Data and Information Committee

Meeting is held in the Council Chamber, Level 2, Philip Laing House
144 Rattray Street, Dunedin

Members:

Hon Cr Marian Hobbs, Co-Chair	Cr Michael Laws
Cr Alexa Forbes, Co-Chair	Cr Kevin Malcolm
Cr Hilary Calvert	Cr Andrew Noone
Cr Michael Deaker	Cr Gretchen Robertson
Cr Carmen Hope	Cr Bryan Scott
Cr Gary Kelliher	Cr Kate Wilson

Senior Officer: Sarah Gardner, Chief Executive

Meeting Support: Liz Spector, Committee Secretary

14 October 2020 01:00 PM - 03:00 PM

Agenda Topic

1. APOLOGIES

No apologies were received prior to publication of the agenda.

2. CONFIRMATION OF AGENDA

Note: Any additions must be approved by resolution with an explanation as to why they cannot be delayed until a future meeting.

3. CONFLICT OF INTEREST

Members are reminded of the need 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.

4. PUBLIC FORUM

No requests to address the Committee under Public Forum were received prior to publication of the agenda.

5. CONFIRMATION OF MINUTES

There are no previous minutes of the Committee.

6. OUTSTANDING ACTIONS FROM RESOLUTIONS OF THE COMMITTEE

There are no outstanding actions for the Data and Information Committee.

7. MATTERS FOR NOTING

7.1 UPDATE ON THE GEOLOGY AND GROUND CONDITIONS OF SOUTH DUNEDIN AND HARBOURSIDE

This paper summarises recent South Dunedin geological and seismic hazard work, including on liquefaction, undertaken both by ORC and via external scientific research programmes.

7.2 UPDATE ON BIODIVERSITY MAPPING PROJECT

This report provides the Committee with an update on the Council's Biodiversity Mapping and Ecological Prioritisation Project.

7.3 STATE OF THE ENVIRONMENT (SOE) REPORT CARD

The purpose of this report is to assess compliance of Otago's water quality (114 sites; 106 river sites and 8 lake sites) with Regional Plan: Water for Otago (Water Plan), Schedule 15 numerical standards.

7.4 PROPOSED ESTUARY MONITORING PROGRAMME

The purpose of this report is to implement a State of the Environment monitoring network for Otago's estuaries that meets ORC's regulatory requirements.

8. CLOSURE

7.1. Update on the Geology and Ground Conditions of South Dunedin and Harbourside

Prepared for:	Data and Information Committee
Report No.	OPS1020
Activity:	Natural Hazards
Author:	Sharon Hornblow, Natural Hazards Analyst Jean-Luc Payan, Manager Natural Hazards
Endorsed by:	Gavin Palmer, General Manager Operations
Date:	14 October 2020

PURPOSE

[1] This paper summarises recent South Dunedin geological and seismic hazard work, including on liquefaction, undertaken both by ORC and via external scientific research programmes. Liquefaction hazard findings are of importance to the City's continued investment in the South Dunedin area, and are relevant to informing climate change adaptation. This paper also outlines proposed next steps for continued development of a work programme which focusses on improving the understanding of the ground conditions of South Dunedin and Harbourside.

EXECUTIVE SUMMARY

[2] Otago Regional Council's understanding of the geological setting of South Dunedin, which helps define the risk from natural hazards, has greatly improved since the publication of the 2016 ORC report, The Natural Hazards of South Dunedin. A wealth of technical data and information, building the scientific knowledge base upon which planning decisions are based, has been made possible thanks to targeted spending on scientific partnership projects.

[3] For example, the 2019 drilling work for the NZSeaRise[1] programme, and geotechnical data gathering (Cone Penetrometer Tests, CPT) initiated by a project led by the Earthquake Commission (EQC) in 2019 and supported by ORC and other partners, have resulted in new geological data across a wide range of sites in the area.

[4] These data have informed a new report on the liquefaction hazard in South Dunedin and variation in ground conditions across the area.

[5] In addition to this, GNS Science have developed a new 3-dimensional geological model of South Dunedin, utilising the same data as well as recent geophysical surveys

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[1] In 2018, ORC joined the NZSeaRise research venture with the research Trust of Victoria University of Wellington and GNS Science. The project objective is to improve sea-level rise projections for New Zealand to better anticipate and manage the impacts of rising sea level on low-lying cities. The project will deliver an authoritative, scientifically-robust set of national probabilistic sea level rise projections to the end of the 21st century and beyond. South Dunedin has been selected as a regional case study as it is a low-lying densely populated urban area likely to be impacted by sea level rise, potentially coupled with land subsidence. The ORC contribution to the project is to improve understanding of groundwater and to work with GNS scientists to collate information about the physical environment of South Dunedin to inform a robust geological model of the area. The NZSeaRise project is due for completion in June 2022.

undertaken by the University of Otago. This model will inform the South Dunedin groundwater model, which ORC is planning to update this coming year, in partnership with NZSeaRise.

[6] These data and models provide critical information about long-term tectonic deformation in the coastal Dunedin area, which is useful information for seismic hazard research, as well as information on the thickness and position of young sediments beneath the city. This kind of information is necessary in order to form a complete picture of relative sea level rise over time, as, for example, areas of softer, younger sediment may settle and subside faster than other areas. This, in turn, allows for more informed decision-making around climate change adaptation and the future of South Dunedin.

[7] This report focuses primarily on updates to understanding the geology and liquefaction hazard of the South Dunedin area. However, further modelling work is planned for extension around the Harbourside area, pending collation of additional subsurface data.

RECOMMENDATION

That the Council:

1) ***Receives** this report.*
2) ***Notes** the current state of knowledge of the geology and ground conditions of South Dunedin and Harbourside.*
3) ***Makes** this information publicly available through the National Geotechnical Database and ORC's Otago Natural Hazards Database.*
4) ***Provides** this information to Dunedin City Council for incorporation into building control, utility infrastructure and land use planning decisions.*

LIQUEFACTION REPORT

[8] In the last 15 years approximately, ORC has undertaken a programme of technical work aimed at providing better understanding of the South Dunedin natural environment, and how the physical environment influences natural hazards and the likely impacts of climate change in South Dunedin. The scope of this programme extends beyond the South Dunedin flat with the plan for encompassing all the low-lying area around the coast of Dunedin's Central Business District (CBD), from the Oval to the University of Otago (Harbourside). The aim of the ORC programme of technical work is progressing the development of a multi-hazard 'Climate Change Adaptation Plan' for South Dunedin and the Harbourside areas. This includes an expanded groundwater monitoring network, a 'next generation' groundwater flood model, a seismic hazard assessment including liquefaction susceptibility, and coastal hazards (erosion and elevated sea level) assessment. A multi-hazard approach recognises that, whilst climate change and sea level rise are frequently referred to in South Dunedin, any future adaptation plan will need to address all natural hazards and their interactions and cascading effects.

[9] Under the Resource Management Act (1991), regional councils are required to control the use of land for the purpose of the avoidance or mitigation of natural hazards (s30 RMA 1991). This includes the identification and assessment of natural hazards in the region.

[10] Through 2019, ORC worked with several organisations (including EQC, GNS Science, University of Otago and the Dunedin City Council) to fund a variety of subsurface investigations in South Dunedin to determine geotechnical and geological properties and groundwater characteristics.

[11] Sixteen cone penetrometer tests (CPT) were carried out as part of work led by EQC and the University of Canterbury to better understand ground conditions and liquefaction potential in South Dunedin (**Figure 1**). A further eight drill holes were completed around the South Dunedin and Harbourside areas, and core recovered and analysed by GNS Science and University of Otago geologists.

Figure 1. Cone Penetrometer Testing (CPT) rig taking pressure readings from the soil beneath South Dunedin in 2019.

[12] Previous work by GNS commissioned by ORC (ORC report Liquefaction Susceptibility of the Dunedin City area, 2014) mapped liquefaction hazard areas based on the potential for liquefaction susceptible materials to be present. The South Dunedin flat and Harbourside areas were classified with a moderate to high liquefaction potential. This reflects the geomorphic history of the area (shallow marine/estuarine) which entails a high likelihood of fine-grained soils and a shallow groundwater across the area.

[13] In July 2020, in order to refine the understanding of the liquefaction susceptibility in South Dunedin, ORC commissioned a report (Review of liquefaction data, GeoSolve Ltd, attached) on the assessment of the raw CPT data from the work carried out by ORC, NZSeaRise, and the consortium CPT and piezometer installations which took place in South Dunedin in 2019. Additional sites from previous CPT work available in South Dunedin were also included in the analysis.

[14] The CPT data from each site has been analysed in relation to theoretical settlement which would occur in standardised earthquake cases (e.g. NZS 1170 Serviceability Limit States and Ultimate Limit States which specify different peak ground accelerations and annual exceedance probabilities). This is an industry standard approach for assessing settlement that may result from seismic shaking, to help determine foundation design for any occupied structures so they are safe and serviceable for a design lifetime with exposure to expected seismic hazards. A Liquefaction Severity Number (LSN) was assigned to the uppermost 10 m of each CPT (sometimes multiple CPTs were completed at a site) which provides a useful summary of relative liquefaction susceptibility across the South Dunedin area.

[15] The LSNs for an earthquake scenario considered to have an estimated annual exceedance probability (AEP) of 1 in 100 years were all below 10, which indicates settlement of only a few centimetres (less than 70 mm, and generally less than 40 mm) is expected at all tested sites in such a seismic event. The LSNs returned for this earthquake scenario are displayed as coloured dots in **Figure 2** to give an idea of the spatial variability of liquefaction susceptibility. 1 in 100 years recurrence event has been chosen as it is commonly used when discussing natural hazard risk. The results from other earthquake scenarios show similar variability across the area.

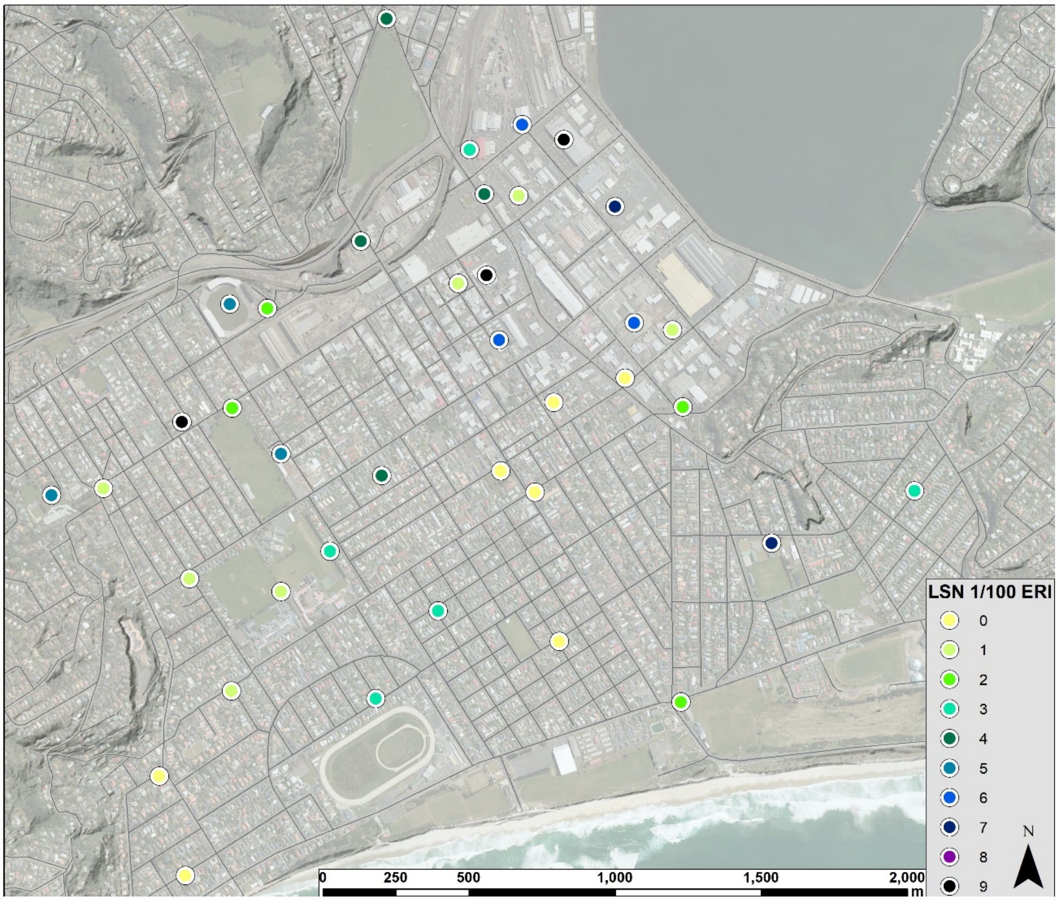

Figure 2. Locations of sites analysed in the liquefaction susceptibility report. Coloured dots represent the Liquefaction Susceptibility Numbers (LSN), summarising how severely the

ground would be impacted by shaking, calculated for a 1 in 100-year AEP (or ERI, estimated recurrence interval) earthquake scenario (Mw5.8, 0.11 g).

[16] Settlement values and LSN for a maximum scenario with a 1 in 2500 years AEP (see Table 1) were also calculated. This attempts to capture a peak ground acceleration equivalent to the February 22nd, 2011 Christchurch event which induced widespread liquefaction there in 2011. Results show the sediments analysed, in the upper 10 m, should not experience severe and widespread liquefaction, nor significant settlement above 70 mm.

[17] The CPT analysis also indicates a high variability in liquefaction potential of soils across greater South Dunedin, with variability in settlement potential observed across single sites. Figure 1 shows how there is not a defined spatial pattern of high vs low LSN and associated settlement. Some areas have groups of CPTs on one building site and results show settlement (and LSN) varies across a single site.

[18] The report does not consider factors such as lateral spreading, which could be an issue near free-faces such as around the harbour edge. It also does not cover other potential hazards from seismic shaking such as specific areas at heightened risk of shaking amplification due to basement geometry, or potential for cyclic softening.

Annual Exceedance Probability (AEP)	Liquefiable Layers	Reconsolidation Settlement	LSN
1/25	Predominately limited liquefiable layers	0-5 mm (mostly 0 mm)	0-1 ground damage not predicted or limited
1/100	Liquefaction starts to occur in layers	0-70 mm (mostly 0-40 mm)	0-9 ground damage not predicted or limited
1/250	Liquefaction occurs in loose sandy and non/low plasticity silts	0-70 mm (mostly 0-40 mm)	0-29 (mostly 0-20) Mostly minor expression of liquefaction, some sand boils and potentially some structural damage in places
1/500	Liquefaction occurs in loose to medium dense sandy and non/low plasticity silts	0-70 mm (mostly 0-40 mm)	0-41 (mostly 0-20) Mostly minor expression of liquefaction, some sand boils and potentially some moderate to severe expression of liquefaction with settlement that can cause structural damage in places
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1/2500	Liquefaction occurs in loose to medium dense sandy and non/low plasticity silts	0-70 mm (mostly 0-40 mm)	0-46 (mostly 0-25) Mostly minor expression of liquefaction, some sand boils and potentially some moderate to severe expression of liquefaction with settlement that can cause structural damage in places

Table 1. Summary of liquefaction results, from the 2020 Geosolve liquefaction susceptibility report to ORC (attachment). Each row gives the results for one of the six earthquake shaking scenarios tested with the CPT data. Most settlement expected in the South Dunedin area is less than 40 mm, even in strong shaking (higher AEP) scenarios.

[19] CPT data of the sites investigated in this report indicates very fine-grained sediments which are naturally highly plastic and cohesive, and therefore not very liquefiable. This interpretation was supported by the samples recovered during bore hole drilling in 2019 (see the following section of this report on geological modelling). For comparison, assessment of CPT data indicates that settlement under peak ground accelerations up to 0.41 g (1 in 2500 year AEP event) would not match the damage experienced in areas affected by liquefaction in eastern Christchurch during the 2011 earthquakes (grouped as 'TC3 land': moderate to significant land damage from liquefaction is possible in future significant earthquakes).

[20] Based on this dataset and current understandings of liquefaction processes, widespread liquefaction in greater South Dunedin, akin to that experienced during the Christchurch earthquake sequence, is unlikely. However, this does not preclude liquefaction occurring in some places, and does not address the possibility of lateral spreading along unconfined saturated embankments, such as the harbour edge. The ground beneath South Dunedin is very soft and may give rise to other geotechnical issues during an earthquake, such as foundation settlement or shaking amplification.

[21] The report also considers that settlement of up to 100 mm may occur in some areas, without this being considered severe. However, complex flood related, and infrastructural issues can result from even small settlements, such as the ongoing drainage issues experienced over large parts of Christchurch after the Canterbury Earthquakes and damage to rigid structures. With a low-lying area such as South Dunedin with a high, and rising, water table, small ground settlement would also exacerbate flood hazard.

[22] The findings from the liquefaction data report do not change or replace the need for site-specific geotechnical advice for individual buildings but confirms the variability of ground conditions across the area. The variability of the CPT data indicates the ground conditions are highly variable and does not support more refined mapping of liquefaction risk at this stage given the relatively low spatial density of CPT soundings.

GEOLOGICAL MODEL OF SOUTH DUNEDIN UPDATE

[23] In addition to the CPT data gathering, deeper boreholes were drilled in the greater South Dunedin area in 2019. These were geologically logged, samples were collected from the drill core for scientific dating purposes, and geotechnical data at each drill site were recorded. This work was funded by ORC as part of the 2018/2019 Annual Plan.

[24] These data, in addition to that collected by University of Otago geologists and existing bore hole and geotechnical data for the area, form the basis of an updated geological model. The work, briefly presented in this report, summarises geological, geotechnical, and geophysical investigations carried out in 2019 and will be used in modelling the impacts of various sea level rise scenarios on the groundwater and future surface flooding. Results of the investigations and groundwater monitoring can also be used in further seismic hazard analyses which will guide assessments of subsurface infrastructure investment and inform planning decisions.

[25] Geological drill hole logs and CPT data have been collated by GNS Science to create an interpretive 3-dimensional geological model of the South Dunedin subsurface geometry.

Figure 3 shows the different kinds of existing geophysical and geotechnical data which were used to support creation of the model. The physical 2019 drill cores were essential in ground-truthing these data.

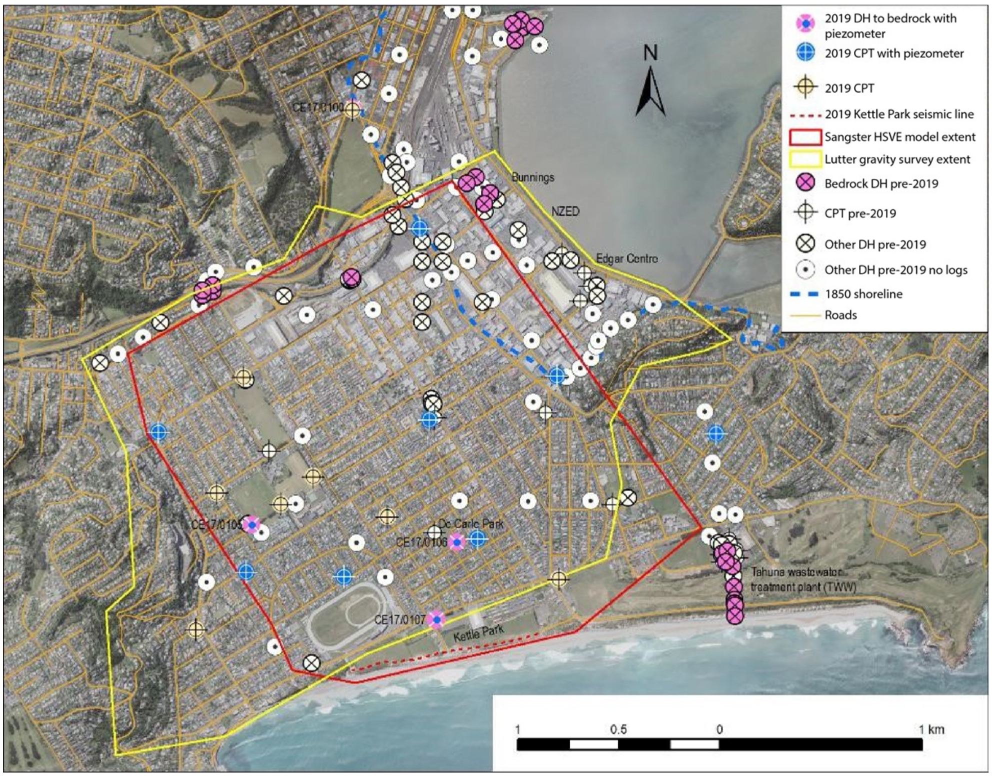

Figure 3. Subsurface investigation data points used for the update of the South Dunedin geological model.

[26] Basement rocks, such as the Dunedin Volcanics and Caversham Sandstone (Figure 4), and the younger Holocene sediments, which in-filled the valley beneath South Dunedin as sea level rose after the Last Glacial Maximum (Figure 5), are depicted in the model. A paper was prepared by GNS (Glassey), along with co-authors from University of Otago and ORC, for this week's NZ Geotechnical Society symposium, to report on the geological model and findings of the deep drilling work carried out in 2019. A final GNS report on the modelling and interpretation of results is currently in preparation.

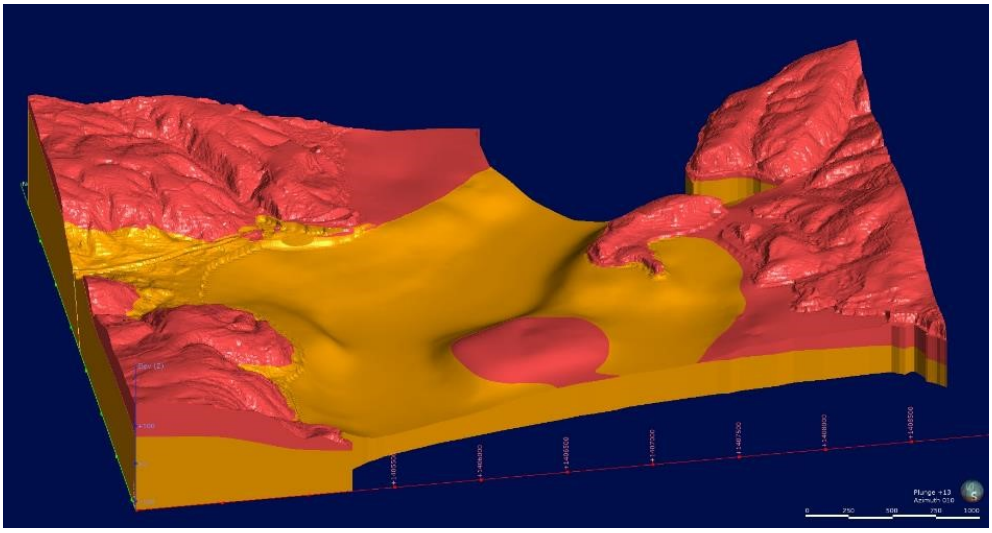

Figure 4. Perspective view of South Dunedin with the younger sediment infill removed and bedrock surface exposed. Volcanic bedrock is shown in red and Caversham Sandstone in orange. (Glassey et al., in prep)

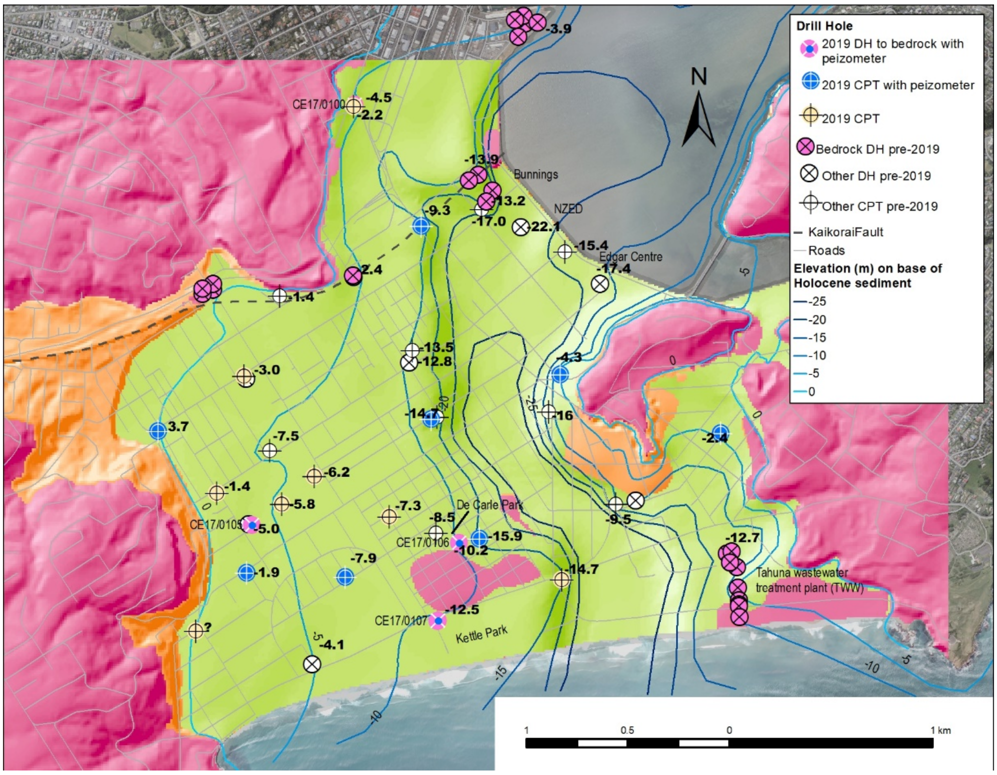

Figure 5. Plan view showing structure contours on the base of the Holocene sediments (green) beneath South Dunedin based on depth interpretations from drill holes and CPT data. (Glassey et al., in prep).

DISCUSSION

[27] This geological model is important to ORC because it will inform the groundwater model which, in turn, will be used to analyse the impacts of various sea level rise scenarios on the groundwater, future surface flooding, and infrastructure in South Dunedin. The new

understanding of geophysical properties of the sediment is important for building purposes such as assisting in appropriate building foundation design through informing the depth of the Holocene (recent, softer) sediment at sites through South Dunedin.

[28] The model also has some importance for considering the above liquefaction susceptibility results. As mentioned in the first section of this report, lack of liquefaction susceptibility does not preclude poor ground conditions being present. The clays and fine sediments deposited in an estuarine setting which are in some places quite deep, do not easily liquefy but may be likely to exhibit ground damage of other kinds due to their plastic nature.

[29] In 2019, when the drilling programme commenced, estimates of the depth to bedrock at the drill sites varied from 40 to 70 m. Carrying out the programme and bringing together as much existing geophysical and geotechnical data as possible to support the geological modelling, has highlighted the complexity of the subsurface ground conditions, and the difficulty of predicting where softer/deeper sediments will be. This shows the importance of investing in invasive, scientific research programmes, along with processing and using pre-existing data, such as existing geotechnical work done for building consents in the area.

[30] The model presented here extends partially into the Harbourside area. It is planned to extend the geological model to fully cover the Harbourside area. This is pending the collation of additional subsurface data and is planned for later in the year.

CONSIDERATIONS

Policy Considerations

[31] There are no immediate policy considerations for ORC.

Financial Considerations

[32] The work described in this paper is part of a multi-year programme. Completion of the programme relies on ORC providing funding in the 2021/31 Long Term Plan and future Annual Plans.

Significance and Engagement

[33] This paper does not trigger ORC's policy on Significance and Engagement.

Legislative Considerations

[34] The work described in this paper helps ORC fulfil its responsibilities under sections 30 and 35 of the RMA.

Risk Considerations

[35] Disclosing the information presented in this paper helps the community understand and manage the risks associated with South Dunedin's multi-hazards.

NEXT STEPS

[36] It is proposed to make this information publicly available through the National Geotechnical Database and ORC's Otago Natural Hazards Database.

[37] It is also proposed to provide this information to Dunedin City Council for incorporation into building control, utility infrastructure and land use planning decisions.

[38] A paper on collaboration with Dunedin City Council on adaptation for South Dunedin/Harbourside and options for the role ORC should play is in preparation.

ATTACHMENTS

1. Geosolve ORC South Dunedin Area Wide Liquefaction Assessment - Rev 1 [**7.1.1** - 11 pages]

GeoSolve Ref: 200038
7 July 2020

Otago Regional Council
70 Stafford Street,
Private Bag 1954,
Dunedin 9054

Attention: Ben Mackey

Review of Liquefaction Data
South Dunedin

Introduction

The Otago Regional Council is wanting to better quantify the liquefaction risk for the greater South Dunedin area. In accordance with our Agreement dated 25 February we have undertaken a liquefaction analysis of existing cone penetration tests (CPT) data across South Dunedin. This includes the CPTs co-funded by the ORC in 2019 along with other readily available CPTs from the Geosolve database.

This letter shall be read as a whole and in conjunction with the limitations at the end of the letter.

Cone Penetration Test Data

16 cone penetration tests have been provided to GeoSolve from the ORC which were undertaken in 2019 as part of other works. To supplement these tests GeoSolve has undertaken a review of readily available CPT data around the South Dunedin area and identified 22 sites. The approximate site locations are presented in Figure 1 in Appendix A.

Liquefaction Assessment Methodology

A liquefaction assessment has been undertaken using the CPT data based on the method of Boulanger and Idriss (2014)[1] as follows:

- Six earthquakes scenarios have been assessed in accordance with NZS1170 – Structural Design Actions[2] which are described below;
- Peak horizontal ground accelerations and effective magnitudes were calculated using the procedure from the NZTA Bridge Manual[3];
- The site has been assessed as subsoil category Class C – Shallow Soil site in accordance with NZS1170 – Structural Design Actions, in terms of liquefaction this is conservative for

[1] Boulanger, R.W. & Idriss, I.M. (2014). CPT and SPT Based Liquefaction Triggering Procedures. Department of Civil & Environmental Engineering, University of California.
[2] NZS1170-5 (2004) Structural Design Actions, Part 5: Earthquake Actions – New Zealand.
[3] NZTA Bridge Manual (2014). SP/M/022, third edition amendment 1, Effective from September 2014.

DUNEDIN
CROMWELL
QUEENSTOWN
WANAKA

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geotechnical purposes, as it is possible areas of South Dunedin will be equivalent to Class D or E.

- Groundwater levels have been adopted at 0.5 m depth. It is likely that parts of South Dunedin will have groundwater levels at greater depths;
- In our analysis the ground level at time of testing has been assumed to be the final ground level.
- A fines content correction (C_{FC}) of 0 and a soil classification index (I_c) cut off of 2.6 has been adopted as we are not aware of a large enough data set of laboratory testing in the South Dunedin area to better refine these parameters;
- Our assessment is focused on indexed settlement and Liquefaction Severity Number (LSN) considered over the upper 10 m to easily compare liquefaction results. Some tests may have reached early refusal. Therefore, additional layers could liquefy which will result in additional settlement and ground damage potential. Settlement and LSN may not reflect damage especially where deep piles/foundations and/or where liquefiable layers directly interact with foundation.
- We have not carried out a lateral spreading assessment as part of the liquefaction assessment. Therefore, it is possible that liquefaction risk may be greater when in close proximity to the sea, Dunedin Harbour and any other local streams, changes in height or other free faces due to lateral spreading risks.

Table 1: *Earthquakes cases considered with reference to NZS1170*

Annual Exceedance Probability (AEP)	Magnitude	a_{max} (g)	Notes
1/25	5.8	0.06 g	NZS1170 Serviceability Limit State (SLS1)
1/100	5.8	0.11 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 1, 50 year design level structure
1/250	5.8	0.17 g	NZS1170 Serviceability Limit State (SLS2) for an Importance Level 4, 50 year design life structure
1/500	5.8	0.23 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 2, 50 year design level structure
1/1000	5.8	0.29 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 3, 50 year design level structure
1/2500	5.8	0.41 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 4, 50 year design level structure

Notes:

- *NZS1170 Ultimate Limit State (ULS) – to avoid collapse of the structural system*
- *NZS1170 Serviceability Limit State (SLS1) – to avoid damage that would prevent the structure from being used as originally intended without repair*
- *NZS1170 Serviceability Limit State (SLS2) – to maintain operational continuity after the SLS2 earthquake*
- *Importance Level 1 – structures presenting a low degree of hazard to life and other property (e.g. garages)*
- *Importance Level 2 – normal structures and structures not in other importance levels (e.g. houses)*
- *Importance Level 3 – structures that as a whole may contain people crowds or contents of high value to the community or pose risks to people in crowds (e.g. large buildings)*

- *Importance Level 4 – structures with special post disaster functions (e.g. fire stations)*

Liquefaction Assessment Results

We have made a summary of liquefaction results attached in Appendix B. These show the following:

Table 2: *Summary of liquefaction results*

Annual Exceedance Probability (AEP)	Liquefiable Layers	Reconsolidation Settlement	LSN
1/25	Predominately limited liquefiable layers	0-5 mm (mostly 0 mm)	0-1 ground damage not predicted or limited
1/100	Liquefaction starts to occur in layers	0-70 mm (mostly 0-40 mm)	0-9 ground damage not predicted or limited
1/250	Liquefaction occurs in loose sandy and non/low plasticity silts	0-70 mm (mostly 0-40 mm)	0-29 (mostly 0-20) Mostly minor expression of liquefaction, some sand boils and potentially some structural damage in places
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Technical Categorisation Based on Canterbury Criteria (MBIE Guidelines)

We have used the MBIE guidance (2012) to assess equivalent technical categories for the site based on the calculated liquefaction risk. We have not assessed lateral spreading so it is possible that liquefaction risk may be greater when in close proximity to the sea, Dunedin Harbour and any other local streams, changes in height or other free faces due to lateral spreading risks.

Note that technical categories are for houses in Canterbury Importance Level 2, 50 year design life structures and are not appropriate for other structures.

Table 3: *MBIE liquefaction deformation limits and house foundation implications*

Technical Category	Index Liquefaction Deformation Limits				Likely Implication for House Foundations (subject to individual assessment)
	Vertical		Lateral Spread		
	SLS	ULS	SLS	ULS	
TC1	15mm	25mm	Nil	Nil	Standard NZS3604 type foundations with tied slabs
TC2	50mm	100mm	50mm	100mm	MBIE enhanced foundation solutions
TC3	>50mm	>100mm	>50mm	>100mm	Site specific foundation solution

As calculated indexed settlements are less than 15 mm in the SLS event and between 0 and 70 mm in the ULS event therefore the testing shows the greater South Dunedin area is likely to be consistent with MBIE TC1 or TC2.

Discussion

Total settlement

Total liquefaction induced settlement and area wide settlement may cause other consequences. Examples of these effects were noted in Christchurch include:

- Total liquefaction and tectonic settlement putting areas into or further into flood zones, or increasing liquefaction vulnerability to sites;
- Area wide differential settlement causing issues with drainage through rivers, streams and pipes; and
- Global lateral movement of areas damaging infrastructure.

We note that we have only summarised indexed settlements (i.e. in the top 10 m) but have calculated total liquefaction induced reconsolidation settlements up to approximately 200 mm.

Other Geotechnical Issues in South Dunedin

Often the soils encountered in the CPTs of South Dunedin were too plastic to liquefy (i.e. moderately plastic silts or clays). Notwithstanding this, although these soils may not be susceptible to liquefaction they pose other significant geotechnical challenges for development, such as:

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- They are soft and compressible and therefore only provide low bearing capacities with associated high rates of settlement for shallow foundations. Note significant areas in South Dunedin do not meet the definition of 'good ground' as per NZS3604:2011;
- Due to the soil type inferred from the CPTs, the liquefaction assessment indicates that some soils are unlikely to liquefy due to their plasticity. However, it is possible that cyclic softening may occur in this layer in a moderate to major earthquake event. Research on cyclic softening is not as clear as liquefaction effects. So the effects of cyclic softening are more difficult to quantify. But if softening occurs it is likely that the consolidation process will be reset and that long-term settlement will start over. It also can cause soft cohesive soils to lose strength.

Uncertainty of earthquake loading

The seismic hazard in Christchurch is greater than in Dunedin, however even if the level of seismic loading is increased the predicted settlements (in the upper 10 m) do not quite reach MBIE TC3 levels, even at PGA's up to 0.41 g (1/2500 AEP event).

The recent events in Canterbury and Kaikoura have highlighted the challenge that previous unidentified faults and site amplification effects may be very significant factors in the actual seismic risk applying to a site. This concern is most relevant where pre-historic faulting is masked by a persistent mantle of recent deposits (and such terrain dominates both in South Dunedin and Coastal Canterbury).

Data gaps

The testing has a relatively good spacing across the greater South Dunedin area. However, as the ground conditions are variable and can change quickly in the area specific site testing is recommended to better define the liquefaction risk.

Applicability

This report has been prepared for the benefit of the Otago Regional Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Yours faithfully,

....

Tim Plunket
Senior Geotechnical Engineer (CPEng)
GeoSolve Limited

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Colin Macdiarmid
Geotechnical Group Director (CPEng)

Appendix A – Figures

Key

CPT1 = Cone Penetrometer Test

Background image aerial photography taken between 2018-2019. Sourced from LINZ

CADFILE:	Site Plan.pptx	DRAWN	TJP	02/2020
SCALE: (AT A4 SIZE)	AS SHOWN	DRAFTING CHECKED	TJP	02/2020
PROJECT No.:	200038	APPROVED	CEM	02/2020

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South Dunedin Liquefaction Assessment
Dunedin
CPT Investigation Locations

FIG No. FIGURE 1
REV No. 1

Appendix B – Liquefaction Results

General

Liquefaction occurs when susceptible, saturated soils attempt to move to a denser state under cyclic shearing. In this report, liquefaction is defined as when pore pressures rise to reach the overburden stress. When this occurs, the following effects can happen at flat sites:

- loss of strength;
- ejection of material under pressure to the ground surface; and
- post-liquefaction volumetric densification as the materials reconsolidate.

In addition, sloping sites or sites with a 'free face' may experience lateral spreading or movement.

Liquefaction Susceptibility

Soils susceptible to liquefaction have the following characteristics:

- Saturated. Below the ground water level;
- Have "sand like" behaviour[4]; and
- Are in loose or medium dense condition.

Soils which are susceptible to liquefaction require a certain level of earthquake shaking (trigger) to cause them to liquefy. Denser soils require more intense and/or longer duration of shaking (higher trigger) than less dense soil.

Analysis Method

Liquefaction analyses were undertaken on the test data using the Boulanger & Idriss (2014)[7] deterministic method.

Assessment of Consequences of Liquefaction

The following can be assessed to estimate the consequences of liquefaction at this site:

- Crust thickness.
- Liquefaction severity index.
- Free field settlements.
- Lateral spread.

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The non-liquefiable upper layer of soils (crust) provides some protection against ground surface damage as a result of liquefaction. The thicker the crust, the less ground surface damage is expected with significant protection provided by thicknesses of more than 5 m.

Empirical correlations have been developed by Ishihara[5] to quantify the thickness of non-liquefiable crust required to prevent the formation of sand boils resulting from the liquefaction of underlying soil layers. These correlations indicate that for a given thickness of liquefiable soil, as the peak ground acceleration increases a greater thickness of non-liquefiable soil is required to prevent liquefaction damage from manifesting on the surface.

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Liquefaction severity number (LSN) is a single value which can be calculated from a liquefaction assessment considering the thickness density and depth of liquefiable layers and the intensity of earthquake shaking. Based on observations of ground surface damage in Christchurch an indicative correlation has been developed between ground surface damage from liquefaction and LSN as described below.

As the LSN increases, so does the risk of severe effects on the land and structure. In general, the following surface effects are considered likely at sites with various LSN values.

Table 1C - Liquefaction Severity Number

LSN	Effects
0 – 10	Little to no expression of liquefaction, minor effects
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> 50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services

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Part: Liquefaction Assessment Summary
By: TJP

Job Number: 200038
Date: 22/06/2020
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CPT118552	20.5	0.6	0.5	0	0	0	0	0	0	0	0	0	0	0	0
CPT118553	11.2	0.6	0.5	0	1	30	3	30	3	30	3	30	3	30	3
CPT118790	12.5		0.5	0	0	15	4	30	12	35	13	35	14	35	16
CPT118802	16.6		0.5	0	0	0	0	0	0	0	0	0	0	0	0
CPT118805	5.5		0.5	0	0	0	0	5	2	10	9	20	16	25	21
CPT118808	7.1		0.5	0	0	10	2	15	3	20	7	25	10	30	14
CPT118810	9.8		0.5	0	0	20	3	25	3	25	3	25	4	25	6
CPT118811	10.9		0.5	0	0	10	2	20	7	30	9	35	12	40	13
CPT118812	5.2		0.5	0	0	5	1	5	1	5	1	5	1	5	2
CPT118813	3.0		0.5	0	0	0	1	15	8	25	12	25	15	30	19
CPT118815	22.7	0.5	0.5	0	0	5	2	25	14	35	18	40	20	50	22
CPT118819	7.9		0.5	0	0	5	1	10	2	10	6	15	9	15	11
CPT118821	9.1		0.5	0	0	20	3	25	8	30	11	30	14	30	15
CPT118823	12.4		0.5	0	0	15	4	45	15	55	18	55	19	60	20
Site A	10+		0.5	0-5	0-1	5-40	1-4	10-40	1-4	15-40	3-6	20-40	4-8	20-40	5-10
Site B	7-10+		0.5	0	0	5-45	1-7	15-80	4-13	25-85	7-16	25-85	10-20	35-90	12-23
Site C	10+		0.5	0-5	0	30-40	4-5	45-50	5-7	50-55	6-10	50-55	6-12	55-60	6-12
Site D	10+		0.5	0	0	0	0	0	0	0	1	0	1-2	0-5	2-3
Site E	4-10+	0.5	0.5	0	0	0-30	0-5	0-70	0-11	0-80	0-12	0-80	0-12	0-80	0-12
Site F	10+		0.5	0	0	0-20	1-6	10-65	5-29	15-80	11-41	15-85	13-44	15-85	15-46
Site G	10+		0.5	0	0	0-5	0-1	5-15	3-12	5-20	3-20	5-25	3-24	5-30	3-26
Site H	10+		0.5	0	0	0	0	0	2	5	3-7	0-5	3-9	5	3-10
Site I	10+		0.5	0	0	20-70	2-9	45-90	6-12	55-95	7-13	55-95	8-15	55-95	8-16
Site J	10+		0.5	0	0	0-5	0-1	0-5	1	0-5	1-3	0-5	1-3	0-5	1-3
Site K	6.5		0.5	0	0	0	0	5	2	5	2	5	2	5	2
Site L	10+		0.5	0	0	10-15	2-3	20-30	8-11	25-40	10-15	30-40	11-18	30-45	12-21
Site M	10+		0.5	0	0	0	0	0	0	0	0	0	0	0	0
Site N	8.5-10+		0.5	0	0	10-20	2-5	30-75	6-24	35-85	8-28	35-85	9-28	35-85	9-28
Site O	10+		0.5	0	0	0-20	0-9	0-35	0-17	0-35	0-17	0-35	0-17	0-35	0-17
Site P	10+	1	0.5	0	0	10-20	3-6	25-30	9-14	25-35	11-15	25-35	11-17	25-35	11-18
Site Q	9-10+		0.5	0	0	5-10	1-2	5-20	1-4	10-20	4-7	10-20	8-10	10-24	9-13
Site R	10+		0.5	0	0	0-25	0-6	0-40	0-14	0-40	0-17	0-40	0-18	0-40	0-19
Site S	10+	1	0.5	0	0	5	1	10-15	4-8	20	10-11	25	12-14	25	14-16
Site T	2.5-8		0.5	0	0	0-10	0-4	0-45	0-13	0-65	1-15	0-70	3-18	0-75	4-22
Site U	10+		0.5	0	0	0-20	0-9	0-35	0-17	0-35	0-17	0-35	0-17	0-35	0-17
Site V	9-10+		0.5	0	0	5-40	2-7	25-60	4-15	25-65	4-22	25-65	5-24	25-75	5-25
Min				0	0	0	0	0	0	0	0	0	0	0	0
Max				5	1	70	9	90	29	95	41	95	44	95	46

Notes:
(1) Pre-drill recorded if 0.5 m or greater
(2a) Indexed settlement and LSN calcuated by considering the upper 10 m only, where data avaiable
(2b) Some tests may have reached early refusal. Therefore additional layers could liquefy which will result in additional settlement and ground damage potentail
(2c) Areas in South Dunedin area is underlain soft silts/clays which are prone to ongoing static settlement, low bearing capacities and/or cyclic softening in a moderate to major earthquake event which is not covered in the above liquefaction assessment.
(3) Refer to Figure 1 for location of testing
(4) Range of results are given for sites with more than one CPT

GeoSolve Ref: 200038
7 July 2020

Otago Regional Council
70 Stafford Street,
Private Bag 1954,
Dunedin 9054

Attention: Ben Mackey

Review of Liquefaction Data
South Dunedin

Introduction

The Otago Regional Council is wanting to better quantify the liquefaction risk for the greater South Dunedin area. In accordance with our Agreement dated 25 February we have undertaken a liquefaction analysis of existing cone penetration tests (CPT) data across South Dunedin. This includes the CPTs co-funded by the ORC in 2019 along with other readily available CPTs from the Geosolve database.

This letter shall be read as a whole and in conjunction with the limitations at the end of the letter.

Cone Penetration Test Data

16 cone penetration tests have been provided to GeoSolve from the ORC which were undertaken in 2019 as part of other works. To supplement these tests GeoSolve has undertaken a review of readily available CPT data around the South Dunedin area and identified 22 sites. The approximate site locations are presented in Figure 1 in Appendix A.

Liquefaction Assessment Methodology

A liquefaction assessment has been undertaken using the CPT data based on the method of Boulanger and Idriss (2014)[1] as follows:

- Six earthquakes scenarios have been assessed in accordance with NZS1170 – Structural Design Actions[2] which are described below;
- Peak horizontal ground accelerations and effective magnitudes were calculated using the procedure from the NZTA Bridge Manual[3];
- The site has been assessed as subsoil category Class C – Shallow Soil site in accordance with NZS1170 – Structural Design Actions, in terms of liquefaction this is conservative for

[1] Boulanger, R.W. & Idriss, I.M. (2014). CPT and SPT Based Liquefaction Triggering Procedures. Department of Civil & Environmental Engineering, University of California.
[2] NZS1170-5 (2004) Structural Design Actions, Part 5: Earthquake Actions – New Zealand.
[3] NZTA Bridge Manual (2014). SP/M/022, third edition amendment 1, Effective from September 2014.

DUNEDIN
CROMWELL
QUEENSTOWN
WANAKA

GeoSolve Limited - Dunedin Office:
Level 1, 70 Macandrew Road, South Dunedin
PO Box 2427, South Dunedin 9044
dunedin@geosolve.co.nz

geotechnical purposes, as it is possible areas of South Dunedin will be equivalent to Class D or E.

- Groundwater levels have been adopted at 0.5 m depth. It is likely that parts of South Dunedin will have groundwater levels at greater depths;
- In our analysis the ground level at time of testing has been assumed to be the final ground level.
- A fines content correction (C_{FC}) of 0 and a soil classification index (I_c) cut off of 2.6 has been adopted as we are not aware of a large enough data set of laboratory testing in the South Dunedin area to better refine these parameters;
- Our assessment is focused on indexed settlement and Liquefaction Severity Number (LSN) considered over the upper 10 m to easily compare liquefaction results. Some tests may have reached early refusal. Therefore, additional layers could liquefy which will result in additional settlement and ground damage potential. Settlement and LSN may not reflect damage especially where deep piles/foundations and/or where liquefiable layers directly interact with foundation.
- We have not carried out a lateral spreading assessment as part of the liquefaction assessment. Therefore, it is possible that liquefaction risk may be greater when in close proximity to the sea, Dunedin Harbour and any other local streams, changes in height or other free faces due to lateral spreading risks.

Table 1: *Earthquakes cases considered with reference to NZS1170*

Annual Exceedance Probability (AEP)	Magnitude	a_{max} (g)	Notes
1/25	5.8	0.06 g	NZS1170 Serviceability Limit State (SLS1)
1/100	5.8	0.11 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 1, 50 year design level structure
1/250	5.8	0.17 g	NZS1170 Serviceability Limit State (SLS2) for an Importance Level 4, 50 year design life structure
1/500	5.8	0.23 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 2, 50 year design level structure
1/1000	5.8	0.29 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 3, 50 year design level structure
1/2500	5.8	0.41 g	NZS1170 Ultimate Limit State (ULS) for an Importance Level 4, 50 year design level structure

Notes:

- *NZS1170 Ultimate Limit State (ULS) – to avoid collapse of the structural system*
- *NZS1170 Serviceability Limit State (SLS1) – to avoid damage that would prevent the structure from being used as originally intended without repair*
- *NZS1170 Serviceability Limit State (SLS2) – to maintain operational continuity after the SLS2 earthquake*
- *Importance Level 1 – structures presenting a low degree of hazard to life and other property (e.g. garages)*
- *Importance Level 2 – normal structures and structures not in other importance levels (e.g. houses)*
- *Importance Level 3 – structures that as a whole may contain people crowds or contents of high value to the community or pose risks to people in crowds (e.g. large buildings)*

- *Importance Level 4 – structures with special post disaster functions (e.g. fire stations)*

Liquefaction Assessment Results

We have made a summary of liquefaction results attached in Appendix B. These show the following:

Table 2: *Summary of liquefaction results*

Annual Exceedance Probability (AEP)	Liquefiable Layers	Reconsolidation Settlement	LSN
1/25	Predominately limited liquefiable layers	0-5 mm (mostly 0 mm)	0-1 ground damage not predicted or limited
1/100	Liquefaction starts to occur in layers	0-70 mm (mostly 0-40 mm)	0-9 ground damage not predicted or limited
1/250	Liquefaction occurs in loose sandy and non/low plasticity silts	0-70 mm (mostly 0-40 mm)	0-29 (mostly 0-20) Mostly minor expression of liquefaction, some sand boils and potentially some structural damage in places
1/500	Liquefaction occurs in loose to medium dense sandy and non/low plasticity silts	0-70 mm (mostly 0-40 mm)	0-41 (mostly 0-20) Mostly minor expression of liquefaction, some sand boils and potentially some moderate to severe expression of liquefaction with settlement that can cause structural damage in places
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1/2500	Liquefaction occurs in loose to medium dense sandy and non/low plasticity silts	0-70 mm (mostly 0-40 mm)	0-46 (mostly 0-25) Mostly minor expression of liquefaction, some sand boils and potentially some moderate to severe expression of liquefaction with settlement that can cause structural damage in places

Technical Categorisation Based on Canterbury Criteria (MBIE Guidelines)

We have used the MBIE guidance (2012) to assess equivalent technical categories for the site based on the calculated liquefaction risk. We have not assessed lateral spreading so it is possible that liquefaction risk may be greater when in close proximity to the sea, Dunedin Harbour and any other local streams, changes in height or other free faces due to lateral spreading risks.

Note that technical categories are for houses in Canterbury Importance Level 2, 50 year design life structures and are not appropriate for other structures.

Table 3: *MBIE liquefaction deformation limits and house foundation implications*

Technical Category	Index Liquefaction Deformation Limits				Likely Implication for House Foundations (subject to individual assessment)
	Vertical		Lateral Spread		
	SLS	ULS	SLS	ULS	
TC1	15mm	25mm	Nil	Nil	Standard NZS3604 type foundations with tied slabs
TC2	50mm	100mm	50mm	100mm	MBIE enhanced foundation solutions
TC3	>50mm	>100mm	>50mm	>100mm	Site specific foundation solution

As calculated indexed settlements are less than 15 mm in the SLS event and between 0 and 70 mm in the ULS event therefore the testing shows the greater South Dunedin area is likely to be consistent with MBIE TC1 or TC2.

Discussion

Total settlement

Total liquefaction induced settlement and area wide settlement may cause other consequences. Examples of these effects were noted in Christchurch include:

- Total liquefaction and tectonic settlement putting areas into or further into flood zones, or increasing liquefaction vulnerability to sites;
- Area wide differential settlement causing issues with drainage through rivers, streams and pipes; and
- Global lateral movement of areas damaging infrastructure.

We note that we have only summarised indexed settlements (i.e. in the top 10 m) but have calculated total liquefaction induced reconsolidation settlements up to approximately 200 mm.

Other Geotechnical Issues in South Dunedin

Often the soils encountered in the CPTs of South Dunedin were too plastic to liquefy (i.e. moderately plastic silts or clays). Notwithstanding this, although these soils may not be susceptible to liquefaction they pose other significant geotechnical challenges for development, such as:

- They are soft and compressible and therefore only provide low bearing capacities with associated high rates of settlement for shallow foundations. Note significant areas in South Dunedin do not meet the definition of 'good ground' as per NZS3604:2011;
- Due to the soil type inferred from the CPTs, the liquefaction assessment indicates that some soils are unlikely to liquefy due to their plasticity. However, it is possible that cyclic softening may occur in this layer in a moderate to major earthquake event. Research on cyclic softening is not as clear as liquefaction effects. So the effects of cyclic softening are more difficult to quantify. But if softening occurs it is likely that the consolidation process will be reset and that long-term settlement will start over. It also can cause soft cohesive soils to lose strength.

Uncertainty of earthquake loading

The seismic hazard in Christchurch is greater than in Dunedin, however even if the level of seismic loading is increased the predicted settlements (in the upper 10 m) do not quite reach MBIE TC3 levels, even at PGA's up to 0.41 g (1/2500 AEP event).

The recent events in Canterbury and Kaikoura have highlighted the challenge that previous unidentified faults and site amplification effects may be very significant factors in the actual seismic risk applying to a site. This concern is most relevant where pre-historic faulting is masked by a persistent mantle of recent deposits (and such terrain dominates both in South Dunedin and Coastal Canterbury).

Data gaps

The testing has a relatively good spacing across the greater South Dunedin area. However, as the ground conditions are variable and can change quickly in the area specific site testing is recommended to better define the liquefaction risk.

Applicability

This report has been prepared for the benefit of the Otago Regional Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

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Colin Macdiarmid
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Appendix A – Figures

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South Dunedin Liquefaction Assessment
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FIG No. FIGURE 1
REV No. 1

Data and Information Committee 2020.10.14

Appendix B – Liquefaction Results

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- loss of strength;
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In addition, sloping sites or sites with a 'free face' may experience lateral spreading or movement.

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				Settlement (mm) (2)	LSN (2)	Settlement (mm) (2)	LSN (2)	Settlement (mm) (2)	LSN (2)	Settlement (mm) (2)	LSN (2)	Settlement (mm) (2)	LSN (2)	Settlement (mm) (2)	LSN (2)
CPT118535	6.1		0.5	0	0	10	3	10	3	15	4	20	5	25	7
CPT118547	5.9		0.5	0	0	0	1	0	1	5	1	5	1	5	2
CPT118552	20.5	0.6	0.5	0	0	0	0	0	0	0	0	0	0	0	0
CPT118553	11.2	0.6	0.5	0	1	30	3	30	3	30	3	30	3	30	3
CPT118790	12.5		0.5	0	0	15	4	30	12	35	13	35	14	35	16
CPT118802	16.6		0.5	0	0	0	0	0	0	0	0	0	0	0	0
CPT118805	5.5		0.5	0	0	0	0	5	2	10	9	20	16	25	21
CPT118808	7.1		0.5	0	0	10	2	15	3	20	7	25	10	30	14
CPT118810	9.8		0.5	0	0	20	3	25	3	25	3	25	4	25	6
CPT118811	10.9		0.5	0	0	10	2	20	7	30	9	35	12	40	13
CPT118812	5.2		0.5	0	0	5	1	5	1	5	1	5	1	5	2
CPT118813	3.0		0.5	0	0	0	1	15	8	25	12	25	15	30	19
CPT118815	22.7	0.5	0.5	0	0	5	2	25	14	35	18	40	20	50	22
CPT118819	7.9		0.5	0	0	5	1	10	2	10	6	15	9	15	11
CPT118821	9.1		0.5	0	0	20	3	25	8	30	11	30	14	30	15
CPT118823	12.4		0.5	0	0	15	4	45	15	55	18	55	19	60	20
Site A	10+		0.5	0-5	0-1	5-40	1-4	10-40	1-4	15-40	3-6	20-40	4-8	20-40	5-10
Site B	7-10+		0.5	0	0	5-45	1-7	15-80	4-13	25-85	7-16	25-85	10-20	35-90	12-23
Site C	10+		0.5	0-5	0	30-40	4-5	45-50	5-7	50-55	6-10	50-55	6-12	55-60	6-12
Site D	10+		0.5	0	0	0	0	0	0	0	1	0	1-2	0-5	2-3
Site E	4-10+	0.5	0.5	0	0	0-30	0-5	0-70	0-11	0-80	0-12	0-80	0-12	0-80	0-12
Site F	10+		0.5	0	0	0-20	1-6	10-65	5-29	15-80	11-41	15-85	13-44	15-85	15-46
Site G	10+		0.5	0	0	0-5	0-1	5-15	3-12	5-20	3-20	5-25	3-24	5-30	3-26
Site H	10+		0.5	0	0	0	0	0	2	5	3-7	0-5	3-9	5	3-10
Site I	10+		0.5	0	0	20-70	2-9	45-90	6-12	55-95	7-13	55-95	8-15	55-95	8-16
Site J	10+		0.5	0	0	0-5	0-1	0-5	1	0-5	1-3	0-5	1-3	0-5	1-3
Site K	6.5		0.5	0	0	0	0	5	2	5	2	5	2	5	2
Site L	10+		0.5	0	0	10-15	2-3	20-30	8-11	25-40	10-15	30-40	11-18	30-45	12-21
Site M	10+		0.5	0	0	0	0	0	0	0	0	0	0	0	0
Site N	8.5-10+		0.5	0	0	10-20	2-5	30-75	6-24	35-85	8-28	35-85	9-28	35-85	9-28
Site O	10+		0.5	0	0	0-20	0-9	0-35	0-17	0-35	0-17	0-35	0-17	0-35	0-17
Site P	10+	1	0.5	0	0	10-20	3-6	25-30	9-14	25-35	11-15	25-35	11-17	25-35	11-18
Site Q	9-10+		0.5	0	0	5-10	1-2	5-20	1-4	10-20	4-7	10-20	8-10	10-24	9-13
Site R	10+		0.5	0	0	0-25	0-6	0-40	0-14	0-40	0-17	0-40	0-18	0-40	0-19
Site S	10+	1	0.5	0	0	5	1	10-15	4-8	20	10-11	25	12-14	25	14-16
Site T	2.5-8		0.5	0	0	0-10	0-4	0-45	0-13	0-65	1-15	0-70	3-18	0-75	4-22
Site U	10+		0.5	0	0	0-20	0-9	0-35	0-17	0-35	0-17	0-35	0-17	0-35	0-17
Site V	9-10+		0.5	0	0	5-40	2-7	25-60	4-15	25-65	4-22	25-65	5-24	25-75	5-25
Min				0	0	0	0	0	0	0	0	0	0	0	0
Max				5	1	70	9	90	29	95	41	95	44	95	46

Notes:
(1) Pre-drill recorded if 0.5 m or greater
(2a) Indexed settlement and LSN calcuated by considering the upper 10 m only, where data avaiable
(2b) Some tests may have reached early refusal. Therefore additional layers could liquefy which will result in additional settlement and ground damage potentail
(2c) Areas in South Dunedin area is underlain soft silts/clays which are prone to ongoing static settlement, low bearing capacities and/or cyclic softening in a moderate to major earthquake event which is not covered in the above liquefaction assessment.
(3) Refer to Figure 1 for location of testing
(4) Range of results are given for sites with more than one CPT

7.2. Update on Biodiversity Mapping Project

Prepared for:	Data and Information Committee
Report No.	P&S1874
Activity:	Governance Report
Author:	Rachael Brown, Senior Policy Analyst
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	14 October 2020

PURPOSE

[1] This report provides the Committee with an update on the Council's Biodiversity Mapping and Ecological Prioritisation Project.

EXECUTIVE SUMMARY

[2] Action 3.1 of Council's Biodiversity Action Plan is to *complete biodiversity mapping and ecological prioritisation of potential sites for active management*. This report provides an update on the Biodiversity Mapping and Ecological Prioritisation Project, which is on track to be completed by 30 October 2020.

[3] There are two key phases to the project. Phase 1: *Mapping of Otago's ecosystems and habitats of significant indigenous fauna* was completed in August 2020. It provides key inputs into Phase 2: *Ecological prioritisation via 'zonation'* (computer modelling), which is underway and due to be completed by the end of October.

[4] Both the mapping and prioritisation are tenure neutral and cover the whole of the Otago region. The main focus of Phase 1 was vegetation mapping, with a significant new body of work being created on the spatial distribution of pre-human ecosystems across Otago. The habitats of Otago's significant indigenous fauna were also mapped, across terrestrial, fresh water and marine environments.

[5] The spatial distribution of ecological priorities that results from the project will provide a fundamental piece of knowledge about the region that has been missing in the Council's biodiversity work to date. It will help to inform both regulatory and non-regulatory work on biodiversity going forward, including ORC's implementation of national directions on fresh water and indigenous biodiversity.

[6] In the non-regulatory space, the project will help to implement Focus Area 1 of the Biodiversity Action Plan: *Active management*, which is to implement prioritised 'on the ground' action to maintain and enhance Otago's indigenous biodiversity.

RECOMMENDATION

That the Council:

1) ***Receives*** *this report.*

2) ***Notes*** *that Phase 1 (mapping) of the Biodiversity Mapping and Ecological Prioritisation Project is complete and Phase 2 (zonation analysis) is on track to be complete by 30 October 2020.*

BACKGROUND

[7] The Biodiversity Action Plan[1] sets out actions that ORC will take to improve biodiversity outcomes in Otago. In Focus Area 3, *Better Information for Better Management*, Action 3.1 is to *Complete biodiversity mapping and ecological prioritisation of potential sites for active management*. The Biodiversity Mapping and Ecological Prioritisation Project will be finalised by 30 October 2020, thus completing Action 3.1.

[8] The spatial distribution of ecological priorities that results from the project will provide a fundamental piece of knowledge about the region that has been missing in the Council's biodiversity work to date. It will help to inform both regulatory and non-regulatory work on biodiversity going forward, including ORC's implementation of the Essential Freshwater package and the proposed National Policy Statement for Indigenous Biodiversity (currently scheduled to be released in April 2021).

[9] The mapping work comprises two phases. Phase 1 of the project was to map ecosystems and habitats of significant fauna across terrestrial, freshwater and marine environments of Otago. In April 2019, ORC commissioned Wildlands Limited, led by Dr Kelvin Lloyd to undertake this mapping work, which was completed in August 2020.

[10] The mapping is tenure neutral and covers the whole of the Otago region. A key focus of Phase 1 was vegetation mapping, with a significant new body of work being created on the spatial distribution of original (pre-human) ecosystems across Otago. The habitats of Otago's significant indigenous fauna were also mapped, across terrestrial, fresh water and marine environments.

[11] In the non-regulatory space, it will inform implementation of Focus Area 1 of the Biodiversity Action Plan: *Active management*, which is to implement prioritised 'on the ground' action to maintain and enhance Otago's indigenous biodiversity and make best use of limited resources. This will be achieved through supporting and working in partnership with others.

[12] The key outputs of Phase 1 are:

Vegetation Mapping
Three separate maps of:
- Actual vegetation (classified according to Singers and Rogers 2014)2;
- Potential vegetation (classified according to Singers and Rogers 2014); and
- Terrestrial habitat of significant indigenous fauna.

Freshwater Ecosystems and Habitat
Two separate maps of:
- Fresh water ecosystem types; and
- Freshwater habitats of significant fauna.

[1] https://www.orc.govt.nz/media/7034/final-orc-biodiversity-action-plan-july-2019.pdf
[2] Singers N.J.D. and Rogers G.M. 2014: A classification of New Zealand's terrestrial ecosystems. *Science for Conservation 325*. Department of Conservation, Wellington.

Coastal/Marine Ecosystems and Habitat (out to 12 nautical miles)
Two separate maps of:

- Ecosystem types; and
- Coastal/marine habitats of significant indigenous fauna.

[13] Phase 1 has then been used as an input to Phase 2 of the project: ecological prioritisation via 'zonation' (computer modelling), which will identify areas where the highest biodiversity values are likely to be found in Otago.

[14] Information based on the mapping and prioritisation will still need to be ground-truthed to determine what is actually there, but the project results will inform what areas to prioritise for more detailed surveys and the location of projects with iwi, landowners, other councils, central government agencies and community groups. The analysis will enable better co-ordination across agencies managing biodiversity for different purposes.

[15] ORC is the first regional council to undertake mapping of the habitats of significant fauna across terrestrial, fresh water and marine environments. The vegetation and habitat mapping will be useful to territorial authorities (i.e. city and district councils) to assist in identifying significant areas of indigenous vegetation and significant habitats of indigenous fauna under Section 6(c) of the Resource Management Act (1991).

[16] Most regional councils and unitary authorities have already undertaken terrestrial mapping and prioritisation using the same ecosystem classification system (Singers and Rogers, 2014) and zonation analysis. Using the same classification system allows data sets to be combined across councils which will help to gain a better understanding at a national level of remaining indigenous terrestrial ecosystems.

ISSUE

[17] Despite the dedicated efforts of many people, groups and agencies to reverse the loss of Aotearoa's indigenous biodiversity, this trend continues. Drivers of biodiversity loss include introduced predators, plants and diseases, land-use intensification for production or urban development, pollution in freshwater and coastal habitats, use of natural resources (e.g. fishing and freshwater extraction), and increasingly, climate change.[3]

[18] Because the task of maintaining and enhancing biodiversity is a huge challenge with limited funding and resources, *prioritisation* is critical to identify where the greatest biodiversity gains will be for the effort expended. This will enable the Council to work with others to develop management responses including prioritising the most threatened species and ecosystems within Otago.

[19] ORC's Biodiversity Action Plan sets out an approach to reverse the decline of indigenous biodiversity in Otago by:

[3] MfE & Stats NZ (2019). *Environment Aotearoa 2019.*
https://www.mfe.govt.nz/sites/default/files/media/Environmental%20reporting/environment-aotearoa-2019.pdf

- Partnering and working with others, so that action to improve biodiversity outcomes can be coordinated through working with rūnaka, landowners, other agencies and groups; and
- Prioritising ecosystems for active management so that areas with the highest biodiversity values can be identified and ORC can work alongside others to help manage these areas.

DISCUSSION

[20] This project is relevant to Council's objective for biodiversity that:

People living in Otago value and better understand biodiversity so that we can all enjoy and share in its benefits, as the foundation of a sustainable economy and society.[4]

[21] The extent and condition of indigenous vegetation and habitats of indigenous fauna are key measures of success in terms of efforts to maintain indigenous biodiversity and ensure that trends are improving rather than declining. The project will highlight the spatial distribution of some of our key natural assets at a regional level. Going forward the Council will be in a better position to make decisions about how it monitors the extent and condition of indigenous biodiversity over time. This will help to provide a level of transparency and accountability that has not previously been possible.

[22] Potential uses of the mapping and ecological priorities include:

- Helping to identify what actions are required in relation to managing indigenous vegetation and habitat, where, and what the priority of those actions are at different scales. This includes providing a basis for ORC to implement our regulatory functions to maintain indigenous biodiversity.
- In catchment planning to identify strategic placement of restoration/ revegetation to provide effective connectivity in local landscapes.
- Spatial analysis in relation to tenure can be used to assess the conservation status of ecosystem types at different scales, and identify who needs to collaborate on actions
- Overlay of riparian corridors (obtained by buffering streams in topographic coverage) with ecosystems could be used to identify high value riparian areas, and measure extent (with information on condition to come later).
- Management of indigenous biodiversity in terms of climate change adaptation and resilience.
- In combination with information on weed distribution – could identify high priority areas of indigenous biodiversity for weed eradication programmes with an asset protection focus.

[4] ORC (2019) Biodiversity Action Plan https://www.orc.govt.nz/media/7034/final-orc-biodiversity-action-plan-july-2019.pdf

CONSIDERATIONS

Policy Considerations

[23] This data will be useful to inform both regulatory and non-regulatory policy options to maintain and enhance indigenous biodiversity across Otago as discussed in paragraphs (8), (11) and (22) above.

Financial Considerations

[24] The project has been completed with the original budgets. There are no additional direct financial considerations as a result of this paper.

Significance and Engagement

[25] This is not applicable however the use of the mapping will need to take into account the Council's Significance and Engagement Policy as it has the potential to affect a large number of people.

Legislative Considerations

[26] Section 30(1)(ga) requires regional councils to develop *objectives, policies and methods for maintaining indigenous biological diversity.* This project provides important information to assist with achieving this function.

Risk Considerations

[27] There are risks associated with publishing the maps of actual vegetation, habitats of significant fauna and ecological priorities as this may create perverse incentives for some landowners if they have concerns about the ramifications of potentially valuable biodiversity being identified on private land. Other regional councils have managed this risk through working with and supporting landowners and territorial authorities to ground truth the mapping and identify appropriate areas and management actions, before it is published.

NEXT STEPS

[28] The next steps are to:

- Complete Phase 2 of the project: Ecological prioritisation. This is on track to be complete by 30 October 2020, following workshops with ORC councillors and staff on 14 October 2020.
- Convene a hui with Rūnaka to determine how the priorities identified align with iwi, hāpu and whānau priorities for māhika kai, wahi tupuna and taoka species across Otago.
- Take the resulting ecological priorities to the next meeting of the Otago Biodiversity Iwi and Interagency Group for further discussion before the end of 2020.
- Share and publish data as appropriate, including:
    a. Establishing data sharing protocols so that the mapping and prioritisation outputs can be shared with territorial authorities to inform the identification of significant natural areas.
    b. Publishing the original ecosystems layer as this will be useful to inform planting projects.

ATTACHMENTS

Nil

7.3. State of the Environment (SOE) Report Card

Prepared for:	Data and Information Committee
Report No.	P&S1876
Activity:	Governance Report
Author:	Rachel Ozanne, Environmental Resource Scientist
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	14 October 2020

PURPOSE

[1] To assess compliance of Otago's water quality (114 sites; 106 river sites and 8 lake sites) with Regional Plan: Water for Otago (Water Plan), Schedule 15 numerical standards.

EXECUTIVE SUMMARY

[2] The Otago Regional Council (ORC) monitors water quality in a selection of Otago rivers and lakes through long-term State of the Environment (SoE) monitoring programmes.

[3] Information from these programmes is used for reporting on the effectiveness of the Regional Plan: Water for Otago (Water Plan).

[4] Schedule 15 of the Water Plan, sets out the numerical limits for water quality for catchments in the Otago region.

[5] Otago's water quality is assessed against Schedule 15 limits and a water quality index is used to grade sites into one of four categories (excellent, good, fair, poor).

[6] In the 2015-2020 period 37 (35%) river sites were classified as 'excellent', 34 (32%) as 'good', 19 as 'fair' (18%) and 16 sites as 'poor' (15%). Of the eight lake sites three were classified as 'excellent', three as 'good' and two sites were classified as 'poor'.

RECOMMENDATION

That the Council:

*1) **Notes** the report*

BACKGROUND

[7] As at July 2020, ORC monitors 114 river, stream and lake sites across the Otago region as part of its long term SoE surface water quality monitoring programme.

[8] A suite of physico-chemical and microbiological water quality variables are measured monthly at each site: water temperature, dissolved oxygen, conductivity, pH, turbidity, total suspended solids (TSS), soluble and total nitrogen and phosphorus, and E. coli (as an indicator for faecal pathogens).

[9] Schedule 15 sets out receiving water numerical limits and accompanying target dates for achieving "good water quality" in Otago rivers and lakes. Limits apply to: nitrate-nitrite nitrogen, dissolved reactive phosphorus, ammoniacal nitrogen, E. coli and turbidity and vary within the five different receiving water groups set out in the water plan.

[10] To enable a water quality classification of rivers and lakes, a water quality index is used to grade sites into one of four categories (excellent, good, fair, poor) depending on how many of the five parameters assessed comply with the limit (or target) set out in Schedule 15.

Grade	Number of parameters complying with water quality standards
Excellent	All five parameters (Table 1) comply
Good	Four (of the five) values comply
Fair	Three (of the five) values comply
Poor	Two or fewer (of the five) values comply

DISCUSSION

[11] The report attached as Appendix 1 shows that in the 2015-2020 period 37 river sites were classified as 'excellent', 34 as 'good', 19 as 'fair' and 16 sites as 'poor'. Of the eight lake sites three were classified as 'excellent', three as 'good' and two sites were classified as 'poor'. A map showing the results is available in Appendix 1.

[12] The results are compared to the previous reporting period (Appendix 1). Compared to the 2014-2019 water quality results, 83 sites retained the same grade, 19 sites improved by one grade and one site improved by two grades (Lake Hayes) ten sites degraded by one grade and one site degraded by two grades (the Kaikorai). The table below shows the overall classification numbers for the two reporting periods.

	Rivers (106 sites)		Lakes (8 sites)	
Schedule 15 classification	2014-2019	2015-2020	2014-2019	2015-2020
Excellent	37	37	3	3
Good	32	34	2	3
Fair	18	19		
Poor	19	16	3	2

[13] Appendix 1, Figure 1 shows that water quality in rivers across Otago show a clear spatial pattern related to land use. Water quality is best (classed as 'excellent' or 'good') at river and stream reaches located at high or mountainous elevations under predominantly native cover. These sites tend to be associated with the upper catchments of larger rivers (e.g. Clutha River/Matau-Au) and the outlets from large lakes (e.g. Hawea, Wakatipu and Wanaka). Water quality is degraded (classed 'fair' or 'poor') at river and stream reaches located in urban areas and catchments with more intensive land uses.

NEXT STEPS

[14] The next annual report card will cover the period July 2016 to June 2021.

[15] Comprehensive State of the Environment reporting is undertaken once every five years and provides a detailed review of water reporting on regional state and trends in river and lake health and performance against the National Policy Statement for Freshwater

Management (NPSFM), and the effectiveness of the Water Plan. The next report will cover the period up until June 2022.

ATTACHMENTS

1. wq-soe-2015-2020-report-card-final [**7.3.1** - 7 pages]

Water quality in Otago

Water quality July 2015 to June 2020

Otago Regional Council

Introduction

The Otago Regional Council (ORC) is responsible for managing Otago's surface-water resources and carrying out regular and extensive long-term water-quality monitoring, as part of its State of Environment (SOE) programme. This report card documents the results of ORC water-quality monitoring undertaken between July 2015 and June 2020 and NIWA monitoring undertaken between January 2015 and December 2019.

Water quality

Schedule 15 of the Regional Plan: Water for Otago sets out the numerical limits for acceptable water quality for all catchments in the Otago region. The receiving water limits (outlined in Table 1) are applied as five-year, 80th percentiles, when flows are at or below median flow.

Table 1: Water quality standards (five-year, 80th percentiles, when flows are at or below median flow)

Schedule 15	Nitrite-nitrate nitrogen mg/l	Dissolved reactive phosphorus mg/l	Ammoniacal nitrogen mg/l	*Escherichia coli* cfu/100ml	Turbidity NTU	Total nitrogen mg/l	Total phosphorus mg/l
Group 1	0.444	0.026	0.10	260	5		
Group 2	0.075	0.010	0.10	260	5		
Group 3	0.075	0.005	0.01	50	3		
Group 4			0.10	126	5	0.55	0.033
Group 5			0.01	10	3	0.10	0.005

114 SOE sites were monitored every month, with six sites monitored monthly by NIWA (as part of the National River Water Quality Network). To enable classification of each site into one of four groups (Table 2), ORC uses a water quality index. Figure 1 shows the results.

Table 2: Water quality index

Grade	Number of parameters complying with water quality standards (June 2012 to July 2017)
Excellent	All five parameters (Table 1) comply
Good	Four (of the five) values comply
Fair	Three (of the five) values comply
Poor	Two or fewer (of the five) values comply

Nutrients: Nitrite-nitrate nitrogen (NNN) and dissolved reactive phosphorus (DRP) are the biologically available nutrients used for algae and plant growth. NNN is a form of nitrogen, mainly derived from land drainage, and DRP is a form of phosphorus, mainly sourced from effluent and fertiliser. Ammoniacal nitrogen (NH_4-N) can indicate the presence of effluent in water.

E. coli: *Escherichia coli* (*E. coli*) are a bacterium which is used as an indicator of the presence of harmful micro-organisms in water (e.g. human or animal faeces). This can be used to gauge whether water is suitable for stock drinking, swimming, surfing or other recreational activities.

Turbidity: Turbidity is a measure of the cloudiness of water, determined by how much light is scattered by suspended particles. Streams with 'high turbidity' often have high suspended sediment loads. Having high turbidity can reduce light penetration, which can affect photosynthesis. High sediment loading also tends to smother the streambed, which reduces macroinvertebrate and fish-spawning habitat.

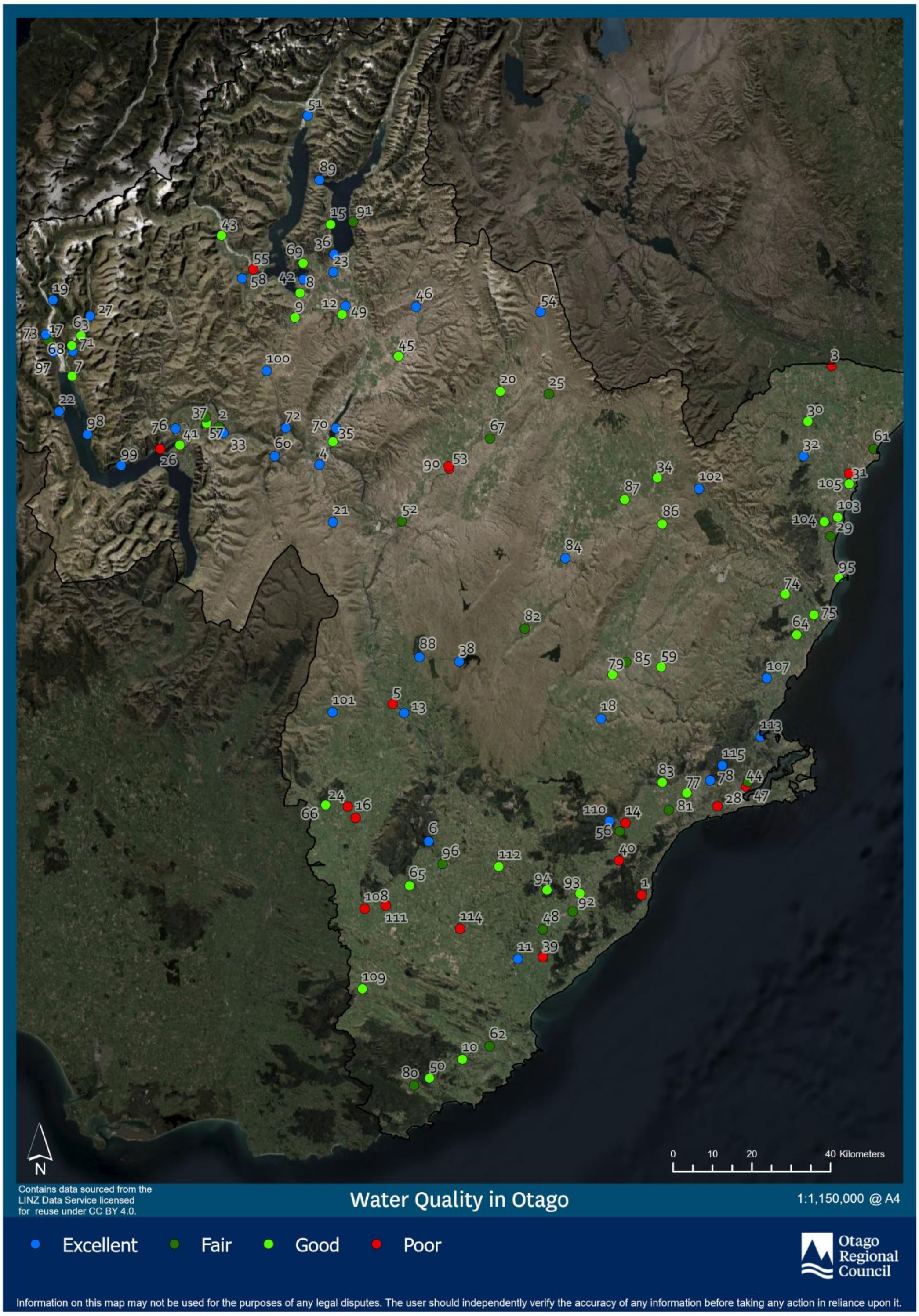

Figure 1: Results of SOE water-quality monitoring (2015 -2020). Site numbers refer to sites in Tables 3-7.

Water-quality monitoring: Results

Table 3: Group 1 sites showing water quality results. The orange cells show where the 80th percentile below median flow exceeded the Schedule 15 limits/targets. Sites with an '*' have not been monitored for five years, therefore the grade is interim. Sites monitored by NIWA are shown with an' N'

Site #		Site Name	Grade	NH4-N	E.coli	DRP	NNN	Turb
				mg/L	cfu/100ml	mg/L	mg/L	NTU
		Schedule 15 limit or target		0.1	260	0.026	0.444	5
6	*	Blackcleugh Burn at Rongahere Road	Excellent	0.0025	38	0.019	0.060	0.49
10		Catlins at Houipapa	Good	0.012	235	0.015	0.448	3.97
11	N	Clutha at Balclutha (NIWA)	Excellent	0.0044	85	0.002	0.09	4.20
16		Crookston Burn at Kelso Road	Poor	0.0344	1499	0.043	1.401	5.41
24		Heriot Burn at Park Hill Road	Poor	0.0321	1330	0.046	1.496	5.31
28		Kaikorai Stream at Brighton Road	Poor	0.0165	1990	0.014	0.471	8.13
44		Leith at Dundas Street Bridge	Poor	0.0141	1174	0.030	0.553	2.28
47		Lindsays Creek at North Road Bridge	Fair	0.02	589.2	0.026	0.753	2.53
48		Lovells Creek at Station Road	Fair	0.0163	603.9	0.018	0.645	3.09
50	*	Maclennan at Kahuiku School Road	Good	0.0144	479.2	0.012	0.031	2.17
62		Owaka at Katea Road	Fair	0.0111	451.5	0.021	1.212	2.62
65		Pomahaka at Burkes Ford	Good	0.0172	145	0.014	0.534	3.81
80	*	Tahakopa at Tahakopa	Fair	0.0097	1221	0.008	0.386	7.27
92		Tokomairiro at Blackbridge	Fair	0.0274	1780	0.029	0.311	4.87
93	*	Tokomairiro at Lisnatunny	Good	0.0215	500	0.023	0.245	4.15
94		Tokomairiro at West Branch Bridge	Good	0.0167	296	0.014	0.261	2.77
96		Tuapeka at 700m u/s bridge	Fair	0.0145	283	0.028	0.110	3.25
108		Waipahi at Cairns Peak	Poor	0.0321	729	0.018	0.641	7.42
109		Waipahi at Waipahi	Good	0.0149	239	0.024	0.872	2.49
11		Wairuna at Millar Road	Poor	0.0512	906	0.107	1.020	14.4
112		Waitahuna at Tweeds Bridge	Good	0.016	505	0.018	0.149	4
113	*	Waitati at Mt Cargill Road	Excellent	0.01	154	0.01	0.019	1.15
114		Waiwera at Maws Farm	Poor	0.0192	348	0.036	0.924	2.96

Table 4: Group 2 sites showing water quality results. The orange cells show where the 80th percentile below median flow exceeded the Schedule 15 limits/targets. Sites with an '*' have not been monitored for five years, therefore the grade is interim. Sites monitored by NIWA are shown with an' N'. Sites with '*' have results that have been monitored by both NIWA and ORC**

Site #		Receving Water Group 2		NH4-N	E.coli	DRP	NNN	Turb
				mg/L	cfu/100ml	mg/L	mg/L	NTU
		Schedule 15 limit or target		0.1	260	0.01	0.075	5
1	*	Akatore Creek at Akatore Creek Road	Poor	0.003	547	0.007	0.454	16.8
2	*	Arrow at Morven Ferry Road	Fair	0.005	309	0.003	0.111	4.27
3		Awamoko at SH83	Poor	0.019	744	0.106	0.632	1.32
4		Bannockburn at Lake Dunstan	Excellent	0.011	144	0.007	0.003	4
5		Benger burn at SH8	Poor	0.015	397	0.017	0.297	1.49
8	*	Bullock Creek at Dunmore Street Footbridge	Good	0.003	579	0.002	0.775	0.52
9		Cardrona at Mt Barker	Good	0.010	171	0.004	0.087	2.21
13	N	Clutha at Millers Flat (NIWA)	Excellent	0.004	37	0.001	0.042	2.95
14		Contour Channel at No. 4 Bridge	Poor	0.070	899	0.040	0.333	6.94
18		Deep Stream at SH87	Excellent	0.005	201	0.003	0.01	0.94
20		Dunstan Creek at Beattie Road	Good	0.007	153	0.005	0.085	0.89
21	*	Fraser at Old Man Range	Excellent	0.003	14	0.002	0.007	0.50
23		Hawea at Camphill Bridge	Excellent	0.006	10	0.003	0.020	0.58
25	*	Hills Creek at SH85	Fair	0.003	604	0.004	0.142	1.26
29	*	Kakaho Creek at SH1	Fair	0.041	457	0.046	0.201	2.94
30		Kakanui at Clifton Falls Bridge	Good	0.006	431	0.003	0.040	0.40
31		Kakanui at McCones	Good	0.013	202	0.005	0.371	0.63
32		Kauru at Ewings	Excellent	0.007	211	0.003	0.028	0.42
34		Kye Burn at SH85 Bridge	Good	0.007	181	0.006	0.085	1.57
45		Lindis at Ardgour Road	Good	0.009	134	0.004	0.096	1.44
46		Lindis at Lindis Peak	Excellent	0.006	89	0.004	0.020	1.75
49		Luggate Creek at SH6 Bridge	Good	0.009	220	0.012	0.004	1.61
52		Manuherikia at Galloway	Fair	0.007	267	0.018	0.047	2.76
53		Manuherikia at Ophir	Poor	0.017	357	0.031	0.109	2.87
54	*	Manuherikia downstream of Fork	Excellent	0.003	62	0.006	0.008	0.48

Table 4 continued. Group 2 sites showing water quality results. The orange cells show where the 80th percentile below median flow exceeded the Schedule 15 limits/targets. Sites with an '*' have not been monitored for five years, therefore the grade is interim. Sites monitored by NIWA are shown with an' N'

Site #		Receving Water Group 2		NH4-N	E.coli	DRP	NNN	Turb
				mg/L	cfu/100ml	mg/L	mg/L	NTU
		Schedule 15 limit or target		0.1	260	0.01	0.075	5.0
56	*	Meggat Burn at Berwick Road	Fair	0.01	461	0.010	0.133	4.39
57		Mill Creek at Fish Trap	Fair	0.013	300	0.007	0.42	4.26
59		Nenthorn at Mt Stoker Road	Good	0.011	140	0.017	0.010	1.50
60		Nevis at Wentworth Station	Excellent	0.008	50	0.005	0.004	0.73
61	*	Oamaru Creek at SH1	Fair	0.024	1948	0.351	0.991	4.63
64	*	Pleasant at Patterson Road Ford	Good	0.008	84.9	0.003	0.034	5.81
65		Pomahaka at Glenken	Good	0.010	325	0.010	0.089	2.98
67	*	Poolburn at Cob Cottage	Fair	0.011	385	0.057	0.115	2.54
70	*	Quartz Reef Creek at SH8	Excellent	0.003	166	0.003	0.013	3.76
72	*	Roaring Meg at SH6	Excellent	0.003	89	0.007	0.024	1.58
74		Shag at Craig Road	Good	0.006	142	0.005	0.152	0.81
75		Shag at Goodwood Pump	Good	0.010	200	0.007	0.283	0.74
76	N	Shotover at Bowens Peak (NIWA)	Excellent	0.003	6	0.001	0.010	4.72
77		Silverstream at Taieri Depot	Good	0.018	307	0.007	0.709	2.16
78	*	Silverstream at Three Mile Hill Road	Excellent	0.005	32.2	0.003	0.020	0.43
79	***	Sutton Stream at SH87	Good	0.003	516	0.009	0.011	1.16
81		Taieri at Allanton Bridge	Fair	0.017	289	0.013	0.063	4.23
82		Taieri at Linnburn Runs Road	Fair	0.008	300	0.005	0.100	1.50
83	***	Taieri at Outram	Good	0.008	100	0.010	0.040	1.69
84		Taieri at Stonehenge	Excellent	0.009	155	0.008	0.012	1.64
85		Taieri at Sutton	Fair	0.010	395	0.014	0.053	3.10
86	***	Taieri at Tiroiti	Good	0.008	173	0.022	0.036	3.90
87		Taieri at Waipiata	Good	0.014	231	0.038	0.040	3.44
88	*	Teviot at Bridge Huts Road	Excellent	0.006	184	0.002	0.006	4.57
90		Thomsons Creek at SH85	Poor	0.022	1362	0.100	0.304	7.13
95		Trotters Creek at Mathesons	Good	0.02	210	0.006	0.440	2.04
100	*	Upper Cardrona at Tuohys Gully Road	Excellent	0.003	165	0.002	0.027	1.64
101	*	Upper Pomahaka at Aitchison Runs Road	Excellent	0.003	92	0.005	0.020	0.98
102	*	Upper Shag at SH85 Culvert	Excellent	0.008	130	0.002	0.041	0.34
103		Waianakarua at Browns	Good	0.010	220	0.003	0.318	0.45
104	*	Waianakarua at South Branch SH1	Good	0.005	218	0.002	0.587	0.43
105		Waiareka Creek at Taipo Road	Poor	0.032	581	0.265	0.640	1.97
107		Waikouaiti at Confluence d/s	Excellent	0.009	68	0.004	0.025	1.18
110		Waipori at Waipori Falls Reserve	Excellent	0.006	36	0.003	0.040	1.79
115	*	Whare Creek at Whare Flat Road	Excellent	0.003	15	0.003	0.051	0.61

Table 5. Group 3 sites showing water quality results. The orange cells show where the 80th percentile below median flow exceeded the Schedule 15 limits/targets. Sites with an '*' have not been monitored for five years, therefore the grade is interim. Sites monitored by NIWA are shown with an' N'

Site #		Receiving Water Group 3		NH4-N	E.coli	DRP	NNN	Turb
				mg/L	cfu/100ml	mg/L	mg/L	NTU
		Schedule 15 limit or target		0.01	50	0.005	0.075	3
98	*	12 Mile Creek at Glenorchy Queenstown Road	Excellent	0.006	6	0.002	0.006	0.30
99	*	25 Mile Creek at Glenorchy Queenstown Road	Excellent	0.005	29	0.002	0.009	0.5
7	*	Buckler Burn at Glenorchy Queenstown Road	Good	0.003	9.2	0.002	0.031	4.46
12	N	Clutha at Luggate (NIWA)	Excellent	0.004	5.2	0.001	0.043	1.01
15	*	Craig Burn at SH6	Good	0.003	55	0.002	0.009	0.90
17		Dart at The Hillocks	Fair	0.014	10	0.003	0.036	15.4
19	*	Dundas Creek at Mill Flat	Excellent	0.003	3.8	0.002	0.042	0.35
22	*	Greenstone at Greenstone Station Road	Excellent	0.003	22	0.002	0.022	0.34
26	*	Horn Creek at Queenstown Bay	Poor	0.013	363	0.008	0.172	3.98
27	*	Invincible Creek at Rees Valley Road	Excellent	0.003	2.7	0.002	0.013	2.02
33	N	Kawarau at Chards Road	Excellent	0.022	27	0.002	0.030	3.81
43	*	Leaping Burn at Wanaka Mt Aspiring Road	Good	0.003	196	0.002	0.030	0.62
51	*	Makarora at Makarora	Excellent	0.003	20	0.002	0.061	1.65
55		Matukituki at West Wanaka	Poor	0.010	24	0.004	0.080	1.79
58	*	Motatapu at Wanaka Mt Aspiring Road	Excellent	0.003	25	0.002	0.042	0.82
63	*	Ox Burn at Rees Valley Road	Good	0.003	9	0.002	0.020	7.01
68	*	Precipice Creek at Glenorchy Paradise Road	Excellent	0.003	23	0.002	0.010	0.65
69	*	Quartz Creek at Maungawera Valley Road	Good	0.003	47	0.002	0.082	0.51
71	*	Rees at Glenorchy Paradise Road Bridge	Good	0.003	13	0.002	0.017	10.1
73	*	Scott Creek at Routeburn Road	Excellent	0.004	20	0.002	0.029	0.52
89	*	The Neck Creek at Meads Road	Excellent	0.003	18	0.002	0.007	0.42
91	*	Timaru at Peter Muir Bridge	Fair	0.003	6	0.006	0.015	20.6
97	*	Turner Creek at Kinloch Road	Excellent	0.003	8	0.002	0.054	0.37

Table 6. Group 4 sites showing water quality results. The orange cells show where the 80th percentile below median flow exceeded the Schedule 15 limits/targets.

Site #		Receiving Water Group 4		NH4-N	E.coli	Turb	TP	TN
				mg/L	cfu/100ml	NTU	mg/L	mg/L
		Schedule 15 limit or target		0.1	126	5	0.033	0.55
37		Lake Hayes at Mid Lake 10m	Good	0.043	2	3	0.055	0.39
38		Lake Onslow at Boat Ramp	Excellent	0.009	8	4.8	0.028	0.29
39		Lake Tuakitoto at Outlet	Poor	0.077	125	8.6	0.147	1.44
40		Lake Waihola at Waihola Mid	Poor	0.027	225	11.9	0.058	0.69

Table 7. Group 5 sites showing water quality results. The orange cells show where the 80th percentile below median flow exceeded the Schedule 15 limits/targets.

Site #		Receiving Water Group 5		NH4-N	E.coli	Turb	TP	TN
		Schedule 15 limit or target		0.01	10	3	0.005	0.1
35		Lake Dunstan at Dead Mans Point	Good	0.006	9	1.1	0.025	0.10
36		Lake Hawea South Open Water 10m	Excellent	0.003	1	1.0	0.002	0.04
41		Lake Wakatipu Open Water 10m	Good	0.003	1	0.8	0.006	0.06
42		Lake Wanaka Open Water 10m	Excellent	0.003	1	0.8	0.002	0.06

Water quality: Summary

The results in the table below show how sites and grades have varied over the years. In 2015-2020 more than half of the SoE sites are classified as having 'excellent' or 'good' water quality. Most the sites with 'excellent' river water quality were in Central Otago and the upper Clutha, where land-use tends to be low-intensity sheep farming and/or dominated by tussock lands. Poorer water quality was found in river catchments with higher-intensity farming or in streams draining urban environments.

RIVERS GRADE	2009-14	2010-15	2011-16	2012-17	2013-18	2014-19	2015-20
Excellent	18	18	16	15	16	37	37
Good	18	18	23	24	20	32	34
Fair	10	13	11	13	15	18	19
Poor	8	13	13	11	12	19	16
TOTAL	54	62	63	63	63	106	106

LAKES GRADE	2009-14	2010-15	2011-16	2012-17	2013-18	2014-19	2015-20
Excellent	2	5	5	4	3	3	3
Good	2	1	1	1	2	2	3
Fair	1			1	1		
Poor	3	2	2	2	2	3	2
TOTAL	8	8	8	8	8	8	8

Compared to 2014-2019 water quality results, 83 sites retained the same grade, 19 sites improved by one grade and one site improved by two grades (Lake Hayes) ten sites degraded by one grade and one site degraded by two grades (the Kaikorai).

In Group 1, three sites (of 23) had 'excellent' water quality (Balclutha, Waitati and Blackcleugh Burn); seven had 'good' water quality (Catlins, Owaka, Maclennan, Pomahaka at Burkes, Tokomairiro at Lisnatunny, Tokomairiro at West Branch Bridge, Waitahuna and Waipahi at Waipahi); six had 'fair' water quality; and the remaining 7 sites were classified as having 'poor' water quality. Schedule 15 limits were most often exceeded for *E. coli* and NNN. Most of the 'poor' sites were in south-west Otago.

For Group 2, thirteen sites (out of 35) had 'excellent' water quality. Most of these were upper catchment sites in the Taieri and Clutha river catchments. Thirteen sites had 'good' water quality, *E.coli*, DRP and NNN were the parameters that most often exceeded the Schedule 15 limit in this category. Thirteen sites had 'fair' water quality, while another two were classified as 'poor'.

Of the 23 sites in Group 3, 13 had 'excellent' water quality, five had 'good' water quality, two sites had 'fair' water quality and three sites had 'poor' water qulaity. The Kawarau improved a grade from 'fair' to 'good'.

In Group 4, Lake Hayes had 'good' water quality, Lake Onslow 'excellent' water quality, Lake Tuakitoto and Lake Waihola both had 'poor' water quality. All but Onslow exceeded Schedule 15 limits for total phosphorus (TP). Lake Waihola was the only small lake to exceed the *E. coli* limit. All Group 5 sites had excellent water quality, except for Lake Dunstan and Lake Wakatipu, both of which recorded total phosphorus as being above the limit.

7.4. Proposed Estuary Monitoring Programme

Prepared for:	Data and Information Committee
Report No.	P&S1875
Activity:	Governance Report
Author:	Dr Sam Thomas, Coastal Scientist
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	14 October 2020

PURPOSE

[1] To implement a State of the Environment monitoring network for Otago's estuaries that meets ORC's regulatory requirements.

EXECUTIVE SUMMARY

[2] Estuaries are important ecosystems providing habitat for a variety of species such as cockles and wading birds as well as providing ecosystem functions such as nutrient cycling. Estuaries are important environmentally, culturally, recreationally, and are valued by the communities living around them. They are the receiving environment for land run-off (nutrients, sediment, heavy metals) and are under increasing stress from overharvesting and changes in land use.

[3] A monitoring network is required to determine estuarine current state, change in state, and to identify management options to improve estuarine health. Due to the importance of estuaries it is proposed to progressively upgrade the current monitoring network to a regulatory compliant State of the Environment (SoE) monitoring network. The proposed expansion of ORC's estuary monitoring programme will provide a robust, representative network across catchment types in Otago, providing the required information to manage the health of estuaries in the region.

[4] The Waikouaiti River, Shag River, Catlin's River/Lake, Kaikorai and Tokomairiro River estuaries are currently monitored. The following additional estuaries will be included in the monitoring programme: Blueskin Bay, Pleasant River, Papanui Inlet, Kakanui River, Akatore Creek, Tautuku and Tahakopa River.

[5] Otago's estuary monitoring programme currently does not meet New Zealand Coastal Policy Statement obligations for Regional Councils, or the requirements of the National Policy Statement for Freshwater Management (2020).

RECOMMENDATION

That the Council:

1) ***Receives*** *this report.*

2) ***Notes*** *the proposal to expand ORC's estuary monitoring programme to create a representative SoE monitoring network for estuaries.*

BACKGROUND

[6] Estuaries are important transition zones between terrestrial, freshwater and marine environments resulting in complex environments which provide many different ecosystem functions and services. These services include acting as habitat for a variety of fish, invertebrates and bird species, nutrient cycling, organic matter breakdown and primary production. They are important areas both culturally and for recreation purposes.

[7] Estuaries are included as Coastal Protected Areas within Otago's Regional Plan: Coast, with the accompanying statement:

"*Estuaries were included in the coastal protection area because they are particularly valuable in terms of biological productivity. This productivity results from the continuous flow of nutrients down rivers, the relative shelter compared to the open coast, and the relatively high (in coastal terms) amount of light available. Estuaries provide a benign environment for flora and fauna and are believed to act as both nursery areas and nutrient suppliers for the open coast and deeper ocean waters. Kai Tahu, in accordance with tikanga Maori, have also identified areas that contain important cultural or spiritual values which the Plan recognises.*"

[8] Many different stressors such as sedimentation, nutrient enrichment, overharvesting, stormwater run-off and land development may influence estuary state due to their position at the bottom of catchments (downstream receiving environment). Stressors to the estuary can be individual (e.g. sediment) or multiple (e.g. sediment and nutrients) with differing impacts on the health of an estuarine system when one stressor is present compared to an estuarine system with multiple stressors present.

[9] Due the importance of these ecosystems, better monitoring is required to determine current state and any change in state within the estuarine system as well as identifying appropriate management actions to be undertaken if estuarine state is degraded or degrading. Fine scale monitoring measures environmental indicators (macrofauna, sediment nutrients, sediment mud content and heavy metal content) at selected sites within the estuary. Broad scale monitoring measuring the extent (in ha and %) of habitat across the estuary such as seagrass, sandflats and extent of fine mud. Both fine and broad scale monitoring will be undertaken as part of the propose monitoring programme.

[10] Otago Regional Council has regulatory obligations under the New Zealand Coastal Policy Statement and the Resource Management Act 1991 (RMA) to monitor estuaries in the region. The National Policy Statement for Freshwater Management (NPS-FM) requires an integrated approach to managing freshwater systems with the lowest sensitive receiving environment such as estuaries used for limit setting in the river systems, therefore, an improved estuary monitoring network is needed to provide data to inform this process.

ISSUE

[11] Currently ORC monitors 5 out of the 16 estuaries listed in the Otago Regional Plan: Coastal. The 5 estuaries currently do not provide a representative network due to lack of estuary numbers, not enough estuarine types and limited geographical coverage to

identify issues across the region or to determine if significant adverse effects are occurring which is an obligation under the New Zealand Coastal Policy Statement. Equally to manage catchments from the mountains to the sea incorporating the lowest sensitive receiving environment under the NPS-FM a representative network of estuaries is needed to provide the data needed for management of these systems.

[12] Otago Regional Council has obligations to adequately monitor estuaries in order to maintain or improve estuarine health under the New Zealand Coastal Policy Statement (2010), specifically policy 11 (b) (iii) which is as follows:

"(b) *avoid significant adverse effects and avoid, remedy or mitigate other adverse effects of activities on; (iii) indigenous ecosystems and habitats that are only found in the coastal environment and are particular vulnerable to modification, including estuaries, lagoons, coastal wetlands, dunelands, intertidal zones, rocky reef systems, eelgrass and saltmarsh*".

[13] Equally in the Regional Plan: Coast for Otago (2009) estuaries are listed as coastal protected areas (CPAs) because of their values, with Policy 5.4.2 stating

"*Priority will be given to avoiding adverse effects on; (a) The values identified in schedule 2.1, associated with any coastal protection area*".

[14] Extra estuaries are required to confidently monitor the estuarine CPAs to determine if adverse effects are occurring on estuarine values. In addition, monitoring extra estuaries will also provide quality information on estuarine health and values to support the upcoming review of the new Regional Plan: Coast which is 20 years old despite being required to be reviewed every 10 years.

DISCUSSION

[15] To meet ORC's responsibilities, a robust and ongoing monitoring programme is needed to determine both current state and potential changes in estuaries. A representative monitoring programme also provides the base data and information for adaptive management resulting in improved management decisions and actions to improve estuarine health.

[16] Inclusion of estuaries as part of Freshwater Management Units (FMU) has been suggested by the Parliamentary Commissioner for the Environment's estuary report (Managing our estuaries 2020, PCE report). This recommendation also aligns with a ki uta ki tai (mountains to the sea) approach. To support this process more estuaries need to be included in the SoE network to provide a representative coverage across the region. An increased network of estuaries will provide the much-needed data for the FMU process.

[17] The New Zealand Coastal Policy Statement Policy 11b requires Regional Councils to avoid significant adverse effects on estuaries. However, the current monitoring programme does not include sufficient estuaries to adequately determine if adverse effects are occurring. In addition, the variability of upstream land use of Otago's estuaries requires additional sites to form a representative network to identify catchment issues.

[18] To improve the monitoring network, and bring it into line with ORC's regulatory obligations, additional estuaries need to be included, and the frequency of sampling needs to increase for estuaries with high mud content. Baseline monitoring data collected during the first 3 years of an estuary being added into the SoE network, will be used to determine if an estuary requires more frequent and fine scale monitoring than the current 5 yearly cycle.

[19] Many other regional councils (e.g. Environment Southland and Bay of Plenty Regional Councils) have increased the frequency of fine scale sampling from 5 yearly to every 2 years, in estuaries under increased stress. Increased monitoring frequency reduces uncertainty, changes in state can be identified quickly, and mitigation actions implemented.

[20] In addition to the expansion of and increased sampling across the network, extra monitoring measures are required to provide data on specific issues within estuaries, such as nuisance macroalgae. These attributes play a key role in determining estuary health. ORC's current sampling programme is conducted externally with internal oversight. Historically this has meant data has not been collected consistently and in the same way. We propose bringing the fine scale estuary monitoring 'in-house' following the 2020-2021 field season. This will address historic issues with data variability introduced by switching external providers, while also improving capability within ORC in field collection, data analysis and interpretation.

<u>Proposed estuary monitoring programme</u>

[21] Two key changes are proposed to improve ORC's current estuary monitoring programme. These two elements are complimentary and will provide the ability for ORC to make more informed management decisions.

[22] First an increase in both the monitoring network and frequency of monitoring. It is proposed to increase the number of estuaries in the SoE network from 5 to 12 over the next 5 years and increase the frequency of fine scale monitoring on selected estuaries, establishing a representative estuary monitoring network across Otago that meets ORC's regulatory obligations. Estuary monitoring frequency will be increased if degradation is detected and state changes occur based on baseline data collected.

[23] The Waikouaiti River, Shag River, Catlin's River/Lake, Kaikorai and Tokomairiro River estuaries are currently monitored. The following additional estuaries will be included in the monitoring programme: Blueskin Bay, Pleasant River, Papanui Inlet, Kakanui River, Akatore Creek, Tautuku and Tahakopa River.

[24] Secondly new monitoring measures to provide further data on specific estuarine issues. These measures may include: macroalgae monitoring to mitigate nuisance macroalgae outbreaks; seagrass monitoring as an important indicator species of estuarine health; sediment plate transects for estuaries with increased sedimentation; and shellfish monitoring of key species such as cockles, pipis and wedge shells.

CONSIDERATIONS

Policy Considerations

[25] Some estuaries will be required to be considered in the current review of the Land and Water Regional Plan. This will include the new NPS-FM requirement of an integrated approach to managing freshwater systems with the lowest sensitive receiving environment such as estuaries used for limit setting in the river systems.

[26] The estuary monitoring programme will also inform the review of the Coast Plan scheduled to be reviewed in the next LTP cycle.

Financial Considerations

[27] This summer 2020/21 ORC will engage consultants to undertake the estuary monitoring. The estimated costs are approximately $25,000 per estuary for fine scale sampling (total estimate for the 20/21 summer is $90,000). Training for ORC staff will be included in this summer's consultant monitoring.

[28] From 2021 onwards, estuarine monitoring will be undertaken primarily by ORC staff, except for laboratory analysis, macrofaunal identification and other one-off projects. This will significantly reduce ORC's future annual estuary SoE monitoring costs.

Significance and Engagement

[29] Not applicable

Legislative Considerations

[30] ORC's current estuary monitoring programme does not meet New Zealand Coastal Policy Statement obligations for Regional Councils, or the requirements of the National Policy Statement for Freshwater Management (2020).

Risk Considerations

[31] ORC will not meet its regulatory obligations should it continue with its current estuary monitoring programme (refer to policy and legal considerations above).

NEXT STEPS

[32] Commence expansion of ORC's estuary monitoring programme in the summer of 2020/21 by including two additional estuaries - Blueskin Bay (including fine scale monitoring) and Kakanui River estuary.

ATTACHMENTS

Nil