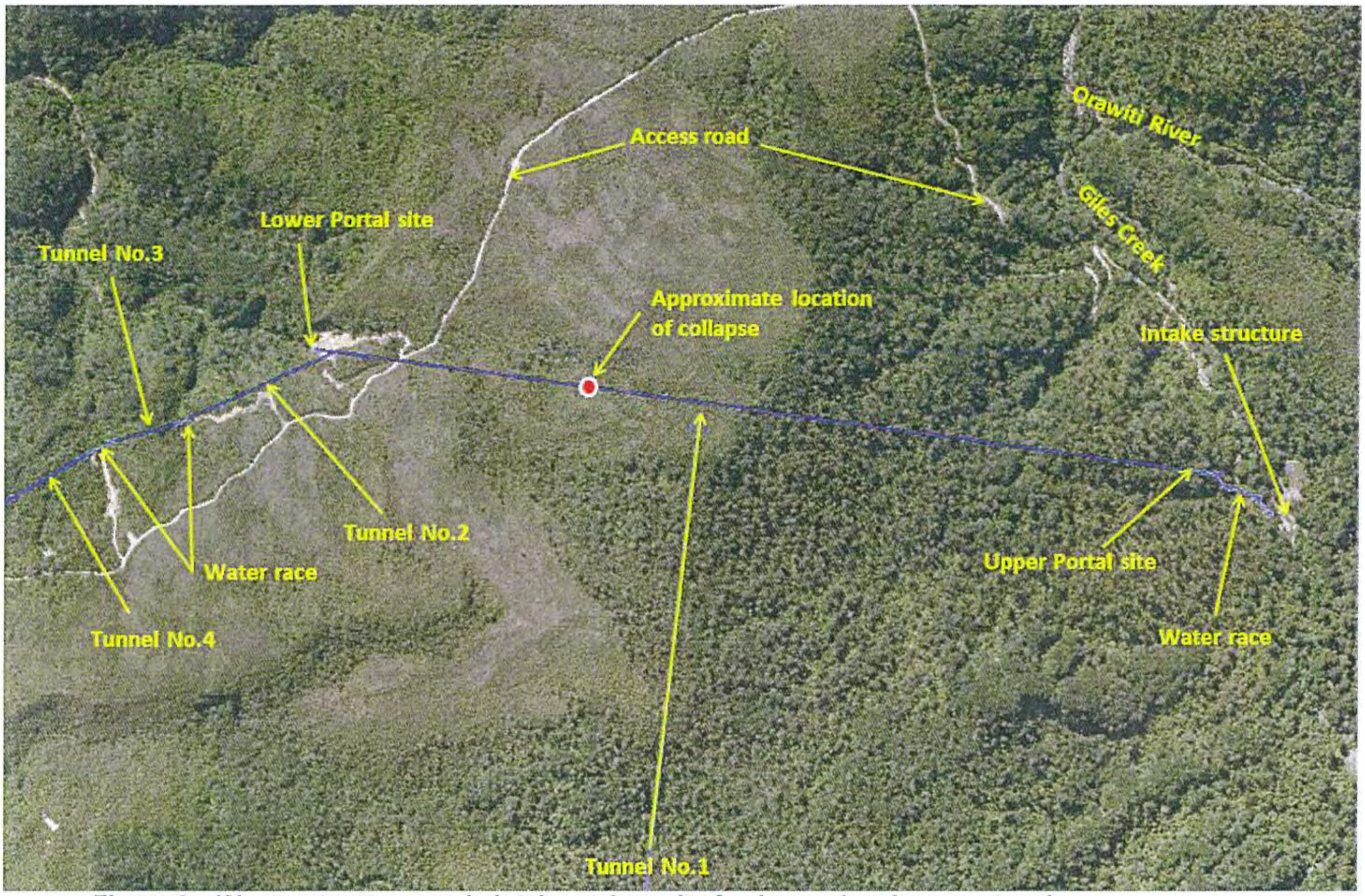


Figure 2 – Westport water supply intake and gravity feed tunnel and race network

In 2000 surveyor Chris Coll was engaged to undertake a survey of the network of pipes, races and tunnels diverting water from the Giles Creek intake to the storage ponds on Caledonian Terrace. Figure 3 shows a plan of the survey work undertaken

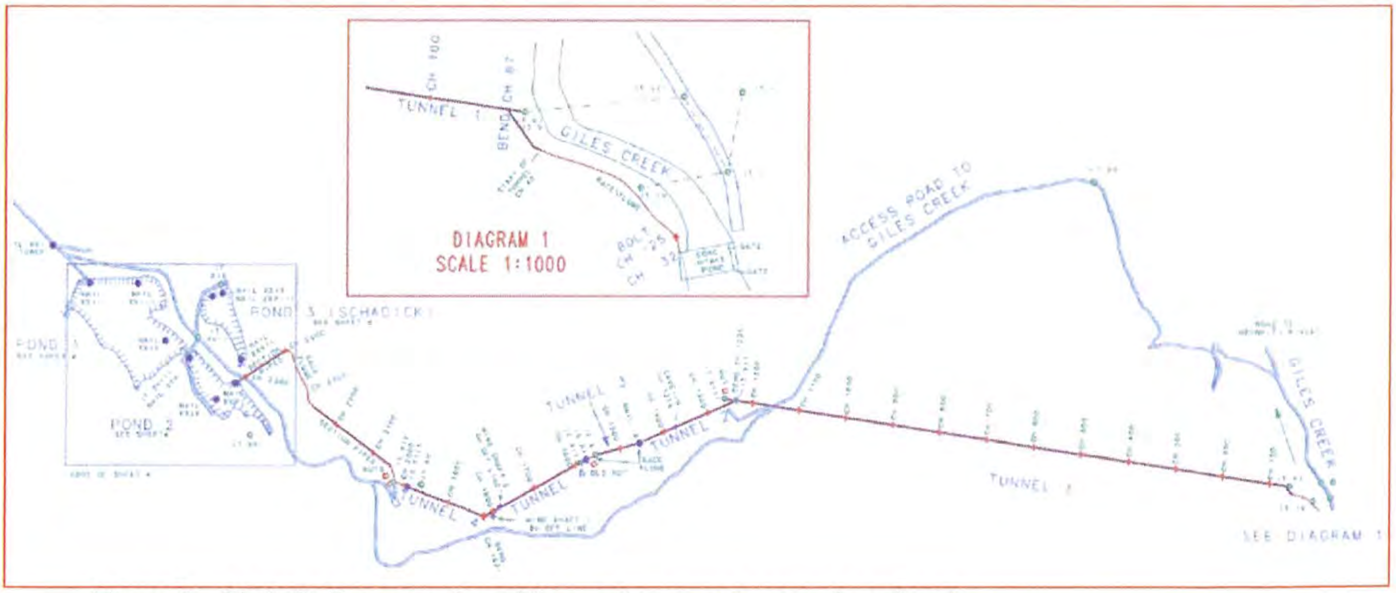


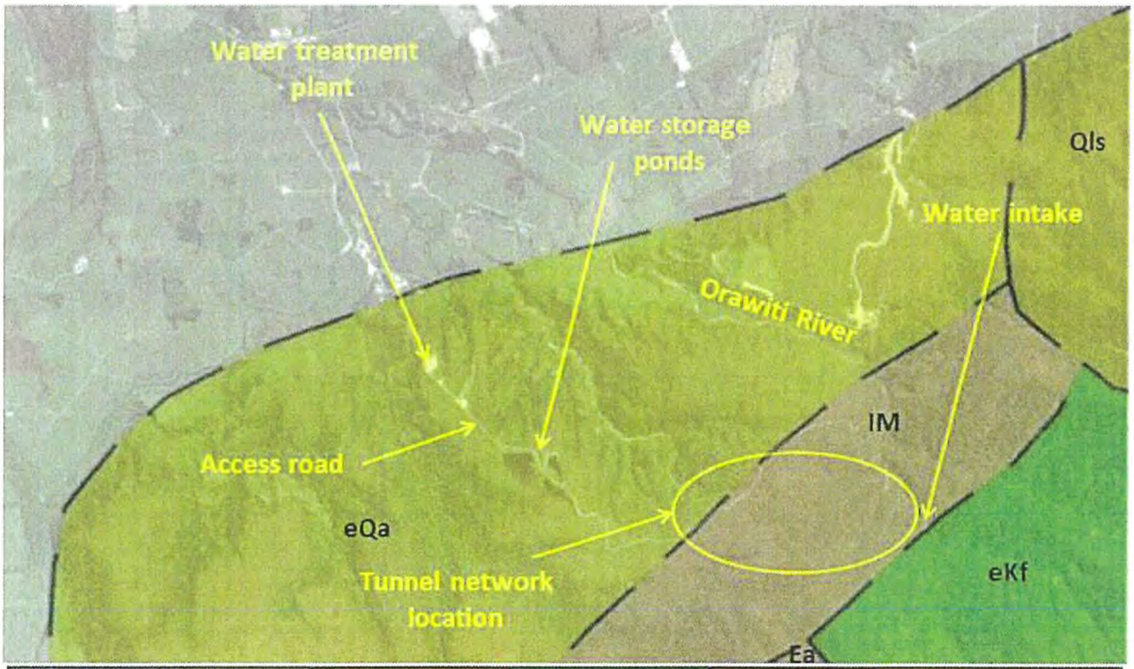
Figure 3 – Chris Coll survey plan of the upstream water supply network

3 Geology

The entire length of Tunnel No.1 is excavated into the very weak sandstone of the Upper Member of the O'Keefe Formation of the Blue Bottom Group. This member comprises yellow-brown, friable fine to medium sandstone which is generally soft, slightly weathered and bedded on a centimetre to metre scale. Clast-supported fine to cobble-sized conglomerate becomes more common towards the top of the unit and are observed in upstream tunnel sections as ~400mm thick layers grading in & out of the tunnel sidewalls & roof.

The Upper Member is laterally variable in thickness, ranging between 300 & 650m and is at least 150m thick in the vicinity of Tunnel No.1. The member is gradational with the underlying middle member, and is truncated above by an angular unconformity.

Unconformably overlying the uppermost Miocene Blue Botttom Group are alluvial deposits of gravel and sand, chiefly the former, constituting high-level terraces, as shown in Figure 4. Alluvial deposits consist of poorly consolidated sands, gravels, cobbles and boulders and are exposed in the cutting above the downstream portal of Tunnel No.1.



Plot symbol	eQa	IM	eKf	Ea	Qls
Name	Early Quaternary alluvium and colluvium	Blue Bottom Group (Late Miocene)	Rahu Suite biotite, granite, granodiorite and tonalite	Brunner Coal Measures	Quaternary landslide debris
Description	Weathered gravel, sand, silt and mud of alluvial and colluvial origin.	Micaceous sandstone and muddy sandstone, with local conglomerate and thin coal seams	Biotite and biotite-muscovite granite, granodiorite and tonalite with quartz diorite and monzodiorite.	Quartzose sandstone, conglomerate, carbonaceous mudstone and coal seams.	Landslide deposits ranging from coherent shattered masses of rock to unsorted angular rock fragments in a fine-grained matrix.
Geologic history	Early Quaternary	Late Miocene to Pliocene	Early Cretaceous	Eocene	Quaternary

Figure 4 – Geology of the project area

4 Project History

The tunnel No. 1 intake is located in Giles Creek and directs water through a series of four tunnels, races and pipes to the Water Treatment plant located on Sergeants Hill. The tunnels were hand dug through very weak sandstone and completed in 1903. The tunnels have performed reasonably well over the first hundred years of their life, but recently increasing levels of instability have been observed. The BDC has previously completed routine maintenance of the tunnels which included standing timber sets and lagging in areas of poorer ground where instability had become more noticeable.

Various geotechnical investigations relating to the water tunnels have been completed since early 2000's in response to tunnel instability. These have included mitigation options ranging from repair and refurbishment of the tunnels through the installation of a new water pipeline to bypass and replace Tunnel 1, Tunnel 2 and Tunnel 3.

Tunnel No. 4 was stabilised in 2009 /2010 by Geotech Ltd after a major collapse in a section of the tunnel prevented the gravity supply of water to the Treatment plant. This work was completed prior to the introduction of the Tunnel and Mining Regulations in 2013 and involved excavation and widening of the existing tunnel and the installation of rock bolts / mesh and some timber supports. A 400m length of 800mm diameter HDPE pipe was then pulled through the tunnel at completion. It has been acknowledged that this work presented many challenges to the contractor and client including challenging ground conditions which resulted in additional strata instability hazards and project risk.

5 Previous Investigations

The risk posed to the Westport town supply by tunnel instability has been recognised for some time and different consultants and contractors have been engaged at different times over approximately the last 12 years to assess various options for tunnel rehabilitation and replacement.

<u>Connell Wagner 2004</u>

A Connell Wagner report prepared in 2004 makes mention of a previous Connell Wagner report prepared in 2002 which determined that there were two favoured options in addressing the risk presented to the Westport water supply by tunnel instability;

- the refurbishment of deteriorating tunnels or,
- abandoning the entire tunnel network in favour for pumping water from the Orowaiti River

According to this report at the time the BDC chose to pursue the tunnel refurbishment option based on its lower long-term costs and designs were prepared for the replacement of Tunnel No.2 and a section of Tunnel No.4 along with a cost estimate (OEC has not seen these designs and has made no comment on them).

In January 2004 Connell Wagner produced another report documenting a limited geotechnical investigation which classified of the rock mass in which Tunnel No.1 is excavated, based on some field and lab testing, using the Rock Mass Rating (RMR) classification system.

A further report by Connell Wagner in November 2004, made a detailed financial comparison of tunnel refurbishment and pumping options. Other tunnel replacement options were also mentioned including:

- installing additional tunnel support
- insert a pipe within only the worst sections of tunnel
- employing micro tunnelling / pipe drilling techniques to drive a pipe around the worst sections of existing tunnel

The November 2004 report identified that the most significant risk associated with tunnel refurbishment is the potential for a collapse that would take longer to repair than the storage lakes could accommodate.

The report noted that "the condition of the existing timbering within the tunnels appears to be deteriorating at a faster rate than it is being replaced..... the existing timbering within the tunnels is not providing any active support to the surrounding rock mass. The Tunnels will continue to collapse around the timbering because the strength of the surrounding rock is less that the forces it is subjected to. As a result, a more intensive maintenance program will not ultimately extend the life of the tunnels."

Finally, the report recommends that;

- The timbering within existing tunnels be bought up to a safe level
- An alternative pumped system be constructed to provide backup to the tunnel water supply

Both recommendations were actioned, additional timber support was installed and a contingency pump system was installed allowing for the pumping water downstream from Orowaiti River to the water treatment plant.

Opus 2015

In December 2015 Opus were engaged to deliver:

- A review of existing information on the tunnels,
- Document an inspection of Tunnel No.1 undertaken on the 25th November 2015,
- Review of proposals submitted by three contractors
- Identify other viable options
- Assessment of the advantages and disadvantages of the different options
- Prepare report for BDC workshop on 17th December 2015

The Opus report makes note of:

- changes to Health and Safety in Employment Act (HSE) in 2013 and the implications these changes have on accessing and refurbishing the tunnels
- that tunnel conditions had not significantly changed since inspection and reporting by Connell Wagner in the early 2000's
- inspection identified a 100m length of Tunnel No.1 requiring remedial work
- failure mechanisms are summarised as slab failures from the roof and side walls of the tunnel, as well as erosion of the base of the side walls due to the action of flowing water

- ongoing inspections and installation of additional timber supports will be required to keep Tunnel No.1 in service
- recognition that manual repair methodologies being most conventional, but also pose high risk to human life
- identification of alternative repair methodologies that avoid having humans in high risk underground environment, namely pipe jacking and horizontal directional drilling
- recognition that repair/refurbishment of existing tunnel would require water to be pumped from alternative source for duration of remedial work at a cost
- that ground instability issues posing risk to the serviceability and longevity to Tunnel No.1 also exist for tunnels No.2 & No.3
- that alternative methodologies (i.e. horizontal directional drilling, micro tunnelling) could be employed to by-pass tunnels No.1, No.2 & No.3

Opus goes on to make the following recommendations listed in order preference:

I. Use alternative methods to install a new pipeline through virgin ground to bypass and replace Tunnel No.1 and tunnels No.2 & No.3. Remove all risk to people working underground, and establish a low risk long term solution to on- going gravity water supply. A cost estimate for this option ranges from $3.5M to $ 6.5M

II. Refurbish the downstream 450m section of Tunnel No.1 including recovering the fall and remediating the worst sections of the tunnel. Pipe jacking and manual tunnel stabilisation methods are identified as possible methodologies, both requiring people to be working underground in a moderate to high risk environment. Both options could be extended to the full length of Tunnel No.1. A cost estimate ranges from $1.5M to $2M for the 450m section or $3 to $4.5M for the full length of Tunnel No.1. Pumping from the Orowaiti River would be required during construction which is expected to be of the order of four to twelve months. Both options would require on-going periodic inspection and maintenance.

III. Manually repair higher risk sections of the tunnel. This options carries high risk to people working in the tunnel, as well as ongoing moderate to high residual risk for the repaired tunnel itself due to on-going deterioration. Repair of the collapse should, as a minimum, cover 100m of tunnel centred on the fall, as well as repairs to deteriorating timbers elsewhere. A cost estimate ranged from $0.3M to $0.5M, plus $0.1M per annum maintenance. Pumping from the Orowaiti River would be required during construction which is expected to be of the order of four to twelve months. A regular routine inspection and maintenance regime would be required for the operational life of the tunnel to manage the ongoing geotechnical risks.

6 Geotechnical Characterisation of Tunnel

6.1 Estimated rock strength

Tunnel No.1 has been developed through very weak silty sandstone. The sandstone is typically thinly laminated, sub-horizontally bedded and contains thin (<0.4m) bands of pebble conglomerate to approximately 300m. Gravels overlie the sandstone and the contact between the gravel and sandstone can been seen to outcrop high on the access road and approximately 10m above the downstream portal.

Connell Wagner completed laboratory and field strength testing of samples collected from the tunnel in 2004 as part geotechnical investigations. The indirect Schmidt Hammer testing provided

estimated Unconfined Compressive Strength (UCS) values ranging 1 – 12MPa consistent with very weak to weak rock. Using the New Zealand Geotechnical Society (NZGS) field descriptions the rock can be classified as very weak (<5MPa) and exhibits less overall variation in strength based on our observations within the tunnel.

6.2 Tunnel Conditions

Our assessment of tunnel conditions is based on review of:

1. Report from Connell Wagner dated January 2004 – Geotechnical Investigation of Westport Water Supply Refurbishment
2. Report from Connell Wagner dated November 2004 – Westport Water Tunnels Additional Information on Upgrade Options
3. Report from Opus dated December 2015 – Westport Water Tunnel No. 1 Refurbishment Options
4. Observations from our December 2016 site inspection

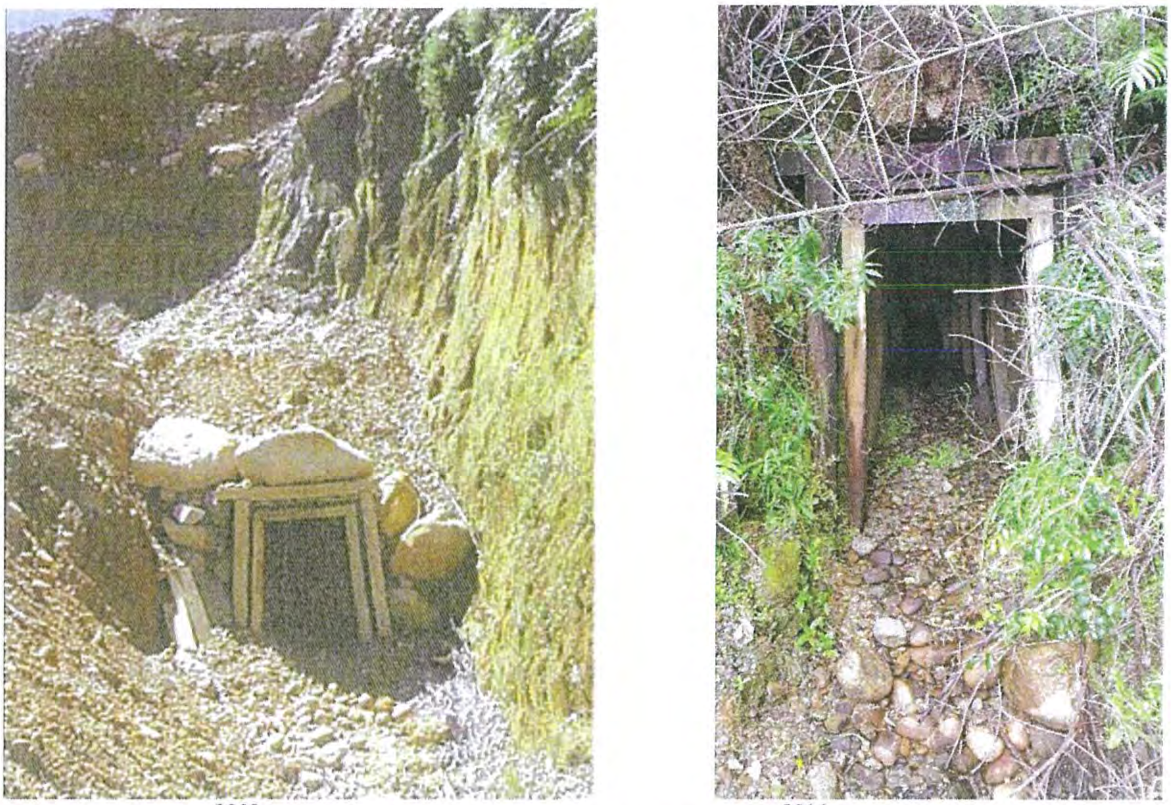
6.2.1 Portals

Access to the Tunnel No. 1 portals is from either the Giles Creek intake via a short walk over a water flume or from a steep, narrow and overgrown 4WD track which branches off the main access track providing access to the downstream portal location.

The Giles Creek portal site is formed of sandstone and appears to be in good condition with no signs of instability on the slopes surrounding the portal at the time of the inspection (see photo in Appendix B).

The downstream portal site is situated in the base of a narrow gully and steep gravel slopes outcrop above the portal. The downstream portal area has had a history of slope instability from surface slips. These slips have been noted in previous investigations from around 2004, with repairs to the portal access tunnel in about 2008. Opus (2015) indicated a moderate to high risk of instability affecting the portals in their current state and we agree with that assessment.

The risk of further instability has the potential to limit or block access to the portal location. Comparison of photos (Figure 5) taken in 2009 and 2016 highlight significant levels of additional loading and deformation particularly on the left-hand side of the wooden tunnel supports at the portal. New rockfall material near the tunnel entrance was also observed.



2009 2016

Figure 5 - Tunnel No. 1 downstream portal showing significant deformation of wooden sets

6.2.3 Tunnel No.1

OEC conducted a detailed inspection of the Tunnel comprising geotechnical mapping on December 12. A complete inspection of the tunnel from the upstream portal end to the upstream side of the 885m rockfall was not possible as further unstable and fallen ground was identified at chainage 815m which was considered impassable due to increasing levels of instability risk. Our inspection was therefore limited to areas starting from the upstream portal to 815m, and the downstream portal to the collapsed tunnel section located at 885. Opus (2015) indicated that the degree of instability is greatest from around 810m to 900m and, although we did not inspect some of that area, observations from either side of the fallen ground into this area highlighted signs of increased instability including other minor rockfall within this zone.

Tunnel No.1 has been excavated to a narrow-arched profile with nominal dimensions of about 0.8m wide and 1.8m high. Depth of cover over the tunnel varies as a function of surface topography (the tunnel gradient being less than 1:1000) and ranges from 10m at the upstream portal to 180m under the topographic high on the ridgeline at chainage 700m (Figure 6).

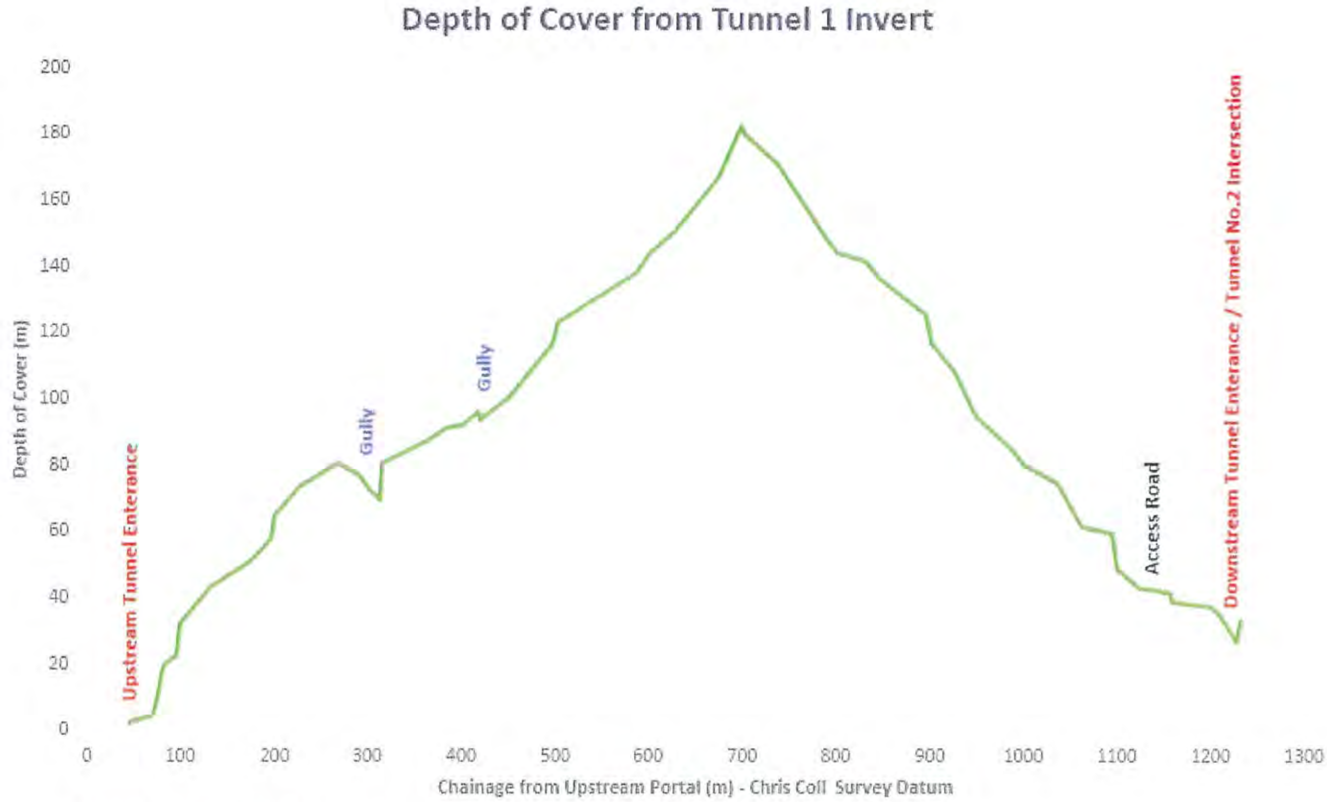
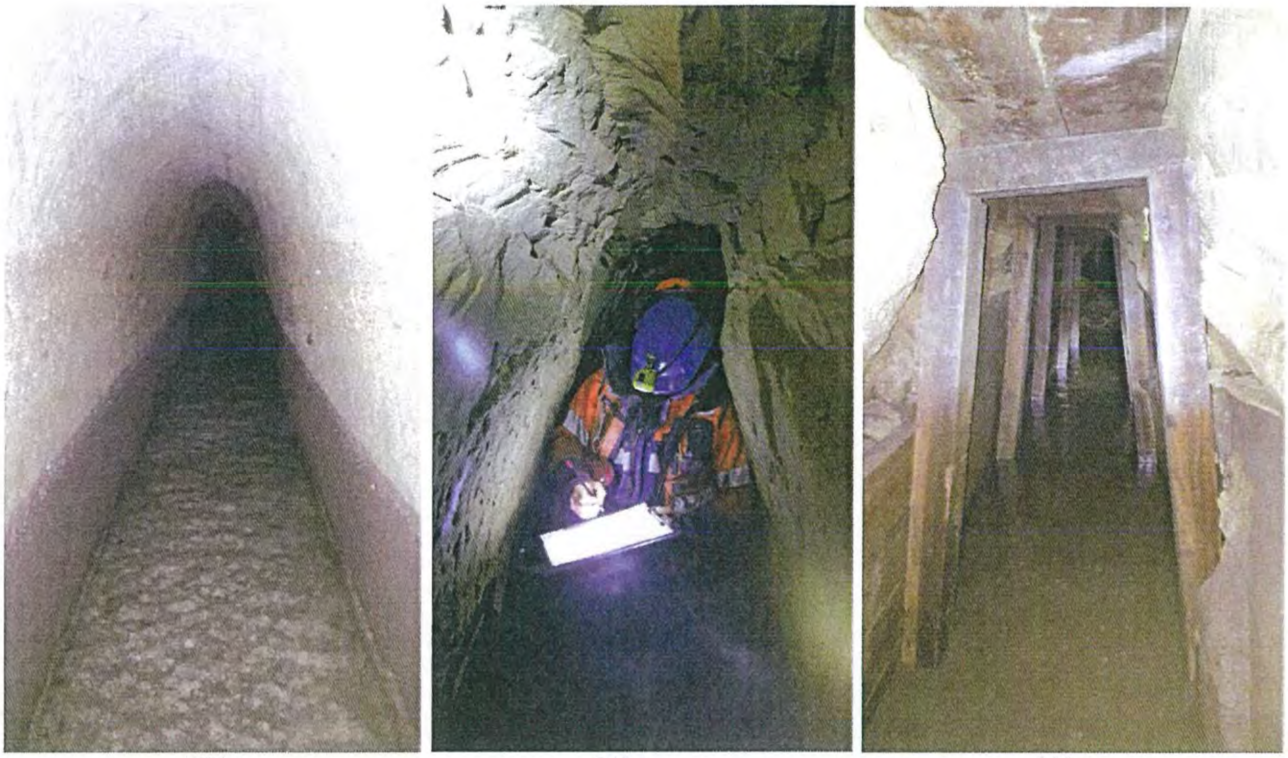


Figure 6 - Depth of Cover along the Tunnel No. 1 alignment

The conditions within Tunnel No.1 are variable and range from extremely good to very poor (Figure 7). Typically roof and sidewall deterioration become more pronounced in the middle sections of the tunnel and varying levels of timber support have been installed between 660m to 1000m in response to the poorer conditions and increasing levels of instability.

There appeared to be evidence of a horizontal stress regime acting on some parts of shallower sections of the tunnel. Typically this was manifest as guttering and shear failure biased to the right hand side of the roof with guttering extending up to 400mm above the roof line in places. Figure 8 displays an example of the guttering at 350m.



100m 550m 800m

Figure 7 - Range of conditions from very good (100m), moderate (550m) to poor (800m)

A moderate to high level of sidewall yield and spalling was noted in the deeper sections of the tunnel. The poor sidewall conditions are the result of overstressing and eventual failure due to depth of cover / vertical stress and are manifest as rock spalling/slabbing and fretting often off bedding planes. The in-situ virgin vertical stress over the deeper sections of the tunnel is estimated to be approximately 3 - 4MPa. Sub vertical fracturing observed in the sidewalls is consistent with an in- situ sandstone strength of approximately 1 – 5MPa.

The sidewall failures have resulted in a "widening" of the tunnel. A wider tunnel is inherently less stable which tends to initiate roof instability. The very weak sandstone has limited natural spanning ability across the roof and without effective ground support is prone to failing in areas where the sidewalls have either deformed or spalled from the tunnel walls. There are many locations in the deeper sections of tunnel were sidewall failures are being contained by the wooden lagging. In many of these areas the wooden lagging is of poor quality (rotting) and displaying signs of significant deformation. The wooden sets in the area leading into the fall at 885m display significant deformation particularly on the right-hand side and are at risk of further collapse as shown in Figure 8.

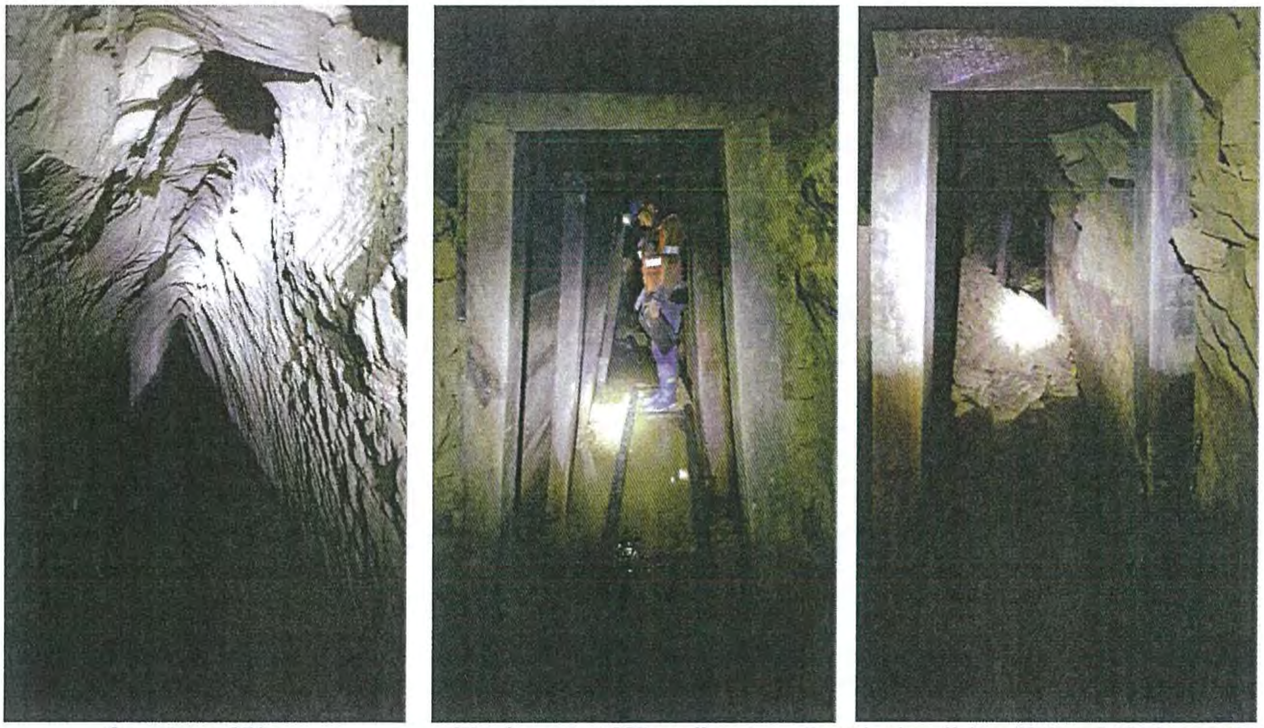
Relatively fresh fallen material was also observed at 815m from the sidewall and roof that was causing ponding to a depth of ~600mm behind the fallen material as well as localised sedimentation at the tunnel invert within the upstream sections of tunnel. The operating water level appeared to have increased on the upstream side of this flow restriction. Opus (2015) noted this same area in their report indicating a moderate size roof slab at 810m and developing wall slab failure at 820m. The failure of this section demonstrates the on-going nature of deterioration in the tunnel. A photo of the localised failure is provided in Figure 8.

Based on our inspection future tunnel deformation and ongoing instability is almost certain to occur in localised sections of tunnel between 600m and 1000m and represents a significant risk, particularly given its distance from the portals, to continuing water flow through the tunnel and to tunnel refurbishment.
The major drivers on Tunnel No.1 stability can be summarised as:

- Evidence of a horizontal stress regime sufficient to fail sandstone roof in the shallower upstream areas
- Depth of cover sufficient to fail sandstone sidewalls
- Increased tunnel width (as a function of sidewall failure) which results in roof failure
- Observed changes to geology (persistence of bedding and defects) which act as planes of weakness

Associated with these factors are variation in roadway dimensions, inadequate levels of reinforcement design and current roadway profile.

Opus (2015) described sidewall erosion as being a secondary mechanism for failure. OEC saw no evidence of this and it is likely that a few sidewall failures along steeply dipping defects were mistaken for erosion.



Guttering at 350m   Wooden sets at 885m collapse   Partial sidewall / roof failure & blockage at 815m

Figure 8 - Example of guttering mapped in the tunnel roof around 350m and collapse at 885m showing significant deformation on timber sets. Recent failure at 815m demonstrates ongoing deformation and instability of the tunnel.

6.3 Summary of mapping information

A summary of the geological and geotechnical mapping information is provided in Appendix A. The Tunnel has been broken down into 100m sections for the purposes of the mapping summary. The mapping information highlights the progressive deterioration of ground conditions particularly from 600m to 1000m. It also provides an estimation of relative geotechnical risk along the tunnel. Areas of higher relative geotechnical risk will be more prone to on-going deterioration and potential collapse.

Appendix B displays a range of photos taken during the site inspection with brief descriptions. It can be used as a simple baseline for future reference to assist with mapping and highlighting any changes in tunnel conditions.

7 Tunnel No.1 Characteristics and Risk

7.1 Key tunnel characteristics and risks

Tunnel No.1 needs to be refurbished to a fit for purpose state or replaced with other solutions to maintain gravity water flow to the Treatment Plant. The tunnel is displaying signs of on-going deterioration in the deeper sections which is likely to result in eventual tunnel collapse and possible loss of the tunnel asset.

WestReef Ltd has requested an initial overview of possible remediation and fall recovery methods for the drift. There are several risks related to the existing characteristics of the tunnel and portal areas that will need to be considered as part of this process. Several of these risks have been provisionally assessed in Section 4 of the Opus 2015 report relating to Tunnel No.1 Refurbishment Options.

The key geotechnical risks related to fall recovery and tunnel refurbishment options can be summarised as:

1. The moderate to high levels of deformation and instability within the middle section of the tunnel (600 – 1000m) both within the collapsed section itself and either side of the collapse.
2. The long length (1200m) of the tunnel and distance of the moderate to poor ground from the portal entries.
3. The very small size and confined workspace within the tunnel which currently limits installation of effective ground support.
4. The less than adequate ground support currently installed in the tunnel.
5. The condition of the downstream portal and identified slope instability hazards.
6. The potential for reduced and variable rock head (competent ground cover) particularly in the downstream sections of tunnel.
7. The existing single entry status of the tunnel due to the impassable collapse at 885m.

7.2 Length of tunnel to be remediated

Previous investigations have provided options for the length of tunnel to be addressed and have included:

1. 20m collapse zone only
2. 100m plus – collapsed zone and adjacent poor sections
3. 450m section from downstream portal (1230m) to upstream side of fall (800m)
4. 1200m section comprising the entire tunnel
5. New alignment

Based on our initial inspections and assessment of ground conditions we recommend that the minimum length of tunnel that would need to be repaired to reduce further instability risk over the short to medium term is an estimated 630m length comprising from the downstream portal (1250m) to approximately 600m chainage. This is in recognition that the tunnel is a critical infrastructure asset on the current water supply network and consequences relating to ongoing failures are water pumping costs and deterioration in water quality.

The slopes surrounding the downstream portal have also been identified as posing instability risk. Although we haven't completed a review of the instability risk it is possible tunnel remediation works would need to extend to the slopes surrounding the portal to ensure the slope instability risk is mitigated to provide safe and secure access and egress to and from the tunnel.

7.3 Tunnelling Regulations

The recent introduction of the Health and Safety in Employment (Mining Operations and Quarrying Operations) Regulations 2013 sets out the new regulatory framework for hazard identification and risk management in tunnelling operations which are expected to be activated by tunnel the refurbishment methodologies outlined below in Section 8 (e.g. widening the tunnel with personnel underground).

A comprehensive Health and Safety Management System (HSMS) would be required to be implemented at the site. The HSMS would determine principal hazards for the site. Identified principal hazards would also require the development and implementation of a Principal Hazard Management Plan (PHMP) and appointment of mandatory statutory positions. This type of HSMS is now common place in mining and tunnelling operations throughput NZ. Worksafe NZ would need to review and approve the HSMS and PHMP prior to tunnel remediation.

Subject to Worksafe confirmation the intention of the tunnelling regulations is to also exclude small diameter tunnels 'usually non-manned' (where entry will come under regulations covering working in confined spaces) and 'non-manned' micro tunnelling, pipe jacking and directional drilling. Directional drilling of a new tunnel has been recommended to BDC as part of previous investigations in 2015. In 2014 Harker also proposed to reinstate the downstream 450m section via a manned pipe jacking methodology.

8 Fall Recovery & Tunnel Refurbishment Options

Based on our assessment we believe that safe and effective repair of the collapsed section and other high risk areas cannot be realistically achieved without increasing the size of the tunnel. This is due to the recognition that:

- the installation of adequate temporary and final ground support cannot be achieved in the existing tunnel dimensions
- some degree of further unravelling and instability of the tunnel would be expected as the existing timber supports are removed
- further strata instability represents a personal exposure hazard given the confined workspace and inability to provide adequate levels of support

To safely access and recover the fall the tunnel will therefore require widening. The main benefits of widening the tunnel would be that this strategy:

- Provides room for some form of mechanised cutting / scaling and/or bolting machine to be used and;
- Allows for effective levels of ground support to be designed and installed in the tunnel
- Allows for a safe system of temporary support to be employed in the tunnel as its widened and stabilised

Methods for tunnel widening have been provided to BDC in 2014 and included conventional tunnelling and pipe jacking. These methods are discussed below.

8.1 Conventional mechanised methods

OEC has not seen the Geotech Ltd proposal to stabilise the tunnel. However, conventional mechanised tunnelling methods could be adopted in Tunnel No.1 with a small roadheader or similar with mucking out to surface by loader. Ground support would be provided by suitably designed rock bolts and mesh. The tunnel would need to be kept as small as possible given the machine, ventilation and support design constraints. An engineered form of temporary support would be required to reduce worker exposure to fall of ground hazards. This can typically be achieved through a cage mesh system utilising temporary supports and has been used successfully in underground coal mining when hand held bolting gear is used.

Given the ground and timber support conditions within the tunnel the preferred, lower risk, option would be to develop a new section of tunnel around the fall and associated poor ground linking in at the upstream tunnel end at approximately 600m chainage as displayed in Figure 9. This strategy reduces risk by "engineering out" as much of possible the strata instability hazards associated with people removing supports in unstable ground, whilst also placing the tunnel in virgin ground that hasn't been weakened by previous deformation and that can be adequately supported immediately after excavation. It is likely that tunnel advance rates would be similar if not quicker in virgin ground with potential for cost savings. The key disadvantages of the method are:

- Potential for slope stabilisation works about downstream portal area
- Earthworks requirement to provide suitable access to downstream portal
- Upstream section of tunnel would remain unsupported
- Requirement for on-going inspection and maintenance of tunnel sections

- New tunnel would need to be completed with a flume or similar to assist water flow
- Pumping costs during tunnel construction
- A single-entry tunnel would also require risk controls to be implemented for the hazard of entrapment

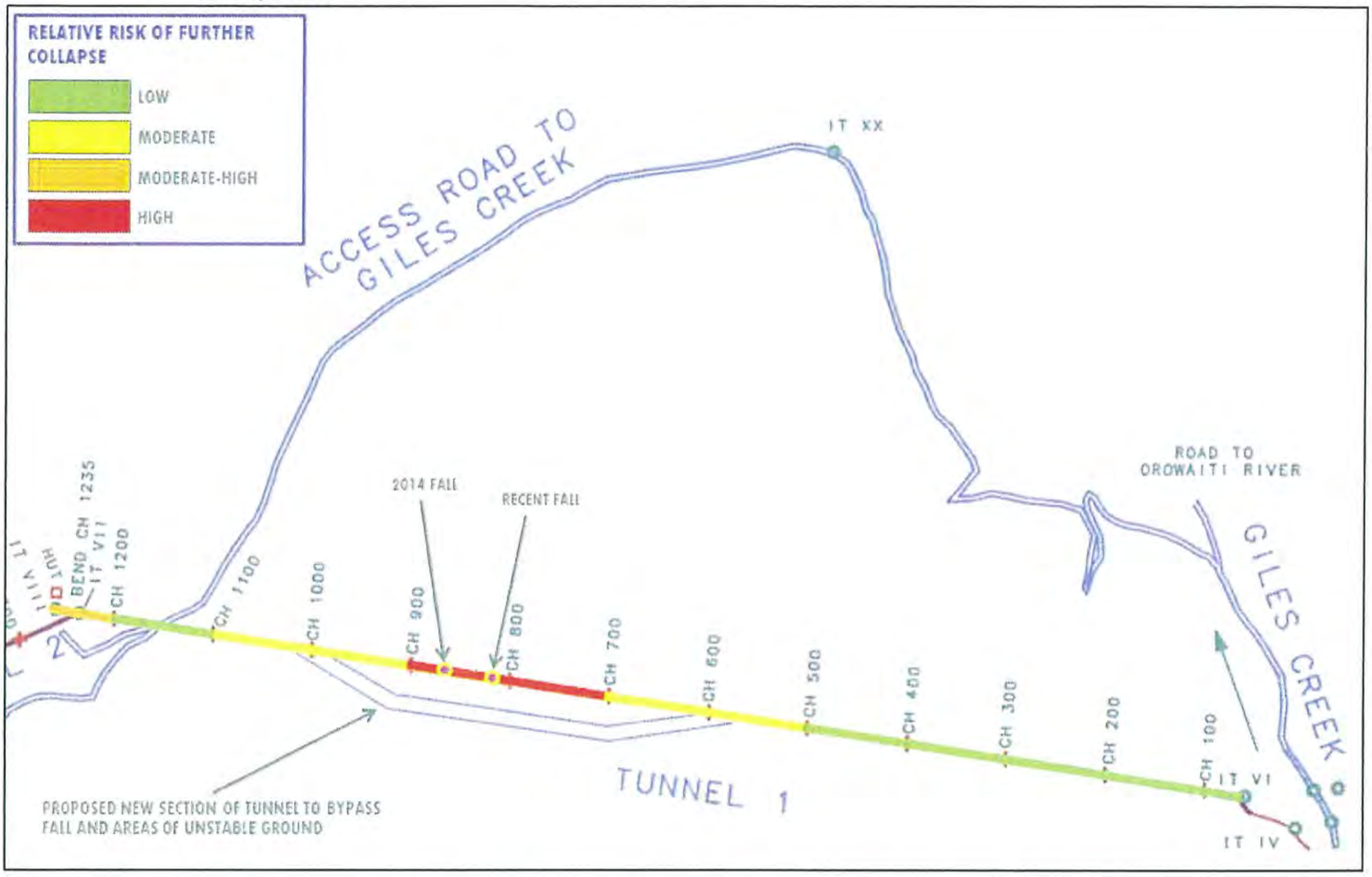


Figure 9 – Plan showing relative geotechnical risk and proposed bypass of fall and areas of high instability

8.2 Pipe jacking

The Harker pipe jacking proposal could provide a safe system for fall recovery and tunnel refurbishment. Harker did not appear to enter the tunnel as part of their proposal to jack a 1050mm diameter pipe up the tunnel. Based on our observations of the tunnel conditions and amount of loose material being retained by the wooden sets in places we suggest the existing tunnel conditions could pose complications with this methodology. Further assessment of this option would be required before it could be considered a feasible solution. The key disadvantages of this methodology are:

- Potential for slope stabilisation works about downstream portal area
- Earthworks requirement to provide suitable access to downstream portal and thrust platform
- Upstream section of tunnel would remain unsupported
- Requirement for on-going inspection and maintenance of unsupported upstream sections
- Pumping costs during tunnel construction

9 Alternative Options for Gravity Water Supply

Previous reports by Connell Wagner and Opus make mention of other gravity water supply methods as alternative to refurbishment of the existing Tunnel No.1. These methods would negate the need for having personnel working underground and would establish a new gravity water supply pipeline along a new alignment in virgin ground, bypassing Tunnel No.1 and with the option of also bypassing tunnels No.2 & No.3 which are noted to also be in poor condition and will likely need refurbishment or replacement in the future. Methods of installing such a pipeline include:

- Horizontal Directional Drilling (HDD)
- Micro-tunnelling

Both these methods involve low level installation risks if adequately assessed and provide long-term value while significantly reducing residual risk to water supply due to further instability of tunnels and to ongoing inspection and maintenance.

In their November 2015 report Opus estimated the cost of installing a 1200m replacement to Tunnel No.1 using HDD along a new alignment in virgin ground to be between $3M and $4.5M. Another alignment designed to bypass tunnels No.1, No.2 & No.3 at 1500m long was estimated to cost between $4M and $6M. It is likely that Micro-tunnelling will be in a similar cost bracket. Ongoing inspection and maintenance costs for both these options will likely be significantly lower than for a conventional tunnel.

Further investigation would be required to fully prove feasibility and costs of both HHD and micro-tunnelling options.

10 Geotechnical Investigations Required to Support Tunnel Options

To date only limited strength data has been obtained on the strength of materials about Tunnel No.1. Further geotechnical investigation and assessment would be required to adequately characterise the geological and geotechnical environment about the preferred tunnel corridor. The information obtained would be used for detailed tunnel and ground support design during feasibility studies.

A programme of work could be developed dependant on the preferred option. The work programme would typically involve:

- Field mapping
- Geotechnical drilling
- Sampling & testing of drill core

11 Recommendations

Our recommendations to address Tunnel No. 1 are:

- Undertake more detailed technical assessment and cost estimation of the preferred tunnelling options being:
    - Tunnel widening using mechanised methods which bypass the higher risk areas of the existing tunnel thereby eliminating geotechnical risk associated with a large portion of the existing tunnel.
    - Installation of a new 1500m pipeline to bypass Tunnel No.1, Tunnel No.2 and Tunnel No. 3 via micro tunnelling or directional drilling methods.
    - Pipe jacking and widening of the existing tunnel.
- A summary of the preferred methods is given in the table below. Estimated costs are as per the Opus November 2015 report.

Water Supply Option	Summary	Rough Cost Estimate	Project Risk
Tunnel stabilisation using mechanised methods	• Tunnel would be designed to bypass poor ground eliminating risk with poorer sections of existing tunnel • New 2013 Mining Regulations would apply • Portal stabilisation and access works required • Pumping of water during tunnel construction	$3.5 – 4.5M	**Medium**
Installation of a new pipeline to bypass Tunnels 1, 2 and 3	• Installation of new pipeline to bypass existing tunnels • Constructed using direction drilling or micro tunnelling methods • New 2013 Mining Regulations would not apply where tunnel is unmanned • Existing water system could be used or pumping as contingency	$3.5 – 6M	**Low**
Installing a pipe via jacking	• Pipe would be jacked through collapsed ground • New 2013 Mining Regulations would apply where tunnel is widened and people are underground • Portal stabilisation and access works required • Pumping of water during tunnel construction	$3 – 4.5M	**Medium**

12 References

1. Report from Connell Wagner dated January 2004 – ***Geotechnical Investigation of Westport Water Supply Refurbishment***

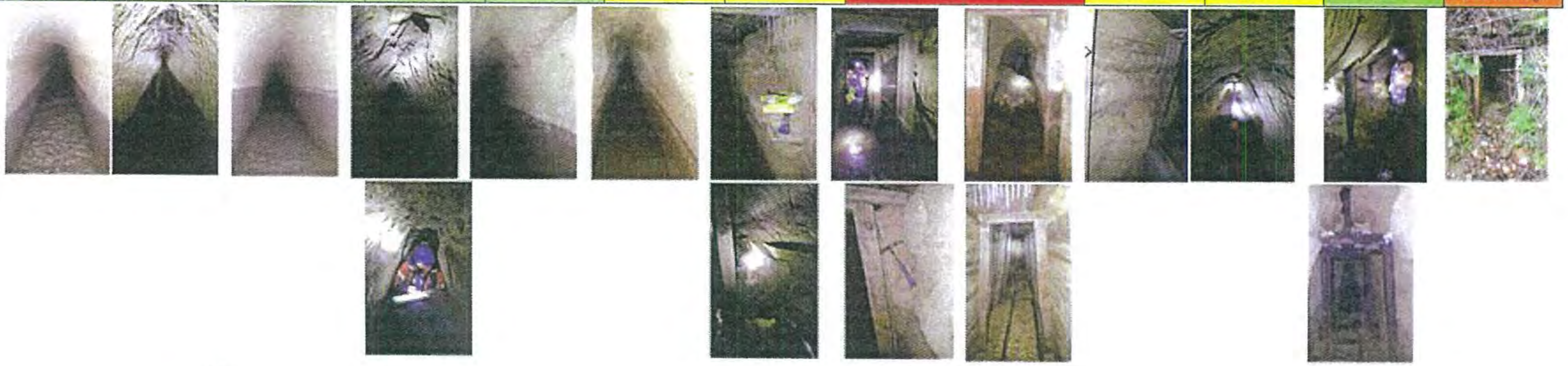
2. Report from Connell Wagner dated November 2004 – ***Westport Water Tunnels Additional Information on Upgrade Options***

3. Report from Opus dated December 2015 – ***Westport Water Tunnel No. 1 Refurbishment Options***

Appendix A – Summary of Mapping Information

	TUNNEL NUMBER 1 - GEOTECHNICAL MAPPING SUMMARY OF TUNNEL CONDITIONS & INSTALLED SUPPORT												
Chainage (m)	0 - 100	100 - 200	200 - 300	300 - 400	400 - 500	500 - 600	600 - 700	700 - 800	800 - 900	900 - 1000	1000 - 1100	1100 - 1200	1200 - 1300
Maximum Depth of Cover (m)	35	60	30	95	120	145	130	130	145	125	30	60	35
Geology	Unweathered yellow-brown massive fine to medium grained silty sandstone, very weak. Single undulating sub-horizontal gravel lense 0.4m thick matrix supported with pebble to cobble sized clasts	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak. Single gravel lense grading into roof	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak.	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak. Undulating sub horizontal gravel 0.3m gravel lense	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak. Undulating sub horizontal gravel 0.3m gravel lense	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak.	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak.	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak.	Unweathered yellow-brown sub-horizontal thinly laminated to moderately thinly bedded fine to medium grained silty sandstone, very weak.	Unweathered yellow-brown sub-horizontal moderately thinly bedded fine to medium grained silty sandstone, very weak. Occasional 2mm carbonate veins dipping 35° towards 225	Unweathered yellow-brown sub-horizontal moderately thinly bedded fine to medium grained silty sandstone, extremely weak. Occasional 2mm carbonate veins dipping 35° towards 225	Unweathered yellow-brown sub-horizontal moderately thinly bedded fine to medium grained silty sandstone, extremely weak
Defects	None	Sub-horizontal bedding	Sub-horizontal bedding	Sub-horizontal bedding and frequent open curved jointing in crown initiated in bedding planes and curving downwards subparallel to tunnel alignment. Jointing on scale of <1cm to 3cm deep and 5-40cm long	Sub-horizontal bedding and frequent open curved jointing in crown initiated in bedding planes and curving downwards subparallel to tunnel alignment. Jointing on scale of <1cm to 3cm deep and 5-40cm long	Massive, frequent open curved jointing in crown initiated in bedding planes and curving downwards in crown subparallel to tunnel alignment. Sub-vertical joints developing in right sidewall parallel to tunnel alignment. Jointing on scale of <1cm to 3cm deep and 5-40cm long	Sub-horizontal bedding and frequent jointing initiated in bedding planes and curving downwards in crown subparallel to tunnel alignment. Sub-vertical joints developing in both sidewall parallel to tunnel alignment. Jointing on scale of 3cm to 40cm deep and 10-400cm long	Sub-horizontal bedding and frequent open sub-vertical joints developing in both sidewall parallel to tunnel alignment. Jointing on scale of 3cm to 40cm deep and 10-400cm long. Blocky brittle failures behind wooden sets and lagging indicate two or three joint sets, blocks in order of 3cm 25cm wide and 10cm to 30cm long.	Sub-horizontal bedding and frequent open sub-vertical joints developing in both sidewall parallel to tunnel alignment. Jointing on scale of 3cm to 40cm deep and 10-400cm long. Blocky brittle failures behind wooden sets and lagging indicate two or three joint sets, blocks in order of 3cm 25cm wide and 10cm to 30cm long.	Sub-horizontal bedding and frequent open sub-vertical joints developing in both sidewall parallel to tunnel alignment. Jointing on scale of 3cm to 40cm deep and 10-400cm long. Blocky brittle failures behind wooden sets and lagging indicate two or three joint sets, blocks in order of 3cm 25cm wide and 10cm to 30cm long.	Infrequent bedding and sub-vertical joints developing in both sidewalls parallel to tunnel alignment. Jointing on scale of 1cm to 3cm deep and 10-40cm long	Infrequent bedding and sub-vertical joints developing in both sidewalls parallel to tunnel alignment. Jointing on scale of 1cm to 3cm deep and 10-40cm long	Infrequent bedding and frequent open curved jointing in crown initiated in bedding planes and curving downwards subparallel to tunnel alignment. Jointing on scale of <1cm to 3cm deep and 5-40cm long
Tunnel Conditions	Very good conditions with original pickmarks still visible	Good conditions with minor delamination & fretting in crown	Good Conditions with minor delamination & fretting in crown	Shear failure of roof biased to right hand side. Roof failed to <300mm above roof line	Good conditions with minor guttering biased to right hand side	Right hand sidewall starting to exhibit minor spall / fretting on sub vertical defects. Roof conditions display minor fretting & delamination	Sidewalls spalling on sub vertical defects developed due to overstressing from vertical stress	Sidewalls spalling on sub vertical defects developed due to overstressing from vertical stress	Poor roof & sidewall conditions with sidewall failure with water ponding to 600mm depth at 815m. Roof collapse at 883m with considerable weight coming on right hand side of lagging (failed behind).	Fair tunnel conditions with sub vertical jointing in sidewalls leading to minor spalling. Fretting in roof becomes more common.	Fair tunnel conditions with uneven roof profile & some fretting	Shallow cover section of tunnel. Old sidewall failure occurred on defect. Localised roof fretting to <300mm above cut roof line	Shallow cover tunnel section with limited rockhead (<10m solid rock) to overlying gravels. Crown of tunnel has distinct asymetric profile due to guttering in right side during development
Support Type	No support	No Support	No Support	No Support	No Support	No Support	Wooden sets in places from 650m	Wooden sets with timber lagging rotting and in poor condition. Lagging mainly on left hand side.	Unsupported in failed section. Poor ground downstream of this. Did not proceed past sidewall failure. Wooden sets to tunnel collapse at 883m. Opus noted support to be in poor condition with rotten lagging.	Wooden sets & intermittent lagging in this section of tunnel	No Support	No Support (although old props installed in wider section)	Timber sets installed at downstream portal area. Display significant loading on right hand side & further deformation since Opus 2015 photos
Comments				Potential horizontal stress impacts causing shear failure to develop in roof			Wooden sets not taking much weight but retaining loose material. Sidewalls undercut in places due to spalling (not erosion)	Water backed up behind fall to depth of 0.6m with fine mud settled on floor. 0.15% CH4 measured as mud disturbed, but quickly dispersed				Low levels of confining stress have resulted in wedge failure of sidewall & localised "dropping out" of small roof sections	Tunnel No 1 intersects tunnel No.2 at 1230m. Portal area is at moderate risk of further slips & timber sets at portal are displaying significant deformation due to loading and at risk of collapse
Relative Risk of further collapse	Low	Low	Low	Low	Low	Moderate	Moderate	High	High	Moderate	Moderate	Low	Moderate - High

Images (Dec 2016)

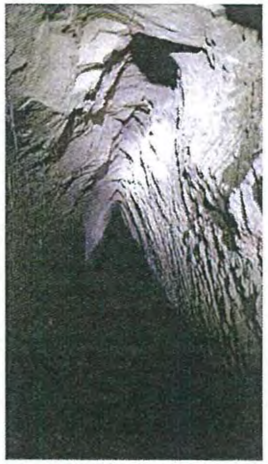


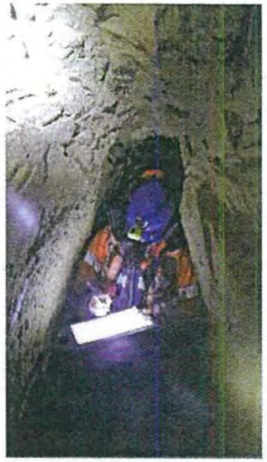
Appendix B – Tunnel Photographs Highlighting Range of Conditions

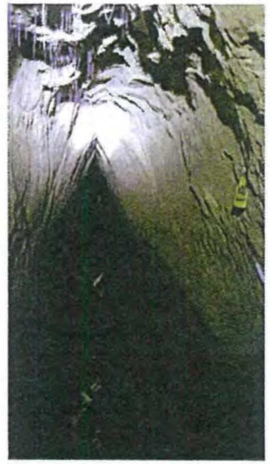

Upstream Portal

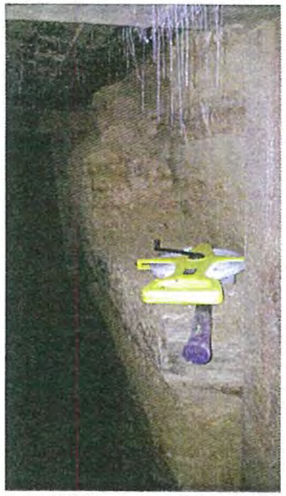

Tunnel ~100m showing very good Ground & thin conglomerate band


Tunnel at ~200m showing very good conditions


Tunnel at ~350m showing onset of guttering in roof


Tunnel at ~550m showing blocky roof

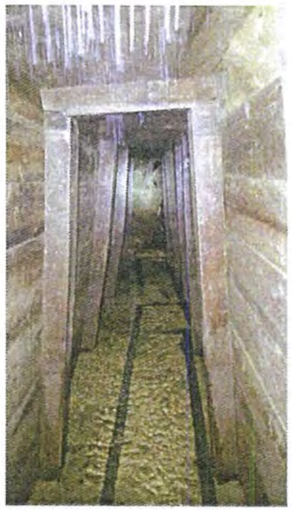

Tunnel at 600m showing good conditions with roof fretting


Tunnel ~660m showing sidewall Spalling & timber supports


Tunnel at ~750m showing poor conditions and rotten timber lagging


Tunnel at 800m showing sidewall failure (815m), blockage and increased water level


Tunnel at 885m showing collapse


Tunnel at ~870m showing deformation of timber sets leading into collapse


Tunnel at 1000m showing recent roof fall material on tunnel invert

GEOTECH
GROUND ENGINEERING

Broad Brushstroke Risk Assessment – Westport water tunnels (proposed remediation works)

Hazard/Risk	Unwanted event	Caused by	Key loss type	Likelihood	Consequence	Risk rating	Controls	Likelihood	Consequence	Risk rating
Traffic on narrow gravel access road	Collision between vehicles	Multiple vehicles on narrow gravel access road	Injury	2	3	M	Vehicles to travel at appropriate speed for road conditions Vehicles to travel with lights on Establish good communications when on-site work is underway Manage vehicle movements if necessary (car pool, radio communications etc) BDC to restrict access during period of works	1	2	VL
	Vehicle leaves road	Inattention Poor driving	Injury	1	3	L	Vehicles to travel at appropriate speed for road conditions	1	2	VL
Injury traversing terrain	Slip, trip or fall Fall from steep edge or bluff	Inattention Undulating terrain Wet, slippery conditions	Injury	2	3	M	Follow slip, trip, fall guidelines or work procedure Consider weather, environment when planning work Ensure footwear is suitable for the terrain	1	2	VL
Rock fall/slope movement near down stream portal	Injury from falling debris Full or partial blocking of portal	Large rocks currently resting above portal Portal not stable enough (stressed) Ground conditions above portal Vibrations from work Seismic activity	Fatality	2	5	H	Dig out area above portal (including large rocks) prior to work commencing Establish appropriate rockfall protections measures/culverts Day light portal to remove stressed sets – establish a new portal Monitor ground conditions around portal on a regular basis Portal watch at all times when staff are working in tunnels	1	3	L
Geological conditions in tunnels	Injury from tunnel collapse Temporary confinement due to collapse	Geological conditions Vibration from works Single entry	Multiple fatality	2	3	M	Portal to be cleared and day-lighted to remove stressed sets Daily checks and monitoring of tunnel conditions prior to works commencing Initial stabilisation and support (design life equal or greater to the construction period) to be installed prior to works commencing (as per documented PHMP) Report any signs of slumping, instability (of ground or supports) or geological changes Geological assessments as required Refuge station holding food, batteries, water, space blankets etc, suitable for maintaining staff during excavation of single entry	1	3	L
Fire/smoke risk in tunnels	Air quality in tunnels affected Staff working in tunnels unable to escape	Machinery fire	Multiple fatality	1	5	M	All machinery operating in tunnel must be fitted with fire suppression and extinguishers Remove all sources of ignition where possible No workers to be in-bye of any ignition source when working in tunnels – workers MUST have direct access to portal (not blocked by machinery) at all times when machinery is operational Refuge bay to be established within stretch of tunnel near excavation works Staff to carry self rescuers	1	3	L
Fumes/gases in tunnels	Air quality in tunnels becomes hazardous to workers	Limited/confined atmosphere affected by contaminants from diesel machines etc	Illness	2	3	M	Ventilation control plan to be in place (as per documented PHMP) Pneumatically powered excavator and muck out wagon on continuous rope (rail/winch) to remove risks posed by diesel fumes and significantly reduce fire risk Winch and other equipment to be sited outside of tunnel environs Monitor air quality and air humidity to manage risk of heat stress	1	3	L
Dust/contaminants	Air quality in	Limited/confined	Illness	3	4	H	Geological assessment to determine soil/rock minerology			

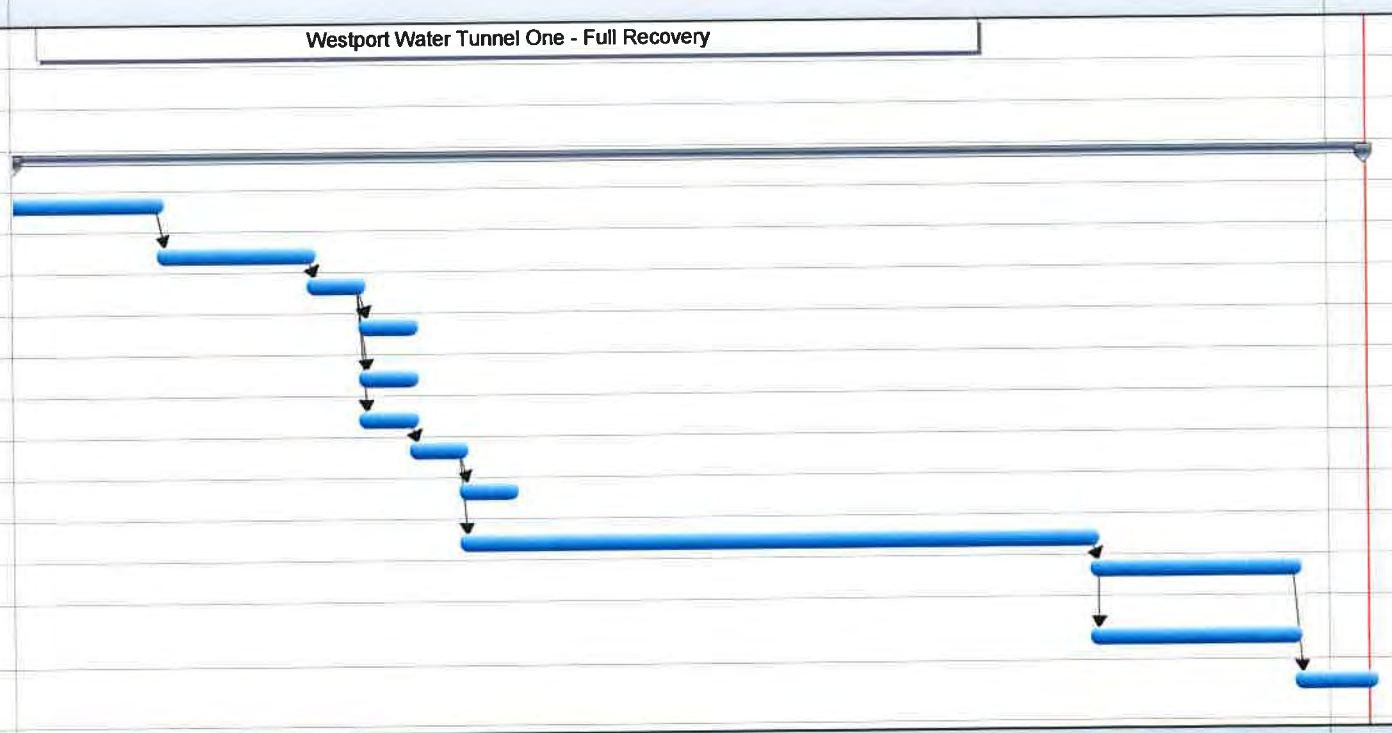
in tunnels	tunnels becomes hazardous to workers	atmosphere affected by dust/particulates from excavation or drilling					Monitor dust generated by works Monitor air quality to ensure adequate fresh air RPE to protect workers from respirable dusts when drilling etc is underway			
Inundation	Drowning	Flash flood Breach of upstream water source	Fatality	1	5	M	Investigation shows that there is very low risk of inundation • Entrance is 4-5m above mean flow • Water levels in the tunnel system are low • Tunnels are at a 1:1200 grade, with collapse at 400m, less than 1m water depth behind the fall • Water flows (even at times of high rainfall) have remained low Monitor weather conditions and local creek and river levels	1	1	VL
Seismic activity	Rockfall or tunnel collapse	Earthquake	Injury or multiple fatality	2	5	H	Portal to be cleared and day-lighted to remove stressed sets Daily checks and monitoring of tunnel conditions prior to works commencing Initial stabilisation and support (design life equal or greater to the construction period) to be installed prior to works commencing (as per documented PHMP) Emergency plan to be in place prior to works commencing. No work subsequent to any noticeable earthquake until a geological assessment has been completed.	1	5	M
Winch machinery	Personal injury	Moving parts, stored energy, trip and fall	Injury	2	3	M	Winching protocols to be established, including visual or audible signals Winch to be established outside portal, monitored by portal watch at all times All workers to stand clear of wire rope and load during operation Wear heavy leather gloves when handling the wire rope Winch to be rated for load capacity Complete commissioning and pre-start checks prior to operation Particular attention to wire rope condition Keep winch operation area clean, tidy and free from obstructions Winch is not to be operational when people are traversing the length of the tunnel	1	3	L
	Injury or damage	Over heating/fire	Injury	2	2	VL	Winch to be located clear of tunnel, where it cannot impede egress Winch to be monitored by portal at watch at all times during operation Fire extinguisher to be on site	1	1	VL

Consequence					
Safety	Injury requiring first aid treatment or less	Injury requiring medical treatment	Injury requiring hospitalisation; or a lost time injury	Serious long term lost time injury	Fatality; or serious permanent disability
Environment	Small amount of environmental damage controlled within the site	Limited environmental damage to low significance area without permanent effect; or exceed a statutory or prescribed limit	Limited environmental damage recoverable within one year; or exceed a statutory or prescribed limit repeatedly	Severe environmental damage requiring extensive rehabilitation; or exceeded a statutory or prescribed limits over 2-5 years	Persistent severe environmental damage; the damage will require > 5years to rehabilitate; or the damage cannot be rehabilitated
Financial	Less than $5,000 loss; or less than 4 hours lost production	$5,000 - $50,000 loss; or 4 hours – 2 days lost production	$50,000 - $500,000 loss; or 2 days – 1 week lost production	$500,000 - $2M loss; or 1 week – 2 weeks lost production	Greater than $2 million loss; or 2 weeks – 1 month lost production
Reputation	Little internal or external attention; or a customer issue raised	Workforce attention; limited external attention; or a customer complaint	Repeated complaints; Regulatory notification; or negative stakeholder, media or customer attention	Negative national media coverage; significant negative perception by shareholder or key stakeholder; or a customer disruption	Negative international media coverage; shareholder or key stakeholder outage; or loss of a key customer

Risk Rating	Minor	Moderate	Serious	Major	Catastrophic	LIKELIHOOD OF THE SELECTED CONSEQUENCE OCCURRING	
	M	M	H	VH	VH	5	• Expected to occur under normal circumstances • Over 90% chance of happening under these conditions
	M	M	H	H	VH	4	• Likely to occur under normal circumstances • Over 75% chance of happening under these conditions
	L	M	M	H	H	3	• Could reasonably be expected to occur under normal circumstances • Around 50% chance of happening under these conditions
	VL	L	M	M	H	2	• Unlikely to occur under normal circumstances • Around 10% chance of happening under these conditions
	VL	VL	L	M	M	1	• Conceivable but only in rare circumstances • Less than 10% chance of happening under these conditions

Residual risk level	Suggested action
VH, H	Reduce the risk to M or below if the rating remains at VH or H conduct a formal Risk Assessment
M	Develop/Review/Follow the JHA /Procedure
L	Develop/Review/Follow the JHA.
VL	Develop/Review/Follow the JHA if required.

Hierarchy of Controls			
Eliminate	Hard Defences (i.e. Guarding, Isolation, etc.)	What could be done to eliminate the hazard?	Difficult to bypass or fail
Substitute		Can the work be done another way?	
Engineering		Can the work be done another way?	
Administration	Procedural (Soft) Controls	What temporary signage, permits, procedures, training, can be used to minimise the risk?	Easy to bypass or fail
PPE		Can the work be done another way?	



Activity Name	Duration (Days)
Summary	270.00
Award tender	30.00
Procurement and design	30.00
Mobilisation	10.00
Outlet portal dig out	10.00
Install ventilation chainage 45	10.00
Install stopping IT VI	10.00
Spot bolt to fall	10.00
Open egress at fall	10.00
Bolt tunnel and recover fall	125.00
Install pipes	40.00
Spot bolt from chainage 735 chainage 45 (extra remedial)	40.00
Pneumatically placed cover to pipe	15.00

From: **Ant Black** ant.black@geotech.net.nz
Subject: Fwd: Euroflo Pipe
Date: 11 October 2017 11:38 am
To: Lisa Dickson lisa.dickson@geotech.net.nz

Lisa,

FYI for BDC tunnel one appendix.

Ant.

> Begin forwarded message:
>
> **From:** Dan Johnson <dan.johnson@opus.co.nz>
> **Subject: FW: Euroflo Pipe**
> **Date:** 10 October 2017 18:06:17 NZDT
> **To:** "ant.black@geotech.net.nz" <ant.black@geotech.net.nz>
> **Cc:** Christopher Bergin <christopher.bergin@opus.co.nz>
>
> Hi Ant,
>
> Please find pipe details for the tunnel reinstatement as per our discussion this morning.
>
> Greg has confirmed the pipe sizes, the profile wall pipe is 696mm OD and SN12. Drawing of the joint and profile are attached with approx. tunnel dimension, which shows the pipe drawn up with 200mm cover over the solid and profile wall options. Either option could be considered, however the solid is definitely going to be more robust.   This has 200mm of material over the pipe. If we can get something self-compacting (e.g. 5mm chip) blown in would be easy, otherwise a crusher dust or similar with some cement would add further confidence and offset the lower SN of the profile wall. Hatched area is approx. 0.6m2. Not sure if the entire length needs to be covered or just the bit through dodge.
>
> The Franks profile wall pipe is SN12 and approx. 38 kg/m ....the SN16 solid wall is 77 kg/m so profile wall much easier to handle and half the weight and price of the solid wall. Either could be obtained in shorter lengths too if that would suit you better (but more cost as more joints). Joints can be single rubber ring and are basically flush which helps.
>
> Drawbacks are 5mm wall for the profile wall pipe so potentially eroded away more quickly – but the bedload can be mitigated by a gravel trap upstream of the tunnel (may be one already), and it would not really matter anyway as the grit/gravel would pack out the void at the invert anyway.
>
> For your consideration, please let me know if you require any further information.
>
> Contact details for the pipe, are:
>
> Chris Price chris@frankpksnz.com
> Business Development Manager
> FRANK PKS (NZ) LTD
> 0274322740

Cheers Dan

OPUS

Dan Johnson
WGM - Water Asset Management & Engineering

Opus International Consultants Ltd, 12 Moorhouse Avenue, Christchurch 8011, New Zealand
PO Box 1482, Christchurch Mail Centre, Christchurch 8140, New Zealand

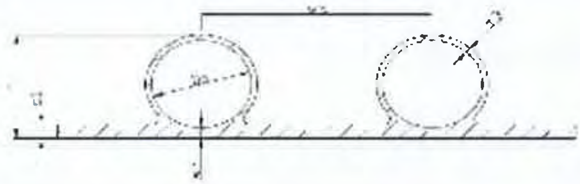
+64 3 363 5570

+64 27 436 1741

dan.johnson@opus.co.nz

www.opus.co.nz

PR 42 - 2.6



Characteristics	Abbreviation	Measures	Unit
Groundwall thickness	s1	6.0	[mm]
Wall thickness	s2	6.0	[mm]
Support ring casing	s3	4.0	[mm]
Top layer thickness	h	48.0	[mm]
Profile height	We	100.0	[mm]
Profile width	Ds	42.0	[mm]

Table 1

Characteristics	Abbreviation	Static Values	Unit
moment of inertia	I	2,858.1	[mm^4/mm]
distance of inertia	e	15.0	[mm]
equivalent wall thickness	s8	31.7	[mm]
moment of resistance (intern.)	Wi	176.8	[mm³/mm]
moment of resistance (extern.)	We	80.5	[mm³/mm]
profile surface	sp	10.5	[mm²/mm]
axially effective profile surface	sp2	6.0	[mm²/mm]

Table 2

	Name	Department	Date	Signature
Approved	N Browne	Manufacturing	02.02.12	
Checked	D. Hodder	Testing	02.02.12	

Flexible Solutions

PPS-FRANK (NZ) LTD
Spiral Pipe Technology

DRR Profix Pipe
DN600 - DN1200

Spigot

Socket

Westport water tunnels - Methodology estimates

Mobilisation		$15,000	
Portal daylighting and stabilisation	Based on $2.5k per 15m	$40,000	
Tunnel stabilisation		$550,000	
Excavation		$40,000	
Pipe purchase and transport (PKS-Franks solid pipe. 77kg per m @ <$4.00 p/kilo)	Based on 500m total length	$154,000	
Pipe installation	Install 2 per/day, equals 12m, 41 days installation	$100,000	
Install rail and winch	Estimate	$100,000	
Install ventilation		$20,000	
Pneumatically place self cementing cover		$55,000	
Management and health and safety		$100,000	
Materials	Purchase	$27,500	
	Placement	$27,500	
Demobilisation		$15,000	
		$1,244,000	**Total**
Contingency/Margin 15%		186,600	Contingency
		1,430,600	**Total**
Spot botling tunnel roof		$200,000	Recommendation

20 Appendix A3 – Capital Cost Estimate

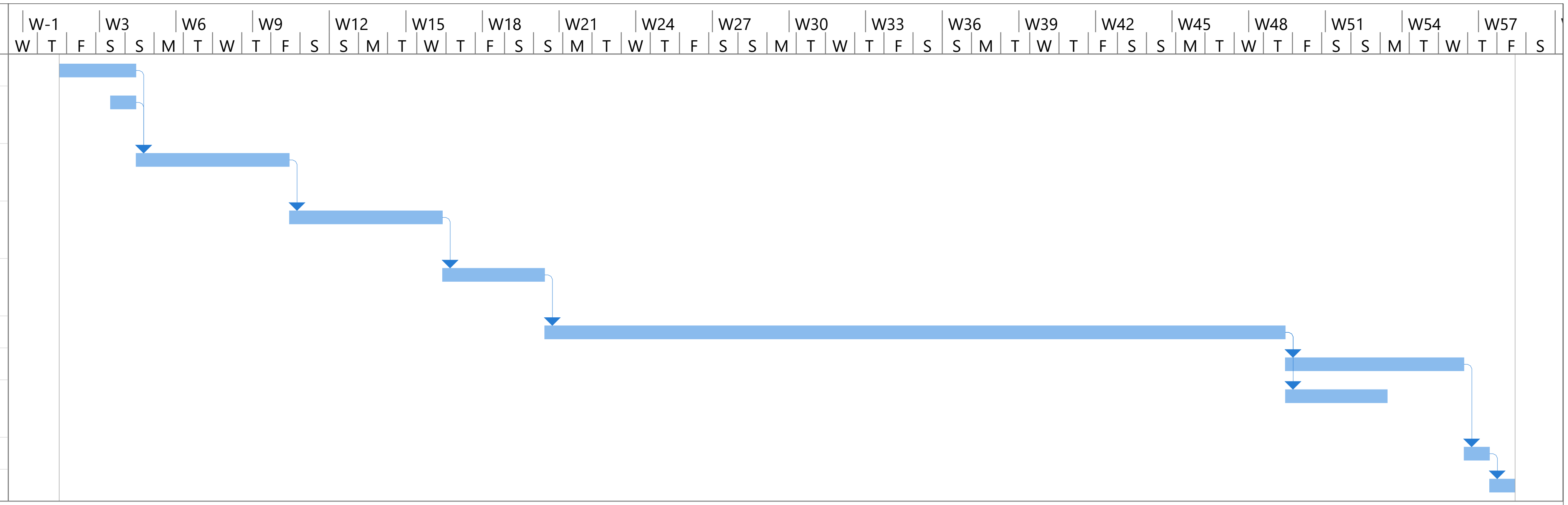
BDC - Westport Tunnel #1 Repair Option 2d

Capital Cost Estimate

Item	Description	Unit	Qty	Median Rate	Median Amount	Assessed Range	Upper Amount	Lower Amount
1	**PRELIMINARY & GENERAL**							
1.1	General Management & Approvals	LS	1	$ 100,000	$ 100,000	*25%*	*$ 125,000*	*$ 75,000*
1.2	Establishment	LS	1	$ 15,000	$ 15,000	*15%*	*$ 17,250*	*$ 12,750*
1.3	Setting Out	LS	1	$ 2,000	$ 2,000	*15%*	*$ 2,300*	*$ 1,700*
1.4	Disestablishment	LS	1	*$ 15,000*	$ 15,000	*15%*	*$ 17,250*	*$ 12,750*
				Subtotal:	*$ 132,000*			
2	**CIVIL**							
2.1	Site earthworks/form laydown area	LS	1	$ 40,000	$ 40,000	*25%*	*$ 50,000*	*$ 30,000*
2.2	Rail & winch system	LS	1	$ 100,000	$ 100,000	*25%*	*$ 125,000*	*$ 75,000*
2.3	Ventilation system	LS	1	$ 20,000	$ 20,000	*25%*	*$ 25,000*	*$ 15,000*
2.4	Tunnel stabilising	LS	1	$ 605,000	$ 605,000	*25%*	*$ 756,250*	*$ 453,750*
2.5	Remove rockfall	LS	1	$ 40,000	$ 40,000	*50%*	*$ 60,000*	*$ 20,000*
2.6	Supply & Install DN600 pipe	m	500	$ 510	$ 255,000	*25%*	*$ 318,750*	*$ 191,250*
2.7	Backfill with lean mix	LS	1	$ 55,000	$ 55,000	*15%*	*$ 63,250*	*$ 46,750*
2.8	Tie in works upstream (bulkhead)	LS	1	$ 10,000	$ 10,000	*15%*	*$ 11,500*	*$ 8,500*
2.9	Tie in works downstream (bend)	LS	1	$ 5,000	$ 5,000	*15%*	*$ 5,750*	*$ 4,250*
2.10	Additional spot bolting	PS	1	$ 200,000	$ 200,000	*50%*	*$ 300,000*	*$ 100,000*
				Subtotal:	*$ 1,330,000*			
3	**COMMISSIONING & HANDOVER**							
3.1	Commissioning	Day	2	$ 5,000	$ 10,000	*25%*	*$ 12,500*	*$ 7,500*
3.2	As-builts	LS	1	$ 2,000	$ 2,000	*25%*	*$ 2,500*	*$ 1,500*
				Subtotal:	*$ 12,000*			
	WORKS TOTAL				*$ 1,474,000*			
4	**PROFESSIONAL FEES & BDC COSTS**							
4.1	Preparation of Contract Documents	%	4%	$ 1,474,000	$ 58,960	*25%*	*$ 73,700*	*$ 44,220*
4.2	Tender Evaluation	LS	1%	$ 1,474,000	$ 14,740	*25%*	*$ 18,425*	*$ 11,055*
4.3	Construction Supervision	%	5%	$ 1,474,000	$ 73,700	*25%*	*$ 92,125*	*$ 55,275*
4.4	Commissioning	LS	1	$ 25,000	$ 25,000	*25%*	*$ 31,250*	*$ 18,750*
4.5	Contract Completion	LS	1	$ 15,000	$ 15,000	*25%*	*$ 18,750*	*$ 11,250*
				Subtotal:	*$ 187,400*			
						Pre-Contingency	*$ 2,126,550*	*$ 1,196,250*
5	**CONTINGENCY**	CS	$ 1,661,400	20%	$ 332,280		*$ 425,310*	*$ 239,250*
	Project Total (rounded)				**$1.99M**		*$ 2,551,860*	*$ 1,435,500*

21 Appendix A4 – Project Program

ID	Task Name	Duration	Start	Finish
1	Preliminary design	15 days	Wed 1/11/17	Tue 21/11/17
2	Preparation of Contract Documentation	5 days	Wed 15/11/17	Tue 21/11/17
3	Tendering, Evaluation, negotiation (if required) and Award	30 days	Wed 22/11/17	Tue 2/01/18
4	Mobilisation, procurement, design & approvals	30 days	Wed 3/01/18	Tue 13/02/18
5	Establishment on site & temporary/enabling works	20 days	Wed 14/02/18	Tue 13/03/18
6	Stabilisaton & fall removal	145 days	Wed 14/03/18	Tue 2/10/18
7	Pipe installation & backfill	35 days	Wed 3/10/18	Tue 20/11/18
8	Additional remedial work (if required)	20 days	Wed 3/10/18	Tue 30/10/18
9	Reinstatement & disestablishment	5 days	Wed 21/11/18	Tue 27/11/18
10	Commission	5 days	Wed 28/11/18	Tue 4/12/18



Project: Westport Water Supply
Date: Wed 18/10/17

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

22 Appendix A5 – Archaeological Assessment

OPUS

7 June 2017

Opus International Consultants Ltd

P +64 3 363 5400

Christchurch Office
12 Moorhouse Avenue
PO Box 1482, Christchurch Mail Centre, Christchurch 8140
New Zealand

Dan Johnson
Opus Consultants
20 Moorhouse Avenue
Christchurch 8011

Dear Dan

Archaeological & Heritage Check: Westport Tunnel No.1

Introduction

This Archaeological and Heritage Check is for the proposed Westport Tunnel No. 1 project. This project involves remediation of an existing tunnel system that will likely impact timber and stone components of the individual tunnels that make up the water system.

The Westport water tunnel system is a gravity flow water system located southeast of the town of Westport that consists of four sections of tunnel and holding ponds which diverts water from Giles Creek to a water treatment plant located on Sergents Hill before it is distributed to the town (Figure 1).

The purpose of this document is to identify any potential archaeological or heritage risks associated with the project, and to outline the legal requirements if any risks are identified.

Figure 1. Client supplied image showing location of gravity feed water supply system.

Definition of an Archaeological Site

An archaeological site is defined in the *Heritage New Zealand Pouhere Taonga Act* 2014 as any place in New Zealand that either:

(a) i) was associated with human activity before 1900; or

ii) is the site of the wreck of any vessel where the wreck occurred before 1900; and

(b) is or may be able through investigation by archaeological methods to provide evidence relating to the history of New Zealand.

Archaeological and Heritage Check Scope

This Archaeological and Heritage Check is a brief desktop-based study of recorded heritage and archaeological sites in the project area. No detailed research, assessment or fieldwork has been undertaken to confirm the location of any archaeological sites.

This assessment of archaeological risks is based on a review of the New Zealand Archaeological Association's (NZAA) Archaeological Site Record Database 'ArchSite', the Heritage New Zealand List, the Buller District Council District Plan maps, and historic aerial photographs and survey plans.

Limitations

This review does not present the views of local iwi regarding the cultural significance of the area. Such assessments can only be made by tangata whenua as Maori concerns may encompass a wider range of values than those associated with archaeological sites. The advice presented here is only for the project design described and does not account for any changes to project scope, design or footprint unless otherwise stated.

This Archaeological and Heritage Check is a preliminary guide to identify potential risk only, and is not a complete archaeological or heritage assessment.

Results

Documentary Sources

Documentary sources indicate that construction of the water tunnel system began in 1901 and was completed in 1903 (Cyclopaedia of New Zealand 1906, New Zealand Herald 01/06/1900, Grey River Argus 04/06/1901). No records were found indicating that any components of the water system dated to the 19th century.

NZAA Archaeological Site Record Database

There are no archaeological site records situated within the proposed project area; the closest site records are over 3 km to the north west and will not be affected (Figure 2). This recorded site is an Urupa.

Heritage New Zealand Pouhere Taonga List

There are no listed heritage items within the proposed project area, nor the immediate wider area.

Buller District Council District Plan

There are no listed heritage sites within the project area.

Historic Survey Plans / Maps

No 19th century survey plans of the project area were identified.

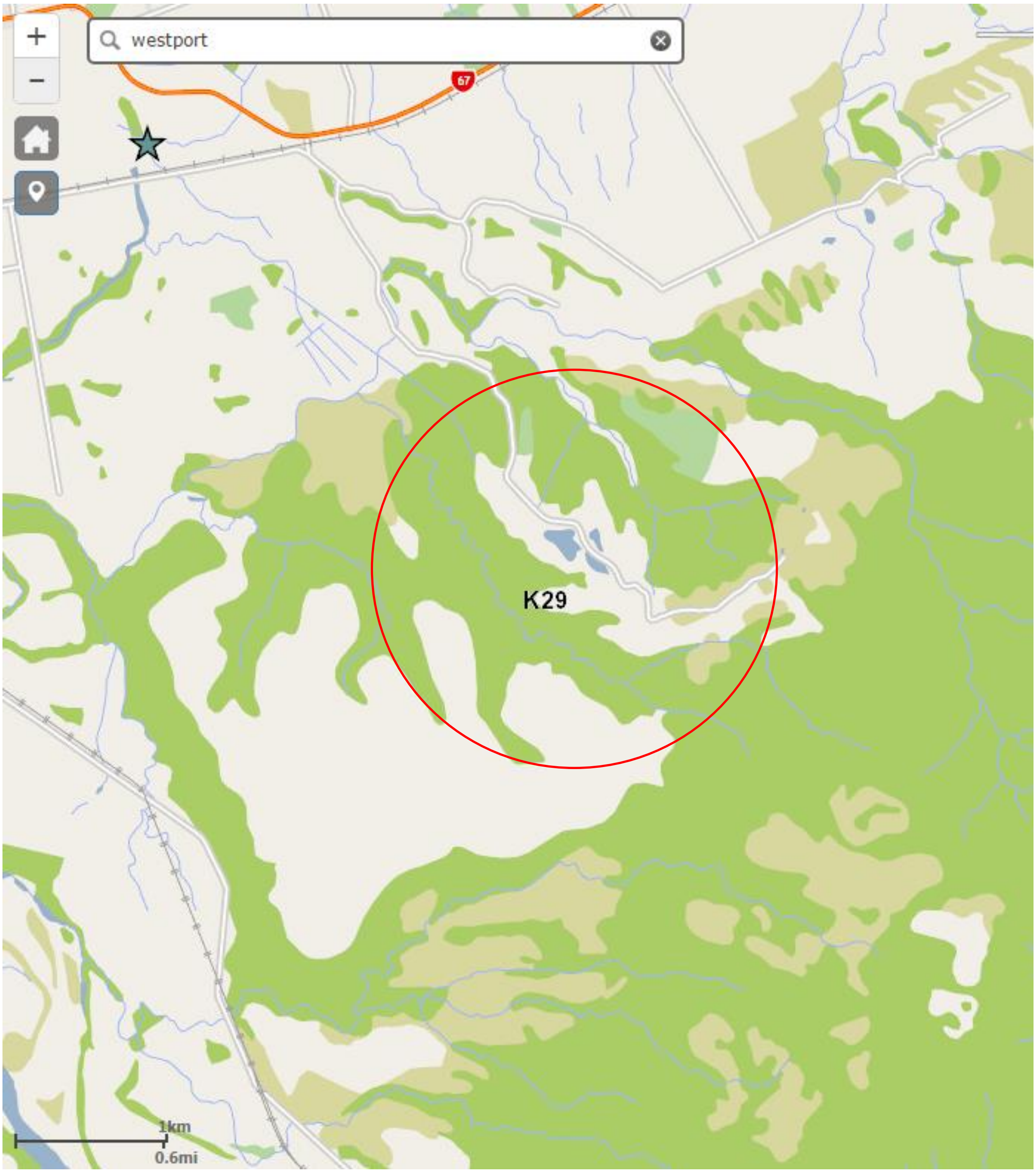


Figure 2: Archaeological site records (green stars) situated within the vicinity of the proposed works (highlighted by red circle).The nearest archaeology site (K29/66, an Urupa identified by green star) is located c. 3 km northwest of the project area.

Conclusion & Recommendations

The Westport water tunnel system does not meet the definition of an archaeological site as defined in the *Heritage New Zealand Pouhere Taonga Act* 2014; nor is it protected by a heritage listing. Never-the-less, the tunnel system may possess significant heritage values associated with the people and events that led to its construction, and its development, design, engineering, construction, and use over more than 110 years; especially as there few if any examples of similar systems of this type and age.

It is therefore recommended that a Heritage Significance Assessment be carried out before the remediation works commence to better determine the heritage values associated with the tunnel system, identify how these values might be impacted by the proposed remediation, and inform decisions about future works.

The Heritage Significance Assessment would be a written report prepared by our Senior Heritage Consultant, and would include the following tasks:

1.	Site visit to observe the existing condition of the tunnel system including the extent of original fabric, accessibility, and stability.
2.	Documentary research into development of the site and the construction of the tunnel system to provide an outline of their history and development.
3.	Assessment of heritage significance of the tunnel system based on physical and documentary research (tasks 1 and 2) in accordance with the criteria given in the Resource Management Act 1991, the Buller District Plan, the ICOMOS NZ Charter 2010, and guidelines prepared by Heritage New Zealand.
4.	Discussion and recommendations regarding the impact of proposed and potential future remedial or replacement works.

Please feel free to contact me if you have any queries relating to this archaeological and heritage check, or if you require further assistance.

Regards

TJ O' Connell
Archaeologist

23 Appendix A6 – Opus Supplementary Options' Report

OPUS

Buller District Council

Westport Water Tunnel No 1 Refurbishment Options

Supplementary Report

March 2016

Buller District Council

Westport Water Tunnel No 1

Refurbishment Options

Supplementary Report

March 2016

Prepared By	David L. Stewart Senior Geotechnical Engineer	Opus International Consultants Ltd	
	Mark Hoyle Principal Environmental Engineer	Wellington Civil L10, Majestic Centre, 100 Willis St PO Box 12 003, Wellington 6144 New Zealand	
	John Black Technical Principal- Pipeline Materials	Telephone: Facsimile:	+64 4 471 7000 +64 4 471 1397
Reviewed By	Alexei Murashev Technical Principal, Geotechnical Engineering	Date:	9 March 2016
		Reference:	5-C2896.00
		Report No: Status:	GER 2016/13 Issue 1b (Table 4 altered)

© Opus International Consultants Ltd 2017

Contents

Executive Summary ii

1 Introduction 1
- 1.1 Purpose 1
- 1.2 Scope 1
- 1.3 Background 1

2 Above Ground Options 2
- 2.1 Gravity Option (along contour) 2
- 2.2 Pumped option from Giles Creek 3

3 Required Pipe Size for pipe options 4

4 Underground Pipeline Options 5

5 Tunnel No 1 Condition Assessment 7
- 5.1 Tunnel condition rating 7
- 5.2 Observations of Partial Collapse at 870m 7

6 Tunnel No 1 Repair Option Costs 9
- 6.1 Sources of information 9
- 6.2 Scope 9
- 6.3 Cost Estimate for repair 10

7 Whole of Life Costs 10
- 7.1 Process used 10
- 7.2 Estimates for Options considered 10
- 7.3 Costs 11
- 7.4 Estimate Assumptions 14

8 Conclusions and Recommendations 15

9 References 16

Appendix A - Tunnel No 1 Condition Observations (from December 2015 Opus Report) 1

Executive Summary

This report was prepared to answer questions posed by Councillors and Council staff following a presentation to Council in December 2015 on the options to refurbish Water Tunnel No 1 following a partial collapse in 2014.

This report supplements the Opus December 2015 report which was the basis for the presentation to Council.

This report should be read in conjunction with the December 2015 report.

Overland alternatives to fixing the tunnel include a gravity and pumped routes from the existing intake. The gravity route is not considered feasible due to the approximate doubling of length compared to the tunnel route which is already nearly flat and likely presence of significant landslide areas which would threaten the integrity of the route.

Overland pumping is feasible, but in our view the best option would require a new intake downstream of the existing intake, pumping water up a height of about 130m to the access road and then to the tunnel system via the access roads. This would incur both greater costs than the current Council pumping situation from the alternative source at Orowaiti River and likely challenges with very high head pressures in the pipe. These options do not address the risk from the landslide which Tunnel 2 passes through.

Assessment of required pipe sizes at current tunnel gradients indicate that DN 630 mm or DN 710 mm diameter pipes would be required, with the choice depending on Councils expectation for flow rates in the future.

Dialogue with Directional Drilling companies has provided good interest in a project to bypass one or more tunnels with a new water pipe. Prices from two contractors have indicated a rough guide of $5M to $9M depending on a pipe size and length of drill (1200 m vs 1500m). Companies have indicated a cheaper option to install a pipe through Tunnel No 1. However realistic prices for these options can only be obtained through a tender process and / or procuring one or more contractors to investigate and carry out a robust cost estimation process. One of the main risks with the in-tunnel piping options is the nature of the supports present in tunnel including those installed as part of any future repair works, as these will likely have to be at least partially removed to get the pipe through.

Communication with organisations with experience in tunnel repairs has involved discussion with Geotech Ltd (who provided a price for an enlarged and stabilised tunnel in 2014) and Key Mining Services. The latter have had significant experience in remedial works in underground mines on the West Coast. Subsequent to the November inspection a tunnel inspection was carried out on 1 March 2016 by experienced underground mining personnel Robin Hughes and Rem Markland (Opus). Their observations have confirmed the fall is only over a 4m long section, with 10m in need of urgent repair, as well as remedial works required elsewhere including spot treatments to deteriorated sections from the downstream portal.

Our updated preliminary estimate for the physical work for the repair option for tunnel No 1 is $650,000 plus GST, including significant amounts for safety management and repair of the downstream portal and fees for investigation, design and construction monitoring.

Apart from the option to bypass of all tunnels by directional drilling all other options require access for the work via the portal at downstream end Tunnel No 1. This portal is in very poor condition and for safety reasons requires works to remediate it prior to works commencing in Tunnel No 1.

Whole of life costs have been put together for the various options which take into account Capital costs, and ongoing maintenance and inspection costs. In addition risks related to safety (injury and death) vary with each option depending on the exposure to hazards during construction and operation. The costs related to these should be taken into account by Council when choosing preferred options, in addition to the considering capital and maintenance costs.

We note that only the drilled bypass of tunnels No's 1 and 2 (and 3) will address the risk to the Council of movement of the landslide which has previously affected tunnel 2. If not addressed this will continue to remain a significant risk for Council.

Our view is that a viable short term repair can be carried out on Tunnel 1 to give Council time to confirm the long term solution for the Westport water supply. Choosing this option will still require annual inspections and allowance for repairs in other areas in the tunnel.

1 Introduction

1.1 Purpose

This report provides supplementary information to the Opus December 2015 report, to assist Buller District Council (Council) to make a decision on the future of Water Tunnel No 1, which was subject to a partial collapse in 2014 (Photo 1).

This report should be read in conjunction with the Opus December 2015 report.

The findings of the December report on refurbishment options were presented to Councillors in a special workshop on 17 December 2015.

Councillors and Steve Griffin have requested further information to enable Councillors to make a decision on the future of the tunnel.

In addition further information is presented on the condition of tunnel No 1 that was not able to be presented in the December report.

Photo 1: Collapsed section of tunnel No 1

1.2 Scope

The following items are addressed by this report:

1. Comment on the feasibility of replacing tunnel No 1 with overland routes (gravity route along contour) and piped route over the high ridge
2. Confirmation of pipe sizes and costs, with allowance for growth, for options that replace the tunnel with a pipe (in tunnel or drilled beside existing tunnel)
3. Improved cost estimates for tunnel repair option (including reference to 1 March 2016 inspection)
4. Improved cost estimates for directionally drilled pipe in virgin ground.
5. Whole of life costs for the options (and others), including construction, operation, maintenance costs and consideration of risks for each option

1.3 Background

The Opus December 2015 report concluded that in terms of solutions for Council :

1. The preferred solution (from a risk perspective) was to bypass the current Tunnels 1 and 2 (and possibly 3) with a directionally drilled pipeline. This option has the highest Capital Cost but inferred to be the lowest long term operational cost and lowest long term risk overall.

2. The intermediate options, in terms of cost and risk, would require enlargement of the tunnel for rockbolt/shotcrete stabilisation or pipe jacking a nominal 1050mm pipe through the downstream 400m or the whole tunnel, or pushing or pulling a smaller sized pipe through the entire 1200m tunnel length.

3. The option to repair the collapse in the tunnel and adjacent highest risk sections without enlarging the tunnel, is technically feasible. However this option has significant feasibility challenges due to the small width of the tunnel and long distance to the outlet portal (to which collapse debris would need to be transported to). The long term performance of this option is questionable as failures can occur in other sections of the tunnel.

4. The do nothing is considered an unacceptable option. While the current situation is allowing water to pass through the tunnel this is not sustainable in the medium to long term. Further tunnel deterioration may result in the need for Council to act with urgency to either abandon the tunnel(s) or undertake extensive and possibly very expensive repairs. Health and Safety obligations necessitate that Council address the situation to manage risks for tunnel inspections and maintenance.

5. From a risk perspective the best option is to bypass all three existing tunnels and the landslide which tunnel 2 passes through.

2 Above Ground Options

2.1 Gravity Option (along contour)

The current water supply intake at Giles Creek, at the intake to Tunnel no 1, is located at RL 133m. The storage reservoir No 2 is located at RL of just over 130m. A gravity route from the current intake would be about 6km long (Figure 1) with a drop in elevation of just 3 m.

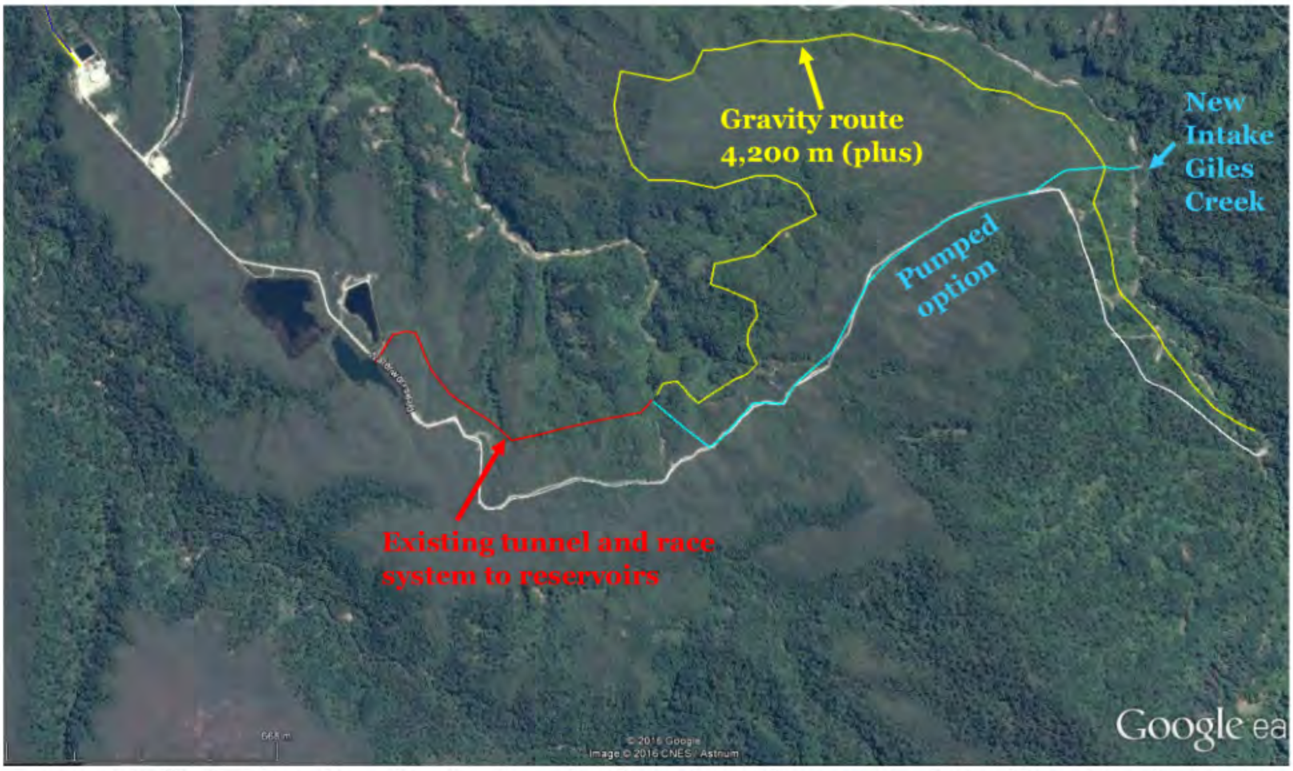


Figure 1: Indicative location of route of overland gravity and pumped options (from Google earth).

An overland gravity option, while theoretically possible, is impracticable and has many significant disadvantages, including:

- The route would need to follow along the 130 m contour. This would more than double the length of the tunnel route. Due to the near flat gradient a fairly large channel (or DN 710 SDR 26 PE pipe) would be needed to deliver a flow of approximately 150 litres per second.
- Preliminary assessment of aerial photos and contour plans suggest that the route is likely to traverse a number of large landslide features which would threaten the integrity of the supply pipe or channel.
- Constructing an open channel (or pipe bench) would create a massive scar on the steep terrain with hugely increased risks of erosion and landslips.
- Maintenance of this approximately 4.2 km channel or pipe bench would be a significant and on-going cost (although repairs would be easier to effect than a tunnel option).
- An open channel option would also require careful selection of low permeability materials for the lining to minimise seepage losses. It is likely that importation of clay materials will be necessary as lining with a PE membrane would be a huge cost.
- Some inverted siphons (or directional drilling) would also likely be required for this "overland" option.

2.2 Pumped option from Giles Creek

We have considered a possible pumped option in place of tunnels No 1 & 2. Such an option would by-pass both tunnels and connect to the existing system in the vicinity of tunnel 3.

The constraints on this option include:

- The head to be pumped to the top of the ridge. The static lift from the existing intake to the high point of the ridge would be approximately 80 metres. From a new intake, the pump head is estimated at just over 125 m and would likely represent a monthly power consumption of $22,000 i.e. over 30% more than that required from the existing pumped source.
- Supply and installation of approximately 1,800 metres of DN 500 or DN 560 SDR 13.6 to SDR 21 PE 100 pipe the full length, along with at least four air vents.
- The presence of likely landslide areas.
- The topography of the true left bank immediately downstream of the confluence of the North and South branches of Giles Creek is suggestive of a large landslide feature. Routing a water channel or pipe route through a large landslide (if proven) here from the existing intake should be avoided if at all possible.
- A better option could be to locate a new intake approximately 200 – 300 m downstream from the above confluence (at approximately RL 90m) and pump water directly up the steep ridge to the access road at approximately RL 220 m. From there the pipe would flow by gravity and follow the access road to the vicinity of Tunnel 3, crossing across the tunnel 2 landslide on the way and re-enter the tunnel system at approximately RL 130 m.
- The cost of establishing a power supply to the pump site.
- The cost of a new intake structure in Giles creek.

3 Required Pipe Size for pipe options

The longitudinal section of the Westport tunnels shows that the gradient varies somewhat along the length. Tunnels 1, 2 and 3 need to be considered together to arrive at the overall gradient.

The relevant data is shown in the Table 1 below:

Table 1: Tunnel length and gradient data Tunnels 1 to 3.

		Tunnel Distance (m)	RL (m)	Fall (m)
Start Tunnel 1		45	132.85	
End tunnel 1 start tunnel 2		1235	131.93	0.92
End tunnel 2		1444	131.87	0.98
Start Tunnel 3		1464	131.85	1
End Tunnel 3		1545	131.82	1.03

The gradients are shown below:

	m/m	1 in X (gradient)
GRADE Tunnel 1	0.000773	1293
GRADE Tunnel 1+ 2	0.00070	1428
GRADE Tunnel 1,2,3	0.000687	1456

The two options considered were DN 630 and DN 710 PN 12.5 PE pipe. The flow capacity using a "k" value of 1.5 mm for each option is shown below (represents a slimed pipe or with some sediment) (k is a pipe roughness coefficient).

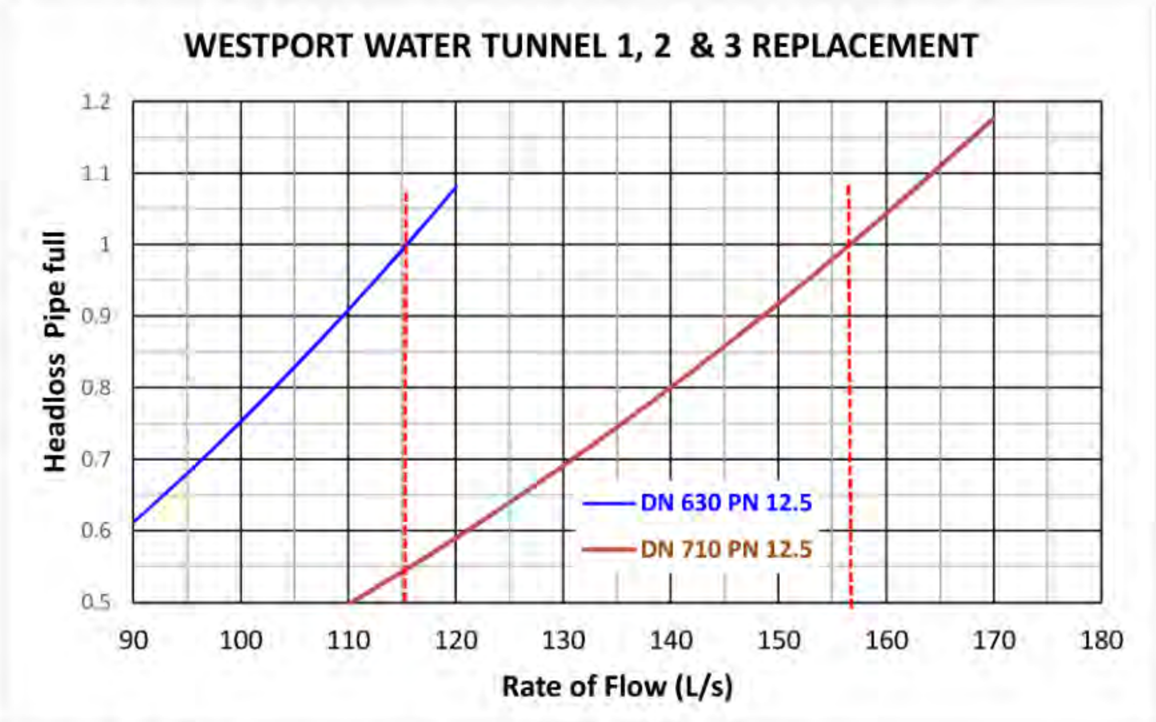


Figure 2: Pipe flow capacity for pipe in tunnels 1 to 3

The DN 630 pipeline would have a capacity of 115 L/s (litres per second) with approximately 0.15 m heading up at the entrance. The DN 710 option would have a capacity of 156 L/s.

The larger pipeline would have capacity to allow much more rapid recovery of the storage lakes after an extended drought or a drain-down situation. How important this is would need to be considered carefully and weighed against the cost difference between the DN 630 and DN 710 options.

A DN 800 PN 12.5 pipeline would have approximately 214L/s capacity.

4 Underground Pipeline Options

Options considered as an alternative to repairing the existing Tunnel No 1 included installing a pipeline through Tunnel No 1 (Option 4a from Opus December 2015), installing a pipeline off set and parallel to Tunnel No 1 (Option 4b), and installing a straight pipeline that would bypass Tunnels No 1, 2, and 3 (Option 4c) that would shorten the distance between the intake and the pipeline in Tunnel No 4. These options have been considered as they require no man entry underground and the pipes provide conduits (PE pipelines) that may be expected to last maintenance free for 100 years.

An initial Registration of Interest was issued to 5 contractors who had been assessed as having appropriate resources to install pipelines for the three options above by “trenchless” methods. All five were issued with a basic pack of information about the existing tunnels, the collapse issues, and some geotechnical records and asked to confirm their interest and to confirm what information they would require in order to provide rough order estimates for the options (including estimates for two different sizes of pipe). All five contractors confirmed their interest and each provided comments that ranged from ‘brief’ to ‘fairly detailed’. Conversations were held with each to probe deeper into their responses. All the contractors expressed the opinion that in order to provide rough order estimates (that would be suitable for us and would be appropriate for the purpose of comparing the underground pipeline options with other options such as tunnel repairs etc.) they would need to undertake investigations to capture data for detailed assessment by their specialist drillers and mud men etc. As a consequence of the outcomes of the written and verbal submissions three contractors were shortlisted as being the most appropriate with which to pursue the quest to obtain rough order cost estimates.

The three selected contractors, CDS New Zealand LTD (CDS), March Construction Ltd (March), and Hadlee & Brunton Ltd (Hadlee & Brunton) were provided with more information (including video recordings made by Opus while inspecting the tunnels) and were asked to provide rough order estimates for four potential drilling/microtunnelling options and for 4 different pipe sizes for each option. The responses re-emphasised that, in their opinion in the absence of data that can only be obtained by on-site inspection by the contractors’ specialists and exploratory investigations (e.g. sampling and chemical assessment of the ground through which the pipeline would be installed, etc.), it would be unwise to place reliance on “rough order estimates” in comparing the underground pipeline options with tunnel repair options.

CDS and March responded with estimates and covering notes. Hadlee & Brunton responded that they could not, at the time, provide any further information or estimates. The estimates received from CDS and March are summarised and tabulated for comparison purposes in Table 2 below. The results show comparisons for only two pipe sizes that have been assessed as the most appropriate (subject to specific design) to meet Westport’s future demand (subject to BDC confirmation).

Table 2: Comparison of Estimates Provided by Directional Drilling Contractors

Contractor	Pipeline Size (mm Dia.)	Option Estimate ($m)		
		(4a) 1200m long pipeline through Tunnel No 1	(4b) 1200m long bypass of Tunnel No 1	(4c) 1600m long bypass of Tunnels No 1, 2, and 3.
CDS	630	2.31	4.01	5.18
*CDS *1*	*600*	*1.98*	*4.06*	*5.00*
March	630	4.62	7.14	8.77
CDS	710	2.53	4.74	5.98
March	710	4.80	7.33	9.02
*CDS *1*	*800*	*2.29*	*4.93*	*6.04*

**1 Estimates provided in December 2015*
NB: Estimates were for "600mm diameter pipes – unclear whether Contractor based estimate on 560 or 630mm pipe and the bypass of Tunnels 1, 2, and 3 was based on a 1550m long bypass.

Notes :

1. March advise that P&G costs (mobilisation to and from site of all plant and personnel and establishment of site facilities, and contingencies constitute 20-25% of their estimates) while CDS equivalent costs including, overheads, constitute approximately 32% of their estimates.
2. None of the options include estimates of cost for the works necessary to connect the pipe to the existing water races at each end or, in the case of Option 4c, the connection to the existing pipeline in Tunnel 4.
3. The contractors have noted that their estimates are, and have to be somewhat conservative, (no estimate of % of the total was provided) in order to cover the uncertainties/unknowns that could be reduced/eliminated after undertaking a programme of investigations and testing of the ground conditions/properties prior to providing more accurate estimates.

The figures in the above table show a wide disparity between the two contractor's estimates; the differences between the contractor estimates range from 50 to 80% for the bypass drilling options and 90 to 100% for drilling through the existing tunnel.

In order to obtain more "reliable" estimates it would be necessary to undertake specific investigations and analysis of those investigations. Directionally drilled/microtunnelling "shots" over 1km in length and to very restricted limits on grade require specialist input (personnel and equipment) generally sourced offshore. It has been estimated that the cost of undertaking the investigations and assessment to obtain a reliable estimate of the cost of each of the three options would be between $20,000 and $30,000.

A pipeline installed through or bypassing Tunnel No 1 (options (4a) and (4b)) would require the installation of a transition from the pipe to the downstream tunnel (Tunnel No 2). This installation would require some manual work to be undertaken underground.

A pipeline installed to bypass Tunnels No 1, 2, and 3 (option (4c)) would require a connection with the pipeline through Tunnel No 4. This connection should be achieved at a surface location at the upstream portal to Tunnel No 4.

5 Tunnel No 1 Condition Assessment

The stability of the tunnel based on the November inspection is discussed in the Opus December 2015 report. A summary of the tunnel condition presented in that report is repeated in Appendix A.

5.1 Tunnel condition rating

Assessment of videos taken in the November inspection allow characterisation of tunnel condition based on the observed changes in profile, locations of wall or roof 'drop-outs' and location of debris on the floor. The tunnel distances are approximate only as these are based on identification of the 100m survey tags in the videos. In some cases a 100m tag was missed on the video. Due to the fact that complete passage from one end of the tunnel to the other is not possible – the tunnel sections were viewed going in both directions.

Characterisation of the tunnel condition has been made into one of 5 categories, as indicated in table 3.

Table 3: Proposed Tunnel condition rating system to facilitate risk management

Rating	Tunnel condition	Example Mitigation Strategy
1	pristine / original condition	Accept
2	Minor current instability noted, or evidence of past instability (perhaps during construction) which has enlarged the profile	Accept
3	Moderate instability of walls or roof which could result in a small to moderate failure and which possibly could develop into a larger failure if not addressed.	Watching brief. Implement measures to halt deterioration in worst areas
4	Significant instability of walls or roof which suggests that failure could occur at any time	Restrict entry. Priority to remediate attention
5	Collapsed.	Urgent attention

While the extremes provide clearly acceptable and unacceptable condition respectively, the intermediate values may be acceptable or unacceptable depending on the conditions of tunnel useage/entry. Using this system a qualitative 'feel' for condition can form a basis for determining an acceptable condition for given scenarios.

The modes of failure (as outlined in the December 2015 report) will determine the appropriate mitigation / ground support method to implement.

5.2 Observations of Partial Collapse at 870m

The collapse section at about 870m was better defined by the 1 March 2016 inspection, as being 3.6m long within a 10m long section requiring removal of timbers, collapse debris and reinstalling support (Photographs 2 and 3). A sketch of this section is presented in Figure 3.

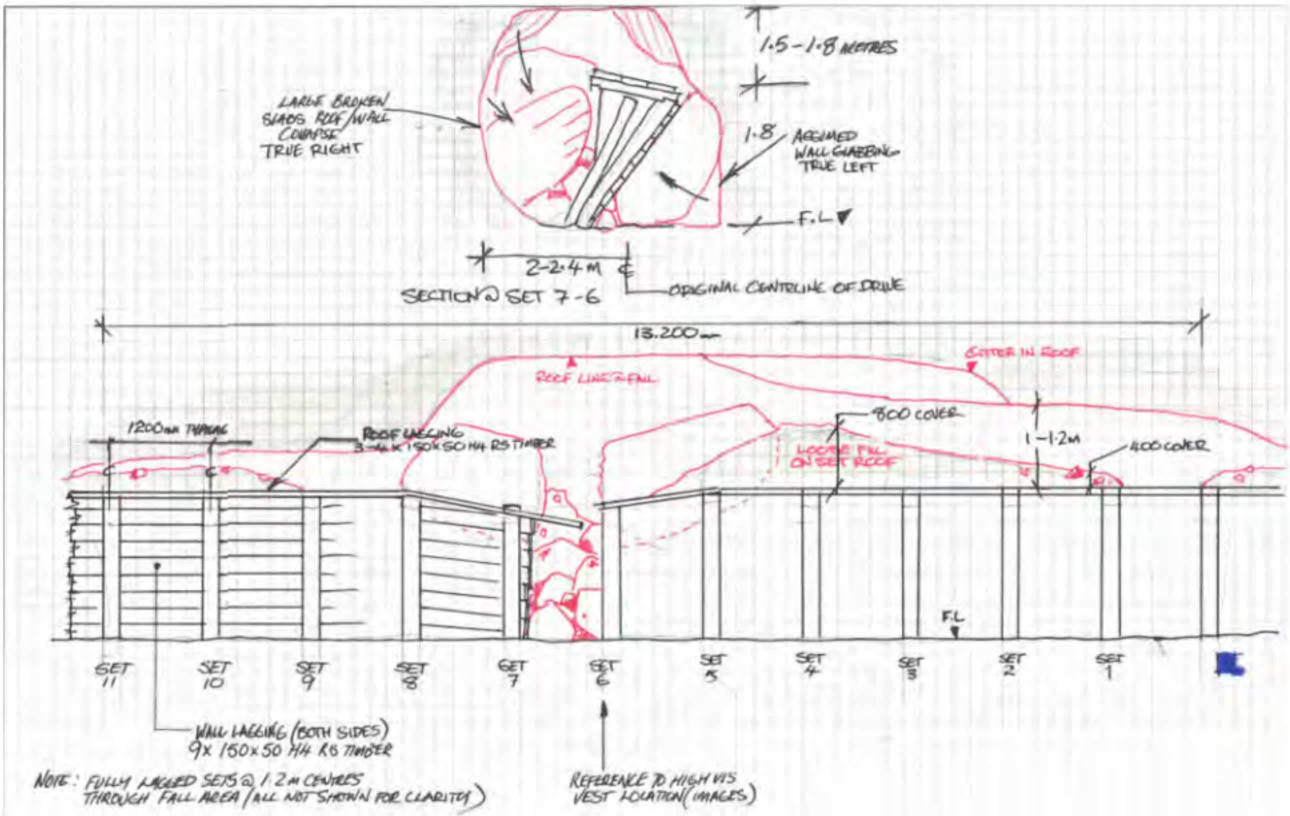


Figure 3: Long section sketch along the fall section of Tunnel 1, showing timber sets and cavity above roof of timbers.

Photograph 2: Collapse section at 870m view looking downstream. Hi-vis item positioned in hole was visible from both directions indicating the tunnel was not fully closed.

Photograph 3: Void above tunnel roof timbers (visible at base) looking towards collapse area at approximately 870m.

6 Tunnel No 1 Repair Option Costs

6.1 Sources of information

Discussions with Geotech Ltd and Key Mining Services of Greymouth have provided additional information to inform tunnel repair costs (Option 2a in Opus December 2015 report). Geotech Ltd have extensive experience in the tunnels, particularly tunnel 4. Key Mining Services (KMS) provide underground construction services to mines on the West Coast. Their staff have extensive experience in similar problems, including the Pike River Mine re-entry. Robin Hughes (on behalf of KMS) inspected the tunnel with Rem Markland of Opus Consultants on 1 March 2016. Rem also has extensive underground mining experience on the West Coast.

6.2 Scope

The preliminary repair scope, as discussed with KMS and Rem Markland, would address the poorer condition sections of the tunnel and tunnel supports as discussed in section 5. This would involve:

1. Preparation of a stringent safety management plan; involving risk assessment, preparation of work procedures and site specific safety plan, training and coordination with Mines Rescue Services.

2. Repair of the downstream portal to ensure safe access to Tunnel no 1, by earthworks to relieve the stress on the portal and/or installation of stronger supports (steel sets / concrete)

3. Installation of props/sets (timber or steel) to support marginally stable sections of wall or roof

4. Installation of waterproof shoring and or fluming locally to halt erosion and support undermined sections of the tunnel wall

5. Retrofitting existing timbering where in poor condition, eg. to provide additional bracing or remove timbering and install new sets.

6. Remove collapsed timbers and debris in the 10m long partial collapse area and provide new sets and fill voids.

6.3 Cost Estimate for repair

Subsequent to the December report rough order cost estimate and the 1 March 2016 inspection, a cost estimate breakdown for the repair tasks outlined in 6.2 above has been prepared by Rem Markland, based on typical rates for underground mining staff on the West Coast. This updated preliminary estimate for the physical work for the repair option is $650,000 plus GST. This includes safety management, repair of the downstream portal, various tunnel repairs over a 100m length, as well as investigation, design and construction monitoring fees.

7 Whole of Life Costs for Options

7.1 Process used

Each of the different options and associated costs were assessed using the 'Hong Kong Method' (HKM) (Mak & Picken, 2000). With this technique the following methodology has been used:

- The 'Base Estimate' amount, estimate of known scope, was estimated based on information from contractor preliminary quotes for the options, and in the case of the repair option Opus preliminary estimates.
- The 'Average Risk' and 'Maximum Risk' allowances were estimated as percentages of the 'Base Estimate' based on the knowledge of the uncertainties associated with different elements of the work.

Taking into consideration the project uncertainties and risks, the average risk estimate has been taken as the "mean" estimate, and the "maximum likely estimate" as the "95 percentile confidence" estimate.

7.2 Estimates for Options considered

Nine options have been considered, as discussed in the December 2015 report. The overland options have not been included for reasons discussed in section 2.

The 2014 cost estimates from contactors were lump sums without detailed breakdowns. Using these numbers as a guide we have used engineering judgement to break down the elements of the work and assess the uncertainty and worst case costs associated with each element of the work.

The estimates are preliminary only and subject to change based on many factors including better knowledge of site and market conditions; and are provided to assist Council in understanding the relative costs for each option.

7.3 Costs

The cost of each option has been considered in two parts:

- capital cost – including costs related to - investigation and design to produce tender documents, contractors costs to complete the works, construction observation (MSQA) services, pumping of water from the alternative source (at $16,000 per month) during construction
- ongoing costs – covering requirements for inspections and provision for maintenance repairs; the life time cost is based on a 30 year analysis period and 6% discount factor in order to represent a present value (PV)

The mean or expected preliminary estimates for each option, are summarised in Table 4.

The anticipated approximate design life of each option is indicated. Implementation of significant refurbishment or an alternative solution will be expected to be required prior to this period.

The expected range of whole of life costs for each option are presented in Table 5 and the associated graph.

Not included in the estimates are:

- costs associated with future significant collapses during the life of the tunnel (including investigation, tunnel repair and loss of service/pumping costs), and
- costs related to the different probability of injury and loss of life during construction and operation for different options. For economic analysis (eg. related to funding applications to justify road safety improvements), a serious injury is costed at approximately $250,000 and death at $5Million.

The higher safety risk options (as noted in the December report) have a greater likelihood of such a negative event occurring with the associated potential additional costs to Council and / or the community.

Table 4: Summary of Preliminary Estimates of Lifetime costs for options

Option	Capital Cost - including fees and pumping cost (Expected)	Ongoing Maintenance Cost (PV) - once built (*Expected* Estimates)t		Total Lifetime Cost (Expected) (Rounded)	Design Life (approx.) (years)	Residual safety and collapse risk[1,2]
		Annual Cost	Total Accumulated (30 years)			
Option 1: Do Nothing	*3	$120,000	$1,674,300	$1,700,000	1	Very High (unacceptable)
Option 2a: Repair of worst sections of tunnel (without enlargement)	$630,000	$50,000	$697,500	$1,300,000	20	Moderate
Option 2b: Stabilisation of 400 m section of tunnel - with tunnel enlargement	$1,500,000	$30,000	$398,700	$2,000,000	40	Low to moderate
Option 2c: Stabilisation of full length of tunnel (1200 m) - with tunnel enlargement	$3,300,000	$5,000	$66,450	$3,400,000	60	Low
Option 3a: Installation of 1050 mm dia. pipe through Existing Tunnel (450 m).	$1,500,000	$30,000	$398,700	$1,900,000	40	Low to moderate
Option 3b: Installation of 1050mm dia. pipe through Existing Tunnel (1200 m)	$3,650,000	$2,500	$33,225	$3,700,000	100	Low
Option 4a: Installation of Pipe, Directional Drilling, through tunnel (1200m)	$3,600,000	$30,000	$398,700	$4,000,000	70	Low
Option 4b: Installation of pipe, directional drilling, through virgin ground (1200 m)	$5,450,000	$2,500	$33,225	$5,500,000	100	Low to very low
Option 4c: Installation of pipe, directional drilling, through virgin ground (1600 m)	$6,700,000	$1,000	$13,290	$6,700,000	100	Very Low

Note:

1. The residual risk excludes safety risks during construction
2. The piped options in particular also have risks of silting up and ground movement which need to be managed
3. For Option 1 in effect a safe repair of the collapse will be required (ie Do Minimum) to enable entry hence cost will be higher than indicated

	Description	Base Estimate ($)	Expected Estimate ($)	"Maximum Likely Estimate" (95% ile) ($)
1	Do Nothing	1,000,000	930,000	2,400,000
2a	Manual Repair without tunnel enlargement	810,000	1,300,000	1,800,000
2b	Stabilisation of tunnel (450 m) - with tunnel enlargement	1,100,000	2,000,000	2,700,000
2c	Stabilisation of tunnel (1200 m) - with tunnel enlargement	1,800,000	3,400,000	5,000,000
3a	Installation of Pipe through Existing Tunnel (450 m) - 1050 mm dia.	1,200,000	1,900,000	4,700,000
3b	Installation of Pipe through Existing Tunnel (1200 m)	2,200,000	3,700,000	6,000,000
4a	Installation of Pipe, Directional Drilling, through tunnel	1,800,000	4,000,000	5,800,000
4b	Installation of pipe, directional drilling, through virgin ground (1200 m)	2,900,000	5,500,000	8,100,000
4c	Installation of pipe, directional drilling, through virgin ground (1600 m)	3,900,000	6,700,000	9,500,000

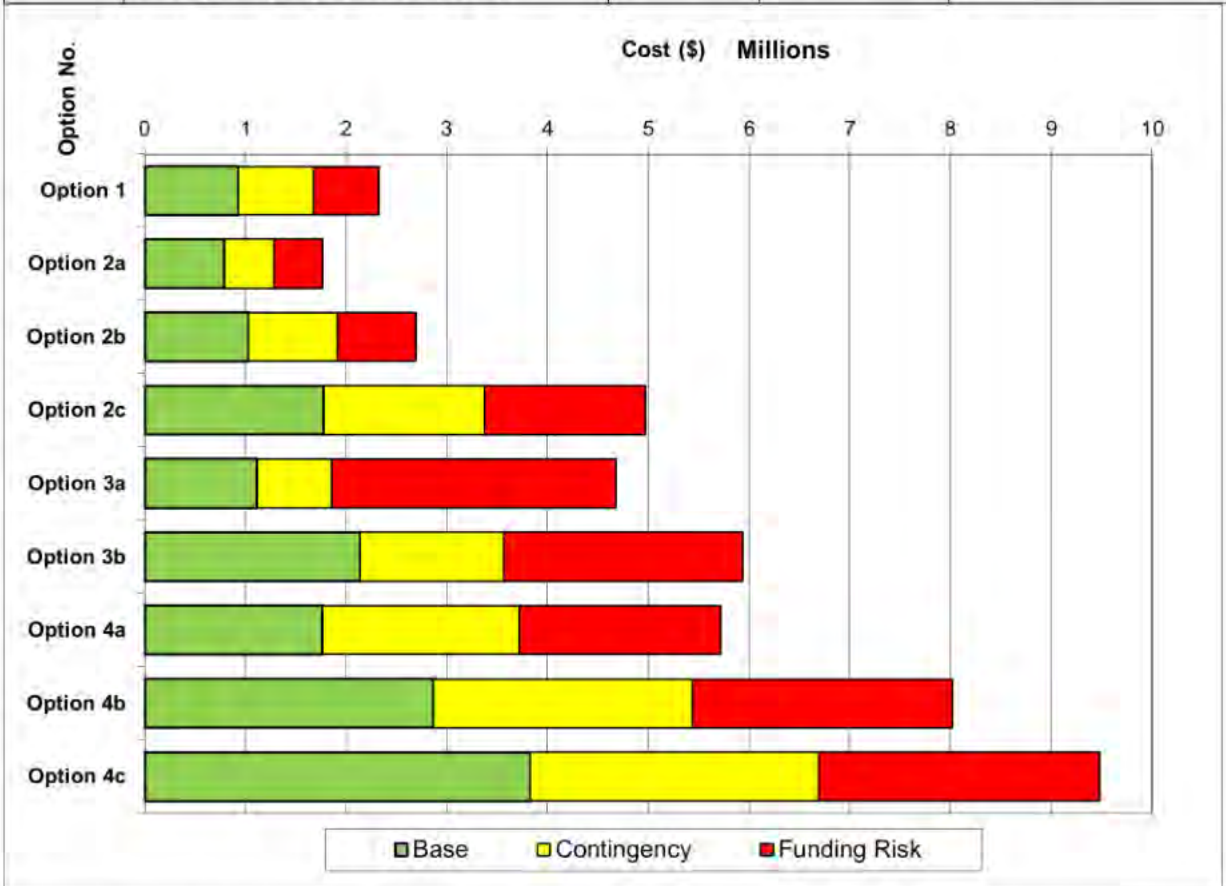


Table 5: Breakdown of whole of life preliminary cost estimates (including annual costs) for Tunnel No 1 refurbishment options, showing 'expected' cost (base plus contingency) and '95% ile' cost (expected plus funding risk)

7.4 Estimate Assumptions

Assumption for physical works base estimate:

- Cost estimates are based on the construction rates for tunnel works from 5 contractors (year rates were from 2014 and 2016)
- Cost estimates assume that pumping from the alternative Council water source will be required during construction of all options except Option 4c.

The estimate includes:

- Fees for engineering design, documentation, and construction supervision
- Ongoing maintenance and inspection costs over 30 years (using a discount factor of 6% to convert to expenses to a singular present value)
- Nominal amounts for Building and Resource Consent

The estimate excludes:

- GST
- Tendering costs
- Consequence of option being unfeasible

8 Conclusions and Recommendations

This report, which should be read in conjunction with the December 2015 Opus report, provides supplementary information on items requested by Council, relating to options to address the collapse in tunnel No 1; including overland options, pipe sizing, long term costings, and more detailed cost estimates for the tunnel repair option and directional drilling bypass options.

The findings of this report do not change the conclusions of the December 2015 report.

Overland piped or pumped alternatives to fixing the tunnel No 1 have been considered. The gravity piped or flumed option is not economically feasible and a pumped option from Giles Creek will incur greater costs than Council's current alternative pumping site.

Assessment of required pipe sizes at current tunnel gradients indicate that DN 630 mm or DN 710 mm diameter pipes would be required, with the choice depending on Councils expectation for flow rates in the future.

An additional inspection of the tunnel on 1st March 2016 by experienced underground mining personnel has identified that the partial collapse is limited in extent and confirmed that a repair option is viable, subject to careful management of safety.

Our updated preliminary estimate for the physical work for the Tunnel 1 repair option is $650,000 plus GST, including significant amounts for safety management and repair of the downstream portal and fees for investigation, design and construction monitoring.

Apart from the option to bypass of all tunnels by directional drilling all other options require access for the work via the portal at downstream end of tunnel No 1. This portal is in very poor condition and for safety reasons requires works to remediate it prior to works commencing in tunnel No 1.

Whole of life preliminary costs have been put together for the various options which take into account Capital costs, and ongoing maintenance and inspection costs. In addition risks related to safety (injury and death) vary with each option depending on the exposure to hazards during construction and operation. The costs related to these should be taken into account by Council when choosing preferred options, in addition to consideration of capital and maintenance costs.

We note that only the drilled bypass of tunnels No's 1 and 2 (and 3) will address the risk to the Council of movement of the landslide which has previously affected tunnel 2. If not addressed this will continue to remain a significant risk for Council.

Our view is that a viable short term repair can be carried out on Tunnel 1 to give Council time to confirm the long term solution for the Westport water supply. Choosing this option will still require annual inspections and allowance for repairs in other areas in the tunnel.

Our recommendations to address Tunnel No 1 are as follows:

1. Proceed with design and procurement of repair of the collapse and other deteriorated sections of tunnel No 1 including the downstream portal, to secure the tunnel for the short term (10 to 20 years).

2. Allow for annual tunnel inspections (by a tunnel expert) and maintenance to repair identified sites of deterioration

3. Carry out investigations and survey to assist the selection of long term solutions including: assessing knowledge gained on the tunnel No 1 repair works, assessing the stability of the 'tunnel 2' landslide, and assessing the site suitability of potential directional drilling launch sites.
4. Investigate funding streams to fund the construction of the currently preferred directional drilling bypass of the tunnels
5. Within the next 5 to 10 years investigate and confirm the long term solution, and procure design and documents for construction
6. Construct the chosen long term solution prior to reaching the design life of the short term repair solution.

9 References

Connell Wagner (2004). Geotechnical Investigations of Westport Water Tunnels Refurbishment, January 2004

Opus (December 2015). Westport Water Supply Tunnel 1, Refurbishment Options. GER Report 2015/62.

Opus (February 2015). Westport Water Supply Tunnel 1, Partial Collapse Repair, Preliminary Design Report, February 2015.

Appendix A - Tunnel No 1 Condition Observations (from December 2015 Opus Report)

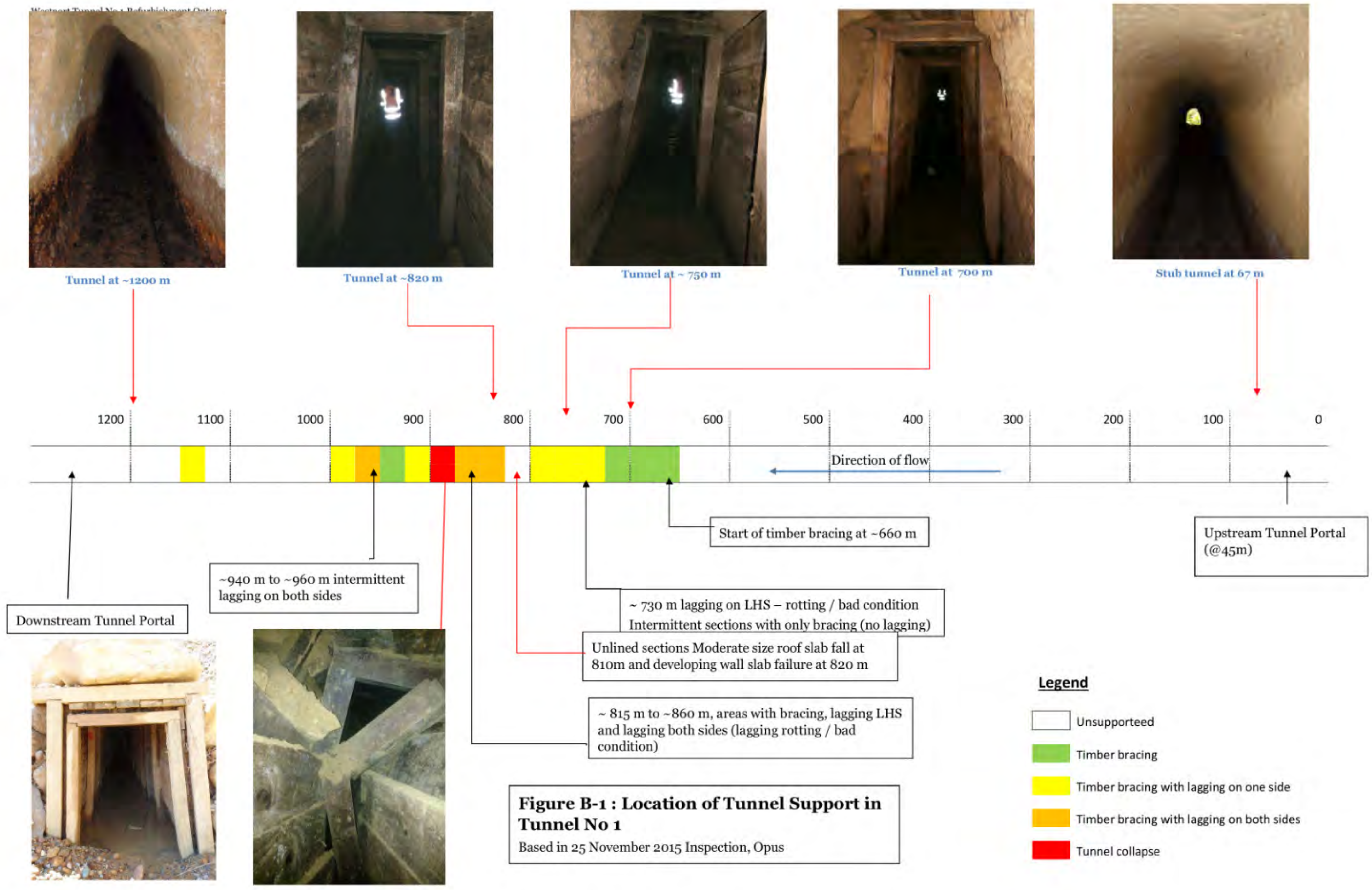


Figure B-1 : Location of Tunnel Support in Tunnel No 1

Based in 25 November 2015 Inspection, Opus

24 Appendix A7 – Options Workshop Report

Westport Number 1 Tunnel

Options Workshop Report

Prepared by Wayne Stewart, 16 May 2017.

Reviewed and approved for release by Christopher Bergin, 17 May 2017.

1 Introduction

An Options Assessment Workshop was held on Tuesday 16 May 2017 from 10.30am to 2.30pm. The purpose of the workshop was to help the Buller District Council select the preferred option for further detailed study to resolve the collapse of the Westport No.1 Water Tunnel. The tunnel is owned and operated by the Buller District Council. The workshop was held at the Westport Library meeting room.

The purpose of the workshop was to review the options table published in the Opus Westport Tunnel No 1 Supplementary Report Mar 2016 (Issue 1). Table 4 of that report had identified six options, half using pipe-jacking and the other half using directional drilling. The range of options offer different levels of design life, resilience, construction risk and cost. While the Opus Supplementary Report had also identified a series of other options including undertaking tunnel repairs, the Buller District Council had resolved prior to the workshop to no longer consider these options.

A list of participants is provided in Attachment 2.

2 Outcomes

The participants agreed that the project seeks to achieve the following outcome: -

An affordable, adequate and reliable water supply for Westport.

3 Objectives

The participants agreed that these outcomes can be realised if the following objectives are achieved: -

- The gravity supply connection is reinstated
- The cost of delay in reinstating the gravity supply connection are minimised
- The risk of running out of water by not having the connection are minimised
- Any safety risks (of construction methodology) are minimised
- The chosen option has acceptably high reliability (from design life and resilience perspectives)
- There is redundancy to accommodate an extreme (Black Swan) event
- The option is affordable in the context of other parameters
- The quality and quantity of water meets ratepayers expectations

4 What we know

The participants already had a good level of knowledge about the tunnels, the problems and the project options. Because of this it was agreed that we would not make a detailed list of everything that the team knew. Nevertheless, the following matters (noting is it not a complete or exhaustive list) were discussed. -

- No water from #1 and # 2 tunnel due to several collapses
- Costing $20k/month for pumping
- Current pumped supply system unable to meet demand (at critical times) with decline in stored water volume
-

5 Evaluation Criteria

Reflecting on the agreed project objectives, the participants developed the following list of evaluation criteria.

- **Speed** to open the tunnel thereby reducing pumping costs and the risk that the community will run out of water.
- **Residual Safety: -** safety to those building the various options and operating the water supply system. It was acknowledged that only options that can be built and operated with an acceptable level of safety should be considered. In some cases, an option may take longer and cost more in order to create a safe working environment.
- **Reliability:** - An assessment of how long an option might resolve the water supply problem before additional investment is needed in future years.
- **Whole of Life Cost**: Consider both construction and operational (ongoing maintenance) costs.
- **Constructability: -** The risk that after investing in an option, it fails to achieving outcomes being sought either in full or in part. It must be acknowledged that while directional drilling and pipe-jacking are regularly used on projects, they do not come without risk of failure. The participants shared a concern that the resistance created by jacking a very long pipe may exceed the force provided by the pipe-jacking equipment and the jacking may need to be abandoned before it achieves the full length needed. There were also concerns about the risk that the directional drilling process would result in the pipe being built with a vertical sag curve that would reduce the volume of water that would ultimately pass through the pipe under gravity flow or (worse) that a "hump" in the very flat gradient of the pipeline (approximately 1 in 1450) did not allow any flow.
- **Maintenance:** the ability for a person to enter the pipeline to undertake inspections and maintenance.

The participants agreed that while safety was an important criteria, any residual safety concerns could be mitigated by taking more time during construction or increasing construction costs. In terms of maintenance, the participants agreed that there was uncertainty as to whether a person would need to access the pipe in the future for maintenance. Future inspections could be undertaken using measures that did not require a person to enter the pipe/tunnel such as remotely controlled vehicles, water jetting to clear sedimentation, etc.

As a result the participants agreed to reduce the evaluation criteria to those that were most important to the decision making process. This gave the following four criteria: -

- Speed
- Reliability
- Whole of Life Cost
- Constructability

6 Option Evaluation

The full option evaluation decision matrix is provided in Attachment 2. Table 1 is the simplified matrix using the reduced evaluation criteria and after removal of Option 4A. Option 4A was considered by the group to have such a high risk of failure (not achieving the objectives) that it should be discarded.

Table 1: - Simplified Decision Matrix

	Option 3A	Option 3B	Option 3C	Option 4B	Option 4C
Speed (months to complete)	3 to 6	6 to 18	6 to 9	6 to 9	7 to 10
Reliability years of life)	40 to 70	70 to 100	70 to 100	70 to 100	100 to 140
Whole of Life Cost	$1.9 to $2.5	$3.7 to $4.0	$2.5 to $3.0	$5 to $6	$6 to $7

Constructability	Low/Med- V Good	Med – V Good	Low/Med - Good	Med V Poor	Low/Med V Poor

The Table 1 simplified decision matrix shows that Option 3A is likely to have the tunnel open within half the time of other options, not only saving $240,000 p.a. (based on current costs of $20,000/month) in pumping costs, but reducing the risk of the temporally supply system being unable to meet demand and the community running out of water. Option 3A can also be delivered at under half the cost of other options. In terms of constructability, Option 3A provides a lower risk of not obtaining the outcomes that are being sought compared to other options.
However, as Option 3A only deals with the rock fall (blockage) about halfway along Tunnel 1, there remains a couple of risks to the water supply line.

- There is a median risk that a slip could still damage Tunnels 2 or 3 in future years. This is considered to be the highest residual risk associated with Option 3A.
- While Option 3A does not eliminate the possibility that a blockage could occur within the section of Tunnel 1 that will not be lined with a pipe, the participants agreed that the probability of this occurring over the next 100 years was acceptably low. By extending the pipe jacking to a point approximately 600 meters from the outlet portal of Tunnel 2 (enhanced option 3A), the remaining part of the tunnel is in almost "as constructed" condition, even after 110+ years.

7 Preferred Option

Based on the Table 1 simplified decision matrix, the workshop participants agreed that Option 3A was the preferred option, rated top in 3 of the 4 key evaluation criteria. Furthermore, it was agreed that Option 3A is in effect a first stage of Option 3B and Option 3C (or even Option 4C). In other words, constructing Option 3A today would not prevent other options being constructed in the future should the need arrive. Furthermore, except for the additional cost of reestablishment, undertaking the repair work in stages does not result in any of the repair cost of Option 3A being wasted. The participants agreed that the additional costs associated with reestablishment in future years was more than offset by the cost savings of spreading expenditure over time rather than spending it all today.

The participants noted that in the unlikely event that failures occur in the remaining length of tunnel 1 or the slip damages tunnel 2, then the Council still has available to it the choice of building Option 3B, Option 3C or Option 4C in future years.

8 Other Matters

Obtaining agreement to use old Holcim Cement Factory water supply system at Cape Foulwind could reduce the demand on the Westport supply by supplying Carters Beach. However, this option has a number of draw-backs which are likely to make it unfeasible.

9 What we need to know going forward

- Safety in confined spaces during construction and maintenance.
- Should 3b or 3c be done now or left to a later date?
- Confirm whether we should extend the project to avoid slip and include tunnel 2.
- Confirm pipe size.
- Determine what consents/designations and approvals are required.
- Do we need to grout voids.
- How far to extend pipe jacking – 450m or 600m? (enhanced 3a)
- Procurement.
- Risk ownership.
- Early contractor involvement.

Attachment One: - List of Participants

Name	Organisation
Mike Duff	BDC
Sam Murphy	BDC
Ian Forsyth	BDC
Tony Robertson	BDC
Chris Bergin	Opus
Wayne Stewart	Opus (facilitator)
David Stewart	Opus
John Black	Opus
Stephen Lowe	Westreef
Dylan Taylor	Westreef
Lucas Hately	Westreef

Attachment Two: - Decision Matrix

Decision Matrix

Evaluation Criteria	Measurement	Option 3A	Option 3B	Option 3C	Option 4A	Option 4B	Option 4C
		Pipe Jack – (450mto 600m)	**Pipe Jack total distance**	**Pipe Jack 450m to 600m and then use directional drilling**	**Directional Drilling within exiting tunnel**	**Directional Drilling Virgin**	**Directional Drilling Virgin Plus extend into Tunnel 2 to avoid potential slip.**
Speed	(Months)	3 to 6	6 to 18	6 to 9	Fatal	6 to 9	7 to 10
Residual Safety	(Safe/Unsafe)	Can be mitigated	Can be mitigated	Can be mitigated		Few	Few
Reliability	Life (Years)	40 to 70	70 to 100	70 to 100		70 to 100	100 to 140
Whole of Life Cost	($) million	$1.9 to $2.5	$3.7 to $4.0	$2.5 to $3.0		$5 to $6	$6 to $7
Constructability							
• **Risk of not achieving outcomes**	Low/Med/High	Low/Med [2,5]	Med[2,3,5]	Low/Med [2,5]	Almost Certain	Med[1,2,,4,5]	Low/Med[1,4,5,6]
• **Quality of outcomes**	V Poor /Poor /Good /V Good	V Good	V Good	Good		V Poor	V Poor
Maintenance	(Yes/No)	Partial Yes	Yes	Yes		No	No

Notes

1. Risk of Portal
2. Risk of making tunnel connection
3. Risks of being unable to push pipe full length
4. Welding Quality
5. Ability to be staged
6. Risk of being unable to pull pipe full length

25 Appendix B1 – Project Charter

ASSETS & INFRASTRUCTURE
PROJECT CHARTER

PROJECT:	Westport No.1 Water Tunnel		
PORTFOLIO:	Three Waters	**COORDINATOR:**	S.Murphy
FUNCTION:	Utilities & Services	**DATE:**	October 2017
PROJECT MANAGER:	TBC	**PREPARED BY:**	TBC
PROJECT SPONSOR:	M.Duff	**REVISION/VERSION:**	A/1
ASSET OWNER:	S.Murphy	**AUTHORITY:**	PCG
CIRCULATION:	PCG		

Assignment

[Insert Project Manager name] is authorised as Project Manager for the Westport No.1 Water Tunnel project. [Insert Project Manager name] is designated to ensure Stakeholder satisfaction and to guide the project to a successful conclusion as described by this charter. [Insert Project Manager name] will be responsible for internal communication and cooperation with responsible parties included in the circulation list.

Responsibility

The Project Manager will:

- Be the primary point of contact for Buller District Council and Stakeholders
- Ensure that team members know and understand their responsibilities
- Monitor team member performance
- Monitor overall project performance
- Prepare a detailed project management plan (PMP) and obtain approval from the Project Control Group (PCG) and Functional Managers.
- Maintain all project information in a secure and datacentric fashion
- Report project status to the PCG and Stakeholders

Authority

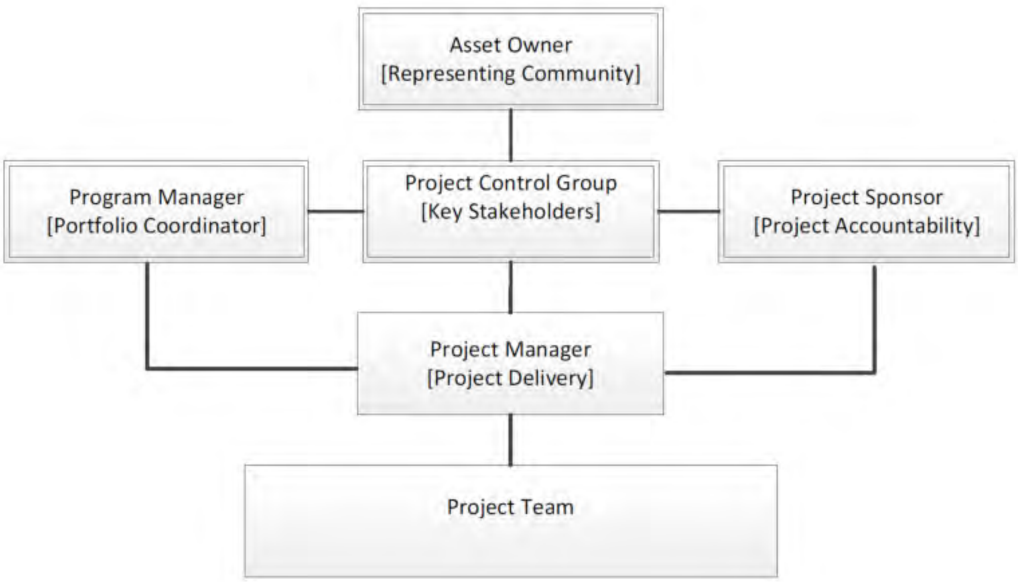
The Project Manager's authority includes:

- Authority to direct the project team
- Access to the PCG, Stakeholders and Functional Managers on all matters related to this project
- Leadership of zero-harm Health & Safety initiatives and practices
- Control of the authorised project budget
- Implementation of a robust change management process
- Delegation of responsibility and authority subject to approval by the PCG

Scope Statement

[Scope statement to be finalised by Project Manager at the commencement of implementation phase].

Project Governance Model



26 Appendix B2 – Project Management Plan (Example)

BULLER
DISTRICT COUNCIL

Project Management Plan

Project Title

Document Location

ECM Subject	
ECM Topic	
ECM Document Description	Template – Project Management Plan – Project Title

Document Revision

Document Date	Version	Prepared By	Approved By	Approval Date

TABLE OF CONTENTS

1. INTRODUCTION 3

2. PROJECT DESCRIPTION 3

2.1. Background & Need 3

2.2. Project Definition 3

2.3. Project Objectives 3

2.4. Project Scope 3

2.5. Related Project Initiatives 3

2.6. Project Constraints 3

2.7. IT Impact Assessment (Optional) 3

3. PROJECT SCOPE & INTEGRATION MANAGEMENT 4

3.1. Change Management 4

3.2. Issue/s Management 4

4. TIME MANAGEMENT - DELIVERABLES AND MILESTONES 4

5. PROJECT ESTIMATED COSTS 4

6. PROJECT QUALITY MANAGEMENT 4

7. HUMAN RESOURCE MANAGEMENT 5

8. STAKEHOLDERS 5

9. PROJECT COMMUNICATION & CONSULTATION 5

10. PROJECT RISK MANAGEMENT 6

11. PROJECT PROCUREMENT MANAGEMENT 6

12. PROJECT REPORTING 6

13. POST IMPLEMENTATION 6

14. PROJECT CLOSE OUT 6

15. TEMPLATES & ATTACHMENTS 7

1. INTRODUCTION

The Project Plan is the document that provides the 'road map' enabling the effective day-to-day (operational) management and control of the project. It is owned, maintained and utilised by the project team to support the delivery of the agreed project outputs. The document should be reviewed and amended to meet changed conditions during the project's life span.

2. PROJECT DESCRIPTION

2.1. Background & Need

Provide a brief summary of the pre-history that has led to the project. Include:

- *What is the problem this project is trying to resolve?*
- *Business Case document number.*

2.2. Project Definition

It is important that there is clarity about what the project is intended to achieve (i.e. one short, succinct sentence)

2.3. Project Objectives

What are the goals / objectives of this project? What will this achieve?

2.4. Project Scope

Briefly summarise the in and out of scope of the work involved with the project

2.5. Related Project Initiatives

Are there any other major projects, organisational initiatives etc. that will impact on this project, or be impacted by?
What is the nature of the relationship?
How can they best be managed and integrated as part of this recommendation?

Related Project / Initiative	Nature of Relationship	How can they best be managed?

2.6. Project Constraints

Time
Budget/ funding
Resources
Technology
Policies/Strategies

2.7. IT Impact Assessment (Optional)

It is vital that there is a comprehensive analysis of the IT requirements involved in undertaking a particular project. Liaise with the IT Project Office if the project requires any of the following:

- *Are you looking at new software, or modifying existing software?*
- *Will the project impact on network capacity?*
- *Do you need new hardware?*
- *Do you need to analyse IT Business requirements?*

3. PROJECT SCOPE & INTEGRATION MANAGEMENT

3.1. Change Management

Change control shall be used by the Project Manager to:

- *Facilitate the introduction of specific project change;*
- *Allow the impact of the change to be assessed;*
- *Provide a method of authorising change; and*
- *Provide an audit trail of change*

3.2. Issue/s Management

Describe the process that will be used to raise, record, review, and resolve issues.

Suggested statement is:

"All issues that arise are to be documented in the Project Issues Log and communicated in writing (eg. Status report) to the Project Manager. Communication will also include the impact on the project and the proposed management strategy for each of the issues. Adjustments to the Project Schedule to be negotiated by the Project Manager with all affected parties through the issues management process."

4. TIME MANAGEMENT - DELIVERABLES AND MILESTONES

Present a summary of the tasks, deliverables, and milestones for the project.

Task	Description	Deliverables / Milestones	Completion	Responsibility

5. PROJECT ESTIMATED COSTS

The estimated costs for the project would need to be taken into consideration the following:

Project item / Component	*Total Amount*	*Completed by (month)*

6. PROJECT QUALITY MANAGEMENT

Explain how you will approach and manage quality for the duration of the project. What tools will be used (eg work break down structure, cost benefit analysis, Gantt chart, risk registers, schedules, project budgets) and how

these will be controlled and monitored (project change control, checklists, quality plan, change control register, audits).Link to Quality Management Plan

7. HUMAN RESOURCE MANAGEMENT

When considering human resource implications on your project, please liaise with the relevant members of our human resource department (i.e. Learning and Development Manager, Change Manager, and/or your Human Resource Advisor)

Human Resource Implications and requirements you may wish to consider include:

- *Project team structure*
- *Roles and responsibilities*
- *Team member performance and evaluation*
- *Skills and expertise required*
- *Training*
- *Change Management*
- *Recruitment*
- *Occupational Health & Safety*
- *Redundancy/Redeployment*

Human resources are to be identified in the Project Charter.

8. STAKEHOLDERS

Guidance on identification of stakeholders:

- *Identify all key stakeholders in the project – remember that stakeholders may be individuals or groups of people.*

- *Categorise them into Primary Stakeholders (those involved in or directly impacted by the project that possess significant influence over the project outcome, Secondary Stakeholders (those who are directly impacted by the project but possess a lesser degree of influence over the project outcome) or Other Stakeholders (interested parties that are directly or in most cases indirectly impacted and have little influence over the project outcome).*

Stakeholder Classification	Internal Stakeholder	External Stakeholder
Primary		
Secondary		
Other		

9. PROJECT COMMUNICATION & CONSULTATION

When developing your communication strategy / plan, liaise with the Communication Team to ensure you have identified all communication, media, public relations, and community consultation requirements, objectives, key messages, costs, responsibilities, methods and frequency of communication.

Use the Communications Plan to detail the communication requirements and activities for your project.

10. PROJECT RISK MANAGEMENT

A risk assessment needs to be carried out as part of the project. Note that analysis should be undertaken with the critical stakeholders and be undertaken regularly throughout the life of the project. Risks may change or arise during the project. Include the project risks in the Status Report and report on changes or additions through the Status Report. Reference ERM documents completed to date.

11. PROJECT PROCUREMENT MANAGEMENT

Project procurement includes the contract management and change control process required to develop and administer contracts and purchase orders, for both internal and external supply. This should include a brief on requirements, delegated authorities, role of procurement in the project and proposed contract management. Reference to:

- *Procurement Policy*
- *Contracts Management Procedure*
- *Purchasing Procedure*

12. PROJECT REPORTING

Outline how you will report on the major project

- *For major projects, use project status report template on a monthly basis or as agreed to by other interested parties / stakeholders*
- *For medium projects, use Project Tracking/Master Program and update at least monthly*
- *For minor projects, use Project Tracking/Master Program*
- *Capital Works Coordination Committee*

13. POST IMPLEMENTATION

Provide details here regarding the overall strategy for transitioning the project from completion to operations and the handover process. Detail those elements below and who the owners will be post project completion

Action	Project Element/Deliverable	Owner at handover	Comments

Delivered internal resources or external contract delivery.

14. PROJECT CLOSE OUT

Project closure / evaluation involves gathering information in order to understand and make judgements about the project and its outcomes. The project closure is a tool designed to allow the organisation to learn from experiences good and bad. They facilitate continuous improvement.

Closure and evaluation criteria are to be expressed in terms of extent of achievement and performance. These can include:

- *To what extent have the intended objectives been achieved?*
- *How well have the needs of staff been met?*
- *Were there any unexpected outcomes achieved by this project?*
- *What changes to service delivery will continue as a result of this project?*
- *Were the resources allocated appropriately, sufficient and efficiently used? (i.e. time, people, money)*
- *Lessons Learned: what are the key lessons learned that could be applied to future projects?*

15. TEMPLATES & ATTACHMENTS

Project Business Case
Project Charter
Project Management Meeting Agenda
Project Management Meeting Minutes
Project Size Risk Matrix - All Projects
Corporate Risk Assessment Matrix
Project Management Plan (Short Form)
Project Management Plan
Project Risk Register
Project Schedule
Project Budget
Quality Management Plan
Human Resource Management Plan
Scope Management Plan
Procurement Plan
Project Status Report
Project Transition Plan
Change Request
Change Request Register
Correspondence Register
Contractor Site Meeting Agenda
Project Checklist
Communications Plan
Project Audit Checklist
Project Handover Report
Project Closure Report
Checklist for Archiving Documents
Lessons Learned Agenda

Signatures	***Date***
Asset Owner:	
Sponsor:	
Project Manager:	

27 Appendix B3 – Project Status Report Template

ASSETS & INFRASTRUCTURE

PROJECT STATUS REPORT

PROJECT:			
PORTFOLIO:		**COORDINATOR:**	
FUNCTION:		**DATE:**	
PROJECT MANAGER:		**PREPARED BY:**	
PROJECT SPONSOR:		**REVISION/VERSION:**	
ASSET OWNER:		**PERIOD ENDING:**	
CIRCULATION:			

Executive Summary

Project Lifecycle	

Report Card	Status	Comment/Action Required
Overall:		
Safety:		
Risk:		
Scope:		
Budget:		
Schedule:		
Resources:		
Quality:		

Key Code for Status		
☆	Blue	Excellent, ahead of target, objective or expectation
☑	Green	Good, on target, in place or performing well
⚠	Amber	Monitor, behind target, unsustainable or at risk
☒	Red	Poor, requires urgent action or intervention

Narrative

[Expand summary under following dot points]

- Overall Performance:
- Critical Issues:
- Critical Risks:

Current Status

[Summarised in dot points]

- Point 1
- Point 2
- Point 3

Achieved this Period

[Summarised in dot points]

- Point 1
- Point 2
- Point 3

Planned next Period

[Summarised in dot points]

- Point 1
- Point 2
- Point 3

Key Milestones/Deliverables

ID #	Description	Target Date	Actual Date

Schedule Recovery

ID #	Description	Explanation/Action

Budget

ID #	Description	Last Period	This Period
A	Baseline	$	$
B	Current Approved	$	$
C	Actuals + Accruals	$	$
D	Estimate to Complete	$	$
E	Forecast (C + D)	$	$
F	Variance (E – B)	$	$

Critical Issues & Risks

Critical Issues				
ID #	Date Raised	Description	Respons.	Action/Timing

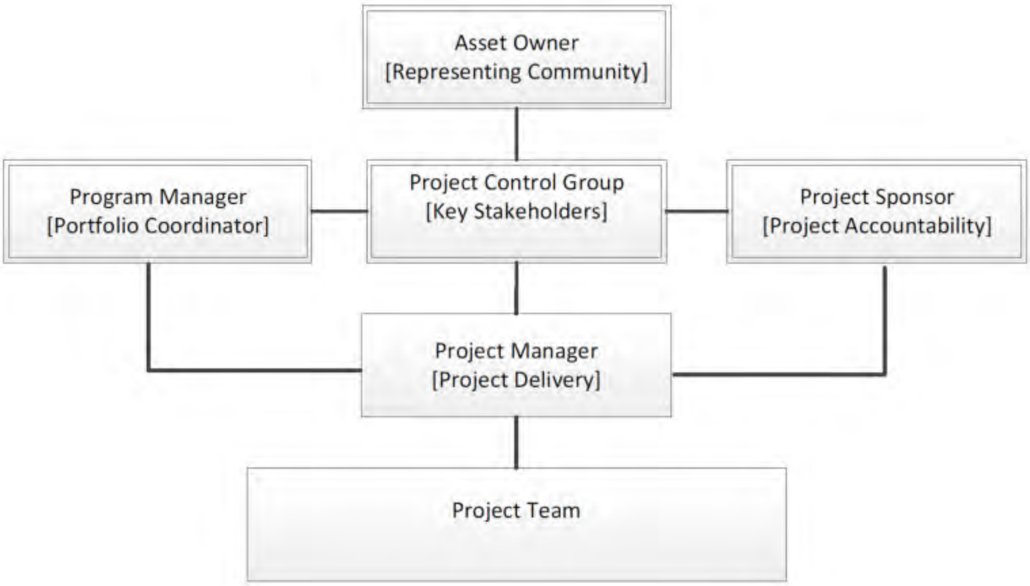
Critical Risks				
ID #	Date Raised	Description	Risk Rating	Controls

Change Management

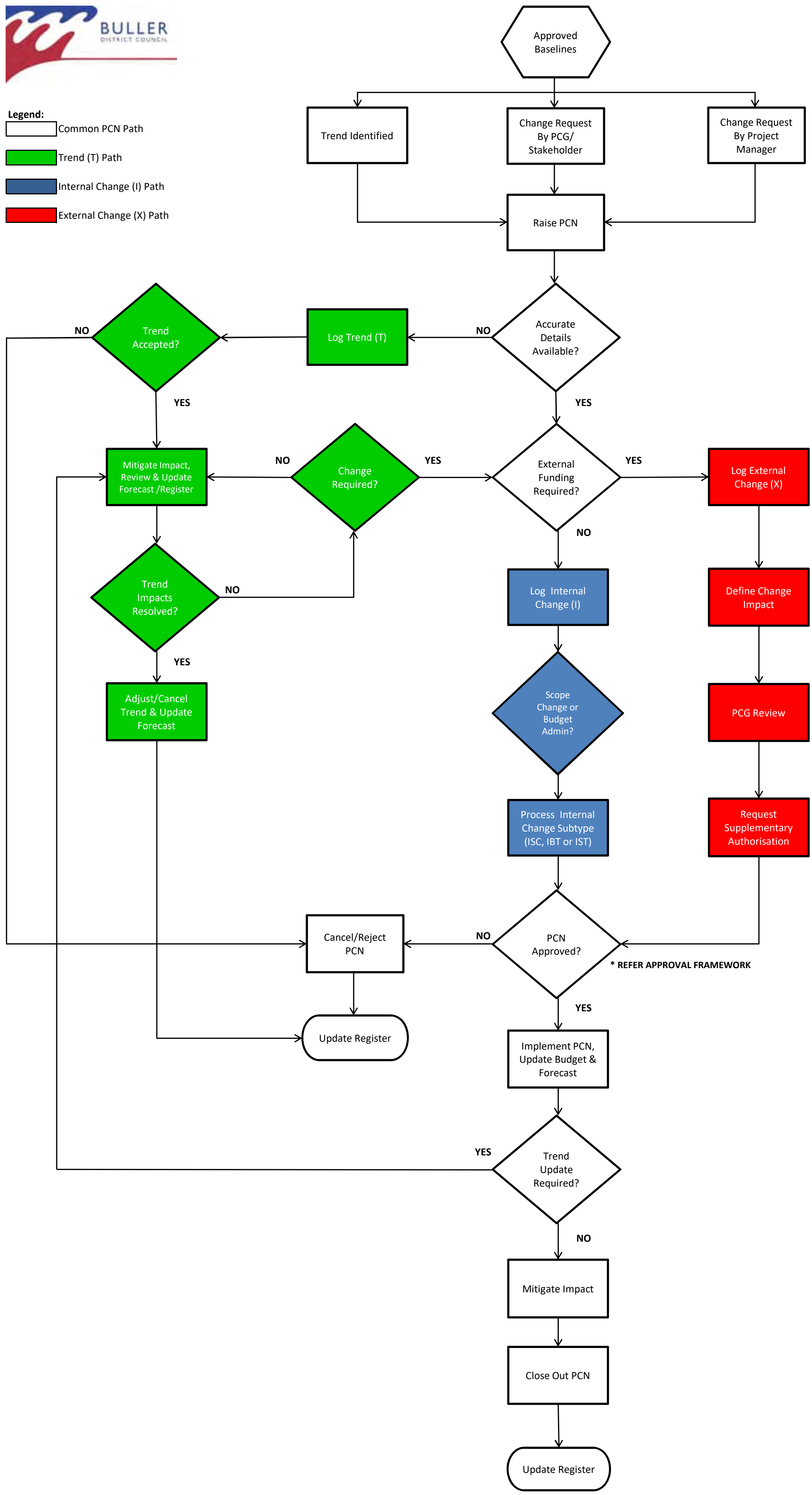
Trend/Change Notices				
ID #	Date Raised	Description	Status	Action/Timing

Contract Variations				
ID #	Date Raised	Description	Status	Action/Timing

Project Governance Model



28 Appendix B4 – Change Management Flowchart



BULLER DISTRICT COUNCIL
Legend:
Common PCN Path
Trend (T) Path
Internal Change (I) Path
External Change (X) Path
Approved Baselines
Trend Identified
Change Request By PCG/ Stakeholder
Change Request By Project Manager
Raise PCN
Accurate Details Available?
NO
Log Trend (T)
Trend Accepted?
NO
YES
YES
Mitigate Impact, Review & Update Forecast /Register
NO
Change Required?
YES
External Funding Required?
YES
Log External Change (X)
NO
Trend Impacts Resolved?
NO
YES
Log Internal Change (I)
Define Change Impact
Adjust/Cancel Trend & Update Forecast
Scope Change or Budget Admin?
PCG Review
Process Internal Change Subtype (ISC, IBT or IST)
Request Supplementary Authorisation
Cancel/Reject PCN
NO
PCN Approved?
* REFER APPROVAL FRAMEWORK
Update Register
YES
Implement PCN, Update Budget & Forecast
YES
Trend Update Required?
NO
Mitigate Impact
Close Out PCN
Update Register

Opus International Consultants Ltd
12 Moorhouse Avenue
PO Box 1482, Christchurch Mail Centre,
Christchurch 8140
New Zealand

t: +64 3 363 5400
f: +64 3 365 7858
w: www.opus.co.nz