



LCLR MINOR WORKS BUTLERS GREEN RETAINING WALL REMEDICATION

We design with community in mind

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C-19-047



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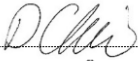


Revision schedule

| Rev No | Date | Description | Signature of Typed Name (documentation on file) | | | |
|--------|---------|-------------|---|------------|-------------|-------------|
| | | | Prepared by | Checked by | Reviewed by | Approved by |
| 1 | 24/3/22 | FINAL | EG | DC | LG | LG |

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Quality statement

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Executive Summary

An iconic historic stacked stone wall supports part of the Buckingham Street road formation around Butlers Green in Arrowtown. In two locations the face of the wall is bulging outward as a result of movement of the retained soil behind the wall. There is a risk of rapid failure of the wall, particularly following saturation of the soil or earthquake.

An option study was produced in 2018 to investigate the risks, high level mitigation options and associated costs of repair for the wall. This report serves as a revision to the option study (report reference: "Butlers Green Retaining Wall Options Study", 80508724.0533, 5 March 2018). It seeks to further develop the provided options for remediation and update cost estimations.

The number of options previously explored as part of the options study has been focused on 3 main viable structural solutions. These are summarised in the table below;

Table 1 - Options Vs Objectives Summary

| Primary Options | Key Objectives | | | | |
|---|------------------------|---------------------------------|---------------------------------|-----------------------------------|---|
| | Retain historic fabric | Improve pedestrian safety below | Improve pedestrian safety above | Improve security of road/services | Increase the life of historic structure |
| Option 1 – Carefully dismantle the existing stacked stone structure and replace with an engineered structure with recreated facing from original rock. | – | ✓ | ✓ | ✓ | ✓ |
| Option 2 - Provide external support to the front of the wall with cantilevered columns | – | ✓ | ✓ | ✓ | ✓ |
| Option 3 - Tie back rock/soil anchors with patress plates | – | ✓ | ✓ | ✓ | ✓ |
| Secondary/Supporting Options | Retain historic fabric | Improve pedestrian safety below | Improve pedestrian safety above | Improve security of road/services | Increase the life of historic structure |
| Fill in front of wall | ✗ | ✓ | ✓ | ✓ | ✗ |
| Proximity fencing/signage/planting around base of wall | ✓ | ✓ | ✗ | ✗ | ✗ |
| Do nothing | ✗ | ✗ | ✗ | ✗ | ✗ |

✓ - Addresses the objective

✗ - Does not address the objective

– - Undetermined whether this constitutes historic sympathy



In addition to the above presented options, there remains the possibility to combine two or more of the above solutions into a comprehensive rehabilitation plan for the wall. Especially if two options are required to ensure the desired key considerations are met. For example, combining tied back pattress plates to lower the risk of total collapse - with proximity fencing to lower the risk of rockfall impacting pedestrians.

Engineered Fill

We understand that it is not desirable to bury any portion of the historic wall as a means of stabilising it. Although the possibility to bury the wall has been dismissed by Council, it may serve as a practical fallback option to save cost on less significant segments of the wall – so to enable the more costly favorable options for the more significant parts of the wall.

Doing nothing

In our original options report, we provided a risk assessment of the residual risks of "doing nothing" to improve the stability of the wall. The following risks were identified if the wall were to partially collapse:

- Risk of injury or death to pedestrians above and below the wall
- Unplanned disruption to services, transport and business to repair the adjacent roads
- Complete loss of the historic nature of the wall during rebuild

One of the above risks has been partially addressed - pedestrians have been rerouted away from the wall down the newly completed stairs, and rockfall mesh has been installed on one of the more actively fretting portions of the wall. Further measures to mitigate injury or death from collapse could consist of signage or fencing around the base of the wall.

Cost Estimates

We have estimated the costs of each option below. A detailed engineers estimate schedule is provided in the Appendices.

1. Construct engineered retaining wall with recreated facing: \$953,000
2. Support wall facing with cantilevered columns: \$588,000
3. Support wall facing with pattress plates and soil/rock anchors \$519,000

Since the original estimates provided in 2018, construction costs and material prices have undergone massive inflation as a knock-on effect of COVID. As such, the prices provided for the options in this report are generally significantly more than previously estimated. We have also increased the contingency percentage from 25% to 30% to account for increased volatility of construction pricing.

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1. Introduction

Queenstown Lakes District Council (QLDC) have engaged Stantec to undertake a feasibility assessment of remedial options for Arrowtown's Butlers Green retaining wall. Several sections of the wall are showing signs of settlement and bulging which will inevitably lead to collapse.

A previous report prepared by Stantec in 2018 (Ref: "Butlers Green Retaining Wall Options Study", 80508724.0533, 5 March 2018) outlines the initial risk assessment, options study and high level cost estimates for potential remediation options. This report should be read in conjunction with our previous options study.

The purpose of this report is to further progress the potential remediation options to improve the safety and lifespan of the Butlers Green historic wall.

2. Short Summary of Condition, Background, and Risk

The Butlers Green wall has two bulging sections with a deflection of approximately 600 mm. This deflection has resulted in cracking of some stones and loss of stones in some areas. Aside from these two failures, much of the remainder of the wall is deformed or settling.

The wall has been subject to ongoing monitoring over the past 20 years. There has been cracking in Buckingham St some 10-12 years ago which was covered with asphalt, with no repairs to the wall. The eastern bulge and subsequent parapet crumbling appears to have occurred approximately 7 years ago.

These failures are likely to have occurred as a result of saturated soil behind the wall due to heavy rainfall events or services leaks. When the wall becomes saturated, soil shear strength is reduced and increases active pressure behind the facing. Sudden collapse of the wall is increasingly likely with subsequent saturation of soils and/or if subject to earthquake loading.



Figure 1 – Location Plan (wall marked in red, primary bulging areas marked in yellow)



Figure 2 – The Retaining Wall viewed from Butlers Green, bulging areas marked in yellow

The following risks are present in the case of sudden wall collapse:

- Injury or death to people below the wall if the failure is rapid
- Damage to water supply and waste water services in Buckingham Street
- Damage to the surrounding roads
- Resulting disruption to business, services and access
- Risk to road users immediately following any rapid collapse
- Loss of the historic wall and loss of the amenity of the area
- Emergency/unpredicted funding to repair any damage

3. Repair Options

Three options have been considered for repair of the wall. A concept of each option along with a detailed cost breakdown is provided in the appendices.

3.1 Option 1 – Remove and Replace Wall

Option one involves completely removing the wall facing stones and constructing an engineered retaining wall. The facing would then be reconstructed from the original materials using masonry ties to the engineered wall.

This option presents the lowest risk of future failures as the wall will be engineered and the facing tied back to mitigate any risk of falling stones or rapid total collapse. This is the only option that could practically obtain code compliance.

Although this is a technically sound option, there are risks that are due consideration:

- It is the highest construction impact option and would require HNZ approval.
- Significant disruption to the adjacent roads is expected
- Services within the adjacent road would need to be considered

3.2 Option 2 – Cantilevered bracing

This option involves cantilevered counterfort posts at the base of the wall with walers spanning horizontally between the counterforts.

We anticipate that this structure would consist of cantilevered UC posts cast into bored holes at the toe of the wall. Walers may consist of similar width channel sections. Self-drilling anchors into the wall may be an efficient way to further support the columns and provide stabilisation to the face.



This option is scalable and construction of this option would avoid interference with services behind the wall. The "windows" between wailers and columns could be retained with steel SE62 mesh.

Risks involved with this option include:

- Risk of increasing instability by drilling at the toe of the existing wall. Careful temporary works design can mitigate this risk
- Possibility to lack support of the community or Heritage New Zealand due to aesthetics

As with other options, this does not eliminate the risk that parts of the wall between the bracing may shed in an earthquake.

3.3 Option 3 – Tie Back with Self Drilling Anchors and Washers

This option involves the use of self-drilling anchors drilled through the wall facing and anchored behind the moving soil block. To capture the facing, pattress plates (steel washers) would be placed over the ends of the anchors. The pattress plates could have a rustic appearance to be sympathetic to the structure. We have assumed a generic "X" shape in our concept sketches, though a quick google search reveals extensive pattress plate options.

We anticipate that the anchors would be placed in several rows with higher concentrations at the least stable areas. There is likely to be a design trade-off between the pattress plate size and the spacing of the anchors. Detailed design is required to determine the optimal spacing for facing retention vs slope stability.



Figure 3 – Closely spaced self-drilling anchors with small plates

This option is considered structurally reliable and a practical solution. It is scalable and can be used as a whole or partial solution. The construction process is relatively simple and fast and can be carried out from the front of the wall with minor disruption to the road above.

The risk of global failure and/or failure of the facing in an earthquake still remains, however implementing additional anchors will reduce this risk.

The construction process of installing self-drilling ground anchors introduces some risks.

- The drilling process involves flushing out the cuttings with a large amount of grout and a heaving effect occurs on the surrounding ground. As with all remedial work, these risks must be closely managed when developing the construction methodology and during construction.

- We anticipate that it will be possible to anchor the ground anchors into rock. However, we are not certain of the rock profile. If no rock is encountered, an increased number of soil only anchors may be installed.
- Service strike along Buckingham Street is risk with self-drilling anchors. There are both sewer and wastewater mains (potentially more unknown services) buried within the adjacent road which will need to be managed during construction through survey and positive identification.

4. Construction Timeline and Cost Estimates

Each of the above options has a unique construction timeline and cost implications.

- Option 1 – Dismantle and replace wall
 - o 7 months construction
 - o \$953,000
- Option 2 – Cantilever bracing to support facing
 - o 3 months construction
 - o \$588,000
- Option 3 – Rock/soil anchored pattress plates
 - o 3 months construction
 - o \$519,000

5. Accuracy and Purpose of Cost Estimates

The cost estimates included in this report are updated from the original estimated given in 2018. The difference in cost from our original estimates are primarily due to the recently inflated price of construction and higher level of detail in the engineers estimates.

We have intended to provide cost estimates of sufficient detail to be used for budgeting purposes. These estimates are based on preliminary assumptions of both conditions and specific design elements which we are not able to confirm at this time. To account for unknown variables and the unstable nature of the construction industry, we have included a 30% contingency into each option.

We have included a professional services fee for design and procurement costs in each of the estimates. We recommend that the cost of any option that Council wishes to pursue is refined by working through the estimate with an appropriate Contractor.

6. Additional Considerations

6.1 Geotechnical Investigation

Geotechnical uncertainty is a risk to the cost and scope of this project. A detailed geotechnical investigation would be useful in assessing the viability of the options presented above and will also provide refinement of scope, design and cost.

We estimate that a geotechnical and pothole investigations required to confirm detailed design would cost in the order of \$15,000 and would involve several boreholes to identify depths and locations of rock and daylight the location of underground services.

6.2 Efficacy of Repairs

While three options have been considered for repair of the wall, it is important to note that only Option 1 will be possible to achieve compliance with the New Zealand Building Code.

Option 2 and 3 will increase the stability of the wall but will not achieve full compliance with the New Zealand Building code. We can design the support mechanisms to retain the unstable mass of soil driving the failures, but accurate modelling of the factor of safety of these repairs is not possible.



For options 2 and 3, there remains a risk of loss of facing rock, particularly during earthquakes or heavy rain. To mitigate this risk Council may also wish to fence off an area around the base of the wall and/or erect signage to prevent pedestrians from standing under the structure.

CREATING COMMUNITIES

Communities are fundamental. Whether around the corner or across the globe, they provide a foundation, a sense of belonging. That's why at Stantec, we always **design with community in mind**.

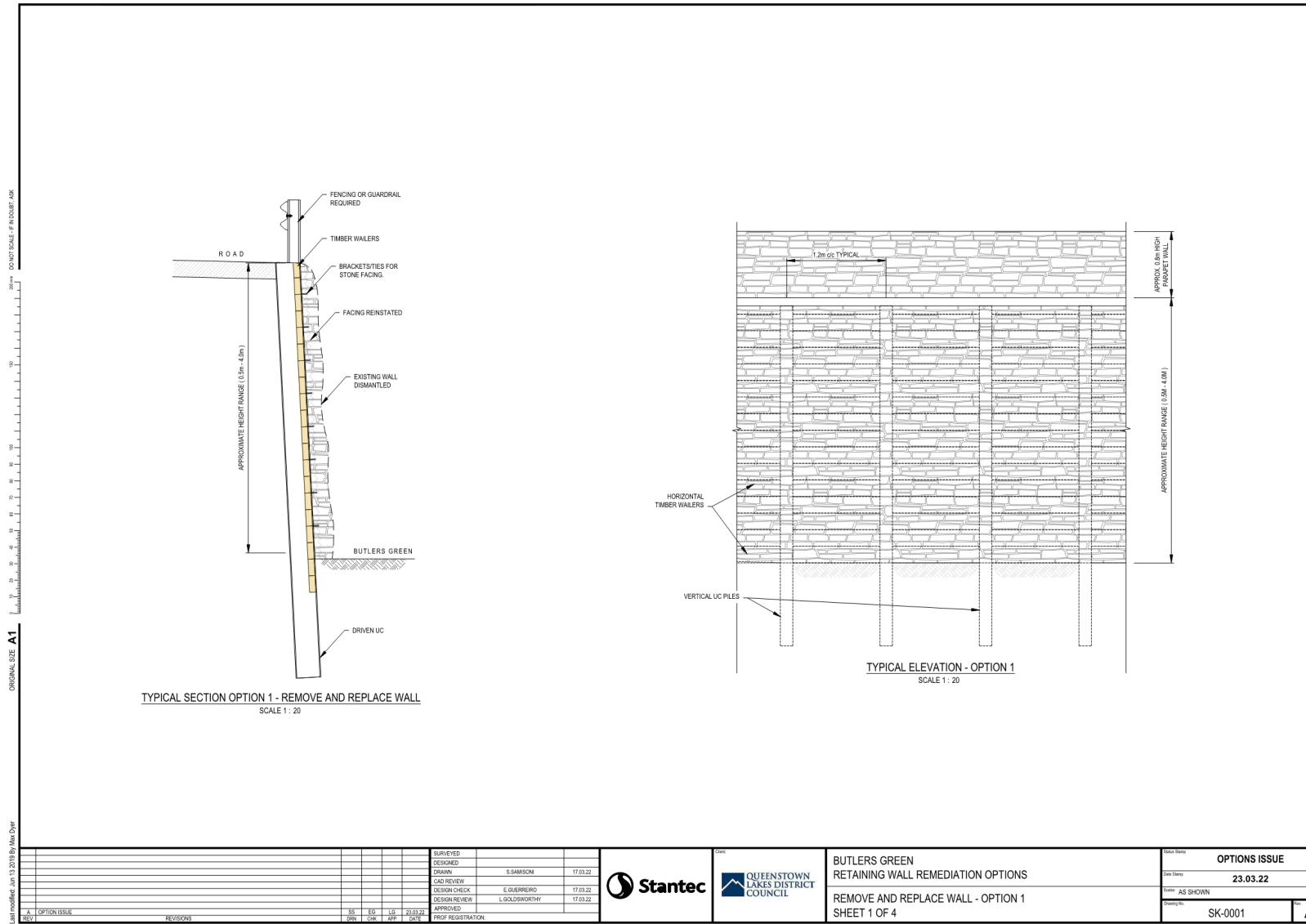
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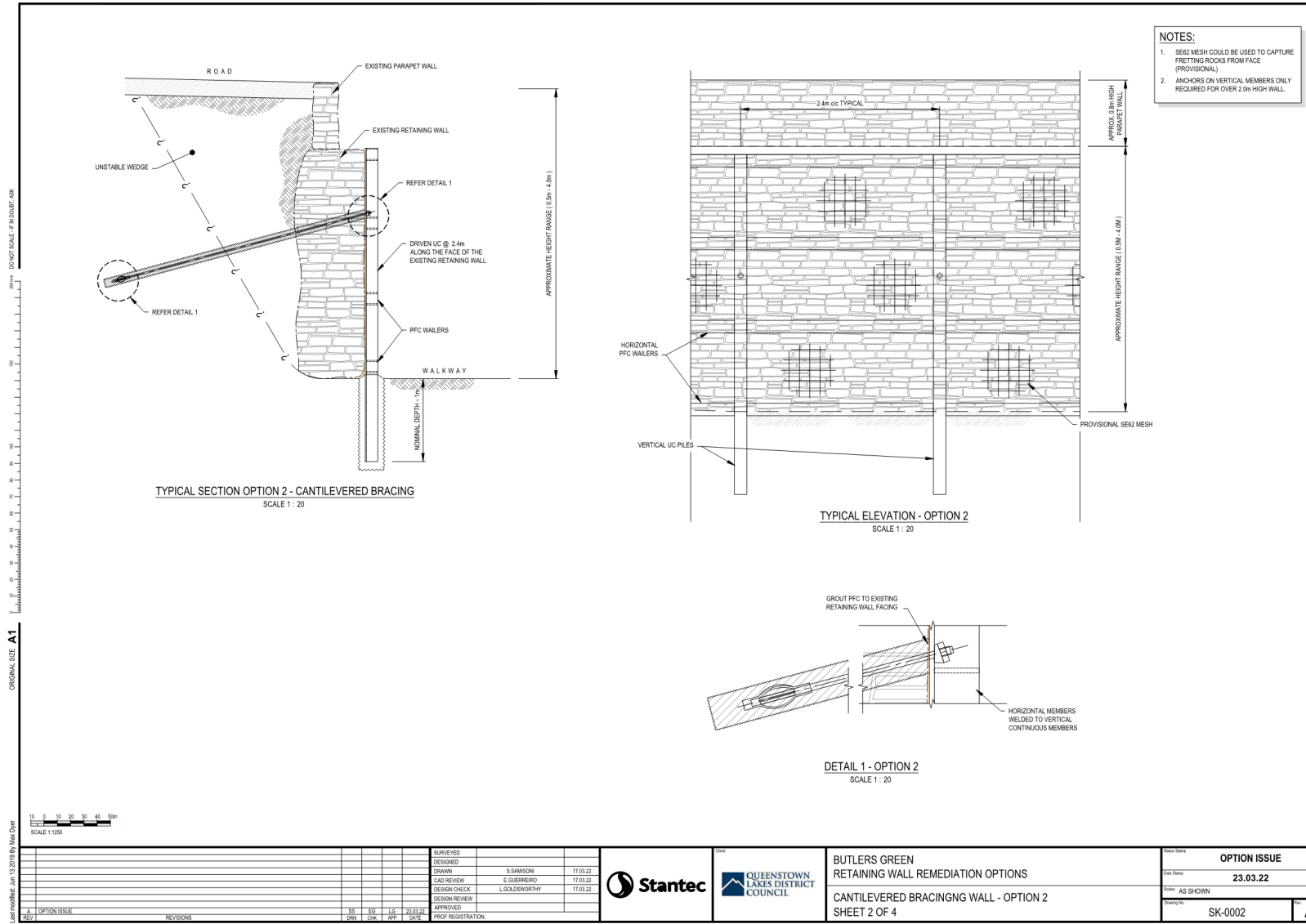
New Zealand offices:

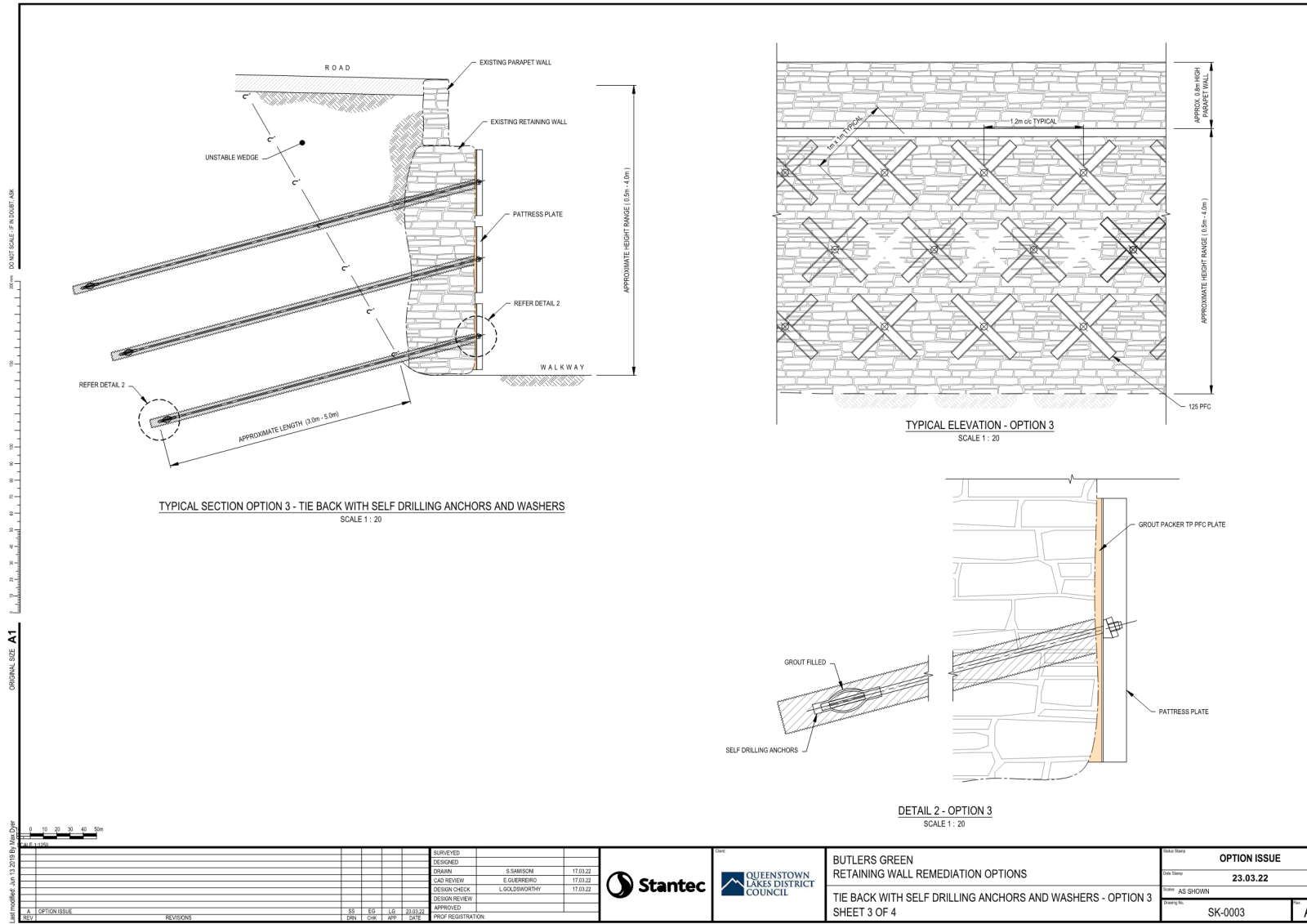
Alexandra, Auckland, Balclutha, Christchurch,
Dunedin, Gisborne, Greymouth, Hamilton, Hastings,
Nelson, Palmerston North, Queenstown, Tauranga,
Wellington, Whangārei



Attachment C - Drawings







ORIGINAL SIZE A1
DATE: 13/03/22 BY: JML/DJF



| NO. | DESCRIPTION | DATE | BY | CHECKED | APPROVED |
|-----|--------------|----------|------------|---------|----------|
| 1 | DESIGNED | 17.03.22 | S. SAMSON | | |
| 2 | DRAWN | 17.03.22 | E. GILBERT | | |
| 3 | DESIGN CHECK | 17.03.22 | L. GILBERT | | |
| 4 | APPROVED | 21.03.22 | | | |

Stantec

QUEENSTOWN
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COUNCIL

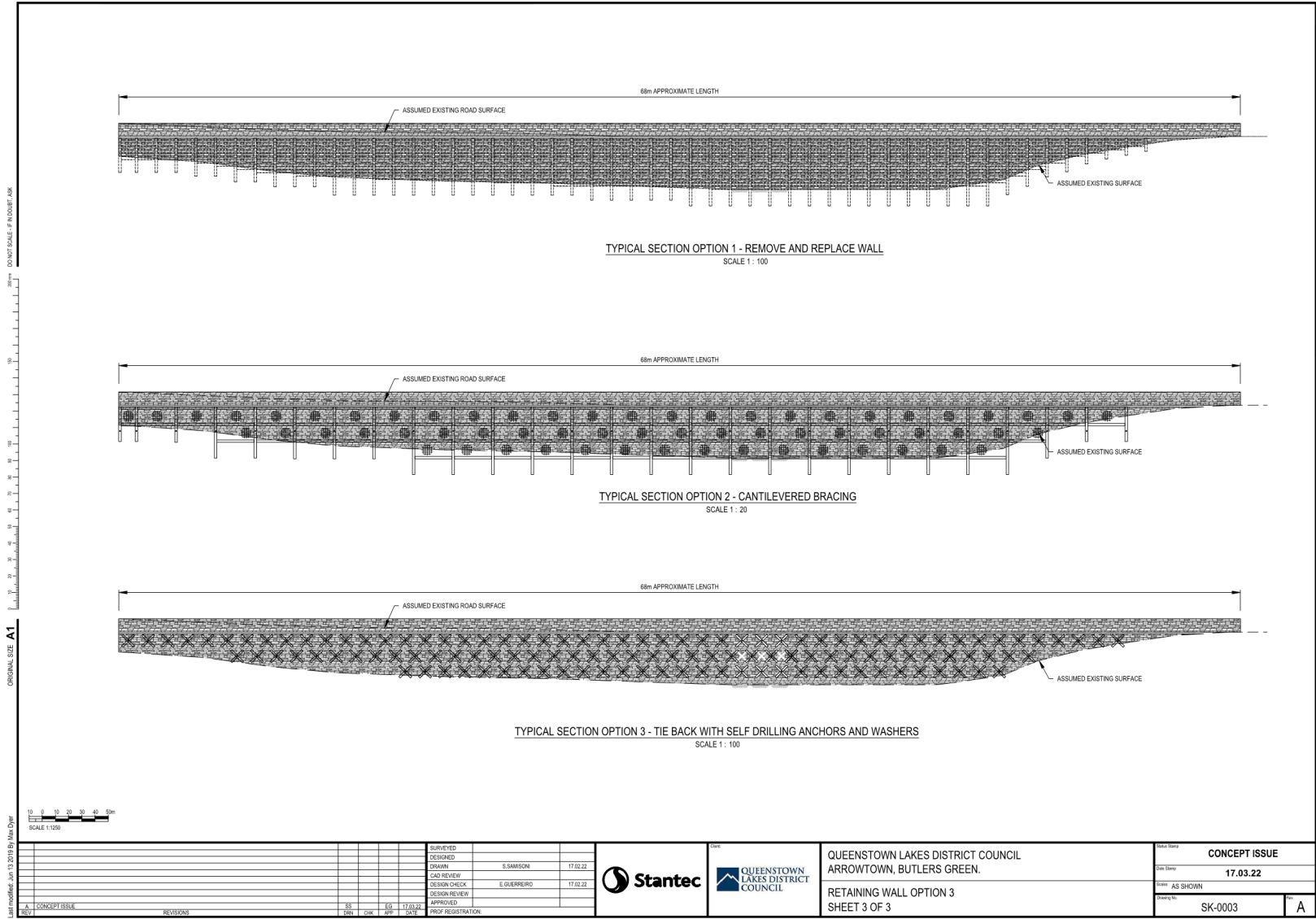
BUTLERS GREEN
RETAINING WALL REMEDIATION OPTIONS

TIE BACK WITH SELF DRILLING ANCHORS AND WASHERS - OPTION 3

SHEET 3 OF 4

| OPTION ISSUE | |
|--------------|----------|
| Date Stamp | 23.03.22 |
| Issue | AS SHOWN |
| Drawing No. | SK-0003 |
| Sheet | A |

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Attachment D: Cost Estimates

Butlers Green Retaining Wall - Remedial Option 1

| Item | Description | Unit | Qty | Rate | Sub-total | Total |
|--------------|--|------|-----|--------------|--------------|---------------------|
| 1 | Design and Consent Elements | | | | | \$92,389.60 |
| 1.1 | Archaeological Assessment and Authority | LS | 1 | \$13,000.00 | \$13,000.00 | |
| 1.2 | professional services | % | 5 | \$661,580.00 | \$33,079.00 | |
| 1.3 | MSQA | % | 7 | \$661,580.00 | \$46,310.60 | |
| 2 | Preliminary and General | | | | | \$32,000.00 |
| 2.1 | Establishment, disestablishment, clean-up and other site operating costs | LS | 1 | \$12,000.00 | \$12,000.00 | |
| 2.2 | Insurances, bonds, warranties/guarantees, as-built requirements, and other costs not related to time | LS | 1 | \$8,000.00 | \$8,000.00 | |
| 2.3 | Quality assurance, traffic management plans, environmental management plans, programming and reporting, health and safety | LS | 1 | \$9,000.00 | \$9,000.00 | |
| 2.4 | Survey and setting out | LS | 1 | \$3,000.00 | \$3,000.00 | |
| 3 | Traffic Management | | | | | \$54,800.00 |
| 3.1 | Wall dismantle/construction period - Management and implementation of traffic management plan (full temporary detour) | wk | 12 | \$3,500.00 | \$42,000.00 | |
| 3.2 | reconstruction of masonry - Management and implementation of traffic management plan (signs and fencing, but no active TM) | wk | 16 | \$800.00 | \$12,800.00 | |
| 4 | Dismantle Existing Wall | | | | | \$128,000.00 |
| 4.1 | temporary wall bracing installation and removal | LS | 1 | \$20,000.00 | \$20,000.00 | |
| 4.2 | dismantle wall (certified stone mason) | m | 60 | \$1,200.00 | \$72,000.00 | |
| 4.3 | Archaeological supervision | wk | 12 | \$1,500.00 | \$18,000.00 | |
| 4.4 | Earthworks behind wall to maintain stability | m | 60 | \$300.00 | \$18,000.00 | |
| 5 | Earthworks | | | | | \$84,280.00 |
| 5.1 | Strip works area | LS | 1 | \$2,500.00 | \$2,500.00 | |
| 5.2 | Strip to stockpile entire unstable soil wedge (assume can be reused as fill) | m3 | 650 | \$50.00 | \$32,500.00 | |
| 5.3 | Reinstate subgrade to road level using stripped stockpile material | m3 | 650 | \$55.00 | \$35,750.00 | |
| 5.4 | Pavement AP65 (200mm) | m3 | 44 | \$120.00 | \$5,280.00 | |
| 5.5 | Pavement AP40 (150mm) | m3 | 33 | \$150.00 | \$4,950.00 | |
| 5.6 | Surfacing (chipseal) | m2 | 220 | \$15.00 | \$3,300.00 | |
| 6 | Construct retaining wall | | | | | \$328,000.00 |
| 6.1 | Construct retaining wall (UC piles with timber wallers) (height varies) (not including backfill) | m | 60 | \$3,000.00 | \$180,000.00 | |
| 6.2 | Reconstruct historical facing (certified stone mason) | m | 60 | \$2,200.00 | \$132,000.00 | |
| 6.3 | Archaeological supervision | wk | 16 | \$1,000.00 | \$16,000.00 | |
| 7 | Misc | | | | | \$34,500.00 |
| 7.1 | Temporary workarround/support for adjacent services | LS | 1 | \$5,000.00 | \$5,000.00 | |
| 7.2 | Signage and line marking | LS | 1 | \$2,000.00 | \$2,000.00 | |
| 7.3 | Reconstruct handrail along top of wall | m | 70 | \$250.00 | \$17,500.00 | |
| 7.4 | Shape final ground and footpaths, etc | LS | 1 | \$10,000.00 | \$10,000.00 | |
| 8 | Contingency | | | | | \$198,474.00 |
| 8.1 | Contingency | % | 30 | \$661,580.00 | \$198,474.00 | |
| Total | | | | | | \$952,443.60 |

Butlers Green Retaining Wall - Remedial Option 2

| Item | Description | Unit | Qty | Rate | Sub-total | Total |
|--------------|---|------|-----|--------------|--------------|---------------------|
| 1 | Design and Consent Elements | | | | | \$61,540.00 |
| 1.1 | Archaeological Assessment and Authority | LS | 1 | \$13,000.00 | \$13,000.00 | |
| 1.2 | professional services | % | 5 | \$404,500.00 | \$20,225.00 | |
| 1.3 | MSQA | % | 7 | \$404,500.00 | \$28,315.00 | |
| 2 | Preliminary and General | | | | | \$32,000.00 |
| 2.1 | Establishment, disestablishment, clean-up and other site operating costs | LS | 1 | \$12,000.00 | \$12,000.00 | |
| 2.2 | Insurances, bonds, warranties/guarantees, as-built requirements, and other costs not related to time | LS | 1 | \$8,000.00 | \$8,000.00 | |
| 2.3 | Quality assurance, traffic management plans, environmental management plans, programming and reporting, health and safety | LS | 1 | \$9,000.00 | \$9,000.00 | |
| 2.4 | Survey and setting out | LS | 1 | \$3,000.00 | \$3,000.00 | |
| 3 | Traffic Management | | | | | \$24,000.00 |
| 3.1 | Management and implementation of traffic management plan (single lane stop/go) | wk | 12 | \$2,000.00 | \$24,000.00 | |
| 4 | Construct Cantilever Frame | | | | | \$296,000.00 |
| 4.1 | temporary wall bracing installation and removal | LS | 1 | \$20,000.00 | \$20,000.00 | |
| 4.2 | bored UC or PFC piles in front of wall, nominal 1m embedment, PFC wailers between columns | m | 60 | \$3,500.00 | \$210,000.00 | |
| 4.3 | soil/rock anchor including all hardware | m | 100 | \$500.00 | \$50,000.00 | |
| 4.4 | Archaeological supervision | wk | 16 | \$1,000.00 | \$16,000.00 | |
| 4.5 | SE62 mesh to facing (provisional) | m | 60 | \$250.00 | \$15,000.00 | |
| 5 | Misc | | | | | \$52,500.00 |
| 5.1 | landscaping/planting within fenced area | LS | 1 | \$10,000.00 | \$10,000.00 | |
| 5.2 | Proximity fencing and signage around base | m | 50 | \$300.00 | \$15,000.00 | |
| 5.3 | Reconstruct handrail along top of wall | m | 70 | \$250.00 | \$17,500.00 | |
| 5.4 | Shape final ground and footpaths, etc | LS | 1 | \$10,000.00 | \$10,000.00 | |
| 6 | Contingency | | | | | \$121,350.00 |
| 6.1 | Contingency | % | 30 | \$404,500.00 | \$121,350.00 | |
| Total | | | | | | \$587,390.00 |

Butlers Green Retaining Wall - Remedial Option 3

| Item | Description | Unit | Qty | Rate | Sub-total | Total |
|--------------|---|------|-----|--------------|--------------|---------------------|
| 1 | Design and Consent Elements | | | | | \$55,690.00 |
| 1.1 | Archaeological Assessment and Authority | LS | 1 | \$13,000.00 | \$13,000.00 | |
| 1.2 | professional services | % | 5 | \$355,750.00 | \$17,787.50 | |
| 1.3 | MSQA | % | 7 | \$355,750.00 | \$24,902.50 | |
| 2 | Preliminary and General | | | | | \$29,500.00 |
| 2.1 | Establishment, disestablishment, clean-up and other site operating costs | LS | 1 | \$12,000.00 | \$12,000.00 | |
| 2.2 | Insurances, bonds, warranties/guarantees, as-built requirements, and other costs not related to time | LS | 1 | \$8,000.00 | \$8,000.00 | |
| 2.3 | Quality assurance, traffic management plans, environmental management plans, programming and reporting, health and safety | LS | 1 | \$9,000.00 | \$9,000.00 | |
| 2.4 | Survey and setting out | LS | 1 | \$500.00 | \$500.00 | |
| 3 | Traffic Management | | | | | \$24,000.00 |
| 3.1 | Management and implementation of traffic management plan (single lane stop/go) | wk | 12 | \$2,000.00 | \$24,000.00 | |
| 4 | Construct Retaining System | | | | | \$249,750.00 |
| 4.1 | temporary wall bracing installation and removal | LS | 1 | \$20,000.00 | \$20,000.00 | |
| 4.3 | soil/rock anchor including all hardware | m | 450 | \$475.00 | \$213,750.00 | |
| 4.4 | Archaeological supervision | wk | 16 | \$1,000.00 | \$16,000.00 | |
| 5 | Misc | | | | | \$52,500.00 |
| 5.1 | landscaping/planting within fenced area | LS | 1 | \$10,000.00 | \$10,000.00 | |
| 5.2 | Proximity fencing and signage around base | m | 50 | \$300.00 | \$15,000.00 | |
| 5.3 | Reconstruct handrail along top of wall | m | 70 | \$250.00 | \$17,500.00 | |
| 5.4 | Shape final ground and footpaths, etc | LS | 1 | \$10,000.00 | \$10,000.00 | |
| 6 | Contingency | | | | | \$106,725.00 |
| 6.1 | Contingency | % | 30 | \$355,750.00 | \$106,725.00 | |
| Total | | | | | | \$518,165.00 |

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