Notice of Meeting:
An ordinary meeting of the Infrastructure, Transport and Environment Committee will be held on:

Date: Wednesday 10 July 2019
Time: 1pm
Venue: Council Chambers, Civic Offices, 53 Hereford Street, Christchurch

Membership
Chairperson Councillor Pauline Cotter
Deputy Chairperson Councillor Mike Davidson
Members Councillor Vicki Buck
Councillor Phil Clearwater
Councillor Anne Galloway
Councillor Aaron Keown
Councillor Tim Scandrett
Councillor Sara Templeton

5 July 2019
Principal Advisor
David Adamson
General Manager City Services
Tel: 941 8235

Aidan Kimberley
Committee and Hearings Advisor
941 6566
aidan.kimberley@ccc.govt.nz
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Note: The reports contained within this agenda are for consideration and should not be construed as Council policy unless and until adopted. If you require further information relating to any reports, please contact the person named on the report.

To view copies of Agendas and Minutes, visit: https://www.ccc.govt.nz/the-council/meetings-agendas-and-minutes/
Strategic Framework
The Council’s Vision – Christchurch is a city of opportunity for all.
Open to new ideas, new people and new ways of doing things – a city where anything is possible.

Whiria ngā whenu o ngā papa Honoa ki te maurua tāukiuki
Bind together the strands of each mat
And join together with the seams of respect
and reciprocity.
The partnership with Papatipu Rūnanga
reflects mutual understanding and respect,
and a goal of improving the economic,
cultural, environmental and social
wellbeing for all.

Overarching Principle
Partnership – Our people are our taonga
– to be treasured and
encouraged. By working
together we can create
a city that uses their
skill and talent, where
we can all participate,
and be valued.

Supporting Principles
Accountability
Affordability
Agility
Equity
Innovation
Collaboration
Prudent Financial Management
Stewardship
Wellbeing and resilience
Trust

Community Outcomes
What we want to achieve together as our city evolves

Strong communities
Strong sense of community
Active participation in civic life
Safe and healthy communities
Celebration of our identity through arts, culture, heritage and sport
Valuing the voices of children and young people

Liveable city
Vibrant and thriving central city, suburban and rural centres
A well connected and accessible city
Sufficient supply of, and access to, a range of housing
21st century garden city we are proud to live in

Healthy environment
Healthy waterways
High quality drinking water
Unique landscapes and indigenous biodiversity are valued
Sustainable use of resources

Prosperous economy
Great place for people, business and investment
An inclusive, equitable economy with broad-based prosperity for all
A productive, adaptive and resilient economic base
Modern and robust city infrastructure and community facilities

Strategic Priorities
Our focus for improvement over the next three years and beyond

Enabling active citizenship and connected communities
Maximising opportunities to develop a vibrant, prosperous and sustainable 21st century city
Climate change leadership
Informed and proactive approaches to natural hazard risks
Increasing active, public and shared transport opportunities and use
Safe and sustainable water supply and improved waterways
Chair: Councillor Cotter

Membership:
Councillor Davidson (Deputy Chair), Councillor Buck, Councillor Clearwater, Councillor Galloway, Councillor Keown, Councillor Scandrett and Councillor Templeton

Quorum: Half of the members if the number of members (including vacancies) is even, or a majority of members if the number of members (including vacancies) is odd.

Meeting Cycle: Monthly

Reports To: Council

Areas of Focus
The focus of the Infrastructure, Transport and Environment Committee is the governance of roading and transport, three waters, waste management, and natural hazards protection.

The Infrastructure, Transport and Environment Committee:
- Encourages opportunities for citizenship, community participation and community partnerships
- Works in partnerships with key agencies, groups and organisations
- Considers the impact of climate change in its decisions

The Infrastructure, Transport and Environment Committee considers and reports to Council on issues and activities relating to:
- Water supply, conservation and quality
- Stormwater drainage including the Land Drainage Recovery Programme
- Natural environment, including the waterways, aquifers, ecology and conservation of resources
- Natural hazards protection, including flood protection and river control
- Solid waste minimisation and disposals
- Sewage collection, treatment and disposal
- Roads, footpaths and streetscapes
- Transport including road operations, parking, public transport, cycle ways, harbours and marine structures consistent with Greater Christchurch Public Transport Joint Committee Terms of Reference

Delegations
The Committee delegates to the following working group the responsibility to consider and report back to the Committee:
• Land Drainage Working Group matters relating to the Land Drainage Recovery Programme, including opportunities for betterment.

**Major Cycleway Route (MCR) Programme**

At the Council meeting of 9 March 2017:

It was **resolved** that the Council:

1. Delegates to the Infrastructure, Transport and Environment Committee the authority to make all decisions in connection with the Major Cycleway Routes (MCR) programme, including final route selections and anything precedent to the exercise by the Council of its power to acquire any property, subject to:
   a. The Infrastructure, Transport and Environment Committee and affected Community Boards being briefed prior to any public consultation commencing on any Major Cycleway Route project.
   b. The relevant Community Board Chair(s) will be invited by the Infrastructure, Transport and Environment Committee to participate in the relevant Major Cycleway Route item discussion and give their Board’s feedback or recommendations.
2. Notes and reconﬁrms Councils previous decision to designate the MCR programme a metropolitan project, as set out in the Council’s resolutions on 29 January 2015.
   13.4 Agree to the Major Cycleway Route programme being declared a Metropolitan Programme and delegate to the Infrastructure, Transport and Environment Committee all decision making powers.

**Christchurch Biodiversity Fund**

At the Council meeting of 20 June 2017:

It was **resolved** that the Council:

5. Delegate authority to the Infrastructure, Transport and Environment Committee to consider and approve applications to the Christchurch Biodiversity Fund.
Part A  Matters Requiring a Council Decision
Part B  Reports for Information
Part C  Decisions Under Delegation

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1. **Apologies**
   At the close of the agenda no apologies had been received.

2. **Declarations of Interest**
   Members are reminded of the need to be vigilant and to stand aside from decision making when a conflict arises between their role as an elected representative and any private or other external interest they might have.

3. **Confirmation of Previous Minutes**
   That the minutes of the Infrastructure, Transport and Environment Committee meeting held on Wednesday, 12 June 2019 be confirmed (refer page 7).

4. **Public Forum**
   A period of up to 30 minutes may be available for people to speak for up to five minutes on any issue that is not the subject of a separate hearings process.

5. **Deputations by Appointment**
   There were no deputations by appointment at the time the agenda was prepared.

6. **Petitions**
   There were no petitions received at the time the agenda was prepared.
Infrastructure, Transport and Environment Committee
OPEN MINUTES

Date: Wednesday 12 June 2019
Time: 1.08pm
Venue: Council Chambers, Civic Offices, 53 Hereford Street, Christchurch

Present
Chairperson
Councillor Pauline Cotter
Deputy Chairperson
Councillor Mike Davidson
Members
Councillor Vicki Buck
Councillor Phil Clearwater
Councillor Anne Galloway
Councillor Aaron Keown
Councillor Tim Scandrett
Councillor Sara Templeton

11 June 2019
Principal Advisor
David Adamson
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The agenda was dealt with in the following order.

1. **Apologies**

   There were no apologies.

2. **Declarations of Interest**

   Part B
   There were no declarations of interest recorded.

3. **Confirmation of Previous Minutes**

   Part C
   Committee Resolved ITEC/2019/00016

   That the minutes of the Infrastructure, Transport and Environment Committee meeting held on Wednesday, 10 April 2019 be confirmed.

   Councillor Davidson/Councillor Clearwater  
   Carried

4. **Public Forum**

   Part B
   There were no public forum presentations.

5. **Deputations by Appointment**

   Part B
   There were no deputations by appointment.

6. **Presentation of Petitions**

   Part B
   There was no presentation of petitions.
7. **Biodiversity Fund Project Applications**

   **Committee Comment**
   
   The Committee selected the Jubilee Stream fencing project in the third recommendation, and were advised that the Edwards Stream project is likely to be put forward for funding in the next financial year. The Committee also requested a briefing on biodiversity matters.

   **Committee Resolved ITEC/2019/00017**

   **Part C**

   That the Infrastructure, Transport and Environment Committee:
   
   1. Receive the information in the report.
   2. Approve full funding to the following three projects, to provide certainty to landowners and facilitate timely completion of proposed works.
      
      a. $9,090 for Head of the Harbour - fencing
      b. $39,986 for Stencliffe Farm - fencing
      c. $40,000 for Island Bay – fencing and pest mammal control
   3. Allocate remainder of funding to the following project, which is highly likely to be feasible with a slightly reduced contribution from the Council.
      
      a. $31,624 for Jubilee Stream – fencing
   4. Requests a briefing on biodiversity matters.

   Councillor Cotter/Councillor Clearwater  **Carried**

   Councillor Galloway left the meeting at 1:41 p.m. during the discussion on item 8.

8. **Gloucester Street Enliven Places Project, Transitional Streetscape Amenity and Pedestrian Improvements.**

   **Committee Comment**

   The Committee discussed the character of the street and whether it would be possible to use this project to add a feature which could attract people to enjoy the area.

   The Committee requested staff to put forward a unique feature for inclusion in the project when this item is reported to the Council.

   **Staff Recommendations**

   That the Infrastructure, Transport and Environment Committee Recommends that the Council:
   
   1. Approves the proposed Enliven Places temporary pedestrian amenity improvement project on Gloucester Street between Colombo and Manchester streets as outlined on Attachment A.

   **Committee Resolved ITEC/2019/00018**
Part C

That the Infrastructure, Transport and Environment Committee:

1. Requests staff to include an extra unique feature of some sort when this item is reported to the Council.

Councillor Buck/Councillor Clearwater  Carried

Committee Decided ITEC/2019/00019

Part A

That the Infrastructure, Transport and Environment Committee Recommends that the Council:

1. Approves the proposed Enliven Places temporary pedestrian amenity improvement project on Gloucester Street between Colombo and Manchester streets as outlined on Attachment A.

Councillor Buck/Councillor Clearwater  Carried

Councillor Galloway returned to the meeting at 1:49 p.m.

9. Transport Unit Bi-Monthly Report

Committee Resolved ITEC/2019/00020

Part C

That the Infrastructure, Transport and Environment Committee:

1. Receive the information in the attached report.

Councillor Cotter/Councillor Clearwater  Carried

Meeting concluded at 2.10pm.

CONFIRMED THIS 10TH DAY OF JULY 2019.

COUNCILLOR PAULINE COTTER
CHAIRPERSON
7. Cycle facilities and connection improvements project scope approval

Reference: 19/419153
Presenter(s): Clarrie Pearce, Senior Project Manager

1. Purpose of Report
   1.1 The purpose of the report is to get approval to proceed with the delivery of the proposed detailed scope (as attached) as individual projects.

2. Executive Summary
   2.1 This capital project was created with a broad scope, following the identification of a budget surplus for the Bike Share scheme project as described below. The items in the attached document are being proposed as appropriate to represent the objective detailed in the Council resolution.

   In order to create a proposed list of sub-projects, a project team was created. The team members cover a range of internal Council departments involved in cycling.

   The team worked through a wide range of possible sub-projects and engaged with Council staff regarding the content to propose those representing appropriate deliverables as detailed in Attachment A.

   The proposed sub-projects were discussed with the Infrastructure, Transport and Environment Committee and representatives of the Waikura/Linwood-Central-Heathcote Community Board.

3. Staff Recommendations
   That the Infrastructure, Transport and Environment Committee recommends that the Council:
   1. Approve the scope of the project as detailed in Attachment A.
   2. Delegate authority for the General Manager City Services to add or delete items to/from this list for investigation and delivery within the overall allocated budget.

4. Context/Background
   Issue or Opportunity
   4.1 The LTP project, “City Wide Bike Share” (ID# 41246) aimed to provide facilities and cycles for a citywide bike share scheme. Specific tasks were to procure an end-to-end solution for the design, supply, commencement and operation of a shared bicycle system cycle facilities and connection improvements. This project did not proceed.

   4.2 At the Council meeting on 24 May 2018 the Council resolved (CNCL/2018/00088) to:

   Instruct staff to carry forward the remaining 17/18 budget to 18/19 financial year and reallocate the funding to cycle projects – such as improving central city cycle connections; and further improving cycle parking facilities across the city. These works will be completed under existing maintenance contracts.

   4.3 A new project was created and the remaining funding of $1.2m was moved to Improvements to existing cycle facilities and connections (ID# 52228).
4.4 The project scope being the provision of new cycle facilities including cycle parking. The objectives of the project are that a package of interventions are proposed which provide a mixture of cycle accessibility, cycle parking and cycle safety improvements to improve the existing levels of service for current users and serve to encourage increased uptake of cycling within the central city.

4.5 A project team was formed to define a range of interventions that would address the objectives of the project. The project team included representatives from the Traffic Operations team, Capital Delivery team, Asset Planning team and Travel Demand Management team. The team undertook a series of workshops involving the project team and other Council staff involved with cycling to develop a long list of options.

4.6 The package of interventions recommended in Attachment A is a balance, designed to improve the connectivity between major cycleways and the central city, as well as facilitating easier, safer circulation within the central city, and providing additional cycle parking facilities to better reflect emerging demand.

4.7 Rough order costing indicates that all the proposed interventions can be achieved within the allocated budget. They have all been prioritised to address the objectives of the resolution.

4.8 The proposed list of interventions has been discussed at a briefing with the Infrastructure, Transport and Environment Committee and with representatives of the Waikura/Linwood-Central-Heathcote Community Board on 10 April 2019.

Strategic Alignment

4.9 This project is identified in the Council’s Long Term Plan (2018 – 2028) as Cycle facilities and connection improvements (ID#52228) and is scheduled for completion in financial year 20/21.

4.10 This report supports the Council’s Long Term Plan (2018 - 2028):

4.10.1 Activity: Active Travel

- Level of Service: 10.5.2.0 Improve the perception that Christchurch is a cycling friendly city - =53%

Decision Making Authority

4.11 The Council has the authority to amend / update the scope of this project under the Local Government Act 1974.

Assessment of Significance and Engagement

4.12 The decisions in this report are of low significance in relation to the Christchurch City Council’s Significance and Engagement Policy.

4.13 The level of significance was determined by internal Council Stakeholder interaction. When individual sub-projects require community engagement, their significance will be re-assessed at that time.

5. Options Analysis

Options Considered

5.1 The following reasonably practicable options were considered and are assessed in this report:

- Option 1 - Create 20 sub-projects and deliver them according to standard Council procedures.
- Option 2 - Add or remove sub-projects based upon Elected Member input.

5.2 The following options were considered but ruled out
Do nothing / cancel the project. – The Infrastructure, Transport and Environment Committee indicated support for continuing with this use of the available budgets.

Possible options that have significant funding implications, more aligned to being delivered as an individual project, were discarded.

**Options Descriptions**

5.3 **Preferred Option:** Option 1 – Deliver all 20 sub-projects.

5.3.1 **Option Description:** Deliver a number of sub-projects, as described in Attachment A.

5.3.2 All 20 sub-projects, detailed in Attachment A, can be delivered in parallel and within the overall budget. The intention is to bundle them as packages of work when practicable, for design and community consultation.

5.3.3 The sub-projects have been created following significant stakeholder discussions within the Council. The proposed sub-projects as per Attachment A were discussed with the Infrastructure, Transport and Environment Committee and representatives of the Waikura/Linwood-Central-Heathcote Community Board Community Board in April 2019.

5.3.4 A level of prioritisation has been undertaken in order to develop the list of sub-projects. This prioritisation has taken into account safety, improved accessibility, connectivity etc.

5.3.5 **Option Advantages**

- The proposed scope for the overall project meets the original Council intention of improving cycling accessibility and cycle parking within the CBD.
- The proposed scope can be delivered for the available budget.

5.3.6 **Option Disadvantages**

- Should the project not proceed the budget could be allocated to other Council projects.

5.4 **Additional Option: Option 2** – Add more sub-projects and / or remove some proposed ones.

5.4.1 **Option Description:** Should Elected Members wish to add or remove sub-projects to the list then these can be tabled for staff to process.

5.4.2 **Option Advantages**

- Additional or changed requirements for cycle facilities and connectivity in the central city will be able to be addressed.

5.4.3 **Option Disadvantages**

Additional work would have to be undertaken to ensure the proposed sub-projects have all been validated by staff. Any newly proposed sub-projects will need to be looked at in detail and have an initial cost estimate done.

**Analysis Criteria**

5.5 The Council asked staff to use existing funding to improve cycle parking and accessibility within the central city. The project team undertook a study of the CBD to determine where cycling related issues exist or where opportunities for improvement might be foreseen.

5.6 Options included linking various Major Cycle Routes (MCRs) to the central city. The desire lines for connecting the MCRs across the central city were reviewed and proposals created to meet this demand.
5.7 Cycle parking demand and future growth areas were assessed and a decision to seek feedback from stakeholders across the central city was thought to be appropriate. This involves seeking feedback for locations where more cycle parking would be desirable.

5.8 A previous review of safety concerns relating to the conflicts between cyclists and tram tracks was reviewed.

5.9 Contact was made with Council staff who cycle to find areas of safety concern such as abrupt kerb drop downs or congested areas. This information was factored into the sub-project definition and prioritisation.

6. **Community Views and Preferences**

   6.1 This report is to seek Council approval for the project scope. The community views will be sought during engagement and consultation when the individual sub-projects are progressed through standard Council delivery processes.

7. **Legal Implications**

   7.1 There is no legal context, issue or implication relevant to this decision.

   7.2 This report has not been reviewed and approved by the Legal Services Unit.

8. **Risks**

   8.1 There are no identified risks directly related to this decision.

   8.2 Once the items proceed to delivery any risks associated with sub-projects will be identified and managed.

9. **Next Steps**

   9.1 Following approval of the scope definition, the individual items will be analysed and packaged for delivery utilising standard Council project delivery processes. Any procurement undertaken will be in line with Council’s Procurement Policy.
## 10. Options Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Cost to Implement</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$1.2m</td>
<td>$1.2m</td>
<td></td>
</tr>
<tr>
<td><strong>Financial Implications</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costing/ongoing</td>
<td>The additional cost of this option is estimated to be $2000/year and will need to be allowed for in 2021-31 LTP budget planning. The increase is mostly due to the additional cycle stands.</td>
<td></td>
<td>This is unlikely to vary significantly from option 1.</td>
</tr>
<tr>
<td>Funding Source</td>
<td>FY18 – FY28 LTP $1.2m (CPMS 52228)</td>
<td>FY18 – FY28 LTP $1.2m (CPMS 52228)</td>
<td></td>
</tr>
<tr>
<td>Impact on Rates</td>
<td>Nil</td>
<td>Nil</td>
<td></td>
</tr>
</tbody>
</table>

### Criteria 1 e.g. Climate Change Impacts

- The decisions in this report will encourage or support cycling in the central city and so reduce greenhouse gas emissions from transport.
- It is not possible to quantify carbon reductions achieved by these decisions, as some improvements relate to ease of use and safety for cyclists.

### Criteria 2 e.g. Accessibility Impacts

- As individual sub-projects are designed, accessibility and pedestrian access will be considered.

### Criteria 3 e.g. Health & Safety Impacts

- Seven of the proposed sub-projects are directly targeted at safety improvements. All the sub-projects have no delivery
- It is unlikely that this will vary from Option 1.
aspects that lead them to being an abnormal Health & Safety risk during delivery.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact on Mana Whenua</td>
<td>This option does not involve a significant decision in relation to ancestral land or a body of water or other elements of intrinsic value, therefore this decision does not specifically impact Ngāi Tahu, their culture and traditions. This reasoning is based upon these sub-projects only enhancing existing assets.</td>
<td>It is unlikely that this will vary from Option 1.</td>
</tr>
<tr>
<td>Alignment to Council Plans &amp; Policies</td>
<td>This option is consistent with Council’s Plans and Policies.</td>
<td>This option is consistent with Council’s Plans and Policies.</td>
</tr>
</tbody>
</table>
Attachments

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Central City cycling accessibility and parking project elements for discussion Version 2</td>
<td>18</td>
</tr>
</tbody>
</table>

Confirmation of Statutory Compliance

Compliance with Statutory Decision-making Requirements (ss 76 - 81 Local Government Act 2002).

(a) This report contains:
   (i) sufficient information about all reasonably practicable options identified and assessed in terms of their advantages and disadvantages; and
   (ii) adequate consideration of the views and preferences of affected and interested persons bearing in mind any proposed or previous community engagement.

(b) The information reflects the level of significance of the matters covered by the report, as determined in accordance with the Council's significance and engagement policy.

Signatories

<table>
<thead>
<tr>
<th>Author</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>Clarrie Pearce - Senior Project Manager</td>
</tr>
<tr>
<td>Approved By</td>
<td>Lynette Ellis - Manager Planning and Delivery Transport</td>
</tr>
<tr>
<td></td>
<td>Peter Langbein - Finance Business Partner</td>
</tr>
<tr>
<td></td>
<td>Richard Osborne - Head of Transport</td>
</tr>
<tr>
<td></td>
<td>David Adamson - General Manager City Services</td>
</tr>
</tbody>
</table>
Central City cycling accessibility and parking project – possible deliverables for discussion at ITE Workshop prior to formal report to Council for confirmation of project scope:

A project team has been formed.

The team members cover a range of internal CCC departments involved in cycling.

The teams involved include:

- Traffic Operations
- Travel Demand Management
- Transport Asset Planning
- Transport Project Management
- Communications and Marketing

The team and a broader audience within CCC have identified 20 pieces of work to be proposed as meeting the scope of this project. They are categorised into three categories being:

- Accessibility
- Parking
- Safety

Please note that there are hyperlinks within this document. If you “Ctrl click” on an underlined item as above this will link you to the details. Eg “safety” above will go to the summary of the safety selections. Within that table if you Ctrl Click on the description, it will take you to the detail.

Once confirmed by Council as representing the intended project scope, each item will be delivered using standard Inner City Transport processes. Some just as maintenance, some via the Parking Sub-Committee through to full CBD engagement.
## Accessibility:

<table>
<thead>
<tr>
<th>ID</th>
<th>Proposed Project Name</th>
<th>Summary</th>
<th>Funding Est</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Rapanui MCR Connectivity from Fitzgerald Ave to the Central City</strong></td>
<td>Create a 30 kph shared road (use sharrows) to get from Worcester / Fitzgerald to Worcester / Manchester such that cyclists on the Rapanui MCR can get into the City. They will go along Worcester and across Latimer Square then follow Worcester to Manchester.</td>
<td>$90,000</td>
</tr>
<tr>
<td>2</td>
<td><strong>Uni Cycle MCR Connectivity on Gloucester to Colombo and Manchester Streets</strong></td>
<td>Gloucester Street has low traffic volumes and can be developed to prioritise cycling having no other priority transport mode status in the AAC. Some minor signals modifications required. The route is relatively central to meet the central city east west connection objective and MCR connectivity. By using Gloucester Street the tram lines on Armagh and Worcester streets are avoided.</td>
<td>$120,000</td>
</tr>
<tr>
<td>3</td>
<td><strong>Shared Path North from Ara on Madras to High</strong></td>
<td>Create a shared path from Ara on the Eastern side of Madras St through to High St. Currently cyclists ride on the footpath. This job involves effectively sealing the berm and the removal of six all day car parks outside Ara. We have a preliminary hand drawn scheme and agreement with Ara.</td>
<td>$80,000</td>
</tr>
<tr>
<td>4</td>
<td><strong>Latimer Square entry points North and South</strong></td>
<td>Investigate possible cycling entry facility / drop downs to enable cyclists to cross Latimer Square, North to South / visa versa. If cycling across Latimer Square is not permitted then this will be removed from the list. A “cycling heat map” of the City shows that cyclists currently use this as a route. An East / West shared path already exists across Latimer Square.</td>
<td>$30,000</td>
</tr>
<tr>
<td>Item No.</td>
<td>Description</td>
<td>Action</td>
<td>Cost</td>
</tr>
<tr>
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<td>-----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>5</td>
<td><strong>Cranmer Square entry points North and South</strong></td>
<td>Investigate possible cycling entry facility / drop downs to enable cyclists to cross Cranmer Square, North to South / vice versa. A “cycling heat map” of the City shows that cyclists currently use this as a route. An East / West shared path already exists across Latimer Square but if cycling across Cranmer Square is not permitted then this will be removed from the list. Cycling has been implemented across Victoria Square so need to check this.</td>
<td>$30,000</td>
</tr>
<tr>
<td>6</td>
<td><strong>Diamond Paint marks</strong></td>
<td>Wherever cycle loops are installed at traffic signals, there should be suitable diamond marks painted on the road to inform cyclists where to cycle. It is not known how many have yet to be painted but if we are to achieve behaviour change and facilitate correct use of the automation, then we need to give the public the tools required to do the job correctly.</td>
<td>$5,000</td>
</tr>
<tr>
<td>7</td>
<td><strong>Review shared path by Antigua Boat Sheds</strong></td>
<td>The Antigua bridge is 4.35m wide-not desirable for a shared path in this location, but sufficient. The path between the planter boxes on the north side narrows to 2.5m. If we modify the planter boxes (the Cancer Society have informally indicated they are happy for us to modify the planters), then a shared pathway width of at least 4.35m can be created (the bridge width) with a centre line and directional arrows on each side. This particular bridge does have a lot of pedestrian dwelling and viewing over the decks and being close to the hospital there are vulnerable users who have high sensitivity to “close shaves” with passing cyclists.</td>
<td>$50,000</td>
</tr>
</tbody>
</table>
### Parking:

<table>
<thead>
<tr>
<th>ID</th>
<th>Proposed Project Name</th>
<th>Summary</th>
<th>Funding Est</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Signage for Lichfield St Cycle parking and other parking buildings with provision for cycles.</td>
<td>Provide guidance to indicate that there is a good cycle parking facility in the centre of the City. The area needs promotional signs on Lichfield St (the City Mall is pedestrian only) and marketing. Also include signs for other CBD Parking Buildings with cycle parking provision.</td>
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<td>Mitigate the safety risks associated with the tram tracks on Armagh St from Rolleston Ave to Colombo St.</td>
<td>The realignment of two intersections with revised signage and guidance through intersections needs a draft scheme. Armagh St at Rolleston Ave guiding cyclists away from tram lines and promote off road section and realign lane on the west approach to Durham and again on the east for Durham improve and promote off road section.</td>
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<td><strong>Addition of Cycleway push buttons along Manchester St &amp; St Asaph St &amp; Durham St</strong></td>
<td>To increase the optimisation of Manchester St, St Asaph St &amp; Durham St for all vehicles. The cycleway auto detection cameras are now the only form of cycleway activation. They used to be auto demanded but this creates a lot of dead intersection time and frustrates drivers. The cameras are not as reliable as originally intended. Ōtākaro delivered to plan, but with the need to further optimise the bus route and with more vehicles it has created the need for cycle call buttons (with call accept light) to be fitted. This is for 45.</td>
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<td><strong>Signal lantern heights</strong></td>
<td>Cycleway lanterns have been delivered by Ōtākaro as per requirements but over the period of development the size of the pole has decreased and the size of the lanterns has increased. This has resulted in vehicle sized (200mm or 300mm) lanterns on short signal poles. The outcome is the bottom of the lantern will potentially injure pedestrians who walk too close to the cycle lanterns. These need to be raised.</td>
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**Accessibility Details:**

1. **Rapanui MCR Connectivity from Fitzgerald Ave to the Central City**

Create a shared road (use sharrows) to get from Worcester / Fitzgerald to Worcester / Manchester such that cyclists on the Rapanui MCR get into the City. This will go along Worcester and across Latimer Square. Latimer Square already has an East / West shared path with cycle traffic signals to cross Madras. The project will primarily involve painting “Sharrows” and a 30kph restriction.
Gloucester Street has low traffic volumes and can be developed to prioritise cycling having no other priority transport mode status in the transport chapter of the central city recovery plan. The route is relatively central to meet the central city east west connection objective. Marked “B” in the above map. This is intended to give cyclists a “no tram tracks” access link to the other MCRs and the central city.

The Gloucester St Section between Rolleston Ave and Oxford Tce has an adjacent land use mix of mainly residential along with the Art Gallery and a few businesses nearing Cambridge Tce.

The new Convention Centre has a wide shared pathway around its southern perimeter that can provide for and has been planned for the cycle demand nearing the Square. Discussions throughout 2017 with Ōtākaro planners were very positive towards the key cycleway route sharing the pathway around the south side of the convention centre. They recognised the mutual benefits with the Convention Centre and active travel access showcased. The shared use is identified in the Ōtākaro plans below. From the Convention Centre, the cyclists would then reconnect to the road network, crossing Colombo St to use Gloucester St past the new library and east to the Manchester St intersection - crossing to the new shared path on the eastern side of Manchester St
leading to Worcester St and the connection to the Rapauni-Shagrock MCR. By continuing South on Manchester St a cyclist can connect to the Heathcote MCR Route at Ferry Rd. Alternatively turning left onto Colombo St will provide a connection to the Papanui Parallel MCR route. This route also crosses the Avon Promenade which provides connectivity to the South for the Quarrymans and Little River MCRs.
3. Shared Path North from Ara on Madras to High

Proposed two way shared cycle path on the east side of Madras Street from St Asaph St to Ara Institute.
Council traffic operations staff have investigated the provision of a contra flow cycle facility on the east side of Madras Street between the new St Asaph Street separated cycle facility and the Ara Institute.
The proposal has a commitment from Ara to complete a connection from the end of the proposed council facility to the entrance to the Ara cycle parking area.

Create a shared path from Ara on the Eastern side of Madras St through to High St. Currently cyclists ride on the footpath. Effectively seal the berm and remove 6 all day car parks outside Ara. Has a preliminary hand drawn scheme and informal agreement with Ara.
4. Latimer Square entry points North and South
Investigate possible cycling entry facility / drop downs to enable cyclists to cross Latimer Square, North to South / visa versa. If cycling across Latimer Square is not permitted then this will be removed from the list. A “cycle heat map” of the City shows that cyclists currently use this as a route. An East / West shared path already exists across Latimer Square.

5. Cranmer Square entry points North and South
Investigate possible cycling entry facility / drop downs to enable cyclists to cross Cranmer Square, North to South / visa versa. A “cycle heat map” of the City shows that cyclists currently use this as a route. An East / West shared path already exists across Latimer Square but if cycling across Cranmer Square is not permitted then this will be removed from the list. Cycling has been implemented across Victoria Square so need to check this.

6. Diamond Paint marks
Wherever cycle loops are installed at traffic signals, there should be suitable diamond marks painted on the road to inform cyclists where to cycle. It is not known how many have yet to be painted but if we are to achieve behaviour change and facilitate correct use of the automation, then we need to give the public the tools required to do the job correctly.

7. Review shared path by Antigua Boat Sheds:

The Antigua bridge is 4.35m wide-not desirable for a shared path in this location, but sufficient. The path between the planter boxes on the north side narrows to 2.5m.

If we modify the planter boxes (the Cancer Society have informally indicated they are happy for us to modify the planters), then a shared pathway width of at least 4.35m can be created (the bridge width) with a centre line and directional arrows on each side.

This particular bridge does have a lot of pedestrian dwelling and viewing over the decks and being close to the hospital there are vulnerable users who have high sensitivity to “close shaves” with passing cyclists.
Parking Details:

8. Signage for Lichfield St Cycle parking and other parking buildings with provision for cycles.
There is an area there to cater for over 100 bikes, currently being used by about 30. No showers but has large toilets to change in and lockers. It is covered by seven security cameras and a prowling security guard and based upon the accessories folk are leaving on their bikes it must be quite secure.
There is no signage for “bike parking” and no promotion.
The area could be modified to cater for at least another 30-40 bikes if current capacity was exceeded.
The area needs promotional signs on Lichfield St (the City Mall is pedestrian only) and marketing.
Investigate other CBD Parking buildings as well.
9. Inner City cycle parking and engagement for locations.
Engage with Inner City stakeholders to understand the desire for cycle parking relating to businesses. These might be a "pallet style" that are lifted into an existing car park or hoops on existing build outs etc. We have some anecdotal requests from businesses for cycle parking in "their car park" but need to canvas the broader City to ensure that we aren't "playing favourites" and consult on the loss of parking. Roughly $12,000 each.

Possible Locations for Moveable On-Street Cycle Corrals in Central City
1. Walker Street location adjacent to dropdown, 4 Walker Street. For use by ABC customers and Anchorage Café, Community Law Canterbury;
New Regent Street; this is becoming quite cluttered with street furniture. While there could be space for one or two individual stands the preference would be to locate an on-street corral at one or other or both ends (ie; Gloucester Street/Armagh Street), subject to engagement with local businesses.

Various cafes eg St Asaph St and Manchester St. These will be visited as part of the “engagement”.

**Additional enhancements for cycle parking in Central City could include;**

1. Installation of Fix It Stand in Lichfield Building Cycle Parking Area
2. Investigate secure cycle parking upgrade at Bus Interchange to maximise usage (using Metro card?)

*Engagement with Central City Businesses will establish demand for using on-street car parking footprint for moveable cycle parking corral (capacity 8 cycles).*
10. Avon Promenade provide additional cycle parking

There is a request for an investigation into the provision of more cycle parking. Staff have done a walk through with Ōtākaro to establish possible locations as follows:

[Diagram of proposed cycle parking locations]
Possible Locations for Moveable On-Street Cycle Corrals on the Promenade:

In front of Pegasus Arms, 14 Oxford Terrace;

In front of Black & White Café, 32 Oxford Terrace;
In the vicinity of Riverside Farmer’s Market Oxford Terrace (x 2);

Corner of Promenade and Worcester Street (demonstration site with intermittent high usages);
Close to the Bridge of Remembrance (3 x 3 existing stands);
On the Terrace (there are existing stands and a desire to retain the visual connection to river; this may be subject to business demand)
Design Elements for Moveable Cycle Corral;
Platform within on-street car park footprint (2m x 5m);

Design element to highlight purpose without need for signage;

Design criteria currently being scoped and costed;
- Vandal-proof design (galvanised or stainless steel stands welded/ bolted onto wooden or galvanised steel base with stainless steel frame (if stands removable, potential to be more flexible space in future/ mixed use parklet)
- Open design given low rainfall in Christchurch
- Tread plate flap to allow kerbside stormwater flow
Universal Design principle for all size bikes/e-bikes; Basic staple design stands with crossbar to allow three points of contact for cycles to security and stability. Optimal spacing of 1.1m

Spacing approx. 1.1m as per Minimum cycle parking dimensions (Christchurch Replacement District Plan)
11. **Covered Cycle parking structure for 60 bikes multi tier**

As per the installation at Wellington City, covered and can have security cameras but requires large footprint. Ideally near toilet / changing facilities. We may not have a suitable location. Cost is over $100,000 but potential advertising reduces the cost to be $70,000 to $80,000.
12. Botanic Gardens northern entry Cycle Parking from car park

Two removable racks of 10 placed upon concrete pads near the car park entrance to the Botanic Gardens entry from Armagh St. These will be an interim solution pending the overarching Botanical Gardens / Car Park work.
Safety Details:

13. **Improve the safety risks associated with the tram tracks on Armagh St from Rolleston Ave to Colombo St.**

This is a natural desire line for cyclists from UniCycle into the City, however it has sections with poor design for safe cycling (tram lines) and features as the worst safety record in the recent tram line cycle interaction survey. Previous cycle lanes in the busier section from Oxford Tce to Colombo St were removed by new street developments under Ōtākaro. This route doesn’t lend itself to the east west demand well for the southern feeder route from Antigua Bridge relative to the other more central options. The proposal is to just mitigate the safety issues associated with the tram tracks at intersections.

The survey project focused on a time span of 2015 to end of Feb 2018 – picking up the post EQ tram operational period and as the inner city travel demand picks up.

Data from the Crash Analysis System (CAS) and Accident Compensation Corporation (ACC) records, along with results of a commissioned public survey were interrogated to better understand the nature of accidents and near-accidents that have occurred since 2015 (i.e. the time from which a full tram loop in the Christchurch CBD was operational after the Canterbury Earthquakes).
Item No.: 7

Attachment A

Item 7

30
Heat map for Tram Track related cycling accidents reported.

CAS had no records, ACC showed 75 claims per year from cycling accidents relating to tram tracks. A specific online survey was developed and publicised to collect information from people who have suffered tram track crashes (or near-crashes) on their bikes since 2015 onwards. The survey responses included 51 accidents (i.e. the person fell off their bike and / or hit the ground or another object) and 35 “near-accidents” Only 12 people who had a tram track cycling accident and 1 who had a near-accident reported their incident to an authority; some of these people reported to more than one authority. Refer to following map points marked “A” for the two locations to be enhanced.
14. Review Oxford Gap and surrounding area for safety issues
A number of safety issues have been highlighted by CCC staff who cycle the area. Now that it is open we need to review the safety audits vs the observations and undertake a walk through.

15. Transitional kerb changes of level
Walk the City looking for areas where there are kerbs where there should be cut downs, where cut downs are too steep etc. eg northern end of Avon Promenade at Armagh St. Need to find them and quantify.
16. Addition of Cycleway push buttons along Manchester St and St Asaph St
The original design of Manchester Street and many other central city cycleways has tried to rely solely on automation for detection (call placement) and removal of cyclist crossing triggers at signalised crossings. The reality is that automation is never a 100% accurate process. Detection and technology issues outside anyone’s control can occur such as devices fail or go out of adjustment and cyclists not being in the right place for detection by the automation devices. The council has been persevering with automation processes due to the value it provides but the reality is that CCC have to change methodology if there is to be a good combination of safety and optimisation.

The automated detection system provided by thermal cameras simply is not reliable enough for consistent and safe operation. They often work fine but even a good site is not a 100%, and a re-think of how automation and manual operation has had to be carried out. In conjunction with that process there is a stronger emphasis on safety in combination with optimisation of limited road space. With those parameters in mind there is a strong need to isolate manual and automation devices so the automation can still work on its own, but if there is a failure of an automation device/system then the manual system of push buttons will override any automation and provide the traveller with a safe and effective alternative. In order to do this signals personalities will also need to be re-written to accommodate the minor operations differences and cycleway manual push buttons will need to be installed. CCC will now be using a standardised manufactured cycle call button which is half the cost of the bespoke units previously used along with other factors such as being more robust and waterproof.

17. Signal lantern heights
The original cycleway signal lanterns within the CBD were going to be a thin small unit that would sit closely to the signal pole and be very unobtrusive. As the rebuild projects have developed there has been a change to a much larger lantern at the request of CCC. The resulting large lantern is now sitting low but is also sitting very proud of the pole and has the ability to scalp a traveller who walks too close to the pole. This is not a desirable situation and could result in harm. It has been highly recommended that CCC review the number of situations where these lanterns are sitting in this position and get the lanterns repositioned to a higher level or consider testing and trialling a change to a “near side” unit to get away from lanterns all together.

18. Antigua / St Asaph signals
We need 2 cycle aspects to control and provide for cyclists traveling in an east – west direction across the southern arm of Antigua Street. 2 cycle push buttons will also be needed to compliment these signal aspects. Need details two new aspects $5k
19. Bus Tracking Issue over cycle hook turn box Lichfield / Manchester

Some form of vertical up stand needs to be provided to guide buses around the left hand rails from Lichfield Street onto Manchester Street. This will also provide a level of protection to any cyclists and pedestrians using the crossing. The tram tracks needed to be considered when developing a solution.

Further to this the cycle hook turn boxes need to be provided to guide northbound cyclists on Manchester Street onto the shared facilities running along the east side of the street.

Please note that the possible extension of the Tram route will require consideration / co-ordination.
20. Tuam Street at Justice Precinct Entrance

41. Tuam Street at Justice Precinct Entrance
Council Resolved CNCL/2019/00074
That the Council:
1. Approves the installation of the detector activated illuminated warning signage on Tuam Street at the accessway to the Justice and Emergency Services Precinct.
2. Approves the improvement of the existing advance signage on the cycleway that warns cyclists of turning vehicles.
3. Approves the installation of supplementary signage to the existing Give Way sign for vehicles that states “turning traffic give way to cyclists” in accordance with clause 4.1 of the Land Transport (Road User) rule 2004.

Councillor Cotter/Councillor Davidson Carried
Councillors East, Keown, Manji, Scandrett and Swiggs requested that their votes against the resolutions be recorded.

To deliver as resolved by Council 11th April 2019 as above.
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**Balance for CBD "parking per engagement"**

- **$1,088,000**
- **$121,000**
- **$1,209,000**
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</tr>
<tr>
<td>14</td>
<td>Safety</td>
<td>Review Oxford Gap and surrounding area for safety issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Accessibility</td>
<td>Cranmer Square entry points North and South</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Accessibility</td>
<td>Latimer Square entry points North and South</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Scheme</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Parking</td>
<td>Covered cycle parking structure for 60 bikes multi tier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>ponder</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Purpose of Report

1.1 The purpose of this report is to inform the Infrastructure, Transport and Environment Committee of the activities undertaken by the Three Waters and Waste Unit, who are responsible for the planning, asset management, operations, maintenance and capital project delivery for all three waters and waste infrastructure. This includes drinking water, wastewater, stormwater, land drainage and solid waste services within the city.

2. Executive Summary

2.1 An update on the Water Supply Improvement programme and the Water Safety Plans is included.

2.2 The last of the water supply connection works at both ends of the Lyttelton road tunnel are complete. This completes the first package of the project which delivers an upgraded water supply main to Lyttelton.

2.3 Battery collection trials started 13th April with positive feedback from the community and management of participating sites. Encouraging uptake with collection containers filling fast at all six sites.

2.4 A significant rain fall event was felt across the city with the greatest rainfall depth on Banks Peninsula with 160 mm recorded at one monitor on 1 – 2 June. Newly constructed and part constructed facilities operated to good effect, particularly in the Heathcote Catchment.

2.5 The CWTP received its certificate confirming that it has successfully implemented an Environmental Management Plan which conforms to the ISO 14001 Standard.

3. Staff Recommendations

That the Infrastructure, Transport and Environment Committee:

1. Receive the information in the Three Waters and Waste April/May report attached.

Attachments

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ITE Report Three Waters and Waste - April May 2019</td>
<td>61</td>
</tr>
</tbody>
</table>

Confirmation of Statutory Compliance

Compliance with Statutory Decision-making Requirements (ss 76 - 81 Local Government Act 2002).
(a) This report contains:
   (i) sufficient information about all reasonably practicable options identified and assessed in terms of their advantages and disadvantages; and
(ii) adequate consideration of the views and preferences of affected and interested persons bearing in mind any proposed or previous community engagement.

(b) The information reflects the level of significance of the matters covered by the report, as determined in accordance with the Council's significance and engagement policy.

### Signatories

<table>
<thead>
<tr>
<th>Author</th>
<th>Helen Beaumont - Acting Head of Three Waters &amp; Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved By</td>
<td>Peter Langbein - Finance Business Partner</td>
</tr>
<tr>
<td></td>
<td>Carolyn Gallagher - Acting General Manager Consent</td>
</tr>
<tr>
<td></td>
<td>ing and Compliance</td>
</tr>
</tbody>
</table>
Three Waters and Waste

APRIL - MAY 2019 REPORT

Christchurch City Council | June 2019
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Overview
This report informs the Committee of progress against the planned activities in the Three Waters and Waste unit for the period ended 31 May 2019.

Consents and Compliance

- There are no outstanding enforcement actions and no significant non-compliance grades.
- A coastal permit has been obtained from Environment Canterbury in May for the erection & placement of flood risk reduction bunds and 50m of rock armouring in Southshore.
- Council has received the decision granting the Comprehensive Stormwater Network Discharge Consent. The consent was granted on 4 June 2019 with a duration of 25 years and is subject to an appeal period of 15 working days.

Health and Safety
There were 132,060 hours worked in May and 136,167 in April, this includes Transport.

In April there were three lost time injuries, with 11 lost days.

- A contractor, with an already injured leg, rolled his ankle and fell onto the ground whilst entering a truck
- A contractor hit his head when getting into an excavator and suffered a concussion
- A contractor turned right in his vehicle and didn’t see another vehicle approaching and hit it; the driver was taken to the hospital for a checkup.

There were no lost day injuries in May.

Please see appendix 1 for the detailed statistics and the measures of LTIFR (lost time injury frequency rate) and TRIFR (total recordable injury frequency rate) of April and May.
Finance

MANAGE TO BUDGET

Operating costs – The May forecast to completion is indicating a favourable position $1.53m at year end, with a forecast carry forward of $4.1m for dredging in the Heathcote River and $0.5m for the Multi Hazard Analysis. If the carry forwards are not approved, it will result in an unfavourable variance of $1.1m for the year. Maintenance costs included in the current forecast have been set at a level in order to maintain current levels of service. Chlorination costs are continuing beyond the end of the financial year due to delays in the well head improvement programme. There is a risk that the maintenance costs could increase further due to increased breaks and higher costs in maintaining wastewater networks and treatment operations. The contracted maintenance costs are being closely managed to minimise the financial impact on the unit.

Trade waste revenue is down $1.74m YTD due to lower volumes and chargeable solids. This is offset by revenue from the Burwood landfill which is $1.252m higher than plan YTD.

<table>
<thead>
<tr>
<th>Year to Date $000's</th>
<th>Activity Summary</th>
<th>Year End $000's</th>
<th>Variance</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
<td></td>
<td>Budget</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8,626</td>
<td>Recyclable Materials Kerbside Collection</td>
<td>9,132</td>
<td>9,188</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Recyclable Materials Collection &amp; Processing</td>
<td>7,615</td>
<td>6,188</td>
<td>98</td>
</tr>
<tr>
<td>5,296</td>
<td>Residual Waste Kerbside Collection</td>
<td>5,735</td>
<td>4,430</td>
<td>(132)</td>
</tr>
<tr>
<td>7,863</td>
<td>Residual Waste Disposal &amp; Transport</td>
<td>8,716</td>
<td>8,294</td>
<td>(423)</td>
</tr>
<tr>
<td>239</td>
<td>Landfill Gas Capture &amp; Treatment</td>
<td>280</td>
<td>250</td>
<td>30</td>
</tr>
<tr>
<td>(862)</td>
<td>Refuse Transfer Stations</td>
<td>(864)</td>
<td>(718)</td>
<td>(55)</td>
</tr>
<tr>
<td>(2,069)</td>
<td>Operation &amp; Care of Closed Landfills</td>
<td>(1,837)</td>
<td>(509)</td>
<td>(1,320)</td>
</tr>
<tr>
<td>10,710</td>
<td>Residual Waste Collection &amp; Disposal</td>
<td>12,250</td>
<td>12,848</td>
<td>598</td>
</tr>
<tr>
<td>7,830</td>
<td>Organics Kerbside Collection</td>
<td>8,206</td>
<td>8,490</td>
<td>(284)</td>
</tr>
<tr>
<td>3,774</td>
<td>Organics Processing Inc Composting Plant</td>
<td>3,829</td>
<td>4,233</td>
<td>(405)</td>
</tr>
<tr>
<td>11,404</td>
<td>Organic Material Collection &amp; Composting</td>
<td>12,164</td>
<td>12,073</td>
<td>91</td>
</tr>
<tr>
<td>21,285</td>
<td>Collecting Wastewater from Properties</td>
<td>22,611</td>
<td>20,180</td>
<td>(2,431)</td>
</tr>
<tr>
<td>21,285</td>
<td>Wastewater Collection</td>
<td>22,611</td>
<td>20,180</td>
<td>(2,431)</td>
</tr>
<tr>
<td>6,500</td>
<td>Treat &amp; Dispose of Wastewater Collected</td>
<td>6,746</td>
<td>6,416</td>
<td>(330)</td>
</tr>
<tr>
<td>6,868</td>
<td>Laboratory Services - Wastewater</td>
<td>148</td>
<td>(110)</td>
<td>(258)</td>
</tr>
<tr>
<td>6,856</td>
<td>Wastewater Treatment &amp; Disposal</td>
<td>6,856</td>
<td>4,500</td>
<td>(2,356)</td>
</tr>
<tr>
<td>17,401</td>
<td>Provide Quality Water to Properties</td>
<td>17,608</td>
<td>15,105</td>
<td>(2,503)</td>
</tr>
<tr>
<td>17,401</td>
<td>Water Supply</td>
<td>17,808</td>
<td>15,105</td>
<td>(2,703)</td>
</tr>
<tr>
<td>10,679</td>
<td>Storm Water Drainage</td>
<td>11,499</td>
<td>14,132</td>
<td>2,633</td>
</tr>
<tr>
<td>10,679</td>
<td>Stormwater Drainage</td>
<td>11,499</td>
<td>14,132</td>
<td>2,633</td>
</tr>
<tr>
<td>2,312</td>
<td>Flood Protection &amp; Control Works</td>
<td>3,267</td>
<td>2,263</td>
<td>(1,004)</td>
</tr>
<tr>
<td>2,312</td>
<td>Flood Protection &amp; Control Works</td>
<td>3,267</td>
<td>2,263</td>
<td>(1,004)</td>
</tr>
<tr>
<td>2,560</td>
<td>Three Waters Asset Management</td>
<td>2,798</td>
<td>2,298</td>
<td>(490)</td>
</tr>
<tr>
<td>4,757</td>
<td>PlanProg Provision of Future Infrastructure</td>
<td>5,349</td>
<td>3,717</td>
<td>(1,632)</td>
</tr>
<tr>
<td>(20)</td>
<td>Horizontal Infrastructure</td>
<td>(20)</td>
<td>-20</td>
<td>0%</td>
</tr>
<tr>
<td>6,965</td>
<td>Three Waters Asset Mgmt &amp; Planning</td>
<td>8,327</td>
<td>6,008</td>
<td>(2,319)</td>
</tr>
<tr>
<td>96,215</td>
<td>Reconciliation to Controllable Net Cost</td>
<td>101,733</td>
<td>102,887</td>
<td>1,154</td>
</tr>
</tbody>
</table>

Note: Reconciliation shown as positive.
Capital Delivery – At the end of May, Three Waters and Waste has delivered $107.5m, or 70% of its capital programme budget of $153.7m. The forecast to year end is currently under budget at $133.6m down from $147.3m at last report. The main drivers for this are:

- Difficult ground conditions were encountered on several projects in the investigation phase, extending the design time and delaying progress.
- The fast track nature of the well head security improvement programme diverted several project managers away from other projects thereby delaying progress.
- High water use during summer meant that fewer wells could be taken offline than planned at any one time delaying the programme of works.
- Contingency (5% to 10% of total budget) was included in forecasts in February but is now excluded from forecast budgets.

![Three Waters Capital Programme Performance Report](image)

Water Supply Improvement Programme

The city has 93 pump stations and 140 operating wells. Four relatively new pump stations (11 wells signed off following minor remedial works) have always operated without chlorination – Keyes, Estuary, Prestons and Gardiners.

Chlorine has been turned off at a further 11 pump stations as works have been completed and/or any remaining unsecure wells have been isolated from the network. Together these pump stations provide approximately one third of the city’s water supply.

**WELL HEAD REMEDIATION**

As at 14 June 2019, 59 wells at 30 pump stations have been signed off as secure.

The following table lists the wells that have been signed off as secure and notes the total number of wells at each of the pump stations.
<table>
<thead>
<tr>
<th>Pump Station &amp; Supply Zone</th>
<th>Well heads Secure / Total</th>
<th>Remedial Works Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kainga Brooklands</td>
<td>1 / 1</td>
<td>Raise well head</td>
</tr>
<tr>
<td>Brooklands</td>
<td>1 / 2</td>
<td>Raise well head</td>
</tr>
<tr>
<td>Brooklands</td>
<td>1 / 2</td>
<td>Raise well head</td>
</tr>
<tr>
<td>Blighs Central</td>
<td>1 / 2</td>
<td>Minor works to make above ground well head secure</td>
</tr>
<tr>
<td>Grassmere Central</td>
<td>1 / 3</td>
<td>Raise well head</td>
</tr>
<tr>
<td>Hillmorton Central</td>
<td>1 / 3</td>
<td>Raise well head</td>
</tr>
<tr>
<td>Hills Central</td>
<td>3 / 3</td>
<td>Minor works to make above ground well heads secure and raise one well head</td>
</tr>
<tr>
<td>Kerrs Central</td>
<td>2 / 2</td>
<td>Interim works to below ground well heads</td>
</tr>
<tr>
<td>Sydenham Central</td>
<td>2 / 4</td>
<td>Complete headworks on new wells</td>
</tr>
<tr>
<td>Trafalgar Central</td>
<td>1 / 3</td>
<td>Minor works to make above ground well head secure</td>
</tr>
<tr>
<td>Worcester Central</td>
<td>1 / 2</td>
<td>Raise well head</td>
</tr>
<tr>
<td>St Johns Central/Ferrymead</td>
<td>2 / 3</td>
<td>Minor works to make above ground well head secure and raise well head</td>
</tr>
<tr>
<td>Woolston Central/Ferrymead</td>
<td>3 / 3</td>
<td>Minor works to make above ground well head secure and interim works to below ground well heads</td>
</tr>
<tr>
<td>Tanner Rocky</td>
<td>1 / 2</td>
<td>Minor works to make above ground well head secure</td>
</tr>
<tr>
<td>Picton Riccarton</td>
<td>1 / 2</td>
<td>Raise well head</td>
</tr>
<tr>
<td>Estuary Central/Rawhiti</td>
<td>2 / 2</td>
<td>Minor works to make above ground well head secure</td>
</tr>
<tr>
<td>Keyes Central/Rawhiti</td>
<td>3 / 3</td>
<td>Minor works to make above ground well head secure</td>
</tr>
<tr>
<td>Lake Terrace Central/Rawhiti</td>
<td>3 / 3</td>
<td>Minor works to make above ground well heads secure and raise one well head</td>
</tr>
<tr>
<td>Auburn Northwest</td>
<td>1 / 2</td>
<td>Raise well head</td>
</tr>
<tr>
<td>Burnside North West</td>
<td>6 / 6</td>
<td>Minor works to make above ground well heads secure and raise below ground well head</td>
</tr>
<tr>
<td>Crosbie North West</td>
<td>2 / 3</td>
<td>Minor works to make above ground well head secure and raise well head</td>
</tr>
<tr>
<td>Farrington North West</td>
<td>5 / 5</td>
<td>Minor works to make above ground well heads secure and raise one well head</td>
</tr>
<tr>
<td>Gardiners North West</td>
<td>2 / 2</td>
<td>New pump station</td>
</tr>
<tr>
<td>Grampian North West</td>
<td>3 / 3</td>
<td>Minor works to make above ground well head secure and raise below ground well heads</td>
</tr>
<tr>
<td>Jeffreys</td>
<td>1 / 2</td>
<td>Minor works to make above ground well head secure</td>
</tr>
<tr>
<td>North West</td>
<td>Thompsons North West</td>
<td>1 / 2</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Prestons Parklands</td>
<td>3 / 4</td>
<td>Minor works to make above ground well head secure</td>
</tr>
<tr>
<td>Parklands Parklands</td>
<td>2 / 3</td>
<td>Interim works to below ground well heads</td>
</tr>
<tr>
<td>Denton West</td>
<td>2 / 5</td>
<td>Raise well heads</td>
</tr>
<tr>
<td>Dunbars West</td>
<td>3 / 5</td>
<td>Raise well heads</td>
</tr>
</tbody>
</table>

The design work is complete, contractors appointed and construction is timetabled or underway for a further 60 wells.

ALTERNATIVE DISINFECTION

The construction work for ultraviolet light disinfection is underway at Main Pumps in the Central supply zone (supplies approximately 5% of the city’s water). The reactors have been installed and commissioning is expected to be completed by August 2019.

REDUCING THE CHLORINE DOSE

A reduction in the chlorine dose, from 1 part per million (ppm) to at least 0.5 ppm, has been agreed with the Drinking Water Assessor where we have at least two minutes’ contact time before the first consumer on the network.

The chlorine dose has been lowered at 28 pump stations across the city:

- Auburn, Avonhead, Crosbie and Redwood in the North West supply zone
- Aldwins, Hillmorton, Kerrs, Main Pumps, Mays, Montreal, Palatine, Sydenham, Thorrington and Worcester in Central
- St Johns and Woolston in Ferrymead/Lyttelton
- Picton and Tara in Riccarton
- Tanner in Rocky Point
- Aston in Rawhiti
- Mairehau, Marshlands and Parklands in Parklands
- Denton, Dunbars, Sockburn and Wilmers in West
- And in Wainui.
### DRINKING WATER QUALITY MONITORING

Council owns and operates the following drinking water supplies:

<table>
<thead>
<tr>
<th>Supplies &amp; Zones</th>
<th>Population</th>
<th>Community Code</th>
<th>Water Source</th>
<th>Water Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHRISTCHURCH CITY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Christchurch Central</td>
<td>235,500</td>
<td>CHR001</td>
<td>Non-secure groundwater</td>
<td>None</td>
</tr>
<tr>
<td>Central</td>
<td>185,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rocky Point</td>
<td>2,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parklands</td>
<td>16,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riccarton</td>
<td>10,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>42,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northwest Christchurch</td>
<td>80,000</td>
<td>NOR012</td>
<td>Non-secure groundwater</td>
<td>None</td>
</tr>
<tr>
<td>Brooklands/Kainga</td>
<td>1,000</td>
<td>BRO012</td>
<td>Non-secure groundwater</td>
<td>None</td>
</tr>
<tr>
<td>BANKS PENINSULA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lyttelton Harbour Basin</td>
<td>4,450</td>
<td>LYT001</td>
<td>Non-secure groundwater</td>
<td>None</td>
</tr>
<tr>
<td>Lyttelton</td>
<td>2,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diamond Harbour</td>
<td>1,200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Governors Bay</td>
<td>750</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akaroa</td>
<td>1,350</td>
<td>AKAO01</td>
<td>Surface and groundwater</td>
<td>Membrane</td>
</tr>
<tr>
<td>Birdlings Flat</td>
<td>150</td>
<td>BIR001</td>
<td>Non-secure groundwater</td>
<td>UV</td>
</tr>
<tr>
<td>Duvauchelle</td>
<td>250</td>
<td>DUV001</td>
<td>Surface water</td>
<td>UV</td>
</tr>
<tr>
<td>Little River</td>
<td>240</td>
<td>LIT001</td>
<td>Surface and groundwater</td>
<td>UV</td>
</tr>
<tr>
<td>Takamatua</td>
<td>150</td>
<td>TAK002</td>
<td>Surface and groundwater</td>
<td>Membrane</td>
</tr>
<tr>
<td>Wainui</td>
<td>200</td>
<td>WAI138</td>
<td>Secure groundwater</td>
<td>None</td>
</tr>
<tr>
<td>Pigeon Bay</td>
<td>26</td>
<td>PIG001</td>
<td>Surface water</td>
<td>UV</td>
</tr>
</tbody>
</table>

Escherichia coli water quality monitoring

552 samples were collected in April and 619 samples in May to monitor for E. coli. The following charts provide a further breakdown by water supply zone.
E. Coli transgressions

One transgression event occurred in April – one sample with E. coli present. One transgression event occurred in May – one sample with E. coli present.

- 18 April 2019 – 159 Kainga Road, Brooklands / Kainga zone:
  The sample was taken from an outside tap at the community centre.
  A total of 15 E. coli samples were taken as part of the sanitary survey and investigation.
  E. coli positive samples associated with this event:

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>E. Coli Result (MPN/100ml)</th>
<th>E. Coli MAV (MPN/100ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/4/2019</td>
<td>159 Kainga Rd (Community Centre)</td>
<td>1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

On 7 May 2019 Council received a letter from the Drinking Water Assessor advising that the transgression had been followed up inadequately which represented a potential non-compliance with the DWSNZ and also a potential breach with the Health Act 1956 – section 69ZF: Duty to take remedial action if drinking-water standards are breached. (This section requires the water-supplier to take all practicable steps to carry out the appropriate remedial action set out in the drinking-water standards).

Council’s response dated 31 May 2019 provided assurance to the Drinking Water Assessor that changes and improvements to existing procedures had been identified and were being implemented.
2 May 2019 – Pigeon Bay water treatment plant:
As the treatment plant was not in service on the sampling day it was necessary to start the treatment plant prior to the sampling technician arriving on site. The maintenance contractor did not follow due process, manually opened the feed valve at the plant and only ran the plant for a very short time prior to the sampling. This resulted in inadequate UV intensity and only partial treatment of the raw water.
A total of 38 E. coli samples were taken as part of the sanitary survey and investigation.
E. coli positive samples associated with this event:

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>E. Coli Result (MPN/100ml)</th>
<th>E. Coli MAV (MPN/100ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/5/2019</td>
<td>Pigeon Bay Treatment Plant</td>
<td>2</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

This incident triggered a review of processes and procedures between Council and the maintenance contractor.

Temporary Chlorination and Chlorine Monitoring

In April 2018 Council started to measure the Free Available Chlorine (FAC) in all compliance monitoring samples collected from the distribution system in Christchurch City and the Lyttelton Harbour Basin. These random network samples are useful for monitoring the potential for customer complaints, whereas Citycare’s FAC samples – which are taken at points in the immediate vicinity of the dosing sites approximately 1 minute and / or 2 minutes downstream from the dosing points – confirm that the chlorine dosing meets the chlorine residual target.
THE PROCESS OF RE-CONFIRMING GROUNDWATER SECURITY UNDER DWSNZ 2005 (REVISED 2018)

DWSNZ section 4.4 states that bore water is considered secure when it can be demonstrated that contamination by pathogenic organisms is unlikely because the bore water is:

- Not directly affected by surface or climate influences, as demonstrated by compliance with bore water security criterion 1 (bore water must not be directly affected by surface or climatic influences) and 3 (E. coli must be absent from bore water).
- Abstracted from a bore head that provides satisfactory protection, bore water security criterion 2 (bore head must provide satisfactory protection).

Bore water security criterion 1: bore water must not be directly affected by surface or climatic influences

Council will demonstrate the absence of surface influences by groundwater age determinations and hydrogeological modelling.

- 17 groundwater samples from various aquifers were collected in July and September 2017 as part of a joint agency project (ECan, CCC and GNS) and analysed by GNS. A GNS report on groundwater age was issued in June 2018.
- A further 7 groundwater samples were collected in late October and submitted to GNS for analysis. The analytical work associated with groundwater age
determinations takes more than six months. The results and associated report is expected in early July 2019.

- Council is planning to collect a further 76 groundwater samples in July and August 2019 for groundwater age determinations. GNS will provide training on sample collection and carry out the analytical work.

- CCC has engaged Aqualinc to provide groundwater modelling services. Currently the modelling approach is being reviewed by a panel of modelling experts (staff from ECan and ESR). This peer review is supported by the DWA. Once the methodology has been agreed upon modelling will commence which will take approximately 10-12 months. Groundwater age data determined by sampling will be incorporated in the modelling.

- Upon successful completion of the modelling a report will be issued to the DWA.

**Bore water security criterion 2: bore head must provide satisfactory protection**

Council’s Well Head Security Improvement Programme (WHSIP) is upgrading the Christchurch water supply to meet the existing Drinking Water Standards and to provide future proofing for likely more stringent DWSNZ requirements. The programme includes:

- Conversion of wellheads to above ground well heads to further improve their security and to make them easier and safer to access for maintenance

- Drilling of new / replacement wells

- UV treatment at Main Pumps

- Other work to provide protection from contamination

- Wellhead security assessments will be carried out by a qualified expert to confirm that the newly converted wellheads meet DWSNZ bore water security criterion 2.

**Bore water security criterion 3: Escherichia coli must be absent from bore water**

This criterion is satisfied by Council’s ongoing drinking water monitoring programme.
Water safety plans (WSP)

The Drinking Water Assessor (DWA) carried out an implementation audit of the Christchurch City and Lyttelton Harbour Basin WSP and issued a formal report which includes findings and recommendations. Work is underway to improve processes relating to the reporting of regular reservoir and wellhead inspections.

The DWA also undertook an implementation audit of the WSP for Akaroa, Pigeon Bay, Takamatua and Wainui and issued an audit report in January which includes findings and recommendations. Work is underway to improve processes relating to the reporting of regular reservoir and wellhead inspections.

In December, the Ministry of Health released the ‘New Zealand Water Safety Plan Framework’. While the Framework outlines the Ministry of Health’s expectations for the content of a water supplier’s WSP, it provides no guidance on how these expectations can be met. Some high level guidance was provided in the ‘Handbook for Preparing a Water Safety Plan’ which was released in May 2019.

It is the Ministry of Health and DWA’s expectation that all CCC water safety plans be updated in 2019 to align them with the new framework. CCC staff met with the DWA and Ministry of Health representatives on 18 January to discuss a plan of action. The aim is to have all water safety plans updated in 2019. This is a very tight timeframe and only achievable if adequate support and information is provided by key staff and the maintenance contractor.

To date, water safety plans for Little River and Duvauchelle have been submitted to the DWA for review and approval. Feedback on the Little River plan has been received and incorporated into the drafts where necessary.

Water Safety Plan Register (does not include 2019 updates as they have not yet been approved or are still in draft)

<table>
<thead>
<tr>
<th>Water Supply</th>
<th>Supply Population</th>
<th>Community Code</th>
<th>Current WSP Status</th>
<th>DWA WSP Approval Date</th>
<th>Number of Non-Conformances</th>
<th>Number of Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Christchurch / Lyttelton Harbour Basin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Christchurch Central</td>
<td>255,500</td>
<td>CHR001</td>
<td>Approved</td>
<td>9/03/2018</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Northwest Christchurch</td>
<td>80,000</td>
<td>NOR012</td>
<td>Approved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brooklands/Kainga</td>
<td>1,600</td>
<td>BRO012</td>
<td>Approved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lyttelton Harbour Basin</td>
<td>4,450</td>
<td>LYT001</td>
<td>Approved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banks Peninsula</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akaroa</td>
<td>1,350</td>
<td>AKA001</td>
<td>Approved</td>
<td>27/09/2017</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Birdlings Flat</td>
<td>150</td>
<td>BIR001</td>
<td>Approved</td>
<td>29/09/2017</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Duvauchelle</td>
<td>250</td>
<td>DUV001</td>
<td>Approved</td>
<td>14/05/2014</td>
<td>-</td>
<td>3</td>
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<tr>
<td>Little River</td>
<td>240</td>
<td>LIT001</td>
<td>Approved</td>
<td>10/04/2014</td>
<td>-</td>
<td>3</td>
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<tr>
<td>Takamatua</td>
<td>150</td>
<td>TAK002</td>
<td>Approved</td>
<td>1/07/2014</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Wainui</td>
<td>200</td>
<td>WAI138</td>
<td>Approved</td>
<td>26/06/2014</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Pigeon Bay</td>
<td>26</td>
<td>PIG001</td>
<td>Approved</td>
<td>1/06/2014</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
### Action tracker for Water Safety Plan Non-Conformances and recommendations

<table>
<thead>
<tr>
<th>Water Safety Plan</th>
<th>Non-Conformance</th>
<th>DWA Comments / Details of Non-Conformance / Recommendation (from DWA implementation audit reports)</th>
<th>CCC Response to DWA Comments on Non-Conformances and Recommendations (CCC comments are recorded in the signed Agreement Sheets which were submitted to the DWA as part of the implementation audit process)</th>
<th>Further Action Required?</th>
<th>Next Steps and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christchurch Central Northwest Christchurch Brooklands / Kainga Lyttelton Harbour Basin</td>
<td>Non-Conformance 1</td>
<td>No evidence was provided to indicate that routine ‘visual checks’ of well heads are being undertaken. Such a programme should ensure that the range of factors that could contribute toward a contamination risk are considered and the checks and actions taken should be recorded.</td>
<td>Council and Citycare are working on a more robust reporting mechanism for visual inspections. The paper check sheet will be replaced with an electronic check sheet which will capture more details and actions. This new check sheet will be rolled out to the below-ground well head inspection rounds first and then modified for the checks of above-ground well heads as well. Please refer to the attached draft check sheet. The timeframe for implementing the check sheet is within a 2 weeks for below-ground wellheads and within 3-4 weeks for above-ground wellheads.</td>
<td>Yes</td>
<td>Review CCC data collected so far. Ensure electronic checkheets are kept up to date (ongoing). Discussions around Gardiners bese maintenance plans may have an impact on this. Incorporate requirements in new maintenance contract.</td>
</tr>
<tr>
<td>Christchurch Central Northwest Christchurch Brooklands / Kainga Lyttelton Harbour Basin</td>
<td>Non-Conformance 2</td>
<td>An updated risk matrix for the chlorination operation needs to be provided to the DWA as it is considered to be part of the WSP. The updated chlorination risk matrix is attached to this letter which should resolve this non-conformance. Citycare’s document ‘Contractors Plan - Christchurch Temporary Chlorination’ can be provided on a USB stick, as offered at the implementation site visit.</td>
<td></td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>Christchurch Central Northwest Christchurch Brooklands / Kainga Lyttelton Harbour Basin</td>
<td>Non-Conformance 3</td>
<td>The CCP for Reverse Flow at Pump Stations should be reconsidered; water is already within the distribution zone and reverse flow is only alarmed at some pump stations. While this CCP may not fully meet the definitions of a CCP due to CCC pump stations not having permanent treatment processes Council still considers the CCP to be an important operational factor and barrier to contamination. CCC Networks Operations are in the process of drafting procedure ‘WSSC Water Safety Plan Critical Control Point Monitoring’. The purpose of this procedure is to document how to monitor the CCPs described in the Christchurch City and Lyttelton Harbour Basin Water Safety Plan. Please refer to the attached draft document. A gap analysis is currently being carried out to identify areas where critical equipment is missing or not working. This gap analysis is due to be completed by 30 November 2018. The next step will be to install the missing equipment and change SCADA monitoring parameters. The timeframe is heavily dependent on finding availability but likely to be in the next LTP round, or possibly to be addressed as part of the WHSP works programme.</td>
<td>Yes</td>
<td>Review CCP as part of new WSP update.</td>
<td></td>
</tr>
<tr>
<td>Christchurch Central Northwest Christchurch Brooklands / Kainga Lyttelton Harbour Basin</td>
<td>Non-Conformance 4</td>
<td>Ensure that regular inspections are undertaken (and recorded) of reservoirs and suction tanks at a frequency and coverage that enable proactive management of potential contamination risks.</td>
<td>The new maintenance contract 2020 is currently being rewritten and new service requirements and information will be included to address this. Citycare has existing SOPs for reservoir ROV camera inspections, reservoir disinfection and monthly reservoir inspections. These SOPs will be reviewed to ensure that more emphasis is placed on proactive management of potential contamination risks.</td>
<td>Yes</td>
<td>Review CCC’s reservoir related SOPs and amend as necessary. Incorporate requirements in new maintenance contract.</td>
</tr>
<tr>
<td>Christchurch Central Northwest Christchurch Brooklands / Kainga Lyttelton Harbour Basin</td>
<td>Non-Conformance 5</td>
<td>Stated re-registration of water carrier by Citycare has not been undertaken.</td>
<td>CCC Procurement Team is currently looking at options to negotiate supply agreements with registered water carriers to provide the reactive service directly, providing safety of service. Timeframe: TBC as the supply agreement needs to be negotiated as per Council’s procurement processes.</td>
<td>Yes</td>
<td>Selective tender underway, closes early March.</td>
</tr>
<tr>
<td>Christchurch Central Northwest Christchurch Brooklands / Kainga Lyttelton Harbour Basin</td>
<td>Recommendation 1</td>
<td>Christchurch City Council should ensure that all contractors working within the wider drinking water programmes are aware of their responsibilities (and liabilities) and clearly ‘own’ the safety of the water supply.</td>
<td>This will be communicated to the maintenance contractor via regular contract meetings.</td>
<td>No</td>
<td>Ongoing review of contractor performance.</td>
</tr>
<tr>
<td>Akaroa</td>
<td>Non-Conformance 1</td>
<td>There is no evidence of visual observations of catchment intakes being undertaken as described in the WSP risk tables.</td>
<td>Council and Citycare are working on a more robust reporting mechanism for visual inspections. An electronic check sheet is currently being developed which will capture more details and actions. Please refer to the attached draft check sheet. The timeframe for implementing the check sheet is 1 March 2019.</td>
<td>Yes</td>
<td>Review checksheet, review CCC data collected so far. Ensure electronic checkheets are kept up to date. Incorporate requirements in new maintenance contract.</td>
</tr>
<tr>
<td>Akaroa</td>
<td>Non-Conformance 2</td>
<td>No evidence was provided to demonstrate that the improvement schedule item of annually reviewing the response to alarms has been undertaken.</td>
<td>Due to the multiple alarm notification methods and complex crossover of response responsibilities there is no current formal SOP in place. A SOP will be drafted which will include information on: what alarms are received and by which method (e.g. CCC Call centre, direct from SCADA, by fax, by phone call, job direct to phone etc.), which department is responsible for responding and escalating hierarchical responsibility. This process will be reviewed annually for effectiveness and opportunities for improvement. The first draft SOP will be completed by 1 March 2019.</td>
<td>Yes</td>
<td>Review CCC’s draft SOP and amend as necessary. Incorporate requirements in new maintenance contract.</td>
</tr>
<tr>
<td>Akaroa</td>
<td>Non-Conformance 3</td>
<td>The information provided does not demonstrate that the backflow risks for Akaroa are controlled as described in the WSP.</td>
<td>The Akaroa water supply system is an on-demand supply which means that there are no static water storage tanks. There are 4 commercial properties on Council’s Warrant of Fitness database which are required to have containment devices with minimum protection for low, medium and high risks. Council does not test privately owned backflow devices. Under the building Warrant of Fitness process (<a href="https://www.ccc.govt.nz/consents-and-licences/building">https://www.ccc.govt.nz/consents-and-licences/building</a>) the property owners are required to get their backflow prevention device tested annually. The test results are recorded in the WoF database. Currently there is no mechanism for the 3 Waters Waste Unit to easily retrieve backflow prevention information from the WoF database. This has been flagged as requiring corrective action. A timeframe for implementation is unknown as this requires the development of an IT system to ensure all data is collected and reported on. This has been flagged as a priority.</td>
<td>Yes</td>
<td>Escalate to senior management, commence discussions with Building Consent Unit.</td>
</tr>
<tr>
<td>Location</td>
<td>Recommendation</td>
<td>Details</td>
<td>Status</td>
<td></td>
<td></td>
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<tr>
<td>-----------</td>
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<td></td>
</tr>
<tr>
<td>Akaroa</td>
<td>Recommendation 1</td>
<td>Consider a system of recording on going professional training that the current system does not capture. This is often 'one off' in nature and could include training given around new plant or equipment.</td>
<td>Yes</td>
<td>Periodically request and review training records.</td>
<td></td>
</tr>
<tr>
<td>Akaroa</td>
<td>Recommendation 2</td>
<td>Include risks associated with those accessing the water from the raw water lines in the next revision of the WSP.</td>
<td>Yes</td>
<td>Add to Akaroa WSP risk register.</td>
<td></td>
</tr>
<tr>
<td>Akaroa</td>
<td>Recommendation 3</td>
<td>Include the calibration of the UVA meter with other calibrations undertaken at the plant.</td>
<td>Yes</td>
<td>Periodically request and review records.</td>
<td></td>
</tr>
<tr>
<td>Akaroa</td>
<td>Recommendation 4</td>
<td>Including explanations within WaterOutlook reporting for events or unusual results is encouraged.</td>
<td>Yes</td>
<td>Periodically review data.</td>
<td></td>
</tr>
<tr>
<td>Duvauchelle</td>
<td>Recommendation 1</td>
<td>Operational staff should receive some training in the identification of cyanobacteria to ensure that they can be usefully vigilant when inspecting the intake and immediately upstream over summer months.</td>
<td>Yes</td>
<td>Ensure CCL implement cyanobacteria management plan.</td>
<td></td>
</tr>
<tr>
<td>Duvauchelle</td>
<td>Recommendation 2</td>
<td>Prepare a procedure specific for Duvauchelle (or potentially generally applicable to all Banks Peninsula surface supplies) that outlines what needs to be considered when a high turbidity event occurs and potentially necessitates the use of an alternative source or tankered water.</td>
<td>Yes</td>
<td>Check with CCL if such a SOP already exists, and if not, request SOP to be drafted.</td>
<td></td>
</tr>
<tr>
<td>Duvauchelle</td>
<td>Recommendation 3</td>
<td>Once City Care have initiated a programme of standardisation and verification of line and manual turbidity meters the DWA should be contacted to approve the personnel and procedures used.</td>
<td>Yes</td>
<td>Discuss with CCL.</td>
<td></td>
</tr>
<tr>
<td>Little River</td>
<td>Recommendation 1</td>
<td>It is recommended that the Water Safety Plan is linked to the Councils Climate Change documents for its monitoring.</td>
<td>Yes</td>
<td>Update all CCC WSPs.</td>
<td></td>
</tr>
<tr>
<td>Little River</td>
<td>Recommendation 2</td>
<td>Council should ensure that standard operating procedures (SOPs) for the plant are stored onsite in a readily accessible and indexed form.</td>
<td>Yes</td>
<td>Check and implement (once SOPs have been updated). This applies to all TP and pump stations.</td>
<td></td>
</tr>
<tr>
<td>Little River</td>
<td>Recommendation 3</td>
<td>There should be a copy of the latest version of the Water Safety Plan on site, so that the operator can refer to it during the course of his work.</td>
<td>Yes</td>
<td>Check and implement (once WSPs have been updated). This applies to all TP and pump stations.</td>
<td></td>
</tr>
<tr>
<td>Takamatua</td>
<td>Non-Conformance 1</td>
<td>No regular inspections of the intake or settlement tanks are undertaken as described in the WSP. It should also be confirmed that both the surge and sand filter tanks are now used as settlement tanks.</td>
<td>Yes</td>
<td>Review checklist, review CCL data collected so far. Ensure electronic checkheets are kept up to date. Incorporate requirements in new maintenance contract. Confirm that the surge and sand filter tanks are now used as settlement tanks and are checked regularly as well.</td>
<td></td>
</tr>
<tr>
<td>Takamatua</td>
<td>Recommendation 1</td>
<td>The revised WSP should specify in greater detail the monitoring and inspection regimes which are used to identify and control risks (at reservoirs).</td>
<td>Noted. This will be incorporated in the next revision.</td>
<td>Add to WSP. Requires discussion with wider WSP working group.</td>
<td></td>
</tr>
<tr>
<td>Takamatua</td>
<td>Recommendation 2</td>
<td>Include Takamatua distribution as a sampling location for checking free available chlorine (FAC).</td>
<td>This has been implemented as of January 2019.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wainui</td>
<td>Non-Conformance 1</td>
<td>Evidence was not provided to demonstrate that any properties that present a recognised backflow risk have appropriate backflow installed that is tested annually.</td>
<td>Yes</td>
<td>Escalate to senior management, commence discussions with Building Consent Unit.</td>
<td></td>
</tr>
<tr>
<td>Pigeon Bay</td>
<td>Non-Conformance 1</td>
<td>Intake inspections, including the setting tanks, are not undertaken as described in the WSP. Council and Citycare are working on a more robust reporting mechanism for visual inspections. An electronic check sheet is currently being developed which will capture more details and actions. Please refer to the attached draft check sheets. The timeframe for implementing the check sheet is 1 March 2019.</td>
<td>Yes</td>
<td>Review check sheet, review CCL data collected so far. Ensure electronic check sheets are kept up to date. Incorporate requirements in new maintenance contract.</td>
<td></td>
</tr>
<tr>
<td>Pigeon Bay</td>
<td>Non-Conformance 2</td>
<td>The improvement schedule item regarding on-going checking of air gaps in onsite tanks has not been undertaken. All residential connections are restricted and include a non-return valve in the connection isolation valve. CCC has no mechanisms to check air gaps in privately owned tanks on private property. CCC checks the restrictors every 2 years, not annually as stated in the WSP, in line with the water meter reading cycles in on-demand water supplies. This information will be updated in the WSP. As an improvement item we will supply the residents / property owners with a pamphlet that outlines information about water safety and how to check that the tank has an air gap. This pamphlet will be drafted by mid-March 2019 and submitted to the DWA for comments. We will also research whether the current restricted water connection assembly could be modified to include a dual check valves instead of the existing single non-return valve. This will require careful consideration as to the practicality of such an installation, and associated head losses.</td>
<td>Yes</td>
<td>Draft pamphlet. Review restricted connection assembly.</td>
<td></td>
</tr>
<tr>
<td>Pigeon Bay</td>
<td>Recommendation 1</td>
<td>Ensure that cartridge filters do meet the specific required for Drinking water Standards compliance. Citycare has been notified of this requirement.</td>
<td>No</td>
<td>Periodically request and review records.</td>
<td></td>
</tr>
<tr>
<td>Pigeon Bay</td>
<td>Recommendation 2</td>
<td>Ensure that lamp hours are counted (root on lamp change) and confirm with the manufacturer / supplier that the lamp should be changed on hours used or intensity – whichever occurs first. Citycare has been notified of this requirement.</td>
<td>Yes</td>
<td>Periodically request and review records.</td>
<td></td>
</tr>
</tbody>
</table>
Planning and Delivery

WASTEWATER AND WATERSUPPLY RETICULATION RENEWALS

**Riccarton Road stage 3 & 4 between Harakeke and Matipo** – Construction of the replacement water main, crossovers and submains between Matipo and Harakeke streets is now largely complete.

Construction of the replacement wastewater main is now underway with six drainage crews working along the length of the site. Good progress is being made and the contractor is running slightly ahead of programme. An option of bringing in a 7th crew to further accelerate the works is also being looked into.

A novel initiative to erect large colourful hoardings around the site to minimize the visual impact of the works and reduce dust and noise are receiving positive community feedback.

The works are scheduled for completion December 2020.

**Tuam Street WW** – Construction works have commenced in Tuam Street to replace the 140 year old brick barrel wastewater main. The first stage of sheet piling for the deep sewer construction is complete with excavation and break out of the old brick barrel commencing in June.

Installation of the replacement of the 1.2m diameter main, along Tuam Street is expected to take until May 2020.

**Colombo Street WW** – The contractor has successfully completed all the works in Beckenham and Colombo Street, including the Heathcote River crossing, leaving only a small section of work in Ashgrove Terrace to complete, and final demobilization and site restoration. Works are expected to be complete in July 2019.
Wastewater Pump Stations

Lyttelton Harbour Wastewater Pipeline Scheme – The last of the water supply connection works at both ends of the Lyttelton road tunnel are complete. This completes the first package of the project which delivers an upgraded water supply main to Lyttelton.

Works to convert the Diamond Harbour wastewater plant is advancing; having resolved on site geotechnical problems. Geotechnical works have included rock stabilisation to protect the people and assets during operation of the plant.

The Governors Bay pump station has been commissioned and is now pumping wastewater to Lyttelton via the two new harbor pipelines, and thereby removing the routine discharge of treated wastewater at Governors Bay.

Works have commenced on the terminal pump station at Simeon Quay. This will be the most visible part of the project in Lyttelton. Once the Simeon Quay and Heathcote pipeline are complete all wastewater flows can be directed to the Bromley wastewater treatment plant.

Construction of the 4.5km Heathcote Valley pipeline from the Lyttelton tunnel to pump station 15 in Woolston is continuing with four construction crews operating along the alignment. Coordination is being undertaken with Mobil, CCC Transport and Orion. Significant planning is now underway on the drill shot under the Heathcote River with installation planned for October. These works are expected to be completed in December 2019.
WATER SUPPLY PUMP STATIONS AND WELLS PROGRAM

Wrights New Wells – The drilling of both new wells is underway. Drilling of well one and two have reached depths of 120 meters and 165 meters respectively. The drilling works is expected to be completed by August. Pipework’s and electrical installation works are in progress. This new pump station is planned to be online by end October 2019. It is expected to supply 100 l/s of water to the network and will replace the existing pump station which is currently offline.

Well drilling at Wrights Road

Ben Rarere New Pump Station – The drilling of both the wells have been completed. The next stage is the construction of the pump station.

The preliminary design of the new pump station is 90% complete. A construction tender is planned to be advertised by October 2019, the construction period is expected to be 12 months. This pump station (production capacity 100 l/s) will replace the earthquake damaged Bexley Pump Station and also cater to the increased demand and improve resilience of the East Water Supply Zone.

Jeffreys Suction Tank Replacement – Well 06 above ground conversion is planned to be completed by end July 2019.

The project includes replacement of the earthquake damaged suction tank, diesel generator and fuel tank, pipework’s, electrical works and landscaping. The preliminary design has been completed. The construction tender is planned to be advertised in September 2019 and the construction period is expected to be approximately 12 months.

Concept Plan of Jeffreys Pump Station and suction tank
Sydenham Suction Tank Replacement – A new suction tank of 500 cubic meter capacity is to be constructed.

A concept plan selecting the proposed location of the new tank and future wells is now being considered and we are reviewing the suitability of this site and space available; in doing so we are considering access issues (during construction and for maintenance), network connectivity, existing infrastructure and future location of the pump station. Geotechnical investigation work has been started.

Hillmorton and Redwood Replacements – Feasibility studies are underway for replacement and new wells at Hillmorton and Redwood Pump Stations.

Metro Sports Water Supply Station – A concept design is being prepared for a new pump station in the Central Zone to provide security of water supply and maintain the levels of service.

WATER AND WASTEWATER PLANNING

Rawhiti water supply zone pressure management trial – water supply pressure has been reduced by a further 5 metres to 600 kPa. As per the agreed transition protocol, fire flow tests and pump performance tests will now be pursued at this half-way point before advancing to the next two stages.

Customer complaints are actively monitored. No complaints have been received that can be related directly to the drop in pressure.

Duvauuchelle water treatment plant – the trial operation has concluded and the assessment of the performance is completed, providing additional certainty on the causes and process requirements for resolving the operational and compliance challenges experienced at the Duvauuchelle water treatment plant.

Duvauuchelle wastewater treatment and disposal upgrade – public consultation for the future use of Duvauuchelle’s treated wastewater has been delayed to allow further work to be done on the option of irrigating treated wastewater to the golf course.

Aranui and Shirley vacuum sewer systems – The vacuum systems have been reconfigured successfully in April 2019. The systems operated adequately during and after the rain event at the start of June 2019. This substantial rain event did not result in flooding as was the case in a similar rain event in July 2017 when Council needed to use sucker trucks to recover the flooded system.

The roll-out of the vacuum monitoring devices will now proceed in August 2019. The reason for the delayed start is to provide additional time to review the configuration settings in order to maximize the life of the devices.

Based on the improved performance of the systems, after its reconfiguration as well as the availability of automatic air admittance devices to reduce the risk of water logging in the event of flooding, it is recommended that residential development could proceed in accordance with the capacity of each vacuum main. Applications for an additional 55 residential dwellings in Aranui and Shirley will now be reviewed in this context.
Wastewater flow monitoring – the upgrade and calibration of the wastewater network model, using the flow monitoring data that has been gathered in late 2018 is underway.

Demand forecasting – the asset planning team is reviewing the future water and wastewater demand in order to advise the need for additional capacity as part of the asset management and long term planning processes.

ASSET MANAGEMENT TEAM

Improvements

The first proof of concept ‘Asset overview dashboard’ has been produced for review using the Business Intelligence reporting tool. The dashboard which covers off all Three Waters & Waste, Facilities, Parks and Transport assets allowing easy visualization and filtering of asset quantities, book value, assets by age, assets by criticality, condition etc. A more detailed dashboard is also available for each business group that allows filtering by asset type and other asset characteristics.

Asset Management Plans

The team is continuing development of the 2021 Asset Management Plans with a strong focus in the last month on the ‘Demand for our services’ section. Refer summary table below.

<table>
<thead>
<tr>
<th>AMP Section</th>
<th>Wastewater</th>
<th>Water Supply</th>
<th>Land Drainage</th>
</tr>
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<tr>
<td>1.0 Overview of the Activity</td>
<td>15% have identified and agreed significant strategic issues with business stakeholders</td>
<td>15% have identified and agreed significant strategic issues with business stakeholders</td>
<td>10% have identified and agreed significant strategic issues with business stakeholders</td>
</tr>
<tr>
<td>2.0 Introduction</td>
<td>90% complete – awaiting completion of other AMP sections to finalise</td>
<td>90% complete – awaiting completion of other AMP sections to finalise</td>
<td>50% complete – awaiting completion of other AMP sections to finalise</td>
</tr>
<tr>
<td>3.0 The Services we provide</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>4.0 Demand for our Services</td>
<td>90% have completed section with review but need updated growth charts from Asset Planning team</td>
<td>90% have completed section with review but need updated growth charts from Asset Planning team</td>
<td>75-80% completed, need to update following review and needs graphics etc</td>
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<tr>
<td>5.0 Delivering our Services</td>
<td>75% complete</td>
<td>25% complete</td>
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<tr>
<td>6.0 Lifecycle Management Plans</td>
<td>5% complete – have valuation data and engaged team members to begin 30+ yr renewal forecasting</td>
<td>5% complete – have valuation data and engaged team members to begin 30+ yr renewal forecasting</td>
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</tr>
<tr>
<td>7.0 Asset-Specific Lifecycle Plans</td>
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<td>5% complete – have valuation data and engaged team members to begin 30+ yr renewal forecasting</td>
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**8.0 Managing Risk and Resilience**

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**9.0 Financial projections and trends**

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</thead>
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**10.0 Continuous Improvement**

| | 5% - have created improvement register to log initiatives as I work through each AMP section | 5% - have created improvement register to log initiatives as I work through each AMP section | 0% |

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**LAND DRAINAGE PLANNING**

**Comprehensive Stormwater Network Discharge Consent (CSNDC)** – The consent hearing has now closed and the consent was granted; subject to a number of conditions. Overall, the outcome was positive with strong alignment between the proposed and granted conditions. The appeals period will close on 26 June.

**Sutherland Basin (Welsh), Hoon Hay Valley and Eastmans Stormwater Facilities** – As anticipated the Civil works have slowed down for the winter with works halted on some sites. The Eastman bund is near to completion and the Sutherland Earthworks are 95% complete.

**Worsley Spur Stormwater Pipe and Drain System** – This project is now complete. It overcame significant challenges of building a pipeline down a steep hillside that necessitated complex construction logistics including helicopter concrete delivery.

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**Reticulation and Maintenance Team**

**SIGNIFICANT NUMBER OF WATER JOBS (DECREASING TREND)**

Last time we reported we were seeing an increasing number of water reactive jobs coming through. For April and May we have seen this number drop back by a reasonable amount. This may be partly due to the weather and leaks not being as easy to identify.

City Care have worked hard to reduce the total number of outstanding jobs down to 430 as of Wednesday 19th June. Even if numbers increase to levels seen in February and March it is expected that we now have the appropriate resourcing levels to keep on top of any new work coming in.

This means we are basically back to normal levels of outstanding jobs and it highlights the great work the Reticulation and Maintenance team have done to address this issue.
WATERS AND WASTE MAINTENANCE CONTRACT PROJECT UPDATE

$1.2m of capital investment was approved in December 2018 to address process, system, contractual and data shortcomings around the Maintenance of Three Waters Assets. After a brief period of mobilisation, the project team has been fully functional for the past four months. Achievements to date are:

- Completion of first drafts of new service information to support new future contracts. This has been a significant piece of work and has led to a greater understanding of which party holds accountability for outcomes. Furthermore, all specified maintenance activity has been linked to key outcomes giving greater visibility of why certain activities are required and the impact of not doing them. It is hoped this will help address the deferred pump station maintenance driven by historical budget saving measures. We are now in the process of establishing a trial with City Care for ten waste water pump stations to test the service information and ensure it is fit for purpose.

- SAP Improvements – SAP is our core Asset Management & Work Order Management system and is not user friendly for the average user. An asset overview screen has been implemented to help business users find all relevant information about an asset in a single screen. Financial benefits from this small improvement have already been realised. The second small improvement was an enhancement to a SAP screen that is used to manage work orders between Council & City Care. More SAP improvements are planned throughout the project. These improvements are also of benefit to Parks & Facilities.

- Asset Dashboard – a prototype dashboard has been completed and is being tested that displays basic information around how many assets we have, how old they are, condition information, whether they are overdue for renewal and most importantly whether we have this key information recorded against each of our assets. This is the first step in many for the asset dashboard – eventually we will be able to report on the currency of the data e.g. how old is the condition rating, provide detailed drill through for users, and incorporation of
performance data. Note: much of the dashboard will not only be rolled out across Three Waters but also across, Parks, Facilities & Transport.

- Contract Expenditure Dashboard – creation of a basic dashboard that uses claim information to demonstrate where expenditure is occurring across the maintenance contract. Financial reporting is a significant challenge for Three Waters Maintenance Contracts and will be an on-going focus for this project.

- FME Portal – this is a web portal that will allow contractors to upload as-built CAT sheets and have them instantly validated. This will remove the current e-mail process and manual upload for validation. This portal is the first of many improvements planned for how to receive new and updated asset data.

Solid Waste Team

LANDFILL AFTERCARE
Planning for Bexley foreshore remediation is progressing well with numerous stakeholders engaged. Coastal-Burwood Community Board have been briefed regarding the project and a community engagement plan is to be actioned.

Landfill gas production from the field has declined due to a period of consecutive high pressure systems. This has necessitated several shut downs of the gas supply to the tri-generator located at Civic.

The closure plan for Burwood Landfill has now been finalised with the closure date, for receiving related material, being December 2019.

ORGANICS PROCESSING PLANT (OPP)
ECAn staff met onsite to view Living Earths operations and to discuss the wider Bromley odour issues. Council are seeking a determination from ECAn on chronic odour.

ECOSORT (MATERIALS RECOVERY FACILITY)
The disposal of soft plastics in the yellow bins, due to the collapse of the National Soft Plastics collection, continues to cause contamination issues. Council are continuing the online education campaign to address this with the public and looking for new approaches to address the issue.

TRANSFER STATIONS
New hazardous waste bunkers are now in operation at the transfer stations replacing the 30 years old bunkers.

KERBSIDE COLLECTION
As of 18 June, 447,621 wheelie bins have been fitted with RFID tags representing a completion rate of 94.5%. 7,280 additional bins have been removed from circulation as of this date.
The three year project is nearing completion and a campaign has now been launched to assist residents in checking if their bins have been tagged and advising that untagged bins will no longer be emptied.

**WASTE DIVERSION INITIATIVES**

Battery collection trials started 13th April with positive feedback from the community and management of participating sites. Encouraging uptake with collection containers filling fast at all six sites.
Stormwater and Land Drainage Teams

LEVELS OF SERVICE

Levels of Service targets for stormwater have been met to date in FY19. We continue to deliver the Land Drainage Recovery Programme of works and improve operational maintenance.

A significant rainfall event occurred on the 1 – 2 June. Rain fell across the city with the greatest rainfall depth on Banks Peninsula with 160 mm recorded at one monitor. The Tyrone Street rainfall gauge in Belfast recorded a short burst of rainfall that was estimated at approximately a 40-year return period. Newly constructed and part constructed facilities operated to good effect, particularly in the Heathcote Catchment. Water was stored during the event in the upper Heathcote storage basins and the Bells Creek pump station operated. The following feedback was received by a Heathcote local:

“We live in one of those bad spots for flooding of the Heathcote. In the past we have had water thigh high on the road. Over the past couple of months you have been lowering the bank so there is more space for the water. During Saturday’s rain event we still had water on the road but it was much less than before at similar rain events and easily drive-able, so “yeah!” for the changes to the bank.”

LAND DRAINAGE WORKING GROUP SUMMARY

A Working Group meeting has not been held since Friday 8 February 2019. In lieu of a meeting a memo summarising programme and project progress was circulated. In summary:

- The Land Drainage and Stormwater Delivery Team has 97 capital projects to deliver in FY19. The total budget for these is $47.0M. The programme is forecast to spend close to its budget this year.
- We have large construction projects underway across the city with many focused on managing flooding in the Heathcote River.

The next meeting is planned for 28 June and will be reported in the next update report.

LAND DRAINAGE RECOVERY PROGRAMME (LDRP)

Other important updates for LDRP projects, not mentioned above:

- Heathcote Dredging – Stage 2 of the dredging project is now underway.
- Cashmere-Worsley Flood Storage – The contractor installing the control gates in the lower valley adjacent to the current Adventure Park entrance have made good progress with the base of the main structure soon to be poured.
- Matuku Waterway – Stage 3 flood mitigation works are nearing completion, which has widened a section of open waterway upstream of Bridle Path Road.
- Wigram Flood Storage Basin – All works except planting and installation on the active controls are planned for completion in June.
- Southshore Emergency Bund – A tender has been awarded for the stabilisation works to the emergency bund and the Avon Stopbank Extension.
- Curletts Flood Storage – The bulk civil works are now complete with only planting in winter remaining.

Wastewater Treatment Plant

Union negotiations continue to be at the forefront of all activities. With negotiations still ongoing into June 2019 (started in May 2018).

Both co-generation engines operated well in April, however in May the smaller co-generation engine’s aftercooler failed. This has rendered the engine inoperable until a replacement aftercooler is delivered from USA (order placed). This confirms that the LTP KPI target of 75% of electricity self-generated by the CWTP for the financial year will not be met. Preliminary design and scoping for the proposed installation of the gas storage facility is well underway, with efforts being made to bring the program forward to assist with hitting the LTP KPI. Delivery of this installation should assist with meeting this target, (due 2020).

In early April, for approximately four weeks, there appeared to be a significant, illegal, unidentified (tradewaste) contaminant being received at the CWTP via the reticulation (i.e. not via the tankered waste import station). The contaminant significantly affected the performance of the primary settlement tanks by keeping the sludge suspended. This resulted in significant overloading of the downstream treatment process.

Intensive investigation of all large industrial and commercial premises across the city was undertaken by the Technical Services team. Whilst the source was not identified, it appeared that the increased site visits / scrutiny by the Technical Services team had the desired effect of ceasing of this illegal discharge to sewer. Increased monitoring of the treatment plant performance has indicated that almost full performance has been restored by the end of May.

Two news articles have now appeared in the local media, (including the front page of Pegasus Post on 14th May). This is following the council paper presented to the Coastal & Burwood Community Board meeting, which provided an update on the midge control program.

In early May, the CWTP received its certificate confirming that it has successfully implemented an Environmental Management Plan which conforms to the ISO 14001 Standard. This represents a full 12 months of dedicated work by Ben Coventry and Lee Liaw to achieve this status. It is worth highlighting that this is a first for Christchurch City Council, to have a system certified to an International Standard.
## Appendix 1 – Health and Safety Statistics

### Health and Safety Statistics

#### 3 Waters Waste and Transport

<table>
<thead>
<tr>
<th>Health and Safety Statistics - Month of April 2019</th>
<th>Totals</th>
<th>Land Drainage</th>
<th>Water Waste</th>
<th>Solid Waste</th>
<th>Transport</th>
<th>Intern</th>
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<tr>
<td>Near Misses</td>
<td>49</td>
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<th>Totals</th>
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<th>Water Waste</th>
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<th>Transport</th>
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Year to Date July 2018 - June 2019
(as at 15-05-2019)
Health and Safety Statistics
Three Waters Waste and Transport

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Year to Date July 2018 - June 2019
(as at 18-06-2019)

Reference: 18/1186768
Presenter(s): Keith Davison, Marion Schoenfeld

1. Purpose of Report

1.1 The purpose of this report is for the Infrastructure, Transport and Environment Committee to be informed of the technical reports on tsunami produced as part of the Multi-Hazard Analysis project.

2. Staff Recommendations

That the Infrastructure, Transport and Environment Committee:

1. Receive the information in the following Multi-Hazard Analysis project technical reports:
   a. Land Drainage Recovery Programme: Tsunami Study
   b. Tsunami inundation modelling for Lyttelton and Akaroa Harbours

3. Key Points

3.1 The Land Drainage Recovery Programme (LDRP) in conjunction with the Strategic Policy Unit have been progressing Stage 2 gap filling studies of the Multi-Hazard Analysis project. This project will inform decisions on long-term floodplain management strategies for the lower reaches of the Avon, Heathcote and Styx Rivers, and for Sumner.

3.2 The Stage 1 gap analysis compared available information with the required information for the project. The result of the gap analysis was reported to ITE on 26 July 2017 and Council on 3 August 2017. Council resolved to progress the gap filling technical studies (CNCL/2017/00175). The attached reports are the reports submitted by NIWA and will be accepted as final upon receipt by Council.

3.3 The first tsunami report (Attachment A) considers local tsunami sources and higher frequency distant source tsunami and how their impact on Christchurch would alter under different sea level rise scenarios. This work enables a better consideration of risk as previous tsunami modelling considered far less frequent events.

3.4 The second tsunami report (Attachment B) extends the findings to the Banks Peninsula area.

3.5 The tsunami extents predicted within these reports are almost entirely within the existing tsunami evacuation areas. Twelve additional Banks Peninsula properties will be included in the area based upon the findings of these reports.

3.6 The Multi-Hazard Analysis Peer Review Panel have reviewed the LDRP report and the findings of this review have been reflected in the final report.

3.7 Subsequent LDRP multi-hazard gap filling reports will be presented to Council, via the Infrastructure Transport and Environment Committee, as other studies are completed.

3.8 These reports will add to Council’s knowledge base on natural hazards and can be used to inform long term planning, civil defence and emergency management procedures.

3.9 The information within these reports will not necessitate a widespread update of LIM comments. However, a review of tsunami related LIM comments is currently underway and this may lead to updates to coverage and comments.
## Attachments

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<td>LDRP 114 Tsunami Study</td>
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<td>B</td>
<td>Tsunami inundation modelling for Lyttelton and Akaroa Harbours</td>
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## Signatories

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<tbody>
<tr>
<td>Tom Parsons - Surface Water Engineer</td>
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<tr>
<td>Marion Schoenfeld - Senior Advisor Natural Hazards</td>
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<tbody>
<tr>
<td>Keith Davison - Manager Land Drainage</td>
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</tr>
<tr>
<td>Helen Beaumont - Acting Head of Three Waters &amp; Waste</td>
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<tr>
<td>Carolyn Gallagher - Acting General Manager Consenting and Compliance</td>
<td></td>
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<tr>
<td>Brendan Anstiss - General Manager Strategy and Transformation</td>
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Land Drainage Recovery Programme: Tsunami Study

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Land Drainage Recovery Programme: Tsunami Study
Executive summary

NIWA was commissioned by Christchurch City Council (CCC) to carry out a numerical modelling study of tsunami inundation in Christchurch caused by two tsunamis originating from distant sources. This study aims to aid the understanding of the tsunami hazard in the greater Christchurch area so that Christchurch City Council has a better understanding of the influence of tsunamis on flooding risk. The results of this project will feed into the multi-hazard analysis being undertaken by the LDRP97 project team in preparing the floodplain management plan.

The selected tsunami sources were a 1:500-year return period event cause by a magnitude 9.28 earthquake and a 1:2500-year return period event caused by a magnitude 9.49 earthquake both at the Peru subduction zone. The simulations were completed for different sea-level rise scenarios (present day, 0.19 m, 0.41 m and 1.06 m) taking into account predicted shoreline changes predicted for 2065 and 2120. Note that the magnitude 9.49 scenario at current sea-level was produced in a previous study and not replicated here.

Both tsunami scenarios result in major inundation in Christchurch which, as expected, worsens with the higher sea-level scenarios. The inundation extent was similar for both tsunami scenarios but the inundation depth and flow velocities along the coastal strip were much larger for the worst-case tsunami (1:2,500-year scenario). The total inundation extent for the higher sea level rise scenario (1.06 m above present sea level) was 70 km$^2$ for the 1:500-year return period tsunami event, 79 per cent more than for the same tsunami occurring at present day sea level.

Such large tsunami events are expected to cause severe erosion of the coastal strip and at the mouth of the Waimakariri River and the Avon-Heathcote Estuary. Severe erosion can also be expected at the Avon Bridge Street bridge and the Heathcote Ferry Road bridge. This erosion could cause increased inundation by removing dunes and opening river and estuary mouths which is not taken into account in this modelling.

The results for areas specifically modelled in this study are considered more robust and should supersede previous interpretations.
1 Introduction

Christchurch is subject to a range of natural hazards and one of these is tsunami. Since the Canterbury Earthquake Sequence (CES), the direct effects of the earthquakes have caused changes that may exacerbate future natural hazards. The Land Drainage Recovery Programme seeks to understand the post-earthquake flood risk in the greater Christchurch area, including multi-hazards in the form of co-location, coincident or cascading hazards. Christchurch City Council (CCC) engaged a project team to investigate these multi-hazard risks and develop a floodplain management plan encompassing these. The project is split into three parts. Firstly, a gap analysis; secondly, studies aiming to fill those gaps; and finally, the development of the floodplain management plan. Tsunamis were identified as one of the areas where future research is need. Consequently, NIWA was commissioned by Christchurch City Council to model tsunami inundation in Christchurch City from two earthquake scenarios and consider various sea level rise scenarios.

This study aims to aid the understanding of the tsunami hazard in the greater Christchurch area so that Christchurch City Council has a better understanding of the influence of tsunamis on flooding risk. The results of this project will feed into the multi-hazard analysis being undertaken by the LDRP97 project team in preparing the floodplain management plan.

The first tsunami source scenario used was the same as that used by Lane et al. (2014, 2017) and involves a tsunami originating from a moment magnitude (Mw) 9.485 earthquake at the South Peru / North Chile Subduction Zone. This scenario was based on the findings of Power (2013) and represents a 1:2,500-year return period event; this is considered an extreme scenario. A less-extreme scenario was also considered based on previous work from Power (2013). The 1:500-year return period earthquake scenario was selected as the most likely magnitude for the most likely source (50th percentile in Power 2013). The most realistic rupture mechanism was selected from two scenarios of fault rupture mechanism presented in a progress report (Lane and Bosserelle 2017).

Kohout et al. (2015) have previously simulated various scenario of earthquake from the Hikurangi faults. These Hikurangi scenario are not used here because they produce smaller wave height at coast than the far-field scenarios.

A local tsunami source was initially considered based on multiple ruptures with recurrence interval of 12,500 – 35,000 years. However, tsunami propagation simulation showed that the tsunami wave height at the coast was significantly smaller than for far-field scenarios (and with return period that far exceeds the return period of the far field events). Results for local source scenarios were presented in a progress report (Lane and Bosserelle 2017). For convenience these results are included as an appendix to this report. Subsequently, CCC decided that local source scenarios were not a priority, and to focus on the distant source tsunami scenarios.

This report presents the results for modelled tsunami inundation caused by these tsunami scenarios at different sea-level. Four sea-level scenarios were considered: current conditions, sea level rise for 2040 (0.19 m), 2065 (0.41 m) and 2120 (1.06 m) all based on the analysis of Tonkin & Taylor Ltd (2017). The modelling assumes the tsunami coincides with Mean High Water Spring tide (MHWS), which was taken to be 1.2 m above Lyttelton Vertical Datum 1937 (LVD37) as calculated in Bell (2011) (this corresponds to 10.24 m in Christchurch Drainage Datum); consistent with the MHWS value used in previous modelling Lane et al. (2014, 2017). MHWS was set as the baseline water level for the modelling and represents the case where the largest wave arrives in conjunction with high
tide for an average spring tide. Flow from the Avon, Heathcote and Waimakariri Rivers were included in the simulation to account for the tsunami wave propagation in the rivers.

Outputs of maximum inundation depth, maximum flow velocity and maximum shear-stress maps are presented as well as time series of water level, speed and shear-stress. Areas of interest include Avon-Heathcote Estuary, the Waimakariri River Mouth, Brookland Lagoon and bridges in the lower reaches of the rivers.

1.1 Use of this report

The distant source scenarios modelled have long estimated return periods (2,500 years and 500 years) and represent extreme scenarios. Information provided in this report may also be useful for strategic development and infrastructure planning as it may, when used with other hazard and risk information, highlight areas of higher vulnerability that are potentially unsuitable for future development. Maps of the inundation extents should not be used at scales finer than 1:25,000. The overview maps are intended as a guide only and should not be used for interpreting inundation.

The main purpose of this report is to provide the Council with a clearer understanding of the potential tsunami inundation extent and the effects of sea level rise on the Christchurch City region (from the Waimakariri River Mouth to Sumner Head). The information provided is intended to aid understanding of the tsunami for current conditions and sea level rise scenarios up to 2120 (1.06 m) including how tsunamis could impact the local estuaries and lagoons in terms of geomorphic changes, scouring and deposition and resulting long-term effects. Results are intended to inform the Land drainage recovery program (LDRP97).

1.2 Caveat

This report is based on state-of-the-art knowledge and modelling capabilities of tsunamis and tsunami inundation at the time of writing. While every effort was made to provide accurate information, there are many uncertainties involved including knowledge of potential tsunami sources, source characteristics, bathymetry and topography (see Section 2.5 of this report for details). In addition, while the hydrodynamic models capture much of the physics involved in tsunami propagation and inundation, they also include some simplifying assumptions, as with all models.

This report also provides a qualitative assessment of the potential erosion caused by the tsunami. This assessment is based on the model prediction of maximum shear stress which is only a proxy for sediment transport potential. As a result, no estimates can be made of the amount of erosion or the depth of scouring of stop banks.

The information provided in this report is of a technical nature and should be considered with the above limitations in mind.
2 Tsunami Inundation Modelling

2.1 Source model and initial conditions

Power (2013) provides a wave height at the Christchurch coast of 12.63 m for the 2,500-year return period tsunami at the 84th percentile confidence level. The de-aggregation of this wave height identified South Peru / North Chile as a major source of the hazard and that an earthquake of Mw 9.485 was required to produce that wave height at the Christchurch coast (Power 2014). For consistency with previous work by Lane et al. (2014, 2017), this source and corresponding modelling approach is used to model the tsunami in this study. The overarching scenario was guided by the GNS Science tsunami database and uses source segments from Tang et al. (2010). In Lane et al. (2014) four earthquake rupture scenarios were modelled. All had the same moment magnitude (Mw) but differed in configurations of rupturing segments and corresponding displacements. For this report we model the largest of those four scenarios as was done in Lane et al. (2017).

This study also analyses the inundation from a 1:500-year return period tsunami at the 84th percentile confidence level also from the South Peru / North Chile region. Two tsunami waves were initially simulated both originating from a magnitude of Mw 9.28 earthquake occurring in the South Peru area. The fault segment involved in the earthquake were selected to produce the largest tsunami waves for Christchurch using a sensitivity analysis of the SIFT (Short-term Inundation Forecast for Tsunamis) database Gica et al. (2008). Both tsunamis produced similar waves in Pegasus Bay offshore of Christchurch. Scenario B (Lane and Bosserelle 2017) was selected for inundation simulation as it was produced by the most realistic fault rupture mechanism.

The two tsunami scenarios show very dissimilar waves with the 1:500-year return period scenario showing only large long period waves whereas the 1:2500-year return period scenario is showing large short period wave riding on top of large long period waves. The scenarios are expected to produce different waves at the coast because the initial tsunami sources were produced using different faults (i.e., the larger earthquake is produced on a longer fault segment) and because the wave interacted differently with the continental shelf when approaching the coast. In addition, the method for propagating the tsunami waves across the Pacific was completed using different models (Gerris for the 1:2500-year return period scenario and ComMIT for the 1:500-year return period scenario) and using different resolutions. However, the models are fundamentally similar (i.e., both are solving the shallow water equations) and are not expected to produce significant differences.

2.2 Progress report - Decisions

In the progress report, initial tsunami propagation simulations (typically completed at a coarser resolution than inundation simulation) were used to decide which scenarios and parameters to focus on in this study.

Far-field tsunami were modelled from sources across the Pacific Ocean to the edge of the inundation grid. De-aggregation results from the New Zealand Probabilistic Tsunami Hazard Assessment (Power 2013, Power 2014) were used to identify a representative source fault rupture, and (Okada 1985)

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1 In probabilistic tsunami hazard assessment, the 84th percentile confidence level refers to the confidence level (or uncertainty) regarding the water level due to the contributions of different fault sources and uncertainty in the parameters of those sources (see Power 2013 for further details).
was used to create the initial surface deformation. Higher resolution modelling of two of these scenarios was approved for further investigation.

Digital elevation models were developed for the new representative beach topography (in 6) under the two most extreme sea level rise scenarios for 2065 (0.41 m) and 2120 (1.06 m) using the results from the Christchurch Coastal Hazards Assessment ((Tonkin & Taylor Ltd 2017).

Four local tsunamis caused by fault rupture in Pegasus Bay and North Canterbury (two single faults and two multi-faults where one fault rupture triggers rupture in a neighbouring fault) were modelled (although the land deformation and potential effect of liquefaction were not taken into account). Faults were taken from an update of the National Seismic Hazard Model and used to create the initial surface deformation. CCC subsequently decided these scenarios were not a priority for this study. These results are reproduced in Appendix B for convenience.

2.3 Inundation modelling and grid

The tsunami modelling is undertaken using the Basilisk model, a partial differential equation solver based on adaptive grids that has been used for tsunami modelling in a range of situations (Popinet 2011, Popinet 2012, Lee et al. 2015).

The Basilisk model (Popinet 2015), a successor to Gerris (Popinet 2011, Popinet 2012), was used to model the inundation together with the river flow. Both Gerris and Basilisk have been used for tsunamis (Popinet 2011, Popinet 2012) and flood inundation (Bind and Smart 2010, Smart 2017) which is why Basilisk, the more recent of the two, was chosen for this modelling. A feature of Basilisk and Gerris is that these models use an adaptive grid where the spatial resolution varies throughout the duration of the simulation, with the grid resolution automatically increasing in areas of interest as defined by Popinet (2012), while lower resolution is maintained elsewhere, improving computational efficiency.

The model grid was confined to Christchurch and Kaiapoi, extending from Taylors Mistake in the south to The Pines in the north. The model grid was rotated by 13.8° counter-clockwise so that the edge of the grid was approximately parallel with the shoreline (Figure 2-1). The model was forced with the incoming wave height at its outer edge taken from the previous modelling. The grid is square in shape with the length of a side of the grid being 27 km. The resolution of the model was adapted to optimise the number of model cells while maintaining high accuracy for the water level, flow speed and river channels with the finest resolution of the grid at 13.2 m. The adaptive resolution of the model is illustrated with a snapshot of the final resolution used for the 1:500-year return period tsunami simulation for present day mean sea level in Figure 2-2.

The inundation model for the Christchurch region (between the Waimakariri River and Sumner Head) was developed using topography from Environment Canterbury LiDAR and bathymetry of the rivers, estuary and ocean developed by NIWA. Although results are only required for the south of the Waimakariri River, the modelling extended further north ensuring that the results were not affected by the boundary. Flow was included in the Avon, Heathcote and Waimakariri rivers. Stop-banks along the Waimakariri and Avon rivers and the Sumner sea-wall were resolved.

The same LiDAR data obtained from Environment Canterbury as used for the previous modelling (Lane et al. 2017) was used for the land area. For the Avon and Heathcote rivers bathymetry developed post-earthquake for Environment Canterbury (Measures and Bind 2013) was used. Environment Canterbury provided bathymetry for the lower reaches of the Waimakariri River (the
lowest 3 km) but this was not comprehensive enough for the purposes of this modelling. We were also able to obtain cross-sections that were used to reconstruct river bathymetry further upstream. Details of this reconstruction technique are provided in Lane et al. (2017). For the more extreme sea level rise scenarios (2065 SLR 0.41, 2100 SLR 1.06m) we used the revised dune topographies documented in Appendix A.

Stop-bank crest levels were provided for the Waimakariri and Avon stop-banks and the Sumner seawall for previous projects (Lane and Arnold 2013, Lane et al. 2014, Kohout et al. 2015, Lane et al. 2017). In order to ensure that these features were resolved within Basilisk’s adaptive refinement, the cells containing these features were refined to the highest level while other regions were allowed to adaptively refine according to details of the flow and whether they were inundated or not.

Following Lane et al. (2017) the rivers were initialised with mean river flows of 1.0, 1.7, and 60 m$^3$/s for the Heathcote, Avon (Cameron 1992, Orchard and Measures 2016) and Waimakariri rivers respectively. The black diamonds in Figure 2-1 indicate where this flow entered the rivers. The model was allowed to run for 1 day of model time to allow the rivers to fill up with water and reach a steady state. During this time the outer boundary was also gradually raised from LVD37 up to 1.2 m above LVD37. This gave us a baseline height of 1.2 m above LVD37 (i.e., MHWWS) without resulting in ponding of low-lying regions of Christchurch that are below 1.2 m above LVD37 but are not connected to the sea. After 24 hours simulation time, a steady state river flow and sea level was reached and the tsunami forcing was initiated.

The model boundary forcing for the 1:2,500-year return period tsunami was extracted from far-field propagation of the tsunami across the Pacific Ocean, modelled using Gerris (Popinet 2003, Popinet 2011) in Lane et al. (2014). We did not repeat this modelling but used the same input conditions taken from it for ocean boundary conditions (the height and timing of the approaching tsunami waves) driving the inundation modelling in this report. The boundary forcing for the 1:500-year return period tsunami was extracted from far-field simulations produced using the ComMIT interface (Titov et al. 2011). The model offshore boundary is located 5,000m off the coast in the south and 6,000m in the north. The model was forced only on the offshore boundary with velocity and water level. Any wave reflected off the Banks Peninsula seaward of the offshore boundary is considered small and not accurately taken into account in the model.

The inundation model was used to simulate a 1:500-year tsunami under current sea level and sea level rise scenarios for 2040 (0.19 m), 2065 (0.41 m) and 2120 (1.06 m) and a 1:2,500-year tsunami (i.e., the maximum credible tsunami) under sea level rise scenarios for 2040 (0.19m), 2065 (0.41m) and 2120 (1.06 m). Results from these simulations (maps of maximum and integrated values of shear stress and time series at selected locations (see Figure 2-3 and Figure 2-4)) were used in a qualitative assessment of potential tsunami-induced changes to the geomorphology of the Avon-Heathcote Estuary and Waimakariri River mouths, as well as likely locations of scour and deposition by the tsunami in the Estuary, Brookland Lagoon and the lower river reaches.

While the model outputs are reported for the locations of the main bridges, the structures were not taken into account in the model because the model is too coarse (relative to bridge dimensions) and too little information about bridge dimension was available. Hence the model simulates the flow at the location of the bridge but ignores how bridge piles, and soffit height may affect the flow.
Figure 2-1: Model extent (white box) and location. The model uses an adaptive mesh that is 27 km wide and is rotated by 13.8 degrees (counter clockwise from the east) to be approximately parallel with the shore. The black lines show where stop-banks for the Waimakariri, Kaiapoi and Avon rivers are specified as well as the Sumner seawall. Black diamonds indicate where water was added to create flow down the rivers.
Figure 2-2: Snapshot of model resolution (shading) at the end of inundation for the 1:500-year return period at present mean sea level. The thick black line is the shoreline and the grey lines are roads. Note that higher resolutions occur in the inundated area and resolution gradually decreases on the dry land.
Figure 2-3: Bridge locations for the Northern Section.
2.4 Model outputs

The outputs listed below were produced using the numerical models:

A. Detailed spatial data depicting the maximum inundation depth (as water depth above ground for places that are normally dry and height above pre-tsunami level for rivers and estuaries) and extent, maximum flow speed, and maximum shear stress for the specified sea levels for each scenario. The modelling covered Christchurch City from Godley Head in the south, to the Waimakariri River Mouth in the north.
a. 1:500-year far-field tsunami under current sea level and sea-level rise for 2040 (0.19 m), 2065 (0.41 m) and 2120 (1.06 m).

b. 1:2,500-year far-field tsunami (i.e., maximum credible tsunami) under sea level rise for 2040 (0.19 m), 2065 (0.41 m) and 2120 (1.06 m).

B. Qualitative assessments of the likely geomorphic changes of the river mouths and scour and deposition within the regions of interest:

- The mouth of the Avon-Heathcote Estuary.
- The mouth of the Waimakariri River.
- Bridge locations in the lower reaches of the rivers.

These outputs describe the propagation and magnitude of the tsunami arriving at the Christchurch coastline and the inundation at the locations of interest. The maps are presented and discussed in this report are all in NZTM coordinate system. Detailed spatial data (in digital ArcGIS format) is provided to CCC in addition to this report.

2.5 Uncertainties

Inherent uncertainties associated with the tsunami modelling stem from the bathymetric resolution of the grid used, the fault rupture scenarios used, the numerical equations and the solver used for the modelling. These uncertainties are described in more detail below.

The quality of the topographic data and the bathymetric data in inshore waters strongly influences the simulation of inundation. For this modelling, we used available DEM data for the land topography and near-shore bathymetry in the vicinity of Christchurch, but in order to capture some of the more complex small-scale processes in harbours and embayed areas, higher resolution data is required. Known topographic uncertainties associated with the DEM used for this study include the bathymetry of the Waimakariri River. Also, in order to resolve the Waimakariri and Avon stop-banks and Sumner seawall, we refined cells in these regions to the highest resolution and then set their elevation to the specified stop-bank and seawall crest levels. Given that the finest resolution is 13.2 m, this means that the stop-banks and seawalls were modelled as having at least that width. In the case of the Sumner seawall, this is wider than the actual sea wall. This resolution also limits how well the dunes can be resolved. Although the model finest resolution is 13.2 m the GIS file that shows model output have been rotated back to a New Zealand Transverse Mercator coordinate system and resampled to a uniform resolution of 15 m for compliance with GIS format.

Other uncertainties in the modelling study include the gridded representation of a continuous coastline (grid-stepping), which can deform the shape of bays and estuaries, and the effects of building and land features on form drag. The latter could substantially modify the onshore propagation of tsunamis. Improving the drag representation remains a goal of current research. Eradication of the other errors is constrained by limitations of data quality and the practicalities of grid resolution. Models always represent an approximation of reality.

The model presented here did not include sediment transport and morphological changes associated with tsunami and hence in places where dunes are severely eroded by tsunami the model is likely to underestimate the inundation. Lane et al. (2017) investigated the effect of dune breach on tsunami inundation near Christchurch.

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Model uncertainty can be quantified by running multiple simulations with small variations in key parameters, an approach known as ensemble prediction or sensitivity analysis. Such an approach provides an envelope of predicted solutions, rather than single "worst-case" or "scenario-type" predictions, on which to base emergency response procedures. However, running many simulations increases the computational and research costs, and, in any event, model forecasts can never be certain because our knowledge of all the geophysical processes involved in tsunami generation, propagation and inundation remains incomplete.

Quantitative calibration of the tsunami inundation model against real measurements is difficult due to the uncertain nature of tsunami impact data from New Zealand and the consequent difficulty in identifying events from the past. Nevertheless, the Gerris and Basilisk models have been continuously validated against standard analytical test cases (e.g., Popinet 2003, Popinet 2011, Popinet 2012, Popinet 2015).

In addition to the uncertainty in the model there is always additional aleatory uncertainty. Changes to ground levels from future local earthquakes could change the results - especially if the epicentres were close to the coast. However, the changes could raise or lower the land depending on the details of where and how the fault ruptures so very little can be said a priori about this. If the earthquake were to cause liquefaction and this was then removed it would cause a lowering of the land with respect to sea level and could increase the flooding hazard. Likewise, effects on the sea level (e.g. relative sea level rise and the geomorphological changes it could cause; tidal cycle, storm surge and sea state at the time of a tsunami) could also change the results given here.
3 Model results

3.1 Water level at coast

For the 1:500-year return period event, the tsunami wave reached a maximum height of 4.4 m above LVD (wave height of 5.7 m from crest to trough) near the Waimakariri River Mouth (Figure 3-1) and 4.7 m at the Estuary mouth (Figure 3-2). For the 1:2,500-year return period event, the maximum level was 7.23 m above LVD (wave height of 8.6 m from crest to trough) at the Waimakariri River mouth (Figure 3-3) and 7.25 m above LVD at the Estuary mouth (Figure 3-4).

![Graph of water level at coast]

Figure 3-1: Water level at the Waimakariri river mouth for the 1:500-year return period event at present sea level.
Figure 3-2: Water level at the Estuary mouth for the 1:500-year return period event at present sea level.

Figure 3-3: Water level at the Waimakariri river mouth for the 1:2,500-year return period event at 2040 Sea Level Scenario – 0.19 m Sea Level Rise.
3.2 Water level at the main bridges.

Tsunami wave propagating along river channels can cause severe damage to infrastructure far upstream. The maximum elevation of tsunami waves at each of the main bridges in the lower reaches of the Waimakariri, Avon and Heathcote rivers is presented in Table 3-1 and Table 3-2. Elevation of the soffit (i.e., underside of the bridge decks) (LVD37) are also presented (where the value is known) and the modelled tsunami heights above LVD37 at each location.

Tsunami waves reached the highest levels at the Waimakariri River SH1 bridge (Figure 3-5 and Figure 3-6). For most scenarios the tsunami waves did not reach the soffit height (where elevation is known) except for the Heathcote River Bamford Street bridge (Figure 3-7 – Figure 3-10) where the soffit elevation is reached by the tsunami wave for all the scenarios. For the 1:500-year return period at the predicted sea level of 2120 (1.06m), the tsunami level reaches within less than 1 m of the soffit for the Avon River Pages Road bridge (Figure 3-11 – Figure 3-14), the Avon River Avondale Road bridge (Figure 3-15 and Figure 3-16), the Heathcote River Ferry Road Bridge (Figure 3-17 and Figure 3-18) and the Heathcote River Tunnel Road bridge (Figure 3-19 and Figure 3-20). This would make these bridges more vulnerable to debris transported by the tsunami waves.

The water level has not yet peaked at the end of the simulation at the Avon River Avondale Road bridge (Figure 3-15 and Figure 3-16). This is because the bridge is at a point that drains the inundation for a large area and water levels are likely to remain high long after the tsunami as the inundation drains back to the sea.

For some of the bridges (e.g., Waimakariri River SH1, Heathcote River Ferry Road) the maximum water level reached with the 1:500-year return period event exceeds the level reached by the 1:2,500-year return period event. While this may appear counter-intuitive, this is the result of the higher frequency waves from the 1:2,500-year scenario losing a large amount of energy while...
propagating along the river channels. The 1:500-year scenarios do not include such high frequency waves. This highlights the potential differences in impacts caused by different tsunami scenarios.
Table 3-1: Bridges on Waimakariri, Avon and Heathcote rivers with heights above LVD37 and modelled maximum tsunami height at those locations for the 1:500-year return period scenario.

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Bridge soffit level</th>
<th>1:500-year return period Tsunami height above LVD37 (m)</th>
<th>Current Sea Level</th>
<th>2040 Sea Level 0.19 m Rise</th>
<th>2065 Sea Level 0.41 m Rise</th>
<th>2120 Sea Level 1.06 m Rise</th>
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<tr>
<td>Bridge</td>
<td>Bridge soffit level above LVD37 (m)</td>
<td>1:2,500-year return period Tsunami height above LVD37 (m)</td>
<td>2040 Sea Level 0.19 m Rise</td>
<td>2065 Sea Level 0.41 m Rise</td>
<td>2120 Sea Level 1.06 m Rise</td>
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<td>2.31</td>
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<tr>
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<td>2.81</td>
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<tr>
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<td>2.60</td>
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Figure 3-5: Tsunami height timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Waimakariri River SH1 bridge.

Figure 3-6: Tsunami height timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Waimakariri River SH1 bridge.
Figure 3-7: Tsunami height timeseries for 1:500-year return period - Current Sea Level at Heathcote River Bamford Street.

Figure 3-8: Tsunami height timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Heathcote River Bamford Street.
Figure 3-9: Tsunami height timeseries for 1:2,500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise at Heathcote River Bamford Street.

Figure 3-10: Tsunami height timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Heathcote River Bamford Street.
Figure 3-11: Tsunami height timeseries for 1:500-year return period - Current Sea Level at Avon River Pages Road.

Figure 3-12: Tsunami height timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Avon River Pages Road.
Figure 3-13: Tsunami height timeseries for 1:2,500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise at Avon River Pages Road.

Figure 3-14: Tsunami height timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Avon River Pages Road.
Figure 3-15: Tsunami height timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Avon River Avondale Road bridge.

Figure 3-16: Tsunami height timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Avon River Avondale Road bridge.
Figure 3-17: Tsunami height timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Heathcote River Ferry Road bridge.

Figure 3-18: Tsunami height timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Heathcote River Ferry Road bridge.
Figure 3-19: Tsunami height timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Heathcote River Tunnel Road bridge.

Figure 3-20: Tsunami height timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Heathcote River Tunnel Road bridge.
3.3 Maximum inundation, speed and shear stress.

3.3.1 1:500-year return period tsunami - Current Sea Level

The inundation extent for the 1:500-year return period tsunami at current mean sea-level covers an area of 39 km² and reaches a maximum depth of 5.4 m near the Waimakariri River entrance. The main inundation locations on the northern side of the area of interest are the floodplain of the Brooklands Lagoon and the Styx River floodplain (Figure 3-21). In this area the high flow speed (>2 m/s) is constrained to the Waimakariri River Channel, the Kaiapoi River channel, Brooklands Lagoon and the Waimakariri River Mouth (Figure 3-22). On the southern side of the area of interest, inundation for the 1:500-year tsunami occurs in the floodplain of the Avon River, near the mouth of the Heathcote River, on the low-lying area along the Avon-Heathcote Estuary (e.g., South Shore) and near low lying "breaches" in the dunes near the New Brighton pier, and the Waimairi Beach surf club (North New Brighton) (Figure 3-23). Extremely high flow velocities are predicted in the Estuary mouth (8 m/s) and the Waimakariri River Mouth (7 m/s). High velocities are predicted near the dune breaches (New Brighton Pier, North New Brighton surf club, South Sumner) (3-4 m/s) and near the main bridges where the flow is constricted (Avon River Bridge Street bridge, 3.2 m/s, and Heathcote River Ferry Road bridge, 2.7 m/s) (Figure 3-24).

The high velocities predicted in the model would entrain large quantities of sediment and radically modify the topography and bathymetry from what was used in the model. This could affect later inundation but is not captured in the modelling.
Figure 3-21: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event Current Sea Level - Northern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
Figure 3-22: Maximum flow velocity for 1:500-year return period event Current Sea Level - Northern Section.
Figure 3-23: Maximum inundation depth (i.e., height above ground) for 1:500-year return period eventCurrent Sea Level - Southern Section. Note that for the river channels the value given is the height above thepre-tsunami water level.
Figure 3-24: Maximum flow velocity for 1:500-year return period event Current Sea Level - Southern Section.

3.3.2 1:500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise

For the 1:500-year return period tsunami at 0.19 m above present mean sea-level (2040 scenario), the inundation covers an area of 45 km² and reaches a maximum depth of 5.6 m. The inundation naturally extends further than the scenario with present day sea level (Figure 3-25 and Figure 3-27). Flow velocity patterns are similar to the present day sea-level and similar flow speeds are observed at the main bridges (Figure 3-26 and Figure 3-28).
Figure 3-25: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Northern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
Figure 3-26: Maximum flow velocity for 1:500-year return period event 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Northern Section.
Figure 3-27: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Southern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.

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**3.3.3 1:500-year return period - 2065 Sea Level Scenario – 0.41 m Sea Level Rise**

Inundation extent for the 1:500-year return period tsunami at 0.41 m sea-level rise (Figure 3-29 and Figure 3-31) covers an area of 47 km² and reaches a maximum depth of 5.1 m. Overall the flow patterns are similar (Figure 3-30 and Figure 3-32), however, more water can overtop the dunes near the New Brighton Pier than in the scenarios presented above and in the dune “breach” the flow speed exceed 4 m/s.
Figure 3-29: Maximum inundation depth (i.e., height above ground) for 1:500-year return period 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Northern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
Figure 3-30: Maximum flow velocity for 1:500-year return period event 2065 Sea Level Scenario – 0.41 m
Sea Level Rise - Northern Section.
Figure 3-31: Maximum inundation depth (i.e., height above ground) for 1:500-year return period 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Southern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
3.3.4 1:500-year return period - 2120 Sea Level Scenario – 1.06 m Sea Level Rise

Inundation extent for the 1:500-year return period tsunami at 1.06 m sea-level rise covers an area of 70 km² and reaches a maximum depth of 5.8 m (Figure 3-33 and Figure 3-35). The dunes on the coastal strip are overtopped at numerous locations causing nearly continuous inundation of the dune backshore. Flow velocity does not increase at the main bridges but increases in the flooded area (e.g., South New Brighton, over the Sumner sea-wall) (Figure 3-34 and Figure 3-36). This overtopping...
would likely erode the dunes and could cause increased inundation, but this is not captured in this model.

![Map of inundation depth](image)

**Figure 3-33:** Maximum inundation depth (i.e., height above ground) for 1:500-year return period event 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Northern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
Figure 3-34: Maximum flow velocity for 1:500-year return period event 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Northern Section.
Figure 3-35: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Southern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
3.3.5 1:2500-year return period tsunami - Current Sea Level

The inundation extent for the 1:2500-year return period tsunami at current mean sea-level covers an area of 50 km² and reaches a maximum depth of 9.5 m near the Waimakariri River mouth. The result of this simulation has previously been reported by Lane et al. (2017) and is not repeated here, however the results are given in Figure 3-37 to Figure 3-40 to allow comparison with simulations at higher sea levels.

Land Drainage Recovery Programme: Tsunami Study
Figure 3-37: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period event
Current Sea Level - Northern Section. Note that for the river channels the value given is the height above the
pre-tsunami water level.
Figure 3-38: Maximum flow velocity for 1:2500-year return period event Current Sea Level - Northern Section.
Figure 3-39: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period event Current Sea Level - Southern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
3.3.6 1:2500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise

Inundation extent for the 1:2500-year return period tsunami at 0.19 m sea-level rise covers an area of 55 km² and reaches a maximum depth of 8.4 m near the Waimakariri River mouth. It is unclear why this maximum value is lower than on the previous scenario but is likely due to the fact that the front of the first tsunami wave travels slightly faster than in scenarios with a lower water level which affect the shoaling of the tsunami waves. The inundation extent is comparable to the 1:500-year return period at 0.19 m sea-level but with higher inundation depth especially in the coastal strip. In this scenario the dunes along coastal strip are consistently overtopped by the tsunami waves leading to major inundation on the low-lying area of the backshore (Figure 3-41 and Figure 3-43). This

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overtopping would likely erode the dunes and could cause increased inundation, but this is not captured in this model. The simulated flow velocity over the dunes is also much faster than in the 1:500-year return period scenario exceeding 10 m/s at the Avon-Heathcote Estuary mouth and over the dunes in New Brighton (Figure 3-42 and Figure 3-44).

Figure 3-41: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Northern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
Figure 3-42: Maximum flow velocity for 1:2500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Northern Section.
Figure 3-43: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Southern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
3.3.7 1:2500-year return period - 2065 Sea Level Scenario – 0.41 m Sea Level Rise

Inundation extent for the 1:2500-year return period tsunami at 0.41 m sea-level rise covers an area of 48 km² and reaches a maximum depth of 8.5 m near the Waimakariri River entrance. The tsunami waves in this scenario is slightly diverted southward compared with the scenario at 0.19 m sea-level rise causing less inundation on the north of the Waimakariri River. In the rest of the model area the inundation is slightly larger (Figure 3-45 and Figure 3-47). As with the previous sea level scenario, the dunes along coastal strip are consistently overtopped by the tsunami waves lead to major inundation on the low-lying area of the coastal strip with velocity exceeding 10 m/s where the dunes are
overtopped (Figure 3-46 and Figure 3-48). This overtopping would likely erode the dunes and could cause increased inundation, but this is not captured in this model.

Figure 3-45: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period - 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Northern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
Figure 3-46: Maximum flow velocity for 1:2500-year return period - 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Northern Section.
Figure 3-47: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period - 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Southern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
3.3.8 1:2500-year return period - 2120 Sea Level Scenario – 1.06 m Sea Level Rise

Inundation extent for the 1:2500-year return period tsunami at 1.06 m sea-level rise covers an area of 73 km² and reaches a maximum depth of 9.5 m near the Waimakariri River mouth. As expected this scenario shows the worst inundation and largest flow velocities. However, the inundation extent is only slightly larger than the 1:500-year scenario at the 1.06 m sea level rise but with significantly larger maximum inundation depth and flow velocity (for the 1:2500-year return period scenario), especially along the coastal strip. The inundation reaches as far as the Waltham suburb on the Heathcote River and the Avonside suburb on the Avon River and covers the entire coastal strip (Figure 3-49 and Figure 3-51). Simulated flow velocities in the Avon-Heathcote Estuary exceed 12 m/s.
near the entrance and 8 m/s where the dunes are overtopped (Figure 3-50 and Figure 3-52). This overtopping would likely erode the dunes and could cause increased inundation, but this is not captured in this model.

Figure 3-49: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period - 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Northern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
Figure 3-50: Maximum flow velocity for 1:2500-year return period - 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Northern Section.

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Figure 3-51: Maximum inundation depth (i.e., height above ground) for 1:2500-year return period - 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Southern Section. Note that for the river channels the value given is the height above the pre-tsunami water level.
3.4 Erosion

Tsunami waves can cause strong currents capable of transporting large amount of non-cohesive sediment. These high velocities predominantly occur at (but are not restricted to) the mouth of rivers and below bridges where the flow is constricted. When high flow velocities are sustained, they can cause scouring and severe erosion. The extent and depth of the erosion depends on the type of scouring, the bed sediment and other flow characteristics. Qualitatively, scouring and severe erosion is likely to occur:

- Around channel bend (Bend scour).

Figure 3-52: Maximum flow velocity for 1:2500-year return period - 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Southern Section.
- Where flow is constricted (by debris or structures) (constriction scour).
- Near weirs and drops in the topography (weir scour).
- Near piers, abutments and near buildings (local scour).

Erosion potential can be evaluated using empirical relationships specific to each scour type but are designed for specific bed type with specific geometric parameters that are not directly applicable in the case of tsunami inundation. In particular, many empirical equations are available to assess the constriction scour but most of these relationships assumes that the flow upstream is restricted to a channel. These types of empirical relationships are not applicable for dune overtopping or scouring around buildings. The effect of flow constriction is calculated in the model for features that are larger than the model finest resolution (13.2 m) and the sediment transport potential is described by the flow bottom shear stress. This allow for a qualitative assessment of the locations where scouring is most likely to occur for each scenario using information of maximum bottom shear-stress, and results presented above (maximum flow velocity and maximum inundation depth). This is done on a broad scale and does not capture smaller scale scouring that may occur around buildings, small-scale structures or small-scale channels.

The critical shear stress is the minimum shear stress necessary to mobilise a particle of sediment of a given size (Table 3-3). Near Christchurch, the dunes are composed of fine sand, but coarser material is present near the rivers.
Table 3.3: Critical shear stress by particle-size classification for determining approximate condition for sediment. Note that critical shear stress only indicates mobility rather than transport. This table was calculated using a fixed sediment density. From Berenbrock and Tranmer (2008).

<table>
<thead>
<tr>
<th>Particle classification name</th>
<th>Ranges of particle diameters</th>
<th>Critical bed shear stress (t.) (N/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse cobble</td>
<td>128 – 256</td>
<td>112 – 223</td>
</tr>
<tr>
<td>Fine cobble</td>
<td>64 – 128</td>
<td>53.8 – 112</td>
</tr>
<tr>
<td>Very coarse gravel</td>
<td>32 – 64</td>
<td>25.9 – 53.8</td>
</tr>
<tr>
<td>Coarse gravel</td>
<td>16 – 32</td>
<td>12.2 – 25.9</td>
</tr>
<tr>
<td>Medium gravel</td>
<td>8 – 16</td>
<td>5.7 – 12.2</td>
</tr>
<tr>
<td>Fine gravel</td>
<td>4 – 8</td>
<td>2.7 – 5.7</td>
</tr>
<tr>
<td>Very fine gravel</td>
<td>2 – 4</td>
<td>1.3 – 2.7</td>
</tr>
<tr>
<td>Very coarse sand</td>
<td>1 – 2</td>
<td>0.47 – 1.3</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>0.5 – 1</td>
<td>0.27 – 0.47</td>
</tr>
<tr>
<td>Medium sand</td>
<td>0.25 – 0.5</td>
<td>0.194 – 0.27</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.125 – 0.25</td>
<td>0.145 – 0.194</td>
</tr>
<tr>
<td>Very fine sand</td>
<td>0.0625 – 0.125</td>
<td>0.110 – 0.145</td>
</tr>
<tr>
<td>Coarse silt</td>
<td>0.0310 – 0.0625</td>
<td>0.0826 – 0.110</td>
</tr>
<tr>
<td>Medium silt</td>
<td>0.0156 – 0.0310</td>
<td>0.0630 – 0.0826</td>
</tr>
<tr>
<td>Fine silt</td>
<td>0.0078 – 0.0156</td>
<td>0.0378 – 0.0630</td>
</tr>
</tbody>
</table>

In all the scenario presented here, the shear-stress exceeds 30 N.m⁻² at the mouth of the Waimakariri River and at the mouth of the Avon-Heathcote Estuary (Figure 3-53 – Figure 3-68). These values far exceed the critical shear stress necessary to transport fine sand (0.14 – 0.20 N.m⁻²) present there. The duration where the flow exceeds the critical shear stress for sand was not recorded in the model, but major scour can be expected there.

3.4.1 1:500-year return period tsunami scenarios

For the 1:500-year return period tsunami scenario, the bottom shear-stress is also high in the area where the dune is overtopped (New Brighton, North New Brighton, South Sumner) (10-15 N.m⁻²) (Figure 3-54, Figure 3-56 and Figure 3-58). This is likely to cause localised dune overwash causing significant erosion and locally worsen the inundation. The shear stress further in the Estuary is high on the Avon at the Bridge Street bridge (5-10 N.m⁻²) and on the Heathcote River at the Ferry Road bridge (5-10 N.m⁻²). There, significant scouring can be expected. At higher sea level rise scenarios, the shear-stress near these bridges is somewhat reduced as the inundation extends around the
structures so the flow can go around the structure. This is likely to cause erosion around the structure, but this is not captured in the model and difficult to assess. Large areas of inundation show a shear-stress lower than 1 N.m⁻² (Figure 3-53, Figure 3-55, Figure 3-57, Figure 3-59), in these areas erosion could still occur but may be localised or limited.

Figure 3-53: Maximum bottom shear stress for 1:500-year return period event Current Sea Level - Northern Section.
Figure 3-54: Maximum bottom shear stress for 1:500-year return period event Current Sea Level - Southern Section.
Figure 3-55: Maximum bottom shear stress for 1:500-year return period event 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Northern Section.
Figure 3-56: Maximum bottom shear stress for 1:500-year return period event 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Southern Section.
Figure 3-57: Maximum bottom shear stress for 1:500-year return period 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Northern Section.
Figure 3-58: Maximum bottom shear stress for 1:500-year return period 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Southern Section.
Figure 3-59: Maximum bottom shear stress for 1:500-year return period event 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Northern Section.
Figure 3-60: Maximum bottom shear stress for 1:500-year return period event 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Southern Section.

3.4.2 1:2,500-year return period tsunami scenarios

For the 1:2,500-year return period tsunami scenario, the dunes are consistently overtopped with flows at high shear-stress (>30 N.m⁻²) likely to cause severe dune overwash along the entire coastal strip (Figure 3-61, Figure 3-63 – Figure 3-68). Dune overwash is likely to severely worsen the inundation depth in the coastal strip, a process not included in this modelling. The maximum shear-stress in the lower part of the Waimakariri River channel (downstream of the Kaiapoi confluence) and in the lower part of the Avon-Heathcote Estuary exceeds 20 N.m⁻² which implies that major scouring and sediment transport is likely. In all the sea-level scenario, a high shear stress also occurs (5-15 N.m⁻²) on the shore of the Avon-Heathcote Estuary. Although vegetation is likely to limit the
extent of the scouring there, significant erosion can be expected. In this tsunami scenario, high shear-stress in the nearshore is likely to cause significant erosion.

Figure 3-61: Maximum bottom shear stress for 1:2500-year return period event Current Sea Level - Northern Section.
Figure 3-62: Maximum bottom shear stress for 1:2500-year return period event Current Sea Level - Southern Section.
Figure 3-63: Maximum bottom shear stress for 1:2500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Northern Section.
Figure 3-64: Maximum bottom shear stress for 1:2500-year return period - 2040 Sea Level Scenario – 0.19 m Sea Level Rise - Southern Section.
Figure 3-65: Maximum bottom shear stress for 1:2500-year return period - 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Northern Section.
Figure 3-66: Maximum bottom shear stress for 1:2500-year return period - 2065 Sea Level Scenario – 0.41 m Sea Level Rise - Southern Section.
Figure 3-67: Maximum bottom shear stress for 1:2500-year return period - 2120 Sea Level Scenario – 1.06 m Sea Level Rise - Northern Section.
3.4.3 Flow velocity at bridges

Bridges are often associated with a flow constriction and subject to constriction scour during tsunami events. Depth-averaged flow velocity is presented here to qualitatively assess the scour at bridges. The tsunami simulation here does not take into account the flow under the bridge as the water level reaches the soffit of the bridge. It is also important to consider that tsunami transport large quantities of debris that can get caught by the bridge structure and further restrict the flow under a bridge.
Bridges that experience the highest flow velocity (Table 3-4 Table 3-5) are the Avon River Bridge Street bridge (e.g., Figure 3-69 and Figure 3-70), the Heathcote River Ferry Road bridge (e.g., Figure 3-71 and Figure 3-72), Heathcote River Tunnel Road bridge (e.g., Figure 3-73 and Figure 3-74) and bridges on the Waimakariri River (e.g., Figure 3-75 and Figure 3-76)

Table 3-4: Bridges on Waimakariri, Avon and Heathcote rivers with heights above LVD37 and modelled maximum tsunami flow velocity at those locations for the 1:500-year return period scenario.

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Bridge soffit level above LVD37 (m)</th>
<th>Current Sea Level</th>
<th>1:500-year return period Tsunami flow speed [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waimakariri River Main North Rd</td>
<td>7.8</td>
<td>1.47</td>
<td>1.58, 1.65, 1.76</td>
</tr>
<tr>
<td>Waimakariri River SH1</td>
<td>6.2</td>
<td>3.08</td>
<td>3.17, 3.00, 2.75</td>
</tr>
<tr>
<td>Avon River Bridge Street</td>
<td>4.2</td>
<td>0.47</td>
<td>0.42, 0.51, 0.44</td>
</tr>
<tr>
<td>Avon River Pages Road</td>
<td>4.2</td>
<td>0.68</td>
<td>0.94, 1.24, 2.00</td>
</tr>
<tr>
<td>Avon River Anzac Drive</td>
<td>4.2</td>
<td>0.63</td>
<td>0.79, 1.05, 1.66</td>
</tr>
<tr>
<td>Avon River Avondale Road</td>
<td>3.8</td>
<td>2.77</td>
<td>2.91, 2.98, 2.99</td>
</tr>
<tr>
<td>Heathcote River Ferry Road</td>
<td>4.3</td>
<td>0.86</td>
<td>1.15, 1.52, 1.91</td>
</tr>
<tr>
<td>Heathcote River Tunnel Road</td>
<td>2.1</td>
<td>0.56</td>
<td>0.65, 0.75, 0.99</td>
</tr>
<tr>
<td>Heathcote River Bamford Street</td>
<td>0.61</td>
<td>0.71</td>
<td>0.81, 1.19</td>
</tr>
<tr>
<td>Heathcote River SH 74A</td>
<td>0.49</td>
<td>0.54</td>
<td>0.60, 1.00</td>
</tr>
<tr>
<td>Heathcote River Connal Street</td>
<td>0.27</td>
<td>0.30</td>
<td>0.27, 0.39</td>
</tr>
</tbody>
</table>

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Table 3-5: Bridges on Waimakariri, Avon and Heathcote rivers with heights above LVD37 and modelled maximum tsunami height at those locations for the 1:2,500-year return period scenario.

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Bridge soffit level above LVD37 (m)</th>
<th>1:2,500-year return period Tsunami flow speed [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2040 Sea Level 0.19 m Rise</td>
</tr>
<tr>
<td>Waimakariri River Main North Rd</td>
<td>7.8</td>
<td>2.34</td>
</tr>
<tr>
<td>Waimakariri River SH1</td>
<td>6.2</td>
<td>2.26</td>
</tr>
<tr>
<td>Avon River Bridge Street</td>
<td>6.2</td>
<td>3.91</td>
</tr>
<tr>
<td>Avon River Pages Road</td>
<td>4.2</td>
<td>0.97</td>
</tr>
<tr>
<td>Avon River Anzac Drive</td>
<td>4.2</td>
<td>0.91</td>
</tr>
<tr>
<td>Avon River Avondale Road</td>
<td>3.8</td>
<td>0.74</td>
</tr>
<tr>
<td>Heathcote River Ferry Road</td>
<td>4.6</td>
<td>2.90</td>
</tr>
<tr>
<td>Heathcote River Tunnel Road</td>
<td>4.3</td>
<td>1.06</td>
</tr>
<tr>
<td>Heathcote River Bamford Street</td>
<td>2.1</td>
<td>0.58</td>
</tr>
<tr>
<td>Heathcote River SH 74A</td>
<td>0.62</td>
<td>0.66</td>
</tr>
<tr>
<td>Heathcote River Connal Street</td>
<td>0.45</td>
<td>0.50</td>
</tr>
<tr>
<td>Heathcote River Radley Street</td>
<td>0.23</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Land Drainage Recovery Programme: Tsunami Study
Figure 3-69: Flow velocity timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Avon River Bridge Street bridge.

Figure 3-70: Flow velocity timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Avon River Bridge Street bridge.
Figure 3-71: Flow velocity timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Heathcote River Ferry Road bridge.

Figure 3-72: Flow velocity timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Heathcote River Ferry Road bridge.
Figure 3-73: Flow velocity timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Heathcote River Tunnel Road bridge.

Figure 3-74: Flow velocity timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at Heathcote River Tunnel Road bridge.
Figure 3-75: Flow velocity timeseries for 1:500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Waimakariri River Main North Road bridge.

Figure 3-76: Flow velocity timeseries for 1:2,500-year return period – 2120 Sea Level Scenario – 1.06 m Sea Level Rise at the Waimakariri River Main North Road bridge.
4 Conclusion

NIWA was commissioned by Christchurch City Council (CCC) to carry out a numerical modelling study of tsunami inundation in Christchurch caused by two tsunamis originating from distant sources. The selected tsunami sources were a 1:500-year return period event cause by a magnitude 9.28 earthquake and a 1:2,500-year return period event caused by a magnitude Mw 9.485 earthquake both at the Peru subduction zone. The simulations were completed for different sea-level rise scenario (present day, 0.19 m, 0.41 m and 1.06 m) taking into account predicted shoreline changes predicted for 2065 and 2120. Note that the magnitude Mw 9.485 scenario at current sea-level was produced in a previous study (Lane et al. 2017) and not replicated here.

The simulations were completed at MHWS (1.2 m above the Lyttelton Vertical Datum 1937) adjusted according each sea level rise scenario. The flow of the Waimakariri River, Avon River and Heathcote River was also included in the model.

Both tsunami scenarios result in major inundation in Christchurch which, as expected, worsen with the higher sea-level scenarios. The model captures the complexity of the flow over the dunes and inland. The attenuation of the tsunami wave leads to a similar inundation extent for both tsunami scenarios but the inundation depth and flow velocity along the coastal strip was much larger for the worst-case tsunami (1:2,500-year scenario). The total inundation extent for the higher sea level rise scenario (1.06 m above present sea level) was 70 km² for the 1:500-year return period tsunami event, 79 per cent more than for the same tsunami occurring at present day sea level.

Such large tsunami events are expected to cause severe erosion to the dunes on the coastal strip and at the mouth of the Waimakariri River and the Avon-Heathcote Estuary. Severe erosion can also be expected at the Avon Bridge Street bridge and the Heathcote Ferry Road bridge.
5 References


Power, W.L. (2014) Tsunami hazard curves and deaggregation plots for 20 km coastal sections, derived from the 2013 Nation Tsunami Hazard Model. GNS Science Report


6 Appendix A Future Topography

Future sea level rise is associated with shoreline retreat for the coast south of Christchurch (Tonkin & Taylor Ltd 2017). This shoreline retreat was applied to the topography of the shore, for the scenario with sea level rise for 2065 (0.41 m) and the scenario for 2120 (1.06 m), by shifting, landward, the present shore topography based on the shoreline retreat estimated by Tonkin & Taylor Ltd (2017). Below are figure showing the present topography (Figure A-1) and the future topography (Figure A-2 and Figure A-3). The comparison of the different topography is illustrated in (Figure A-4).

![Diagram of topography and bathymetry]

Figure 6-1: Topography and bathymetry of the Brighton shore – Present. The dotted line shows the present shoreline, as defined by LINZ datasets at MHWS; the blue plain line shows the extent of the domain change in the tsunami simulations; the thick black line shows the location of the 600 m long cross-shore profile presented in Figure 6-4. The estuarine/marine edge of the green shading is defined by mean level of sea. Colour shading is indicative.
Figure 6-2: Topography and bathymetry of the Brighton shore – 2065. The dotted line shows the present shoreline, as defined by LINZ datasets at MHWS; the blue plain line shows the extent of the domain change in the tsunami simulations; the thick black line shows the location of the 600 m long cross-shore profile presented in Figure 6-4. The estuarine/marine edge of the green shading is defined by mean level of sea. Colour shading is indicative.
Figure 6-3: Topography and bathymetry of the Brighton shore – 2120. The dotted line shows the present shoreline, as defined by LINZ datasets at MHWS; the blue plain line shows the extent of the domain change in the tsunami simulations; the thick black line shore shows the location of the 600m long cross-shore profile presented in Figure 6-4. The estuarine/marine edge of the green shading is defined by mean level of sea. Colour shading is indicative.
Figure 6-4: Topography along a cross-shore profile. The black line is the present topography (along the cross-section shown in Figure 6-1), the grey line is the 2065 topography (along the cross-section shown in Figure 6-2), the dashed line is the 2120 topography (along the cross-section shown in Figure 6-3). Where only the black line is visible, the three lines are on top of each other.
7   Appendix B Progress Report

7.1   Local Source

Local faults with a high likelihood of causing a significant tsunami in Christchurch between Sumner and Waimakariri River mouth were identified in consultation with Dr Phil Barnes based on data in Barnes et al. (2016). Faults rupture parameters are taken from Barnes (personal communication). Figure 7-1 shows the locations of the faults used and Table 7-1 give some of their parameters. The maximum values for rupture parameters were used to test the worst-case scenarios for local faults. The four scenarios modelled were two single fault ruptures and two multiple fault ruptures, viz.:

- LeithfieldNC1137.
- Pegasus1nw.
- LeithfieldNC1137 and NorthCant8.
- Pegasus1nw and NorthCant4.

![Map showing local tsunami faults](image)

Figure 7-1: Faults used in local tsunami modelling. Single fault rupture scenarios of LeithfieldNC1137 and Pegasus1nw are modelled as well as combined fault of LeithfieldNC1137 and NorthCant8 and Pegasus1nw and NorthCant4.
Table 7-1: Faults used in local tsunami scenarios. Maximum length, slip, magnitude and associated recurrence interval.

<table>
<thead>
<tr>
<th>Fault Name</th>
<th>Length (km)</th>
<th>Slip (cm)</th>
<th>Mw</th>
<th>Recurrence interval (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leithfield1137</td>
<td>45.1</td>
<td>236</td>
<td>7.4</td>
<td>12,500</td>
</tr>
<tr>
<td>Pegasus1nw</td>
<td>40.7</td>
<td>213</td>
<td>7.3</td>
<td>22,500</td>
</tr>
<tr>
<td>NorthCant4</td>
<td>25.3</td>
<td>132</td>
<td>7.0</td>
<td>35,000</td>
</tr>
<tr>
<td>NorthCant8</td>
<td>37.4</td>
<td>195</td>
<td>7.3</td>
<td>21,000</td>
</tr>
</tbody>
</table>

The magnitude of the combined LeithfieldNC1137 and NorthCant8 faults rupturing is $M_w$ 7.7, and for Pegasus1nw and NorthCant4 combined it is $M_w$ 7.6.

Figure 7-2 to Figure 7-5 show the maximum water level over four hours of simulation from the four scenarios and Figure 7-6 to Figure 7-9 show close-ups for the region of interest. Note that the baseline water level for these runs is set to mean sea level. In all four scenarios, the northern portion of Pegasus Bay and the northern facing bays on Banks Peninsula are considerably more affected than the area of Christchurch City between Sumner and the Waimakariri River mouth. The scenario that most affects that region is the combined LeithfieldNC1137 and NorthCant8, where maximum wave height at coast exceed 3 m in some parts of that region and run-up can be up to 6 m. The combined Pegasus1nw and NorthCant4 scenario has maximum wave heights at coast of up to 2 m, with run-ups potentially higher. The single faults scenarios (LeithfieldNC1137 fault and Pegasus1nw fault) give maximum wave heights at coast around Christchurch of up to 1.5 m. Figure 7-10 shows time series of the water levels at locations approximately 500 m off-shore New Brighton, Sumner and Lyttelton for the four scenarios. Based on this modelling we recommend inundation modelling of the combined LeithfieldNC1137 and NorthCant8 scenario and the combined Pegasus1nw and NorthCant4 rupture scenario.
Figure 7-2: Maximum water level over entire simulation for rupture of LeithfieldNC1137 fault.

Figure 7-3: Maximum water level over entire simulation for rupture of Pegasus1nw fault.
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Figure 7.10: Time series for tsunamis off-shore New Brighton, Sumner and Lyttelton.

7.2 Far field tsunami

The following scenarios were chosen for far-field tsunami inundation modelling based on the disaggregation analysis of Power (2013,2014):

- 1:500-year tsunami inundation in Christchurch City due to a $M_w$ 9.28 subduction earthquake occurring off the coast of Peru (the most likely source for a 1:500-year tsunami for Christchurch City at 50th percentile as identified by Power 2013; 2014).

- 1:2,500-year tsunami inundation (maximum credible tsunami) in Christchurch City due to a $M_w$ 9.485 subduction earthquake originating off the coast of Peru (the most likely source for a 1:2,500-year tsunami for Christchurch City at 84th percentile as identified by Power 2013; 2014).

7.2.1 Source

Tsunami propagation of the 1:2500-year tsunami event was previously completed by Lane et al. (2017) and will be reused here. However, a rupture scenario had not been selected for the 1:500-year tsunami originating off the coast of Peru. The de-aggregation analysis (Power 2013) does not provide the fault segments involved nor the amount of slip to be expected for each segment. To determine the fault segments involved for each scenario, a sensitivity analysis was completed using the SIFT (Short-term Inundation Forecast for Tsunamis) database (Gica et al. 2008) and the ComMIT interface (Titov et al. 2011).

The SIFT database is a collection of Pacific-wide tsunami propagation results modelled from unit sources (1 m slip on fault segments 100 km long by 50 km wide, each with its own fault parameters,
covering all the major Pacific subduction zones). Approximations of trans-Pacific tsunamis can be quickly estimated using super-position of the unit sources.

To establish the most suitable fault units for a $M_w$ 9.28 in south Peru, the SFIT databased was downloaded for fault segments on the coast of South America from 5° S to 25° S. A 20 m slip was applied to each segment of the database and the resulting wave height in the center of Pegasus Bay was extracted.

The segments that produced the largest waves for Pegasus Bay (Figure 7-11) are located just North of the border between Peru and Chile. The segment producing the largest waves in Pegasus Bay are:

- cs68z.
- cs69z.
- cs70z.

![Figure 7-11: Maximum wave height in Pegasus Bay resulting from a 20 m slip earthquake applied at each fault unit in the SFIT database for South America. A scenario producing a $M_w$ 9.28 earthquake would involve more faults segments than the three segments identified. The scenarios (Table 7-2) were designed to produce the desired moment magnitude earthquake and a continuous fault rupture.](image)

<table>
<thead>
<tr>
<th>Table 7-2: Earthquake scenario for 1:500-year tsunami inundation.</th>
</tr>
</thead>
</table>

Land Drainage Recovery Programme: Tsunami Study
7.2.2 Transpacific propagation

Both scenario show waves between 1 and 3 m propagating across the South Pacific with scenario B generating smaller waves.

Figure 7-12 and Figure 7-13). These waves are greatly amplified in Pegasus Bay with maximum wave amplitudes exceeding 4.0 m. Off the coast of Christchurch (3 km offshore), the two scenario produces similar waves with wave amplitude exceeding 4.5 m in scenario A and 3.5 m in scenario B (Figure 7-14).
Figure 7-12: Maximum wave amplitude [m] across the South Pacific produced by Scenario A.

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7.3 References


Tsunami inundation modelling for Lyttelton and Akaroa Harbours

1:500-year event from South America

Prepared for Christchurch City Council

May 2018
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Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Executive summary

NIWA has previously completed tsunami inundation modelling of 1:500-year and 1:2,500-year events for Christchurch City (from Taylor’s Mistake in the south through to the Waimakariri River in the north) as part of the Land Drainage Recovery Programme (LDRP) Tsunami Study (Bossirelle et al. 2018). This study adds to this previous modelling to better understand the tsunami hazard in Lyttelton and Akaroa Harbours, in order to have consistent tsunami inundation maps over the whole area.

This study simulates the tsunami inundation in Lyttelton and Akaroa Harbours for a 1:500-year tsunami event produced by an Mw 9.28 earthquake occurring in South Peru (same event as in the previous study) for three sea level conditions: 1) Mean High Water Spring (MHWS) at present mean sea level (MSL); 2) MHWS for 2065 MSL (0.41 m above present MSL); and 3) MHWS for 2120 MSL (1.06 m above present MSL). This study also evaluates the flow velocities associated with the tsunami waves and identifies the erosion potential using bottom shear stress as a proxy for sediment transport.

Results indicate that, in Lyttelton Harbour, Lyttelton Port, Purau and Charteris Bay are the most affected by the tsunami but inundation also occurs in the Head of the Bay and Governors Bay. Tsunami amplification at the Head of the Bay leads to inundation extending 2.5 km inland, with inundation depth exceeding 7 m.

In Akaroa Harbour, most bays are inundated by the tsunami, with more properties and residences exposed than in Lyttelton Harbour. Although not as severe as in the Head of the Bay in Lyttelton Harbour, the inundation extent and depth exceeds 300 m and 4 m in Akaroa town, respectively, as well as in most bays in the harbour.

The scenarios with increased sea levels result in an increase in the inundation depth and extent, and expose many more properties and residences in Akaroa Harbour (especially Akaroa town) to inundation and damage. Similar increases in tsunami depth and inundation did not significantly expose more properties in Lyttelton Harbour.
1 Introduction

NIWA has completed inundation modelling of the impact of a 1:500-year and a 1:2,500-year tsunami event on Christchurch City (from Taylor’s Mistake in the south through to the Waimakariri River in the north). This work was conducted for Christchurch City Council (CCC) as part of the Land Drainage Recovery Programme (LDRP) Tsunami Study (Boisserelle et al. 2018). The CCC’s purview covers a wider geographic region encompassing Lyttelton Harbour and Banks Peninsula. As such CCC are also interested in understanding the tsunami hazard in this wider region, especially in Lyttelton and Akaroa harbours, in order to have consistent tsunami inundation maps over the whole area for use in planning purpose. See Figure 6-1 and Page 47 for definitions of tsunami inundation terms used in this report.

This study simulates the tsunami inundation in Lyttelton and Akaroa Harbours for the same 1:500-year event as in the previous study for three sea level conditions (as calculated by Tonkin & Taylor (2017)): 1) Mean High Water Spring (MHWS) at present mean sea level (MSL); 2) MHWS for 2065 MSL (0.41 m above present MSL); and 3) MHWS for 2120 MSL (1.06 m above present MSL). This study also evaluates the flow velocities associated with the tsunami and identifies the erosion potential using bottom shear stress as a proxy for sediment transport (e.g., Powell 1998).

1.1 Use of this report

Whilst information provided in this report are intended to inform about the tsunami hazards, they may also be useful for strategic development and infrastructure planning as it may, when used with other hazard and risk information, highlight areas of higher vulnerability that are potentially unsuitable for future development. Digital GIS files and maps of the inundation extents should not be used at scales finer than 1:25,000. The overview maps are intended as a guide only and should not be used for interpreting inundation.

The main purpose of this report is to provide CCC with a clearer understanding of the potential 1:500-year tsunami inundation extent and the effects of sea-level rise on Lyttelton and Akaroa Harbours. The information provided is intended to aid understanding of the tsunami for current conditions and sea-level rise scenarios up to 2120 (1.06 m), including how tsunami could impact the local bays in terms of geomorphic changes, scouring and deposition and resulting long-term effects.

1.2 Caveat

This report is based on state-of-the-art knowledge and modelling capabilities of tsunamis and tsunami inundation at the time of writing. While every effort was made to provide accurate information, there are many uncertainties involved including knowledge of potential tsunami sources, source characteristics, bathymetry and topography. In addition, while the hydrodynamic models capture much of the physics involved in tsunami propagation and inundation, they also include some simplifying assumptions, as with all models.

This report also provides a qualitative assessment of the potential erosion caused by the tsunami. This assessment is based on the model prediction of maximum shear stress which is only a proxy for sediment transport potential. As a result, no estimates can be made of the amount of erosion or the depth of scouring.

The information provided in this report is of a technical nature and should be considered with the above limitations in mind.

---

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
2 Methods

2.1 Models

The tsunami modelling was undertaken using ComMIT for Trans-Pacific tsunami propagation and Basilisk for the harbour simulation.

ComMIT stands for COMMunity Model Interface for Tsunami, and is an interface around NOAA’s Method of Splitting Tsunamis (MOST) tsunami model (Titov et al. 2011). It uses initial conditions from the pre-computed propagation database SIFT (Short-term Inundation Forecast for Tsunamis database (Gica et al. 2008)).

Basilisk (Popinet 2015) is a partial differential equation solver based on adaptive Cartesian meshes that has been used for tsunami modelling in a range of situations (Lane et al. 2017, Lee et al. 2015, Popinet 2011, 2012).

In this study we follow the methodology of Bossereille et al. (2018), where ComMIT is used to produce tsunami water levels near the coast at the boundary of the Basilisk model grid. Water levels simulated using ComMIT were then “nested” (i.e., used as a boundary forcing) in Basilisk for simulating tsunami propagation and inundation in Lyttelton and Akaroa Harbours.

2.2 Tsunami source

The aim of this work is to simulate the inundation from a tsunami generated by an earthquake on the South American subduction zone. Using a sensitivity analysis of tsunami wave heights in Pegasus Bay, Bossereille et al. (2018) previously identified the fault segments from the SIFT database that would produce the largest waves in Pegasus Bay, namely, segments cs68z, cs69z and cs70z (Figure 2-1). While these faults are likely to produce large waves in Akaroa and Lyttelton Harbours, they may not necessarily be the fault segments that produce the largest waves in either harbour. In fact, Borreiro and Goring (2015) showed, using a similar method, that the fault segments that produce the largest waves in Lyttelton Port for Mw 8.5 earthquake in South America are located between 25° and 30°S. However, because this study is following up from the work of Bossereille et al. (2018) and to remain consistent with this previous study, the same tsunami source for the 1:500-year event is used. The event consists of a Mw 9.28 earthquake involving 13 SIFT fault segments (Figure 2-2) and a uniform slip of 35.89 m along each segment. The default SIFT rigidity of $4.4 \times 10^{11} \text{dyn/cm}^2$ was assumed as is the case in Bossereille et al. (2018). This was identified in the Probabilistic Tsunami Hazard Assessment undertaken in Power (2013) as being the most likely source scenario for the 1:500-year event (50th percentile) for Christchurch City.
Figure 2-1:  Maximum wave height in Pegasus Bay resulting from a 20m slip earthquake applied at each fault unit in the SIFT database for South America.  Source: Bosserelle et al. (2018).

Figure 2-2:  Fault segments involved in the Mw 9.28 earthquake scenario for 1:500-year tsunami inundation (highlighted in red).  SIFT segments used are: cs67a, cs67z, cs68a, cs68z, cs69a, cs69y, cs69z, cs70a, cs70y, cs70z, cs71a, cs71y, cs71z. Source: Bosserelle et al. (2018).
2.3 Trans-Pacific Tsunami Propagation

In order to assess the inundation in both harbours, the tsunami wave had to be simulated from the source to the inundation model boundaries across the Pacific Ocean. This was done using the ComMIT interface which provides access to the propagation database for all of the SIFT faults (Figure 2-3). ComMIT was used with three grids of increasing resolution to the North and South of Banks Peninsula (Figure 2-4). The water levels extracted from the ComMIT simulation were then nested to the Basilisk grid to simulate the tsunami in each harbour (e.g., Figure 2-5).

![Figure 2-3: Maximum water level for the 1:500-year tsunami event trans-Pacific propagation.](image)

![Figure 2-4: Nested grid extents used in ComMIT to propagates the tsunami waves to the Basilisk boundaries. Akaroa ComMIT grids layout on the left and Lyttelton on the right. The A-grid is the extent of the figure, the B-grid is in the yellow rectangle and the C-grid in the red rectangle. A and B grids were the same for both Lyttelton and Akaroa harbours.](image)
2.4 Local bathymetry/topography

The Basilisk model topography/bathymetry grids were created by collating available topography and bathymetry data sourced from LiDAR and bathymetry surveys, as well as nautical charts information. The data sources were all shifted to the Lyttelton Vertical Datum (LVD37) equivalent to MSL and then interpolated to a 10 m grid.

2.4.1 Lyttelton Harbour

For Lyttelton, 2008 and 2015 LiDAR datasets were available for most of the shore of the harbour. The 2008 dataset was used to complement the extent of the 2015 survey in low lying areas. Bathymetry data collected by Hart et al. (2008) was used in most of the upper harbour while the LINZ chart data (NZ 6321) was used in the lower part of the harbour and a single beam survey for the main entrance channel (MGD77-557371) (Figure 2-6). In several areas, the LINZ chart contours or soundings were removed because they were inconsistent with the survey from Hart et al. (2008). Similarly, some line survey data from Hart et al. (2008) were removed as they were either inconsistent with other lines of the same survey, or inconsistent with data from the LiDAR survey.

Figure 2-5: Water levels at the entrance of Lyttelton and Akaroa harbours as simulated using ComMIT.
Figure 2-6: Bathymetry and topography data collated to produce the Lyttelton model grid.

The datasets were combined and gridded with a 10 m resolution using a continuous curvature spline in tension (Smith and Wessel 1990). The gridded bathymetry was then rotated 40° clockwise so that the model’s boundary on the right would be parallel to the harbour entrance (Figure 2-7).

Figure 2-7: Lyttelton Harbour bathymetry grid as used in the Basilisk model.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
2.4.2 Akaroa Harbour

For Akaroa, the 2008 LiDAR data covered the shores of the upper half of the harbour. The bathymetry data collected by Hart et al. (2009) was used in most of the harbour while the LINZ chart data (NZ 6324) was used in the harbour entrance. Other parts of Banks Peninsula were extracted from the NIWA 205m New Zealand bathymetry (Figure 2-8).

Figure 2-8: Akaroa Harbour bathymetry grid as used in the Basilisk model.
2.5 Erosion evaluation

The erosion potential is described by the flow bottom shear stress (Powell 1998). This allows for a qualitative assessment of the locations where scouring is most likely to occur for each scenario using information of maximum bottom shear-stress, maximum flow velocity and maximum inundation depth. This is done on a broad scale and does not capture smaller scale scouring that may occur around buildings, small-scale structures (e.g., bridges, culverts) or small-scale channels (e.g., streams).

The critical shear stress is the minimum shear stress necessary to mobilise a particle of sediment of a given size (Table 2-1). In Lyttelton Harbour, fine sediment (silt and clay) dominate the upper harbour (Hart et al. 2008). In Akaroa the seabed in mostly muddy coarsening to sand at the harbour entrance. Pockets of sand also occur on the tidal flats at the head of the bays (Hart et al. 2009).

Table 2-1: Critical shear stress by particle-size classification for determining approximate condition for sediment. Note that critical shear stress only indicates mobility rather than transport. This table was calculated using a fixed sediment density. From Berenbrock and Tranmer (2008).

<table>
<thead>
<tr>
<th>Particle classification name</th>
<th>Ranges of particle diameters</th>
<th>Critical bed shear stress (t.) (N/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse cobble</td>
<td>128 – 256</td>
<td>112 – 223</td>
</tr>
<tr>
<td>Fine cobble</td>
<td>64 – 128</td>
<td>53.8 – 112</td>
</tr>
<tr>
<td>Very coarse gravel</td>
<td>32 – 64</td>
<td>25.9 – 53.8</td>
</tr>
<tr>
<td>Coarse gravel</td>
<td>16 – 32</td>
<td>12.2 – 25.9</td>
</tr>
<tr>
<td>Medium gravel</td>
<td>8 – 16</td>
<td>5.7 – 12.2</td>
</tr>
<tr>
<td>Fine gravel</td>
<td>4 – 8</td>
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2.6 Validation

The tide gauges in Lyttelton Port have previously recorded several historical tsunami events (see Borrerro and Goring 2015). The largest recorded tsunami at the Lyttelton tide gauge was the Valdivia tsunami in 1960 originating from Chile. Replicating this historical tsunami using the ComMIT and

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Basilisk numerical models provides an opportunity to confirm the validity of the methodology used in this study.

The Valdivia earthquake that occurred on the 22 May 1960, was the most powerful earthquake ever recorded (Mw 9.5) and produced one of the most destructive tsunami in the Pacific. Even though the largest wave arrived in Lyttelton Harbour at low tide, the tsunami inundated paddocks at the head of the harbour (Scott 1963), and inundation of the Port caused damage to electrical gears (De Lange and Healy 1986). The tide gauge located in Lyttelton Port recorded the tsunami wave in great detail (Bell 2003), and can be used to evaluate the validity of the tsunami simulation used in this study.

The Valdivia tsunami wave in Pegasus Bay near the entrance of Lyttelton Harbour was obtained using the ComMIt interface and the same fault mechanism from Fuji and Satake (2013); which was adapted to the SIFT database by Borrero and Goring (2015).

In order to adequately compare the tsunami simulation methodology of this study and the record of the Valdivia tsunami, the Lyttelton gauge record was de-tided (i.e., the predicted tide was removed from the original record) and shifted to MHWS. The water level was extracted from the model at each time step for the approximate location of the tide gauge inside Lyttelton Port.

![Graph](image)

**Figure 2-9: Model validation for the Valdivia tsunami of 1960.** Note that the tidal component of the signal was removed from the Lyttelton gauge and the record was shifted to MHWS (1.2m above LVD37). The model time was shifted forward by 10 minutes to match with the arrival of the first wave.

The methodology used in this study when applied to the Valdivia event captures the height of the tsunami very well. The amplification of the wave in the harbour is well captured, the elevation of the tsunami is well captured and the timing of the second waves is good, but less so for the third and fourth waves (Figure 2-9). This could be due to a number of factors such as inaccuracies of the earthquake source, interaction between the tide and the tsunami wave (not included in this simulation), or changes in the harbour bathymetry since 1960. Nevertheless, this result confirms that the methodology produces accurate tsunami waves in Lyttelton Harbour.
3 Results

3.1 Lyttelton Harbour

3.1.1 Inundation for 2018

Lyttelton Harbour has a steep topography on the coast protecting most of the shoreline from tsunami waves. Low lying areas of the harbour that are exposed to tsunami inundation are the port site, Purau Bay, Charteris Bay, the Head of the Bay and Governors Bay.

Analysis of the inundation from the 1:500-year event occurring at MHWS for the present mean sea level indicates that the Head of the Bay shows the most extensive inundation reaching 1.5 km inland near Teddington. The inundation depth was also the highest at the Head of the Bay exceeding 7 m seaward of Teddington road on the western side of the bay (Figure 3-1).

Purau and Charteris Bay were also inundated with the inundation extending 300–400 m inland and with inundation depths exceeding 2.5 m.

The port site is heavily inundated with most of the site exceeding inundation depths of 2.5 m which would cause severe damage. Although not modelled in this study debris from the port (e.g., logs, shipping containers) could be spread throughout the harbour and significantly exacerbate tsunami damage. Because of its steep topography, Lyttelton township is not significantly inundated by the tsunami, with inundation reaching only a few properties on the town side of Norwich Quay (Figure 3-2) but Norwich Quay itself could be affected.

3.1.2 Effect of higher sea level scenario

As expected, the inundation extends further inland and inundation depth is greater with each increasing sea level scenario.

In the Port site, the maximum inundation depth up to 4.5 m for 2018 (MHWS), 5.4 m for 2065 (MMHWS+0.41) and 6.7 m for 2120 (MHWS+1.06 m). This difference is higher than expected from the increase in mean sea level, which suggests that the tsunami wave amplification is higher with higher sea level (Figure 3-3, Figure 3-7, Figure 3-9).

At the head of the Bay the amplification caused by higher sea level is also evident, with maximum inundation depths at Teddington Junction of 7.5 m for 2018 (MSL), 8 m for 2065 (MSL+0.41) and 9.5 m for 2120 (MSL+1.06 m) (Figure 3-4, Figure 3-6, Figure 3-8). The higher flow depth does not directly translate to much larger inundation extent as the inundation reaches slightly steeper topography and extends about 90 m further inland for both the 2065 and 2120 scenarios.

At the head of Charteris Bay, compared with the 2018 scenario, inundation extends a further 45 m inland for the 2065 scenario and a further 190 m inland for the 2120 scenario. Similarly, in Purau (Figure 3-5), the inundation extent reaches 100 m further inland in both the 2060 scenario and the 2120 scenario compared with the 2018 scenario. The similar inundation extent for 2065 and 2120 in Purau is because the inundation reaches steeper topography at the end of the bay, thus limiting the inundation extent. However, the inundation depths are affected by higher sea level with nearly 5 m for 2018 (MSL), 5.8 m for 2065 (MSL+0.41) and 5.4 m for 2120 (MSL+1.06 m) Note that the maximum depth for the 2120 scenario is lower because some of the lower lying land in previous scenarios is now below high tide.
Figure 3-1: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event current sea level - Head of the Bay.

Figure 3-2: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event current sea level – Lyttelton and Diamond Harbour. Note that the black coastline in the image does not include the reclamation that has occurred near Sticking Point.
Figure 3-3: Tsunami water level at the Port entrance for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).

Figure 3-4: Tsunami water level at Teddington for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).
Figure 3-5: Tsunami water level at the head of Purau Bay for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).

Figure 3-6: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2065 sea level scenario – 0.41 m sea level rise - Head of the Bay. Dark blue represents current land that will be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.
Figure 3-7: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2065 sea level scenario – 0.41 m sea level rise - Lyttelton and Diamond Harbour. Dark blue represents current land that will be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.

Figure 3-8: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2120 sea level scenario – 1.06 m sea level rise - Head of the Bay. Dark blue represents current land that

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
will be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.

Figure 3-9: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2120 sea level scenario – 1.06 m sea level rise - Lyttelton and Diamond Harbour. Dark blue represents current land that will be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.

3.1.3 Maximum velocity

The tsunami simulation consists of four successive tsunami waves with a maximum amplitude (peak to trough) of 10 m. These waves successively flood and drain the head of the harbour creating strong currents and large eddies. For the 2018 sea level scenario, the largest velocities occur off diamond Harbour (Pauahinekotau head) with velocities reaching close to 10 m/s, near Sticking Point (Figure 3-10, Figure 3-11) and South of Godley head. Such flow velocities are capable of causing severe damages to cables and pipelines crossing the Harbour (note that some pipelines and telecom cables were significantly damaged during the much smaller Maule tsunami in 2010).

Both higher sea level scenarios indicated faster flows in the main channels of the Harbour and at the entrance of the main bays. This is likely due to the higher water level in these scenarios, which means there is more water to drain in the Head of the Bay, and the greater depth of the harbour would allow faster flows due to a decrease in seafloor drag with depth (Figure 3-15–Figure 3-18).

Flow velocity in the inundated area is not significantly affected by higher sea level scenarios. At the Port entrance the maximum flow velocity is close to 5 m/s in all three scenarios (Figure 3-12). In Teddington the pattern of flow velocity is slightly modified in the different scenario but the maximum value remains identical close to 3.5 m/s (Figure 3-13). Similarly, in Purau the flow velocities are mostly identical in all three scenarios (Figure 3-14).
Figure 3-10: Maximum flow velocity for 1:500-year return period event current sea level - Head of the Bay.

Figure 3-11: Maximum flow velocity for 1:500-year return period event current sea level - Lyttelton and Diamond Harbour.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-12: Flow velocity at the port entrance for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).

Figure 3-13: Flow velocity at Head of the Bay for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-14: Flow velocity at the head of Purau Bay for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).

Figure 3-15: Maximum flow velocity for 1:500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Head of the Bay.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-16: Maximum flow velocity for 1:500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Lyttelton and Diamond Harbour.

Figure 3-17: Maximum flow velocity for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Head of the Bay.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
3.1.4 Erosion potential

The maximum shear stress for the present sea level scenario significantly exceeds the critical shear stress necessary to transport the soft sediment present in the Harbour (Figure 3-19–Figure 3-24). It is likely that the eddies forming at the bay entrance are going to resuspend and transport sediment causing temporary morphological changes to the bathymetry by deepening channels and depositing coarser sediment where the current slows.

In Teddington the inundation occurs as a series of high waves that reaches the road with high velocities and high shear stress that are likely to cause some scouring near the road.

Figure 3-18: Maximum flow velocity for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Lyttelton and Diamond Harbour.
Figure 3-19: Maximum shear stress for 1:500-year return period event current sea level - Head of the Bay.

Figure 3-20: Maximum shear stress for 1:500-year return period event current sea level - Lyttelton and Diamond Harbour.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-21: Maximum shear stress for 1,500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Head of the Bay.

Figure 3-22: Maximum shear stress for 1,500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Lyttelton and Diamond Harbour.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-23: Maximum shear stress for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Head of the Bay.

Figure 3-24: Maximum shear stress for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Lyttelton and Diamond Harbour.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
3.2 Akaroa Harbour

3.2.1 Inundation for 2018 sea level

Similar to Lyttelton Harbour, results indicate that low lying areas in Akaroa Harbour are the most affected by the tsunami, namely Wainui, Akaroa, Takamatua, Duvauchelle Bay, Barrys Bay and French Farm Bay. Although the tsunami scenario in this study does not produce waves in Akaroa as high as in Lyttelton (Figure 3-25, Figure 3-26), more properties are exposed to the inundation.

For the 2018 (MSL) scenario, the inundation depth in Akaroa exceeds 5.0 m and reaches as far as 250 m inland, inundating most of the historical town. North, in Takamatua, the inundation reaches beyond the Christchurch—Akaroa road as far as 440 m inland, with a maximum inundation depth of 6.5 m in the stream. In Duvauchelle, the inundation reaches 298 m inland with a maximum inundation depth of 5.7 m. In Barrys Bay the inundation extends up to 30 m inland and a maximum inundation depth of 6.0 m. In French Farm Bay, the inundation extends 300 m and reaches a maximum depth of 5.6 m. Finally, in Wainui, the inundation extent reaches 280 m with a maximum inundation depth of 3.4 m (Figure 3-27 and Figure 3-28).

3.2.2 Higher sea level scenario

As with Lyttelton Harbour, the scenarios with higher sea levels seem to amplify coastal inundation in some locations. This effect is strongest at Wainui, Akaroa, French Farm Bay and Takamatua. The effect of sea level on tsunami inundation becomes more linear in the upper harbour in Duvauchelle Bay and Barrys Bay. Inundation extent at each location reflects this effect. That is, for the 2120 sea level (MSL+1.06 m) scenario, an increase in the inundation extents of 100 m in Akaroa, 80 m in Wainui, 60 m in Takamatua, and 30 m in Duvauchelle Bay is observed. No increase is observed in Barrys Bay (Figure 3-29–Figure 3-32).

![Figure 3-25: Tsunami water level at Wainui for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).](image)

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Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-26: Tsunami water level at Duvauchelle Bay entrance for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).

Figure 3-27: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event current sea level - Wainui and Akaroa.
Figure 3-28: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event current sea level – Upper Akaroa Harbour.

Figure 3-29: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2065 sea level scenario – 0.41 m sea level rise - Wanui and Akaroa. Dark blue represents current land that will

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.

Figure 3-30: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2065 sea level scenario – 0.41 m sea level rise - Upper Akaroa Harbour. Dark blue represents current land that will be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.
Figure 3-31: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2120 sea level scenario – 1.06 m sea level rise - Wainui and Akaroa. Dark blue represents current land that will be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.

Figure 3-32: Maximum inundation depth (i.e., height above ground) for 1:500-year return period event - 2120 sea level scenario – 1.06 m sea level rise - Upper Akaroa Harbour. Dark blue represents current land that

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
will be below high tide in this sea level rise scenario. Erosional processes during the sea level rise may affect the position of the shoreline, this change is not taken into account here.

### 3.2.3 Maximum velocity

As with Lyttelton Harbour, the tsunami waves in Akaroa Harbour successively flood and drain the harbour creating very strong currents and eddies. Most of the strong velocities are located near steep bathymetry and topographic headlands.

For the present sea level scenario, results indicate that the maximum flow on the western side of the harbour between Wainui Bay and French Farm Bay exceeds 10 m/s. These high velocities are caused by eddies that form at topographic headlands and flow back and forth along the coast before dissipating. Inside the bays, the shallow water forces the flow to slow down to below 3.0 m/s (Figure 3-10, Figure 3-11).

With the higher sea level scenarios (Figure 3-37–Figure 3-40), the increased depth allows faster flows in the harbour. The location and size of the eddies are also affected. In the inundated areas, flow velocity is not greatly affected by the higher mean sea level (Figure 3-33, Figure 3-34).

![Figure 3-33: Flow velocity at Wainui for the three sea level scenarios.](image)

The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).
Figure 3-34: Flow velocity at Duvauchelle Bay entrance for the three sea level scenarios. The black line shows the tsunami at Mean High Water Spring (MHWS) at present mean sea level (MSL) scenario, the dark grey line shows the tsunami at MHWS for 2065 MSL (0.41 m above present MSL) scenario and the grey line shows the tsunami at MHWS for 2120 MSL (1.06 m above present MSL).

Figure 3-35: Maximum flow velocity for 1:500-year return period event current sea level - Wainui and Akaroa.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-36: Maximum flow velocity for 1:500-year return period event current sea level - Upper Akaroa Harbour.

Figure 3-37: Maximum flow velocity for 1:500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Wainui and Akaroa.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-38: Maximum flow velocity for 1:500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Upper Akaroa Harbour.

Figure 3-39: Maximum flow velocity for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Wainui and Akaroa.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-40: Maximum flow velocity for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Upper Akaroa Harbour.

3.2.4 Erosion potential

Similar to findings in Lyttelton Harbour, the maximum shear stress for the present sea level scenario significantly exceeds the critical shear stress necessary to transport the soft sediment present in Akaroa Harbour (Figure 3-41, Figure 3-42). A large tsunami such as that simulated in this study, is expected to at least temporarily affect the morphology of the seabed throughout the harbour, especially on the neck of Bays and around headlands.

For the higher sea level scenarios (Figure 3-43–Figure 3-46), the maximum critical shear stress becomes even higher, thus amplifying the effect at present sea level.

Strong shear stresses are predicted at the shore in Duvauchelle Bay and Barrys Bay which are likely to affect the morphology of the shoreline there. In addition, return flow is likely to concentrate velocities at the mouth of streams causing large morphological changes there. In several locations, the tsunami is expected to scour parts of roads, bridges and culverts, however not enough resolution is available for a more detailed assessment.
Figure 3-41: Maximum shear stress for 1:500-year return period event current sea level - Wainui and Akaroa.

Figure 3-42: Maximum shear stress for 1:500-year return period event current sea level - Upper Akaroa Harbour.
Figure 3-43: Maximum shear stress for 1:500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Wainui and Akaroa.

Figure 3-44: Maximum shear stress for 1:500-year return period event 2065 sea level scenario – 0.41 m sea level rise - Upper Akaroa Harbour.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
Figure 3-45: Maximum shear stress for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Wainui and Akaroa.

Figure 3-46: Maximum shear stress for 1:500-year return period event 2120 sea level scenario – 1.06 m sea level rise - Upper Akaroa Harbour.
4 Discussion and Conclusion

Tsunami simulation of a 1:500-year return period tsunami event originating from South America showed the inundation in Lyttelton Harbour and Akaroa Harbour for three different sea level scenarios.

In both Lyttelton and Akaroa harbours, the low-lying bays are significantly inundated by the 1:500-year event. Under sea level rise scenarios, the inundation depths are deeper even if the inundation extent does not change much due to topographic constraint.

Inundation of port areas could cause severe damage to infrastructure, especially as unattached objects like shipping containers and logs could become debris moved by the tsunami, which could impact into fixed structures exacerbating their damage and end up distributed throughout the entire harbour and beyond.

In both harbours, the tsunami wave in the upper part of the harbour was much greater than near the harbour mouth. This amplification is because, in each case, the tsunami excites the fundamental resonant mode of the harbour (Rabinovich 2008). This amplification appeared greater for the scenarios at higher sea level both in Lyttelton and Akaroa, except for the uppermost bays in Akaroa (Duvauchelle Bay and Barrys Bay) which showed an increase of the inundation depth equal to sea level rise. The amplification of the inundation with higher water level could be because the tsunami waves are better able to excite higher frequency resonant mode of the Bay. It is unclear whether this would occur with other tsunami source or how interaction with the tidal flow of the Bay (not simulated here) would affect these resonant modes.

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Tsunami inundation modelling for Lyttelton and Akaroa Harbours
5 References


Power, W. L. (2014). Tsunami hazard curves and deaggregation plots for 20km coastal sections, derived from the 2013 Nation Tsunami Hazard Model. GNS Science Report


6  Glossary of abbreviations and terms

Flow depth  Vertical height of tsunami above land (also known as inundation depth)
Inundation depth  Vertical height of tsunami above land (also known as flow depth)
Inundation extent  Horizontal distance from shoreline to maximum inland extent of tsunami
Run-up height  Vertical height the tsunami reaches above mean sea level at the limit of inundation. Runup is dependent on the type of wave and local bathymetry
Tsunami water level  Vertical height of the tsunami above mean sea level

Figure 6-1: Tsunami inundation terminology.

Tsunami inundation modelling for Lyttelton and Akaroa Harbours
10. Resolution to Exclude the Public


I move that the public be excluded from the following parts of the proceedings of this meeting, namely items listed overleaf.

Reason for passing this resolution: good reason to withhold exists under section 7.
Specific grounds under section 48(1) for the passing of this resolution: Section 48(1)(a)

Note

Section 48(4) of the Local Government Official Information and Meetings Act 1987 provides as follows:

“(4) Every resolution to exclude the public shall be put at a time when the meeting is open to the public, and the text of that resolution (or copies thereof):

   (a) Shall be available to any member of the public who is present; and
   (b) Shall form part of the minutes of the local authority.”

This resolution is made in reliance on Section 48(1)(a) of the Local Government Official Information and Meetings Act 1987 and the particular interest or interests protected by Section 6 or Section 7 of that Act which would be prejudiced by the holding of the whole or relevant part of the proceedings of the meeting in public are as follows:
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<th>PLAIN ENGLISH REASON</th>
<th>WHEN REPORTS CAN BE RELEASED</th>
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