TECHNICAL COMMITTEE AGENDA

WEDNESDAY 29 NOVEMBER 2017

Council Chamber
70 Stafford Street, Dunedin

Membership

Cr Andrew Noone	*(Chairperson)*
Cr Ella Lawton	*(Deputy Chairperson)*
Cr Graeme Bell	
Cr Doug Brown	
Cr Michael Deaker	
Cr Carmen Hope	
Cr Trevor Kempton	
Cr Michael Laws	
Cr Sam Neill	
Cr Gretchen Robertson	
Cr Bryan Scott	
Cr Stephen Woodhead	

Disclaimer
Please note that there is an embargo on agenda items until 8:30 am on Monday 27 November 2017. Reports and recommendations contained in this agenda are not to be considered as Council policy until adopted.

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1. APOLOGIES

2. LEAVE OF ABSENCE

Leave of Absence for Cr Laws noted.

3. ATTENDANCE

Nick Donnelly, (Acting CE, Director Corporate Services)
Sian Sutton, (Director Stakeholder Engagement)
Tanya Winter, (Director Policy, Planning & Resource Management)
Gavin Palmer, (Director Engineering, Hazards and Science)
Scott MacLean, (Director Environmental Monitoring and Operations)
Sally Giddens, (Director People & Safety)
Lauren McDonald, (Committee Secretary)
Ian McCabe, (Executive Officer)

4. CONFIRMATION OF AGENDA

5. 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.

6. PUBLIC FORUM

NIL

7. PRESENTATIONS

NIL

8. CONFIRMATION OF MINUTES

Recommendation

That the minutes of the meeting held on 18 October 2017 be received and confirmed as a true and accurate record.

Attachments

1. 08 Minutes of the Technical Committee - 18 October 2017 **[8.1.1]**

Minutes of a meeting of the Technical Committee held in the Council Chambers at Otago Regional Council on Wednesday 18 October 2017, commencing at 10:30 am

Membership

Cr Andrew Noone	*(Chairperson)*
Cr Ella Lawton	*(Deputy Chairperson)*
Cr Graeme Bell	
Cr Doug Brown	
Cr Michael Deaker	
Cr Carmen Hope	
Cr Trevor Kempton	
Cr Michael Laws	
Cr Sam Neill	
Cr Gretchen Robertson	
Cr Bryan Scott	
Cr Stephen Woodhead	

Welcome

Cr Noone welcomed Councillors, members of the public and staff to the meeting.

1. APOLOGIES

Resolution

That the apologies for Cr Brown be accepted.

Moved: Cr Noone
Seconded: Cr Woodhead
CARRIED

Resolution

That the apologies for Cr Brown be accepted.

Moved: {mover}
Seconded: {seconder}
CARRIED

2. LEAVE OF ABSENCE

The Leave of Absence by Cr Deaker was noted.

3. ATTENDANCE

Peter Bodeker	*(CEO)*
Nick Donnelly	*(DCS)*
Tanya Winter	*(DPPRM)*
Sian Sutton	*(DSHE)*
Gavin Palmer	*(DEHS)*
Scott MacLean	*(DEMO)*
Dean Olsen	*(Manager Resource Science)*
Deborah Mills	*(Environmental Scientist)*
Lauren McDonald	*(Committee Secretary)*

4. CONFIRMATION OF AGENDA
The agenda as tabled was confirmed.

5. CONFLICT OF INTEREST
No conflicts of interest were advised.

6. PUBLIC FORUM
No public forum was held.

7. PRESENTATIONS
No presentations were held.

8. CONFIRMATION OF MINUTES
Resolution

That the minutes of the meeting held on 13 September 2017 be received and confirmed as a true and accurate record.

Moved: Cr Robertson
Seconded: Cr Hope
CARRIED

9. ACTIONS
(Status report on the resolutions of the Technical Committee). No actions required.

10. MATTERS FOR COUNCIL DECISION

10.1. Director's Report on Progress
The report provided information on the: Heavy rainfall event of 21 and 22 July; Southern Alpine Lakes; Climate change and sea level rise; Leith Flood Protection Scheme engineering works; Robson lagoon improvements and Urban Water Management.

Southern Alpine Lakes - Dr Palmer confirmed the initial focus was for the identification of the scientific research and information jointly sought by ORC, Environment Canterbury and Environment Southland. He confirmed this would be aligned into the ORC Long Term Plan.

Resolution
That this report is noted.

Moved: Cr Robertson
Seconded: Cr Neill
CARRIED

10.2. Air Quality Research Opportunities
The report outlined the development and implementation of the national research strategy and its alignment with ORC's air quality research needs. The report included current strategic thinking for national interest research topics, emission control technology opportunities and public health considerations.

Ms Mills responded to questions on air quality reduction initiatives for domestic chimneys, monitoring of particulates, public health impacts and affordable residential monitoring methods.

A request was made for the report *Health Affects of Ambient Air Quality in Otago* to be circulated to Councillors, to assist with future discussion.

Resolution

a) That this report be noted.
b) That the ideas presented in this report are endorsed for consideration for inclusion into the 2018/28 Draft Long-Term Plan.

Moved: Cr Robertson
Seconded: Cr Scott
CARRIED

11. MATTERS FOR NOTING
There were no items tabled.

12. NOTICES OF MOTION
There were no Notices of Motion tabled.

13. CLOSURE
The meeting was declared closed at 11:10 am.

Chairperson

9. ACTIONS

Status report on the resolutions of the Technical Committee.

Report No.	Meeting	Resolution	Status
10.2 **Air Quality Research Opportunities**	18/10/17	The report "Health Affects of Ambient Air Quality in Otago" be circulated to councillors.	CLOSED. Report circulated to councillors on 20/10/17.

Attachments
Nil

10. MATTERS FOR COUNCIL DECISION

11. MATTERS FOR NOTING

11.1. Director's Report on Progress

Prepared for: Technical Committee
Activity: Governance Report
Prepared by: Dr Jean-Luc Payan, Manager Natural Hazards
Dr Dean Olsen, Manager Resource Science
Chris Valentine, Manager Engineering
Date: 10 November 2017

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1. Précis

This report presents an update on the following matters:

1. The climate, river flow and groundwater situation and outlook for Otago;
2. The review undertaken by NIWA of the weather causing the July 2017 coastal Otago flood and progress with key actions arising from the event, and;
3. Progress with design and construction of the Leith Flood Protection Scheme.

2. Climate and river flow situation – November 2017

In general, higher than normal sea level pressures prevailed over New Zealand and its surrounding areas during October, which caused "generally" settled and warm weather over most of Otago. This resulted in dry conditions, with lower rainfall than the long-term average for the month in most of Otago, with some areas being extremely dry, particularly around the Southern Lakes (Figure 1). Over the last 3 months, conditions have been moderately to severely dry in South Otago and parts of Central Otago (Figure 1). However, parts of Northern Otago received higher than normal rainfall for October.

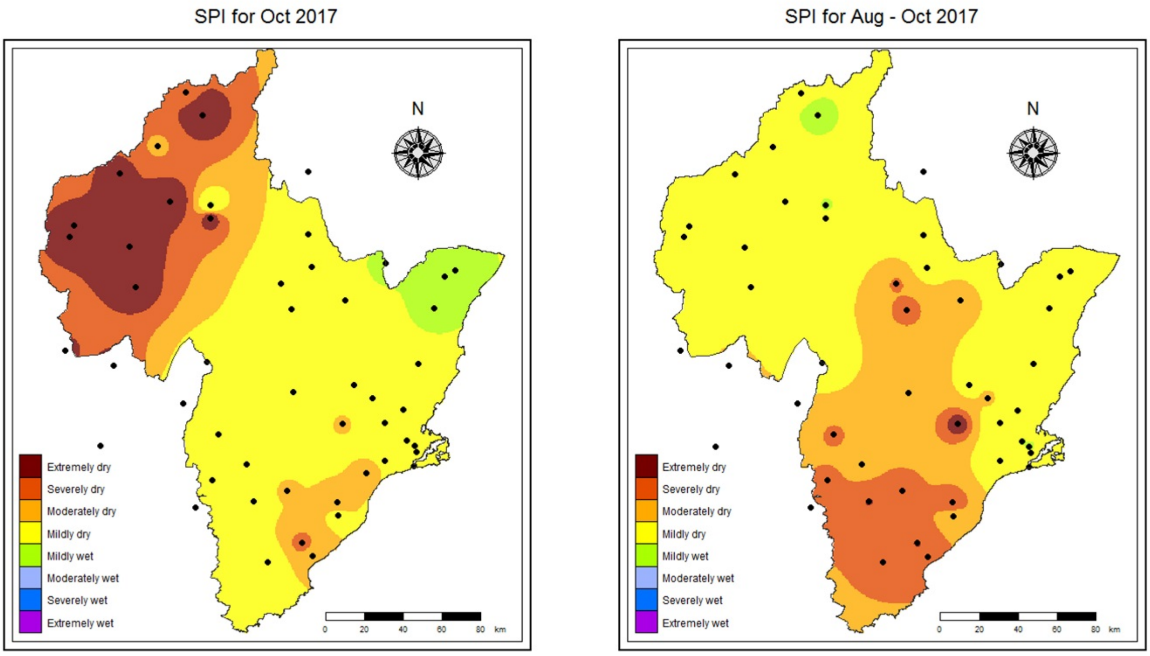

Figure 1: Maps of 30- and 60-day Standardised Precipitation Index (SPI[1]) for Otago

Summary of NIWA Seasonal Outlook for Otago – November 2017 to January 2018

At the start of each month, NIWA produces a seasonal outlook for the upcoming 3 months. The following are the predictions for the period November-January:

Eastern Otago: Rainfall totals are most likely to be in the near normal range. Soil moisture levels and river flows are most likely to be below normal (45% chance).

Western Otago: Rainfall totals are about equally likely to be in the below normal (40% chance) or near normal (35% chance) range. Soil moisture levels and river flows are likely to be in the below normal range (45% chance). The full seasonal outlook can be viewed at https://www.niwa.co.nz/climate/seasonal-climate-outlook/seasonal-climate-outlook-november-2017-january-2018.

River flows - October

The October 7-day low flows "7dLF" were generally lower than their corresponding long-term averages apart from those in North Otago. The 7dLFs for the Taieri River for October 2017 were almost half their corresponding long-term averages. The flows in the Manuherikia River and Pomahaka River are slightly lower than those of October 2016, but they are around 30 to 40% lower than their long-term average October 7dLFs. This indicates that dry conditions, in general, prevailed during October of this year. This is a direct response to the lower than average rainfalls which were received during that month.

It should be kept in mind that conditions in October may not be a reliable indicator of summer low flows, as is evident for some of the historical low-flow years presented in Table 1.

Table 1 October flow statistics for sites in the Taieri, Kakanui, North Otago, Manuherikia and South Otago catchments. All flows are expressed as 7-day October average low flows, i.e. the lowest flows averaged over a 7-day period within October.

Site	Length of record (year)	Long-term average (m^3/s)	Long-term minimum (m^3/s)	Previous Octobers with significant 7dLF (m^3/s)			October 2017 (m^3/s)
				1999	2003	2015	
Taieri at Canadian Flat	35	3.58	1.77	1.98	2.73	4.22	1.77
Taieri at Waipiata	25.2	7.74	1.81	1.81	4.60	5.53	2.27
Taieri at Tiroiti	35.5	10.23	2.60	2.60	8.18	7.37	5.33
Taieri at Sutton	57.2	14.01	3.39	3.39	11.77	8.14	7.77
Taieri at Outram	49.6	21.96	6.66	6.66	16.71	14.03	11.67
Kye Burn at Water Take d/s 300m	5.1	1.38	1.00	NA	NA	1.00	1.66
Deep Stream at SH87	25.5	1.98	0.88	0.88	0.94	2.02	1.04
Kakanui at Clifton Falls Bridge	36.6	1.72	0.45	0.73	1.21	1.10	2.16
Kakanui at Mill Dam	27.9	2.02	0.52	0.52	1.44	1.07	2.85
Kakanui at McCones	14.8	2.32	0.54	NA	1.64	1.08	3.86
Waianakarua at Browns	12.6	0.96	0.34	NA	NA	0.64	0.98
Shag at Craig Road	24.1	0.76	0.26	0.29	1.23	0.46	1.20
Waikouaiti at 200m d/s DCC intake	3.1	1.05	0.50	NA	NA	0.58	1.29
Dunstan Creek at Beattie Road	15	2.87	1.66	NA	3.76	1.66	3.34
Manuherikia at Ophir	46.8	13.17	3.38	3.38	11.30	5.51	8.98
Manuherikia at Campground	9	10.18	4.36	NA	NA	4.94	6.10
Waitahuna at Tweeds Bridge	25.4	1.61	0.98	1.06	1.12	1.70	1.36
Pomahaka at Burkes Ford	56.3	15.27	6.84	9.81	13.92	19.46	9.54

[1] SPI is a standardised index commonly used to indicate the dry/wet weather conditions based on observed rainfalls. Observed rainfalls in 49 rainfall sites around Otago have been utilised to produce the SPI maps shown.

Groundwater levels at restriction level bores
Schedule 4B of the Regional Plan: Water for Otago (RPW) identifies water levels at which the taking of groundwater will be restricted, and identifies the nature of the restriction, in terms of a reduction in the take of water authorised by water permits. The aquifer maximum height refers to the historic record of the water level or pressure head after the recharge season. Note that the areas over which the restrictions apply are shown on Maps D1-D4 in the RPW.

There are 5 restriction level bores. The name of the location, name of the bores and restriction levels assigned to each bore as shown in Schedule 4B are presented below in Table 2. Groundwater levels at the nominated restriction level bores are generally at one of the highest recorded levels since monitoring began, with the exception of Websters Well located in North Otago (Table 2).

Table 2 Water levels in restriction level bores (from Schedule 4B of the RPW) in Otago aquifers

Aquifer	Aquifer Reference Bore	Aquifer max. height (m above datum)	Restriction levels (m above datum)			Current water level (m above datum)
			25% restriction*	50% restriction	100% restriction	
North Otago Volcanic	Websters Well	130.8	126.0	125.5	125.0	130.058 (17/11/17)
Lower Taieri – West	Momona Bore	101.24	100	99.5	99	100.832 (9/11/17)
Lower Taieri – East	Harleys Well, Piezo. 2	112.5	110.5	110.0	109.5	112.096 (9/11/17)
Ettrick Basin	Cemetery Bore	172.29	170.29	169.79	169.29	171.814 (17/11/17)
Roxburgh Basin (Coal Creek Terrace)	White-Hall Bore	189.5	188	187.8	187.5	189.845 (17/11/17)

* When the aquifer reaches this level there shall be either a 25% restriction or a water allocation committee, appointed by the Otago Regional Council, will implement a protocol to take all practical steps to curb the decline in the aquifer level so as to avoid a 50% restriction. If there is no water allocation committee or the water allocation committee does not use a protocol approved by the Council, the 25% water restriction will apply.

Conclusion
Predictions of weak La Niña conditons, with more east- and northeasterly winds suggest that there is the potential for the current dry conditions to persist over summer. Staff are keeping a watching brief on climate conditions and river flows and will provide regular updates to Councillors.

3. July 2017 Coastal Otago Flood Event

NIWA has completed the report[1] on the weather conditions that resulted in the coastal Otago flood event on 21 and 22 July 2017 (attached). The report also compares the weather situation in July 2017 to historical rainfall events such as the June 1980 event.

The report shows that the eastern-most areas of Otago recorded heavy rainfall with the largest amounts recorded in the lower parts of the Taieri catchment (downstream of Sutton) in particular the Silver Stream (Swampy Spur), Three O'Clock Stream and Deep Stream catchments. The coastal parts of the Waitaki District near Oamaru also recorded large amounts of rain.

The report also suggests that the relatively low freezing level in the Taieri River upper catchment (Maniototo area) resulted in precipitation falling as snow on higher

[1] Macara, G. 2017. Heavy rainfall in eastern Otago, 21-22 July 2017, NIWA Report 2017331WN.

elevations, probably reducing the runoff contribution of this part of the Taieri River catchment during the event.

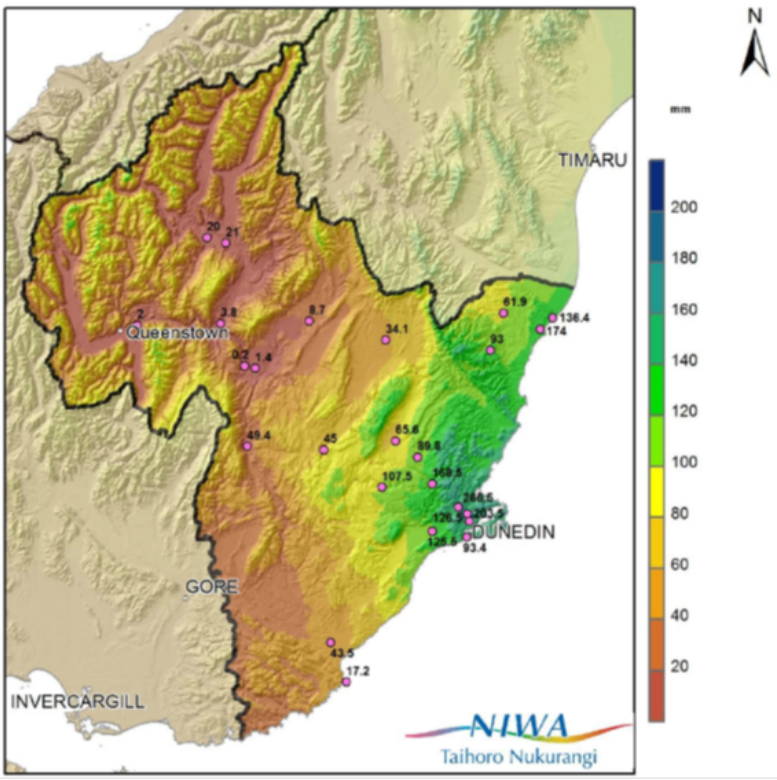

Figure 2. Map of rainfall totals observed throughout Otago. The 60-hour period from 0000 hours 21 July to 1200 hours 23 July 2017 is mapped. The pink dots are rainfall stations and their associated rainfall totals recorded, while colours represent interpolated rainfall estimates (NIWA, 2017).

Although the intensities of the precipitation were remarkable in some areas (e.g. Swampy Spur recorded up to 18mm/h), the critical factor of the July 2017 event was the persistence of the heavy rainfall.

The analysis by NIWA indicates that the July 2017 heavy rainfall event had a similar weather pattern to the June 1980 and June 2015 events: a low pressure system with high moisture content centred over or near New Zealand being injected with warm and moist air originating from the tropics, a meteorological phenomenon referred to as “atmospheric river” (refer to NIWA’s report for more details). The rainfall totals in July 2017 were in general lower than in June 1980. In June 2015, the heaviest rainfall was recorded in the Water of Leith catchment and over Dunedin City whereas the heaviest rainfall in July 2017 were centred on the lower parts of the Taieri catchment. Precipitation was also in general more intense during the June 2015 event compared to the July 2017 event.

In addition to the report prepared by NIWA, information to assist further reporting on the severity of the July 2017 heavy rainfall event and on its impact on streams and rivers (flows, erosion, river forms) has been prepared: debris marks surveys on the Taieri Plain, Waitaki Plain (between Pukeuri and the Waitaki River) and on some sections of the Water of Leith have been completed; cross section survey data for the Taieri River and the Silver Stream has been received and is being analysed. The performance of the different flood protection and drainage schemes will also be assessed in more detail.

4. Leith Flood Protection Scheme

Engineering works on the Union to Leith Footbridge stage of the Scheme are progressing (Figure 3).

Figure 3: Leith Flood Protection Scheme works between Union Street and Leith Footbridge on 13 November 2017. The photograph is looking upstream.

As previously advised to committee, some of the construction works will extend beyond the planned completion date due to the discovery of asbestos, the weather events in April and July and other factors. Whilst the contractor anticipates that there will still be some siteworks continuing into early 2018, most of the works will be completed by the end of this calendar year with the remainder of the works happening on the river bed near the downstream end of the site. Parts of the site will be handed back and site fencing removed as packages of work are completed later this year. Staff are continuing to liaise closely with University of Otago Property Services so as to minimise disruption to students, staff and visitors and with University communications staff to ensure that the University community has regular updates.

Investigations on the Dundas Street Bridge stage of the Leith Flood Protection Scheme are continuing. The options study and preliminary design phases have been largely completed. Detailed design will commence once the results of the physical hydraulic model study become available (Figure 4). The physical hydraulic model calibration has been undertaken based on the May and July 2017 flood events.

Figure 4. Calibration of the physical model of the Water of Leith near Dundas Street at the University of Auckland. The photograph is looking upstream.

The construction of this stage of the Scheme will be deferred until the summer of 2018/19 although some enabling works will be undertaken this year. This will allow more time to optimise the hydraulics and fully inform a risk based approach to the final design solution.

Planning for public consultation and establishment of the working group to facilitate and develop options for amenity improvements between Forth Street and the harbour has progressed. The DCC, University of Otago, and Otago Polytechnic have confirmed interest in participating in the projects working group. Discussions with Ngai Tahu and Aukaha are continuing in order to identify an appropriate representative on the working group.

5. Recommendation

a) That this report is received and noted.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments
Nil

11.2. Rangitaiki River Scheme Review - April 2017 Flood Event

Prepared for: Technical Committee
Activity: Governance Report
Prepared by: Gavin Palmer, Director Engineering, Hazards & Science
Date: 6 October 2017

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1. Précis

On 6 April 2017 the Rangitaiki River breached the floodwall at Edgecumbe. The matter was the subject of an independent review commissioned by Bay of Plenty Regional Council (BOPRC). This paper sets out the key issues for Otago arising from the review, in the opinion of the writer.

Aspects of each of the key issues are being addressed by Otago Regional Council (ORC) as part of planned work programmes and in response to the July 2017 coastal Otago flood. Additional actions are being scoped for inclusion in the 2018/28 Draft Long Term Plan.

It is recommended that this ORC report is received and noted and that the findings of the Rangitaiki River Scheme Review are noted.

2. Introduction

On 6 April 2017 the Rangitaiki River breached the floodwall at Edgecumbe (Figure 1). The floodwall is part of the Rangitaiki River Scheme managed by BOPRC. Several hundred homes were flooded (Figure 2).

Figure 1 **The College Road floodwall at Edgecumbe at 0814hrs on 6 April 2017. Structural failure of the floodwall occurred at approximately 0830hrs (photo credit: Tony Dunlop, Bay of Plenty Regional Council).**

Figure 2 Edgecumbe township in the vicinity of the College Road floodwall at 1106hrs on 6 April 2017 (photo credit: Radio New Zealand).

The matter was the subject of an independent review commissioned by BOPRC[1]. The findings of the review were reported in September[2]. A copy of the report is attached.

Whilst it was a review of a particular scheme in a particular set of circumstances, there are some attributes of that scheme and its setting that are relevant to schemes in Otago. Many of the matters addressed by the review are therefore relevant to the flood protection and natural hazards management functions of ORC. Some are applicable to the management of natural hazards in general, as well as to flood hazard specifically. Some are also relevant to places where there is exposure to a hazard and no permanent engineered mitigation works.

This paper sets out the key issues for Otago arising from the review, in the opinion of the writer. It is not a critique of the review nor a comprehensive summary.

Aspects of each of the key issues are being addressed by ORC as part of planned work programmes and in response to the July 2017 coastal Otago flood. Additional actions are being scoped for inclusion in the 2018/28 Draft Long Term Plan.

3. The Rangitaiki Scheme Review

It is noteworthy that the reviewers chose to use NZS9401:2008[3] to provide the framework for their review. This puts the review of the performance of an engineering structure into a much wider environmental and social context. That is because NZS9401:2008 sets out a principles and process-based approach to flood risk management to achieve the following outcomes:

1. Engaging communities and stakeholders;

[1] https://www.boprc.govt.nz
[2] *Rangitaiki River Scheme Review – April 2017 Flood Event*, 18 September 2017, Prepared by the Rangitaiki River Scheme Review Panel, 163p.
[3] New Zealand Standard 9401:2008 *Managing Flood Risk – A Process Standard*, Standards New Zealand, 31p.

2. Understanding natural systems and catchment processes;
3. Understanding the interaction of natural and social systems;
4. Decision-making at the local level;
5. All possible forms and levels of management;
6. Residual risk.

NZS9401:2008 does not prescribe standards of flood protection nor construction standards for flood mitigation structures. The reviewers note that the great majority of the questions raised from the community input to their review can be encompassed within NZS9401:2008.

The reviewers make 29 recommendations covering the following matters:

1. Legal and planning framework;
2. College Road floodwall (the floodwall at Edgecumbe that failed);
3. Operation of Matahina Dam;
4. Reid's floodway (part of the Rangitaiki River Scheme presently being upgraded);
5. Evacuation planning;
6. Long-term strategy, and;
7. Community engagement.

The writer notes that NZS9401:2008 evolved from a "draft flood protocol" developed by the Flood Risk Governance Group comprising representatives of local and central government and the Institution of Professional Engineers New Zealand[1]. In 2010 local government prepared a case to government for the development of a National Policy Statement on Flood Risk Management. A draft National Policy Statement on Natural Hazards is being prepared by government officials.

ORC has used NZS9401:2008 in support of submissions on development proposals[2], however it has no formal status and does not have the weight of an instrument of national direction like a National Policy Statement. Given the apparent importance that the reviewers placed on NZS9401:2008 to do with a matter of wide community interest it is appropriate that the sector more formally consider the status to be accorded to it for managing flood risk in New Zealand.

4. Discussion

In the writer's opinion there are five key issues for Otago arising from the Rangitaiki River Scheme review. There are other issues that are of a more detailed operational or technical nature, such as redundancy in hydrometric networks and approaches to flow forecasting (rainfall/runoff modelling versus flow based). These are not discussed here but are being followed up by ORC staff in the course of their work.

The five key issues are discussed in the Otago context as follows:

1. *Whether the flood risks for every community in Otago are being managed strategically based on modern management principles ("room for the river", NZS9401:2008, etc).*

[1] *Managing Flood Risk, Draft New Zealand Protocol*, Centre for Advanced Engineering, University of Canterbury, 2005.
[2] For example: Otago Regional Council v Dunedin City Council [2010] NZENVC 120. This is the case to do with the Holt property at 96 Stornoway Street, Karitane.

ORC generally takes a principles-based approach to managing natural hazards risks and commonly uses NZS9401:2008 as the framework for decision-making. Examples are the Wakatipu/Wanaka Flood Mitigation Strategy developed jointly with Queenstown-Lakes District Council and the Milton 2060 Strategy developed jointly with Clutha District Council. The principles and approaches of NZS9401:2008 and the concept of "room for the river" have been used to develop the Lower Waitaki River Scheme options management plan jointly with Environment Canterbury and various river morphology and riparian management plans (e.g. Kakanui River, Pomahaka River).

ORC has put significant effort into "demand management" over the past 10 years, through advocacy on development proposals, active engagement with territorial authorities on District Plan natural hazards provisions and the changes proposed to the natural hazards provisions of the Proposed Regional Policy Statement. These have typically drawn on the principles set out in NZS9401:2008.

Despite these initiatives, Council needs to ensure it has taken a clear position on the acceptability of the flood risk for every community in Otago that is exposed to flood hazard. It would be appropriate therefore to conduct a stock take of the present situation to verify that active consideration has been given to the flood risks of all Otago communities exposed to flood hazard, especially smaller ones, based on the principles set out in NZS9401:2008 and that appropriate risk management measures are being implemented for each of those communities.

2. *Whether "safe capacity" has been adequately assessed for every flood protection scheme, having regard to failure modes in addition to floodbank overtopping.*

   Historically there was some degree of standardisation of flood protection standards across New Zealand through the thresholds for obtaining central government funding subsidies. The cessation of government subsidies in the late 1980s devolved decision-making on standards for flood protection including structural integrity and maintenance to individual regional councils and their communities.

   These standards are implicitly set through the Local Government Act annual planning process. This uses a single mandatory performance measure for flood protection and control for schemes of a certain size and value in New Zealand[1]. The writer was a member of the Working Party convened by the Department of Internal Affairs in 2011 to develop the measure. ORC uses the measure in accordance with the rule.

   Despite the mandatory measure, standards for the structural integrity, condition and level of flood protection are not legislated in New Zealand. As noted above, NZS9401:2008 is a non-regulatory and outcomes-based document. Floodbanks are not "dams" under the Building Act and to date have not been

[1] The mandatory performance measure is "*the major flood protection and control works that are maintained, repaired and renewed to the key standards defined in the local authority's relevant planning documents (such as its activity management plan, asset management plan, annual works programme or long term plan)*". The measure and the criteria for when it must be used are specified in Non-Financial Performance Measures Rules 2013.

considered for inclusion in the proposed National Environmental Standard for Dam Safety (NESDS). Recent international interest in the performance of flood control levees (floodbanks) has however seen the International Commission on Large Dams (ICOLD) form a sub-committee on levees. This development is being monitored by regional councils.

In simple terms, failure of the floodwall at Edgecumbe occurred due to it sliding sideways and then breaking up, allowing floodwater to escape from the river. The floodwall was not overtopped – it failed during a flood that was smaller than the design flood. This highlights that flooding can occur as a consequence of one of several modes of failure and that the most critical mode is not necessarily overtopping. The standard or level of service for safe human occupation during a flood may therefore be lesser than the nominal "flood protection" standard. It follows that a scheme could have a level of service specific to safe occupation during floods and a potentially different level of service for the protection of land and property.

This issue has particular significance when intra-scheme flood protection standards vary by location, as is the case with Lower Taieri and Clutha Flood Protection Schemes. A location with the highest flood protection standard does not necessarily have the lowest flood hazard.

These matters will be given further consideration and may lead to a new way of expressing the levels of service for ORC's flood schemes. The floodbank integrity assessments being undertaken for the Taieri, Clutha and Alexandra Flood Protection Schemes will help inform this. The assessment is using the Flood Protection Assets Performance Assessment Code of Practice that has recently been agreed between regional councils, as well as the methodology used for the 2005 assessments (for comparison).

3. *Whether the risks associated with complex hydraulic structures, including uncertainties in performance during floods, have been adequately determined.*

The review highlighted the inherent uncertainty in the known condition and expected performance of earthen structures like those owned by ORC. This arises from variable ground conditions and construction and alteration of floodbanks over time with varying quality of materials. This is relevant to ORC as its flood protection structures are predominantly earth floodbanks, totalling approximately 221km in length and up to 6 metres high in some locations.

There are short sections of concrete floodwall on the Water of Leith near the Information Technology Services (ITS) Building and on Lindsay Creek (Figure 3). The former has recently been increased in height as part of the Leith Flood Protection Scheme works[1]. The nature of this floodwall and those on Lindsay Creek is such that sliding cannot occur. That is because they are integral to the channel lining located against the inside of the river bank.

[1] Director's Report on Progress to 18 October 2017 meeting of Otago Regional Council Technical Committee, p10.

Figure 3 ORC floodwall on Lindsay Creek, North East Valley, Dunedin

Despite these differences, the increased risks associated with complex or unusual hydraulic structures is relevant to ORC's Riverside Spillway (Figure 4) and other structures such as pumping stations that are embedded within earth floodbanks.

Figure 4 **ORC's Riverside Spillway (Lower Taieri Flood Protection Scheme) at 0912hrs on 22 July 2017 with the collapsible section lowered. The flow in the Taieri River was approximately 1900 cubic metres per second at the time based on the pre-flood discharge rating.**

The collapsible section of Riverside Spillway failed catastrophically in 1993 (Figure 5). This occurred shortly after commissioning and during a flood that was smaller than the design flood. This required it to be redesigned and reconstructed[1]. The scope of the floodbank integrity assessment referred to above has therefore been extended to include Riverside Spillway and other large embedded structures.

Figure 5 **Some of the remnants of ORC's Riverside Spillway following failure of the collapsible section in December 1993**

The reviewers of the Rangitaiki River Scheme also comment on the complexity of operating a control gate system during a flood. The July 2017 flood highlighted once again the difficulties and risks associated with the collapsible portion of the Riverside Spillway, despite the operating rules agreed with the community in 2010.

For these reasons a project to consider decommissioning the collapsible portion of Riverside Spillway will be considered for inclusion in the 2018/28 Draft Long Term Plan. There is precedent for this, having decommissioned the Lower Clutha spillway gates in 2007.

4. *Whether there is clarity in the respective roles of ORC and dam owners during floods with respect to forecasting reservoir inflows and managing reservoir drawdown and outflows.*

Principles for the safe management of dams during floods are set out in the New Zealand Dam Safety Guidelines 2015 published by the New Zealand Society on Large Dams. Dam safety was one of the priorities for national direction of the previous government with an indicative date of completion of early 2018[2]. The proposed NESDS is in development and it is yet to be seen how the new government will progress the NESDS. The writer is a member of

[1] *Lower Taieri Flood Control and Drainage Scheme Consultant's Report on Spillway Control Gate Structure Failure*, Otago Regional Council Report 94/52, Prepared for Operations and Rural Services Committee, 2 February 1994, 2p.
[2] http://www.mfe.govt.nz/rma/rma-legislative-tools/priorities-national-direction

the Dam Safety Technical Working Group advising Ministry for the Environment officials on the possible content of the NESDS.

It is important that the operation of a dam during a flood event is determined prior to any such event and clearly set out in operating rules or procedures. There are dams on the Clutha/Mata-Au, Lower Waitaki River, Waipori River and other rivers in Otago, with rules on how they are operated during floods incorporated into conditions of consent. It would be appropriate for ORC to check that flood management plans for each dam are clear on roles and responsibilities and the dam owners' expectations regarding expert assessment and advice from ORC (if any) on hydrology and reservoir operations. Alignment between management of the safety of dams and management of the safety of ORC's flood schemes during floods should also be assessed, including any interdependencies.

5. *Whether there is adequate community awareness and understanding of natural hazards risks, especially in locations where there is reliance on engineered mitigation works, and adequate systems and processes for maintaining that awareness and understanding over time.*

All four of the issues discussed above are technical issues that must be managed within a wider social context. Effective community engagement is vital. There must be programmes in place to maintain continuity of community awareness and understanding over time, as knowledge and risk perceptions and tolerances can change.

ORC has undertaken a comprehensive programme of engagement with communities on natural hazards risks over the past 10 years. Annual information sessions have been held with Taieri and Clutha communities to explain flood risk, flood scheme performance and limitations, and advice on how to access information through WaterInfo, Twitter and ORC's Otago Natural Hazards Database[1]. In recent years those sessions have been leaned back in favour of consultation sessions focussing on Council’s corporate plans. There has been extensive engagement throughout Dunedin City, jointly with Dunedin City Council, through the 2GP District Plan public information sessions and supporting technical publications. The Database has been widely promoted through sessions with solicitors and real estate agents. At the request of the territorial authorities the Database was enhanced so as to assist them with the preparation of Land Information Memoranda.

5. Implementation of Improvements

As noted above, actions to address the issues outlined in this report are being scoped for inclusion in the 2018/28 Draft Long Term Plan, where not already part of planned work programmes.

There are two initiatives that will assist ORC with progressing these matters, both of which have funding implications for the Draft Long Term Plan.

[1] http://hazards.orc.govt.nz/intramaps/mapcontrols/nhdb/index.html

The first is the work being undertaken by the regional council sector through the River Managers' Forum[1] (RMF), to standardise and improve the way flood protection assets are managed. RMF has undertaken a stocktake of flood protection schemes across New Zealand and an economic assessment of the value they provide. As part of that work, RMF has identified ways the sector can continue to work together and is developing a business plan for sector improvements across four themes:

1. Working across the sector;
2. Practices, methodologies and standards;
3. Quality People;
4. Communication and enabling environment.

ORC is an active participant in this collaborative work and the writer is a "champion" of one of the themes.

The second initiative involves ORC engineering, operation and flood management staff improving how ORC's flood schemes are managed during floods. This initiative commenced earlier this year and has taken on greater impetus as a result of the July 2017 coastal Otago flood and the Rangitaiki River Scheme Review. It is being facilitated by two former senior managers of other regional councils, one with direct involvement in the Rangitaiki River Scheme and the April 2017 Bay of Plenty flood. It is taking the form of staff workshops using the two floods as case studies. Key issues emerging from the first workshop are the need for a statement of purpose of ORC's flood risk management responsibility (with clarity on service provision e.g. what are the circumstances in which ORC will provide augmentation of installed pumping capacity during floods?), improving scheme and system knowledge across staff, clarifying flood management roles and responsibilities for critical decisions and actions, improving both internal and external communication during flood events, formalising procedures and resourcing arrangements (staff, specialist advice, contractors) and identifying the vulnerability of infrastructure and systems particularly in larger events. An action plan is being prepared to address these issues.

6. Recommendations

a) This report is received and noted.

b) The findings presented in the report Rangitaiki River Scheme Review - April 2017 Flood Event are noted.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

1. Rangitaiki River Scheme Review Attachment Summary of recommendations **[11.2.1]**
2. Rangitaiki River Scheme Review April 2017 Flood Event Final report 17 September 2017 Attachment **[11.2.2]**

[1] RMF is a Regional Council Special Interest Group (SIG), reporting to the Regional Chief Executive Officers Group. It comprises staff of regional councils and unitary authorities with management responsibilities for flood protection and river management. ORC staff participate in RMF.

11.3. 2017 Air Quality Results

Prepared for: Technical Committee
Activity: Environmental - Ambient Air Quality Monitoring & Reporting
Prepared by: Deborah Mills, Environmental Scientist
Date: 7 November 2017

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1. Précis

State of the Environment (SoE) ambient air quality monitoring of PM_{10}[1] continued this year at eight towns across Otago. Continuous, year-round monitoring was performed in four towns: Alexandra, Arrowtown, Mosgiel and Central Dunedin. Monitoring was performed from 1 May through to 31 August in Balclutha, Milton, Clyde and Cromwell.

Monitoring shows that, except for the Central Dunedin airshed, ambient air quality did not meet the National Environmental Standards for Air Quality 2016 compliance targets for particulates. Table 1 shows the number of days during 2017 when average daily PM_{10} exceeded the NESAQ threshold in each monitored town, and provides comparison to the typical number (average of 2014-2016) of exceedances.

Table 1: Number of exceedances recorded at Otago PM_{10} monitoring sites.

Location	Number of exceedance days - (2017)	Number of exceedance days - (2014-2016)
Alexandra	35	34
Arrowtown	42	36
Balclutha	14	8
Clyde	23	16
Cromwell	42	36
Dunedin	0	0
Milton	48	26
Mosgiel	7	7

This paper describes the state of Otago air quality this year using key air quality indicators assessed against current standards. The status of the NESAQ review is also discussed.

2. Background

2a. Air quality assessment criteria and reporting

In 2004, the Ministry for the Environment (MfE) introduced national environmental standards for ambient air quality which, among other things, set threshold concentrations of PM_{10}. The limits set in the NESAQ were, at the time, considered minimum requirements for providing a nationally consistent level of protection for human health and the environment. The National Ambient Air Quality Guidelines (1994, revised 2002) were the pre-cursor to the NESAQ and provide additional assessment guidelines for PM_{10}.

[1] Particulate matter with an aerodynamic diameter of less than 10 micrometres.

Additional assessments of air quality can be made against the World Health Organisation (WHO) guidelines[1] which establish recommended levels of both short-term (daily) and long-term (annual) PM_{10} and $PM_{2.5}$[2].

The Otago Regional Plan: Air (Air Plan) sets a daily average PM_{10} guideline value of 35µg/m^3, known as the Otago Goal Level.

Current standards and guidelines related to particulate matter are shown in Table 2.

Table 2: Current standards and guidelines related to particulate matter.

Indicator	Standard/Guideline	Threshold concentration (µg/m^3)	Averaging period	Allowable exceedances per annum
PM_{10}	NESAQ standard	50	24-hour	1
PM_{10}	Otago guideline	35	24-hour	n/a
PM_{10}	NAAQG guideline	20	Annual	n/a
$PM_{2.5}$	WHO guideline	25	24-hour	3
$PM_{2.5}$	WHO guideline	10	Annual	n/a

2b. Monitoring network

PM_{10} monitoring began in 1997 in Alexandra, Mosgiel and Central Dunedin with samples taken every third day. These centres represent three distinct climatic regions in Otago.

In 2004 the ORC gazetted 23 towns into four airsheds, fulfilling a requirement of the NESAQ. Decisions on towns' designations were based on evaluations of their climatology and topography and the expected level of air quality. Airshed 1 towns were to represent the poorest winter air quality, and Airshed 4 towns were expected to have the best air quality.

In response to the NESAQ requirement for daily monitoring, the three original sites were upgraded to continuous, MfE-approved monitors from MetOne Instruments and a fourth such monitor was added to Arrowtown. These sites fulfil the requirements of the NESAQ to monitor in airsheds where ambient air quality is not expected to meet standards.

In 2008 the network was expanded to include several other towns; these sites typically run during winter months. Results of monitoring have been used to gain information regarding the ambient air quality levels in 10 towns around the region.

The current ORC network consists of eight continuous PM_{10} monitors in towns across the region. Four monitors (Alexandra, Arrowtown, Central Dunedin, and Mosgiel) run year-round and four monitors (Balclutha, Clyde, Cromwell, and Milton) operate during winter (May – August) months. Results from all monitors are used to track long-term trends in air quality.

This year it was necessary to move the long-standing Alexandra monitor due to a change in property ownership. The permanent monitor was re-located to grounds belonging to the Alexandra Primary School, approximately ¾ km closer to the town

[1] Guidelines are considered recommended values, as opposed to standards which require compliance.
[2] Particulate matter with an aerodynamic diameter of less than 2.5 micrometres.

centre from the original site. A temporary monitor was set up over winter at the original site in order to obtain co-location data.

Monitoring locations are shown in Figure 1.

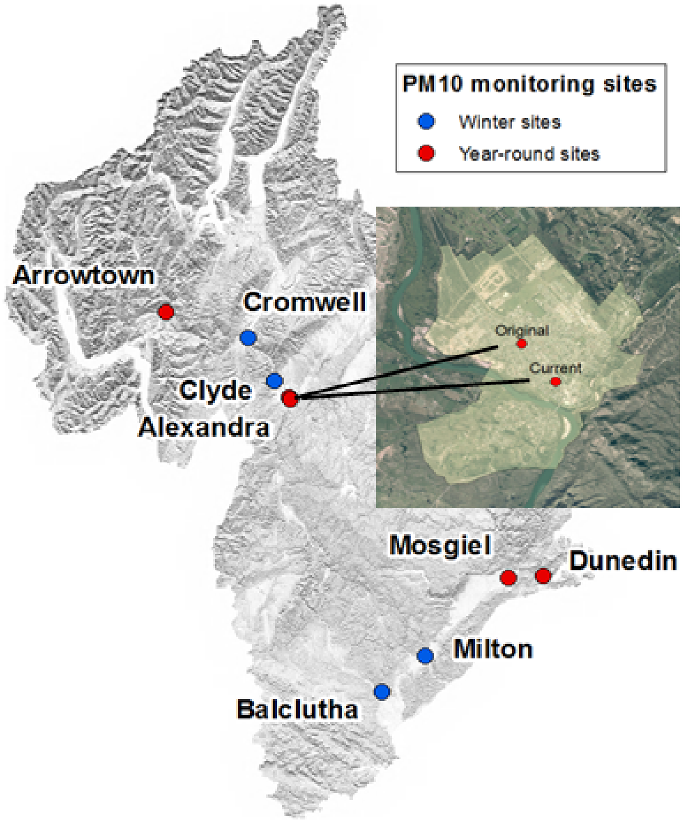

Figure 1: Monitoring locations for 2017; inset indicates the current and original Alexandra sites.

3. Key results

Results of provisional data for key indicators of PM_{10} during winter months (May-August) are given in Table 3. For sites with less than 75% data capture for the season, an average is considered not applicable. This situation occurred in Alexandra this winter due to the re-location of the monitor.

Table 3: Key indicators of air quality during winter 2017 in Otago. Except where noted, all values are μg/m^3.

	Maximum One-day average PM_{10}	Winter Mean PM_{10}	Average of 10 highest days	Days > 50μg/m^3 (# of days)	Days > 35μg/m^3 (# of days)
Alexandra – Original	96	n/a	88	35	51
Alexandra – Current	70	n/a	52	4	22

Arrowtown	146	44	113	42	63
Balclutha	93	33	67	14	45
Clyde	66	32	60	23	46
Cromwell	123	43	96	42	67
Dunedin	42	17	32	0	2
Milton	154	47	101	48	73
Mosgiel	89	26	63	7	20

By most metrics, Milton experienced the poorest air quality of all monitored sites this winter with 48 days breaching NESAQ limits. Arrowtown, Cromwell and Alexandra all recorded at least 35 days when PM_{10} breached the NESAQ limit. The maximum PM_{10} levels in these towns were two-to-three times the national limit.

National standards were also not met in Balclutha, Clyde, and Mosgiel but to a lesser degree. Central Dunedin continued to meet national standards and recorded just two days above the Otago Goal Level of 35µg/m^3; this is the best result to date for the Central Dunedin airshed.

4. Alexandra monitoring results

After 15 years of monitoring at 65 Ventry Street, the PM_{10} monitor had to be re-located this year due to a change in ownership of the section. The monitor was moved to 5 Ventry Street, approximately 750 metres to the southeast and closer to the centre of town. ORC was granted permission by the new owner of 65 Ventry Street to install a temporary monitor at the original site, thereby allowing us to obtain concurrent PM_{10} data for the winter months.

Differences in PM_{10} concentrations between the two sites were expected. Land use around the original site consists of older residential housing situated on relatively small sections; this results in relatively high-density particulate emissions from home heating appliances and, subsequently, high concentrations. In contrast, land use at the new site is mixed: there is commercial activity to the north and east, residential to the west, and school grounds to the south. This configuration yields lower emission amounts and densities and, subsequently, lower concentrations than the original site.

Results from a paired t-test indicate that the difference in daily PM_{10} concentrations between the two sites is statistically significant and that the concentrations between the two sites are highly correlated ($R = 0.91$). Figure 2 is a scatterplot of the daily values through winter showing the relationship between the two sites; the original site is shown along the horizontal axis. The linear trend line is represented by the equation:

PM_{10} at 5 Ventry St = 0.53 * (**PM_{10}** at 65 Ventry St) + 0.49

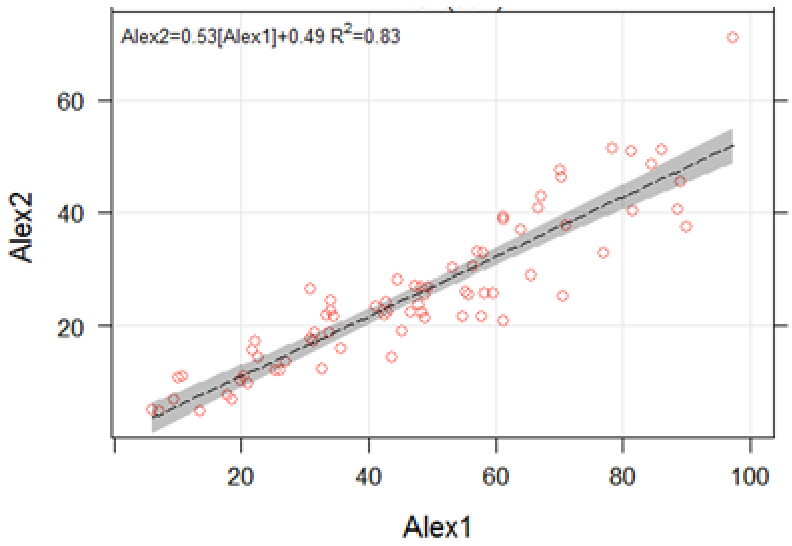

Figure 2: **Scatterplot of winter daily PM_{10} concentrations at two sites in Alexandra. The original site is shown along the horizontal axis (Alex1) and the new site is shown on the vertical axis (Alex2).**

Relevant metrics from the two sites are given in Table 4.

Table 4: **Air quality metrics for two sites in Alexandra. All units are micrograms per cubic metre, except where noted.**

PM_{10} metric	65 Ventry Street	5 Ventry Street
Mean	48	26
Minimum	7	5
Maximum	96	70
Median	47	23
95th percentile	90	49
99th percentile	92	68
# NES Exceedances	35 days	4 days

Key points of the winter monitoring in Alexandra are that:

1. The lower PM_{10} values at 5 Ventry do not necessarily indicate that there was a marked improvement in Alexandra's air quality from previous years.

2. Based on the results from the original site, air quality in town was comparable to previous years.

3. A designated airshed is not necessarily a homogeneous area of PM_{10} concentrations. Spatial studies have shown that previously, but this is the first time two monitors in one town have illustrated the point.

4. Daily PM_{10} concentrations at the new site are approximately half what they are at the original site.

   Most of that difference appears during the evening PM_{10} peak. Figure 3 represents a composite July day at both sites. A morning peak occurs at both sites at 9am and the evening experiences higher concentrations from about 7pm onwards. Both sites have good air quality during the early afternoon when the atmosphere is in its most unstable condition.

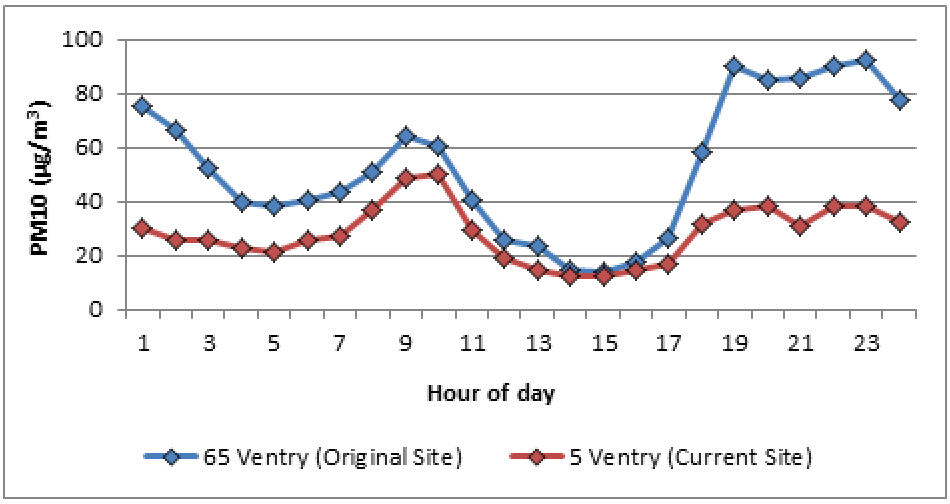

Figure 3: Composite diurnal trend during July for two sites in Alexandra.

The difference between the two sites can be addressed by:

- Developing a synthetic record for the original site, based on this winter's co-location relationship, and/or
- Deploying low-cost, temporary monitors at both sites during winter months to verify the co-location relationship and provide a complete dataset, or by
- Continuing to try to locate a viable site with similar characteristics to the original site.

5. Comparison to typical winter PM_{10} air quality

The typical air quality situation is described by aggregating statistics for the previous three years; in this case, an averaged dataset was created using data from 2014 through 2016. Using three years minimises the influence of annual climatic differences from year to year on air quality.

Two of the common metrics for assessing winter air quality are:

- Number of days that exceed the daily NESAQ standard of 50µg/m^3
- Winter average PM_{10} (May-August)

By both of these metrics, air quality this winter was worse than usual in most Otago towns. Figure 4 indicates that this year, except for Dunedin and Mosgiel, all other monitored centres had more exceedance days than usual. This result is consistent with the graph of winter average PM_{10} (Figure 5) which shows higher than normal winter PM_{10} in all monitored centres except for Dunedin and Mosgiel.

The exact cause of this result is not known. The fact that it was a region-wide effect points to the likelihood that a broad-scale climate setting played some part in the results.

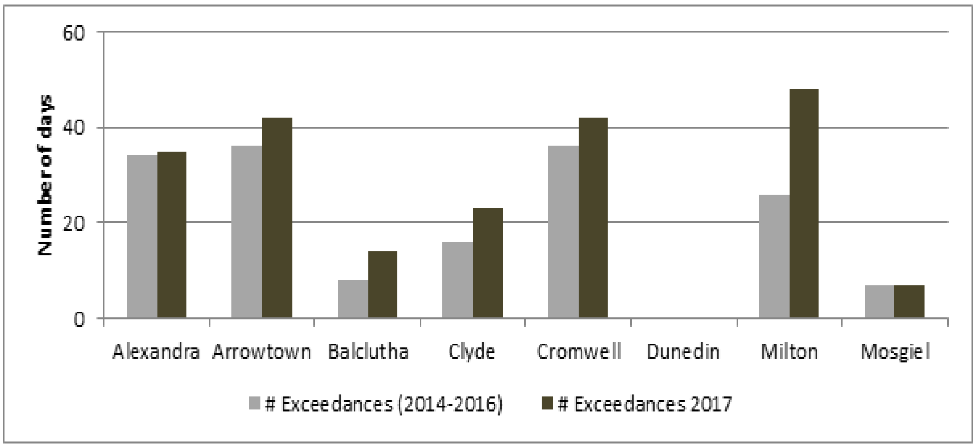

Figure 4: Number of exceedances in 2017 compared to the typical number

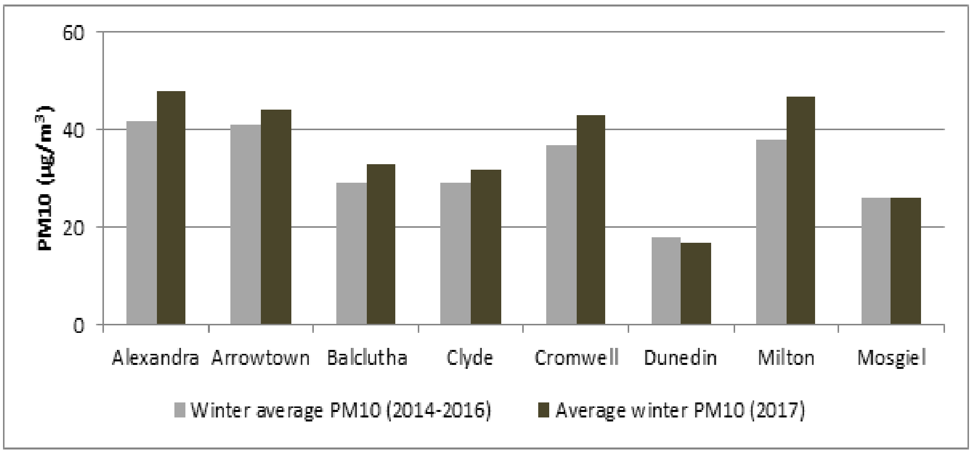

Figure 5: Average winter PM_{10} values in 2017 compared to the typical winter

6. NESAQ status

In 2015, the Parliamentary Commissioner for the Environment (Dr. Jan Wright) provided commentary[1] on the state of air quality in New Zealand as reported by MfE in their Domain Report – Air[2]. A significant recommendation of the commentary was that the MfE should review how particulate matter is managed. The review should determine:

1. Whether $PM_{2.5}$ should be measured in airsheds where it is likely to be a problem
2. The value of setting rules for $PM_{2.5}$, and for long-term (annual) exposure
3. Whether the PM_{10} short-term (daily) rule still has value
4. The impact of air quality rules on other public health issues
5. How air quality policies might be designed to achieve progressive improvement

In light of Dr. Wright's recommendations, the MfE initiated a review of the NESAQ. The outcome of the review has not yet been determined.

[1] Parliamentary Commissioner for the Environment (2015), *The state of air quality in New Zealand: Commentary by the Parliamentary Commissioner for the Environment on the 2014 Air Domain Report,* Wellington.

[2] Ministry for the Environment and Statistics New Zealand (2014), *New Zealand's Environmental Reporting Series: 2014 Air domain report.* Wellington.

It is likely that a $PM_{2.5}$ standard will be included in a proposed NESAQ. What is still unknown is how other parameters of a $PM_{2.5}$ standard would be addressed. These include:

- Averaging time – daily versus annual average standard.
- Threshold concentration – the limit that should not be exceeded
- Number of allowable exceedances
- Final compliance date
- Whether PM_{10} is still a viable standard

An analysis of the implications of a $PM_{2.5}$ standard on Otago's compliance is currently underway; a report will be forthcoming.

7. Recommendation

a) That this report be received.
b) That the state of air quality in Otago be noted.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments
Nil

11.4. Continuous Environmental Monitoring: Opportunities and Challenges

Prepared for: Technical Committee
Activity: Environmental - Regional Plan: Water Quality
Prepared by: Deborah Mills, Environmental Scientist
Date: 7 November 2017

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1. Précis

The science of environmental monitoring is continually evolving as new measurement and data acquisition techniques come to fruition. Long gone are the days when technicians had to change cumbersome circular paper charts collecting month-long readings recorded by a pen. Today, using sophisticated measuring technologies and vastly developed communications capabilities, it is possible to receive continuous, real-time environmental data on a personal smartphone.

Progress has not been equal across the water quantity and water quality domains, and manually-collected data collection techniques have not been made obsolete. Overall, sensor technology has matured at different rates, providing an uneven platform for robust, affordable real-time environmental monitoring. Some of the most recent developments have taken place in the area of nutrient monitoring in waterbodies.

This paper provides a brief review of the technologies used by the Otago Regional Council and outlines our involvement in bringing emerging technologies to our region. Section 2 describes the two types of data collection and how they are used in current monitoring programmes. Section 3 discusses the role of emerging technology in characterising the environment and what the needs of council and community are in the area of rural water quality. Section 4 describes the applicability of new continuous technology in State of the Environment and science studies. Future investigations into the use of new continuous monitoring tools are discussed in Section 5. Challenges of moving to new continuous monitoring platforms are indicated in Section 6. The future direction for investing in new technologies and applications is outlined in Section 7.

2. The state of data collection

Historically, much of environmental monitoring has been done by organisations charged with studying, managing, and reporting on natural resources. More recently, drivers for improvements to continuous sensors come from the changing needs of organisations, whether that is pollution incident investigation, estimating appropriate catchment nutrient loads for setting limits, or enabling farmers to self-monitor their discharges.

The move towards more localised involvement in understanding the surrounding environment has led to a large “citizen scientist” movement. This interest has helped spawn the low-cost sensor phenomenon, one of the current revolutions in the field of environmental monitoring.

Council’s environmental monitoring programme supports a variety of functions. These include:

- Flood warning and response management
- State of the Environment (SoE) reporting
- Supporting policy development through targeted scientific investigations
- Plan effectiveness monitoring

- Compliance with council rules
- Responding to adverse environmental effects

These individual functions each have their own programme objectives which drive their development and a range of established monitoring options is used to collect relevant data.

There are two basic types of monitoring data:

1. Discrete Data

   Techniques where a single sample is taken at a discrete point in time, reflecting environmental quality conditions that exist at that time. Samples can be taken either by a person or, in some cases, by deploying a programmed auto-sampler. They are taken by dipping a specially-prepared bottle into the water or, where the sensor technology is mature enough, by holding a probe in the water for short period of time. Bottled samples are collected and sent to a certified laboratory for analysis, and it may take several days before the results are known. Methods of analysis are considered standard reference methods and yield results of certified accuracy and precision. Handheld probe results are instantaneous.

   Samples taken to acquire this type of data can also referred to as "grab samples" and, taken at regular intervals over a period of time, provide information about long-term trends. Taken over a short period, or as a one-off, they can provide robust data about the nature of an environmental situation or event.

   The benefits of grab sampling are:

   - relatively easy to do
   - flexibility in deploying monitoring officers to sample as needed
   - existence of protocols means data are robust and dependable
   - extensive range of parameters for which analysis is available
   - relatively easy for farmers to participate in taking their own samples
   - does not require any maintenance or infrastructure

   Discrete data have two main limitations which, depending on the objectives of the specific monitoring project, can limit their usefulness. One drawback is that between sampling events, the state of the environmental parameter is unknown; a second limitation is that there is a delay between taking the sample and acquiring the results, depending on what is being tested for. This delay may be on the order of days for standard analytes.

   Except for the obvious exclusion of flood warning systems, grab sampling is used in all Council monitoring functions.

2. Continuous Data

   These techniques utilise parameter-specific, unattended sensors that continuously measure and record data. Measurements are performed at programmed intervals, typically on the order of every 5 to 15 minutes and recorded on a data logger. Data collected this way are either downloaded in the field on a monthly or bi-monthly interval or are, more commonly, sent via telemetry to the office on a regular, hourly basis.

Telemetered continuous monitoring requires some form of power, either supplied through solar panels or via the mains power supply. Along with power, there are accompanying data loggers, modems, and back-up power installed at sites.

Continuous data can be collected on either a constant or intermittent basis, depending on the objective of the monitoring programme/project.

The benefits of continuous data are:

- near real-time nature of data for public awareness, e.g. flood warning, low flows
- enhanced understanding of environmental systems that comes from acquiring high-resolution data
- once installed, a site can run unattended for relatively large amounts of time

The disadvantages, relative to grab sampling are: sensors can be expensive and require frequent calibration, installations are costly, and the parameters that are readily available for continuous monitoring more limited.

Currently, Council regularly collects data at approximately 250 sites across the region for servicing multiple projects. This includes 80 SoE flow sites, 70 SoE water quality sites, 30 rainfall sites, 30 groundwater SoE sites, 8 SoE air quality sites, and 20 contact recreation sites.

Both continuous and grab sampling serve valuable purposes in the ORC environmental monitoring programme. While most data collection is continuous, water-quality (whether surface or groundwater) and compliance sampling currently depend almost entirely on grab sampling. Due to the robustness of monitoring protocols developed over time for these processes, data accuracy and reliability are high.

For a continuous sensor platform to be considered ‘mature’ it must be tested, proven and widely used, with developed and accepted protocols. At this time, the most proven and affordable technologies exist for measuring water temperature, conductivity and turbidity. Continuous nutrient and microbial sensors, used to measure parameters such as nitrogen, phosphorous, and *E.coli*, fall into the category of emerging technology. Currently, these platforms are relatively costly and not yet widely used.

3. Using emerging technology to characterise the environment

The setting of contaminant limits for water quality in the Regional Plan: Water (Water Plan) and the introduction of the National Policy Statement on Freshwater (NPS) require new ways of studying and, consequently, monitoring the environment. This has stimulated an interest in these emerging technologies for continuous measurement, not only in Otago, but throughout New Zealand.

Interest is high overseas as well. Recently, the United States Environmental Protection Agency (USEPA) ran an international competition to find the best low-cost, low-maintenance, compliance-grade, continuous nitrate sensors. Competitors engaged in design, construction and testing phases, with the winner receiving a significant amount of money for commercialisation purposes.

Council has two distinct interests in using these emerging tools: as data inputs into the scientific studies that underpin water management policy decisions and in the area of compliance with the Water Plan. The remainder of this section discusses some of council's efforts to date.

3a. Rural Water Quality Activities

The Regional Plan: Water (RPW) sets out numerical water quality limits for five areas in the Otago region (Schedule 15). The Otago Regional Council carries out monthly State of the Environment (SOE) water quality monitoring, the results from which are reported against Schedule 15 limits[1] .

The RPW also sets out numerical water quality discharge thresholds for two areas in the Otago region (Schedule 16). Land owners need to make sure any discharge from their land meets the numerical contaminant thresholds (when flows are at or below median flow). Council's approach to managing rural water quality has been effects-based and relies on the principles of self-management. We encourage farmers to self-monitor their farm discharges in a meaningful and effective manner. The challenge is how to do this effectively, efficiently, and affordably.

Currently, the best tool available is that of taking grab samples at representative points. Over time, individuals and groups are becoming more familiar with this process. From a community perspective, dipping bottles for grab samples is a relatively simple, straightforward process.

Other available tools include the nitrate test strip; a simple, small handheld dip stick similar to litmus paper which, once dipped into water, provides a general indication of nitrate levels.

In an effort to assist the community with monitoring, Council undertook to investigate ways that new technologies could be introduced and taken up by community groups and individual farms. Two such efforts are described below.

3a.1. AgHub conductivity trial

In 2015, ORC entered into an agreement with AgHub, a provider of online farm management services, to determine whether real-time monitoring and reporting of in-stream parameters could provide meaningful feedback to farmers for effective management for water-quality purposes.

AgHub, owned by Ballance Agri-Nutrients, provides an online system that collects and displays automated data related to aspects of farm management. AgHub engages the relevant partners to deliver this service via their subscription website. Data on topics such as milk production, irrigation status, soil tests, weather and pasture cover are provided online to assist farmers with decision-making.

ORC purchased and had environmental sensors installed on a Balclutha farm, providing readings at what were considered input, output, and central locations of the farm. At the time, the only water-quality sensor available for use in the AgHub system was a combined water temperature and conductivity probe. Conductivity itself is not a direct measure of water-quality, nor is it one of the parameters with a discharge threshold in the 6A Schedule 16. An investigation into whether conductivity can be reliably used as a proxy for water-quality was a key component of this project.

A year-long trial of the system on a Balclutha farm included taking weekly grab samples alongside the conductivity sensor. (Figure 1). All samples were analysed for

[1] Using five-year, 80th percentiles, when flows are at or below median flow

nitrite/nitrate nitrogen, ammoniacal nitrogen, dissolved reactive phosphorus and *E. coli,* all of which have Schedule 16 6A discharge thresholds. Analyses were performed to determine what, if any, relationships existed between parameters and if conductivity could be used to identify either point-source pollution events or non-point-source pollution effects. Results of that work indicated that, in this case, there was no useful relationship.

Figure 1. Rachel Ozanne (water quality scientist) takes a grab sample next to the conductivity monitor set up by AgHub.

Results from similar work done overseas indicate that understanding conductivity is a site-specific exercise and that a thorough appreciation of the underlying influences is critical. This requires a long-term and significant commitment of time and resources for each site of interest. We concluded that this particular continuous monitoring process would not be appropriate for widespread on-farm use in a compliance sense.

This project was regarded as testing and developing new applications of existing technology and sat in the category of council's Research and Development (R&D) work.

3a.2. Freedom4 investigation

Also in 2015, ORC investigated a potential collaboration with researchers at the University of Otago into the use of their recently commercialised Freedom4 device. Freedom4 had been developed over the past several years as a fully mobile qPCR[1] platform for use in the near real-time analysis of selected microbial organisms. The device was originally developed for field work in the health sciences; however, we saw

[1] A DNA-based analysis activity

potential for its use in monitoring microbial elements for water management purposes (e.g. contact recreation).

Figure 2. The Freedom4 component of a system designed to rapidly detect and quantify microbials. Four sampling ports can be seen on the lefthand side.

Normally, analysis of *E. coli* is done via grab samples that are sent to a laboratory for analysis; results can take on the order or 24-48 hours. While the Freedom4 is not a continuous monitor, it significantly reduces the analysis time to approximately one hour, providing for the future possibility of on-farm field deployment.

Discussions were held with senior researchers at the University about the possibility of developing a robust, farm-ready field-testing system for detecting and quantifying microbial contamination in rivers and drains. This was seen as a 5-step process, requiring the following:

1. Sample concentration
2. Preparation
3. Diagnostics
4. Analysis
5. Data generation

The actual Freedom4 device provided step 3; the remainder would require research, development, and rigorous testing. In late 2015, we participated in an end-to-end process laboratory test of the device where we provided grab samples for analysis. This assisted with trialling sample concentrations and preparation methods.

In 2016, we became part of the University's research team applying for contestable MBIE Smart Ideas research funds. It had been estimated that to fully develop the Freedom4 system for farm-ready deployment by farmers would require a 5-year, multi-million dollar effort for development and testing; this grant would fund the research for the first two years. Unfortunately, the grant was unsuccessful and further efforts at collaboration were hampered by changing priorities at the University.

Two key lessons were learned from this experience:

- Emerging, real-time (and/or continuous) technologies are often highly sophisticated technical instruments; this necessitates acquiring an in-depth knowledge of their operation and context before being able to make an informed decision on embarking on a long-term commitment to them.

- The ORC and pure (as opposed to applied) research communities will have different institutional requirements for project advancement; these can be difficult to line up satisfactorily.

4. Continuous monitoring in environmental studies

In a different context, continuous monitoring of relevant parameters can provide valuable data for use in studies seeking to understand the drivers of water quality outcomes; characterising contaminant loading is an important component of that process.

The use of discrete sampling alone may not provide enough data to adequately describe temporal variations in concentrations of nutrients. Continuous nitrate sensors are seen as a way to provide accurate and timely information on nutrient concentrations[1]. The increased resolution of continuous monitoring is required for catchment modelling studies such as the Kakanui and Shag River studies currently underway. Understanding the values and timings of contaminant load delivery to the river systems should be greatly enhanced using this technique.[2]

Ion-selective (IS) continuous nitrate sensors have been in existence for a number of years; however, they do have drawbacks mainly related to their relatively high maintenance requirements. Originally, two IS sensors were installed in the Kakanui River; however, clean data proved elusive given their frequent need for extensive re-calibrations.

New, optical sensing technology is being introduced into New Zealand by Councils and CRIs; ORC is an early adopter of this technology and has installed five such sensors in the Kakanui and Shag River catchments. Because the optical sensors are relatively new, ORC is participating in a NZ-wide collaborative effort to share knowledge and experience related to the sensors. This is a working group seeking to develop national data collection and analysis protocols.

In late 2015, ORC became acquainted with Rezo – Water and Energy, the New Zealand distributor of the German-made TriOS optical, continuous nutrient sensors. Rezo is located in Dunedin and they provided us with expert technical assistance both during and after purchase. When deploying new and unfamiliar gear, the importance of strong technical support from the manufacturer and/or distributor cannot be overstated.

Two TriOS Opus model sensors were purchased and installed in the Kakanui catchment. Along with the sensors, solar panels, a NIWA data acquisition system and related telemetry gear were installed at each site. In total, one site installation cost approximately $30,000. A year-long monitoring programme, coupled with grab sampling has yielded good data for inputs into the modelling for the catchment.

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[1] Pellering, etl al. emerging Tools for continuous nutrient monitoring networks: Sensors advancing science and water resources protection, Journal of the American Water Resources Assocation,

[2] Cameron et al, 2014

Figure 3 **shows the nitrate probe along with the wipers that keep the lenses from fouling, a key component in obtaining clean data.**

Figure 4. **The TRIos continuous nitrate sensor with a wiper system designed to eliminate fouling of the lenses.**

A graph of the discrete and continuous record shows the difference in the levels of information received from each data type (Figure 5). While the general trend of nitrate is captured in the discrete samples, there is a much greater level of detail in the continuous record as response to change is much more sensitive.

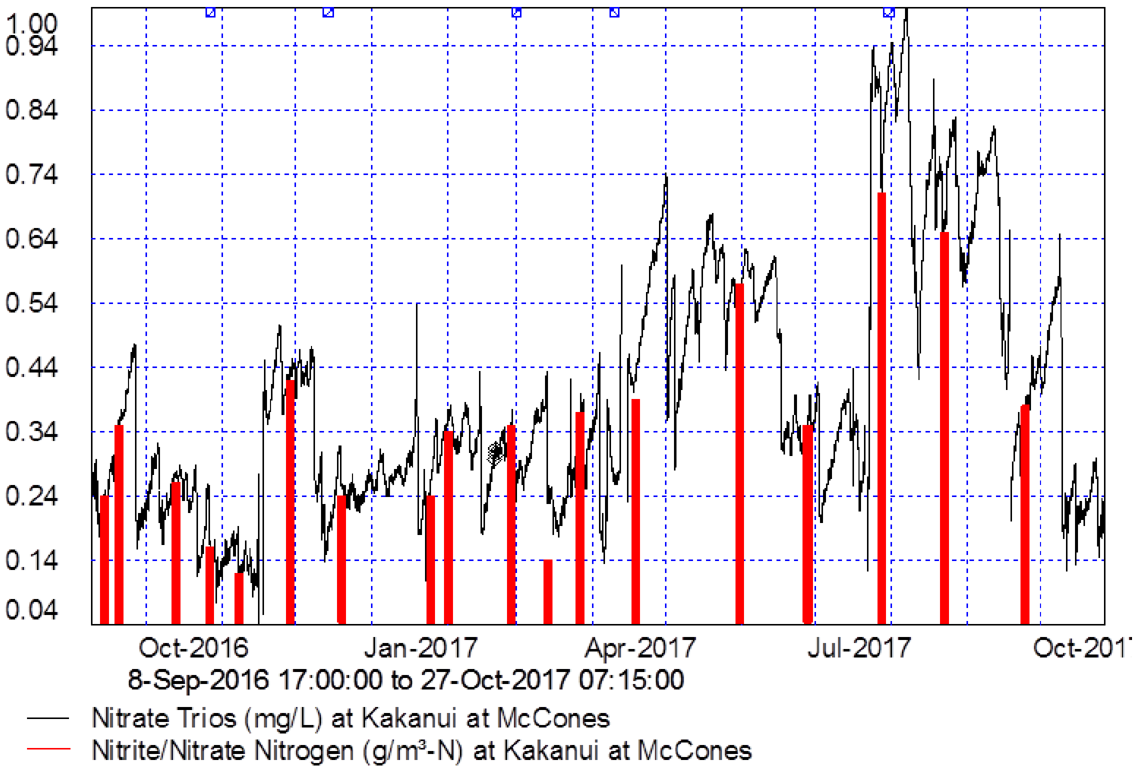

Figure 5. The black trace depicts the continuous, 5-minute data and the red bars represent the grab samples. There is good agreement between the two technologies at this site.

Due to the expense and power requirements of the system, these types of installations are suited for Schedule 15, State of the Environment sites for use in building long-term records of nutrients and/or as inputs to catchment models where detailed information is required. They would not be considered appropriate for on-farm Schedule 16 monitoring.

5. Integrating technological solutions

Robust, low-maintenance continuous monitoring of nutrients is still relatively expensive, making it impractical for a region-wide approach to compliance monitoring, either by council or by the rural community. However, work on reducing costs while enhancing reliability is ongoing in the international and national water quality community. This section discusses two such efforts.

5.a. Low-cost, cloud-based systems

There are now numerous miniature, low-cost sensors to measure most environmental parameters, but the challenge is turning these sensors into commercialised products with the accuracy of high-end sensors. Much of this work is done online in collaborative environments such as Public Lab, a development platform where researchers and interested members of the public can share their work.

Low-cost environmental sensors are now available from Libelium, a wireless sensor network platform provider that delivers, open-source, low-power consumption devices. A Spanish company, there is a distributor in Australia with whom we've had discussions regarding our requirements in the rural water quality sector. At this stage, we are considering a trial of their Smart Ions sensor technology (Figure 6) alongside our existing nitrate sensors. Any trial would examine issues of sensor longevity, range of detection, maintenance and calibration requirements, and data reliability.

Figure 6. Libelium Water Ions sensor package. The box is easily held in the hand.

5.b. Groundwater nitrate sensor

New Zealand research environments include CRIs and Universities. Lincoln Agritech, a multidisciplinary R&D company owned by Lincoln University, has developed a low-cost sensor designed to measure the concentration of nitrates in groundwater via monitoring wells. This can provide valuable information for tracking nitrate gains and losses with good spatial and temporal resolution.

Lincoln Agritech has tested the technology extensively in New Zealand environments and the system is currently at the commercialisation stage. They are actively seeking partners for this phase of development. Due to it being significantly less than the price of current optical nitrate sensors, the sensor platform could be cost-effective for the deployment at the farm scale for on-farm management.

There is interest in trialling one of the sensors for the Shag River project, particularly as we now have continuous surface nitrate readings there. We are pursuing talks with staff there.

6. Challenges to adopting new technology

There are a number of challenges in moving towards continuous monitoring platforms, particularly as related to community self-monitoring. These challenges relate to:

- Ease of use
- Data integrity
- Power requirements
- Installation considerations

- Maintenance schedules
- Sensor longevity
- Data processing and analysis
- Data security

Ease of Use
Moving to any platform involving continuous monitoring requires infrastructure, data acquisition and interpretation. Systems need to be designed so that farmers can easily and reliably use any new device/technique.

Data integrity
Several factors contribute to a high-quality dataset; these include sensor accuracy, precision, resolution, and range of detection. High-cost sensors (such as the TriOS nitrate sensors) have spent considerable time and effort into ensuring their products meet strict technical specifications for data integrity; low-cost sensors often forfeit one or more of these specifications.

To understand the relationship between these data factors, the graphic in Figure 7 depicts their relationship. Accuracy refers to how true the values are; precision is related to the repeatability of the measurement. The high end of sensors will have both high accuracy and precision; they will also be able to measure at both very low, as well as, very high levels. They will be thoroughly tested in varying environments for reliability. The challenge of providing this level of data integrity in low-cost systems has not yet been overcome in the marketplace.

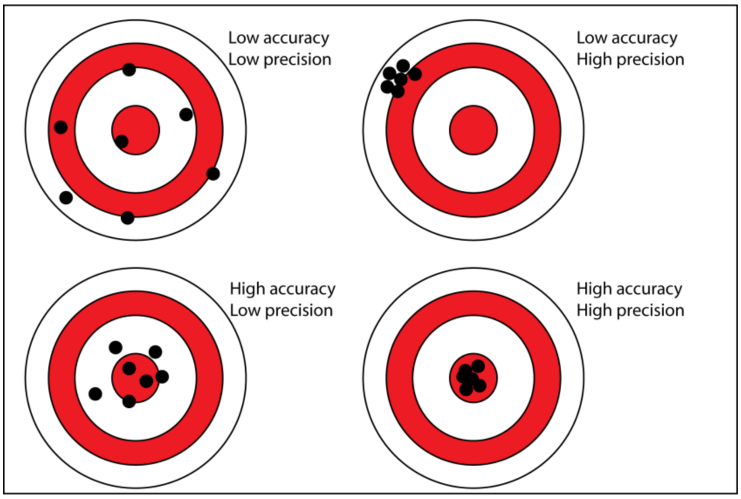

Figure 7. The relationship between accuracy and precision.

Power Requirements
A serious limitation to region-wide deployment of continuous sensors is the power required to support not only the sensor, but possibly a wiper, the data acquisition system, and the communications hardware.

When continuous optical nitrate sensors first came onto the market, it appeared that mains power was required to support all of these activities. This severely limits the deployment of such systems in more remote areas. (NB: Most Schedule 15 sites do not rely on mains power, and Schedule 16 locations would not have access to mains.) The

current optical nitrate sensors are deployed in the Kakanui catchment using 2 large 40W solar panels.
Low-cost sensors will likely require less power, enabling them to be deployed in more types of areas.

Installation considerations
Along with high power consumption, continuous monitors currently require relatively large site footprints due to the gear associated with them, i.e. datalogger enclosures, solar panels, battery back-ups and the like.

Low-cost sensors are often smaller packages with less surrounding physical infrastructure required. However, they must be able to be deployed without being lost during high-flow events. In addition, optical sensors can be influenced by sunlight so installing low-cost sensors in shallow water may yield inaccurate data.

Maintenance schedules
Low-cost sensors like those offered by Libelium require relatively frequent calibration to ensure that drift of the signal does not compromise data integrity. This may make their use less than practical.

Sensor longevity
The TriOS optical sensors will have a long life expectancy, i.e. on the order of 10-15 years. Low-cost sensors, on the other hand, due to their less robust nature, only have a life expectancy of 1-2 years. Over time, this may make them impractical.

Data processing and analysis
One of the challenges of continuous monitoring is simply the amount of data being collected, stored, and analysed. At any particular site, moving from monthly grab samples to 10-minute data means jumping from 12 data points to 52,560 data points per year.

With enlarged datasets comes the need for more sophisticated data analysis as continuous data provide a much more detailed look at the real-time nature of the state of a river. Only now can discerning background (daily, seasonal, annual) from events (diffuse or point-source) be progressed.

Data security
Many of the low-cost sensor systems rely on the cloud for storage. One of the current issues with cloud storage is the lack of system security.

One additional important challenge is the concept of "fit-for-purpose". If we think that we want all farmers to be using a network of low-cost continuous monitors on their farms with automated telemetry and alarm capability, an enormous amount of work must be done to make sensor platforms not only affordable, but easy-to-use, reliable, and robust in what may be a harsh environment. This is simply not yet available.

These issues relate generally to all continuous monitoring platforms, but particularly to low-cost systems. These are the challenges to innovators.

7. Direction of future investment in technology
Research into making continuous monitoring platforms and new tools more accessible is ongoing at university, Crown Research Institute, and private market sectors. The ORC will have a role in helping to bring new ideas and products into the Otago context.

At this time, the best way for council to support the application of new ideas and assist the community is to become 'early adopters' of technology and working to understand its applicability in the Otago context. This is best done by continuing to watch and identify new developments in the field of water-quality monitoring and then, by designing meaningful trials of the most promising of these ideas.

Trials could be run either in partnership with interested groups and/or by council creating a test-bed site for parallel testing of new systems with established reference systems. By employing this approach Council will be able to make a valuable contribution to the national conversation around water-quality monitoring.

8. Recommendation

a) *That this report is received.*

b) *That the ideas presented in this report be considered for inclusion into the Long-term Plan.*

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

Nil

11.5. Management flow reports for the Cardrona and Arrow Rivers

Prepared for: Technical Committee
Activity: Environmental - Minimum Flows and Allocation Limits
Prepared by: Pete Ravenscroft, Environmental Resource Scientist, Freshwater
Xiaofeng Lu, Resource Scientist, Hydrology
Magdy Mohssen, Senior Hydrologist
Jason Augspurger, Environmental Resource Scientist, Freshwater
Dean Olsen, Manager Resource Science
Date: 10 November 2017

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1. Précis

These reports are an update to the original 2011 report "Integrated Water Resource Management for the Cardrona River" (Dale & Rekker) and 2012 report "Management flows for aquatic ecosystems in the Arrow River" (Kitto). The objective of these update reports is to present additional information on the Cardrona and Arrow catchments including:

- the hydrology and existing water allocation
- the in-stream aquatic values
- presentation, analysis and interpretation of the results of instream habitat modelling undertaken by NIWA to estimate the flows required to maintain aquatic, ecological and natural character values.

The update to the original Cardrona River report (2011) includes a detailed assessment of the drying reach between Ballantyne Road and State Highway 6, a naturalised 7-day mean annual low flow and the inclusion of additional habitat curves (Wilding curves) which provide a more suitable representation of brown and rainbow trout. Outcomes suggest the Cardrona dries naturally downstream of Ballantyne road and therefore this should be reflected in the minimum flow. Upstream of Mt. Barker, this report establishes flows which will provide appropriate habitat for adult and juvenile trout.

The updates to the Arrow River report (2012) include using a more robust method to estimate flow statistics resulting in a higher 7-day mean annual low flow and inclusion of additional habitat curves. Outcomes of the updated report provide a range of flows appropriate for maintaining the natural character of the Arrow River.

These technical reports have been peer reviewed by Maurice Duncan (Senior Scientist, NIWA), including a detailed assessment of the hydrological analyses, and will be used to inform the minimum flow setting process for the Cardrona and Arrow catchments.

2. Recommendation

a) The technical reports are received and noted.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

1. Arrow River Science Update 2017 (v A 1817205) **[11.5.1]**

2. Cardrona River Science Update 2017 V 2 **[11.5.2]**

12. NOTICES OF MOTION

13. CLOSURE