

## Introduction

The Otago Regional Council (ORC) is responsible for managing Otago's surface-water resources. ORC carries out regular water-quality monitoring and ecological assessments, as part of its State of Environment (SoE) programme. This report card is a snapshot of monitoring undertaken between July 2016 and June 2021. Discussion of results is presented in regular State of Environment reports. The last report can be found here: <https://www.orc.govt.nz/media/9781/state-and-trends-of-lake-and-river-water-quality-in-the-otago-region-2000-to-2020.pdf>

## Water quality (Water Plan, Schedule 15)

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

**Table 1: Water quality limits and targets (five-year, 80<sup>th</sup> 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	<i>Escherichia coli</i> 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

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

- **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, primarily sourced from effluent and fertiliser. Ammoniacal nitrogen (NH<sub>4</sub>-N) can indicate the presence of effluent in water. Total nitrogen (TN) and total phosphorus (TP) are the nutrients used when monitoring eutrophication potential in lakes.
- ***Escherichia coli* (*E. coli*)** are a bacterium used to indicate the presence of harmful micro-organisms in water (e.g., human or animal faeces). This indicator is used to gauge whether water is suitable for stock water, swimming, surfing or other recreational activities.
- **Turbidity:** Turbidity is a measure of the cloudiness of water and assesses how much light is scattered by suspended particles. Streams with 'high turbidity' often have high suspended sediment loads. High turbidity can reduce light penetration and affect photosynthesis. High sediment loading also can smother the streambed, which reduces macroinvertebrate and fish-spawning habitat.

**Table 2: Water quality index**

Grade	Number of parameters complying with Schedule 15 limits and targets (June 2016 to July 2021)
Excellent	All five parameters comply
Good	Four (of the five) values comply
Fair	Three (of the five) values comply
Poor	Two or fewer (of the five) values comply

## Water quality results

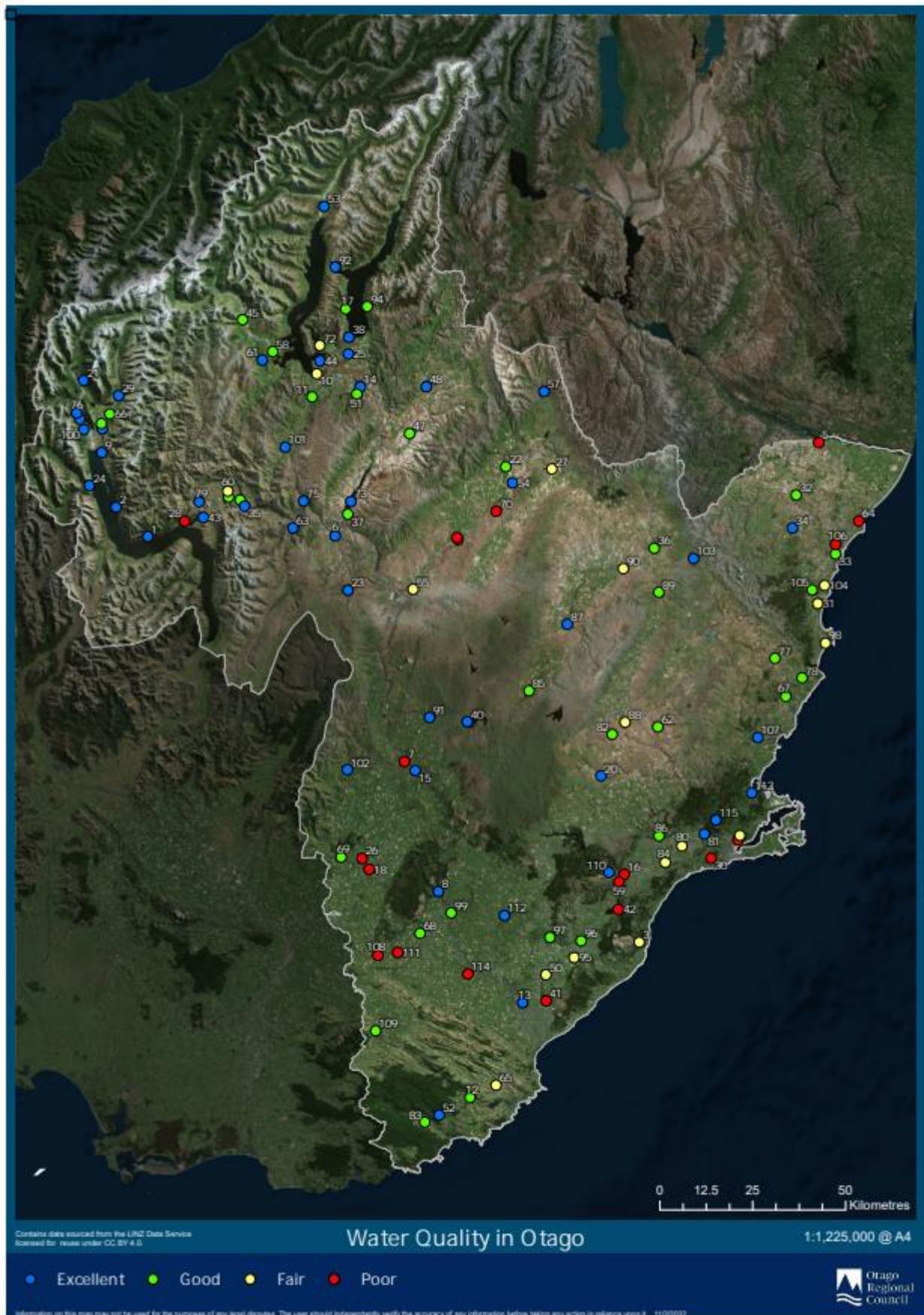


Figure 1: Results of SoE water-quality monitoring (2016 -2021). Site numbers refer to sites in Tables 3-7.

## Water quality results

Table 3: Water quality results for Group 1 sites. The orange cells show where the 80<sup>th</sup> percentile below median flow exceeded the Schedule 15 limits and targets. Sites with an ‘\*’ have been monitored for less than five years, therefore the grade is interim. Sites monitored by NIWA are shown with an ‘N’.

Site #	Name	Grade	NH4-N mg/l	E.Coli cfu/100ml	DRP mg/l	NNN mg/l	Turb NTU
	<b>Schedule 15 limit or target</b>		<b>0.1</b>	<b>260</b>	<b>0.026</b>	<b>0.444</b>	<b>5</b>
8 *	Blackcleugh Burn at Rongahere Road	Excellent	0.0025	20	0.0194	0.0674	0.59
12	Catlins at Houipapa	Good	0.0120	204	0.0150	0.4950	3.80
13 N	Clutha at Balclutha	Excellent	0.0050	101	0.0020	0.0856	4.29
18	Crookston Burn at Kelso Road	Poor	0.0298	1300	0.0419	1.4890	5.26
26	Heriot Burn at Park Hill Road	Poor	0.0239	1012	0.0409	1.5950	5.30
30	Kaikorai Stream at Brighton Road	Poor	0.0209	4411	0.0160	0.5420	8.42
46	Leith at Dundas Street Bridge	Poor	0.0121	1553	0.0271	0.5930	2.86
49	Lindsays Creek at North Road Bridge	Fair	0.0120	1320	0.0231	0.8320	3.62
50	Lovells Creek at Station Road	Fair	0.0160	590	0.0142	0.7200	3.00
52 *	Maclennan at Kahuiiku School Road	Excellent	0.0098	178	0.0120	0.0312	2.10
65	Owaka at Katea Road	Fair	0.0120	354	0.0201	1.2120	2.24
68	Pomahaka at Burkes Ford	Good	0.0160	154	0.0124	0.5750	3.63
83 *	Tahakopa at Tahakopa	Good	0.0090	700	0.0081	0.3480	3.77
95	Tokomairiro at Blackbridge	Fair	0.0357	3514	0.0257	0.3390	5.57
96 *	Tokomairiro at Lisnatunny	Good	0.0173	381	0.0216	0.1260	3.99
97	Tokomairiro at West Branch Bridge	Good	0.0130	367	0.0119	0.1418	2.37
99	Tuapeka at 700m u/s bridge	Good	0.0101	268	0.0240	0.1727	3.50
108	Waipahi at Cairns Peak	Poor	0.0209	558	0.0169	0.7170	5.07
109	Waipahi at Waipahi	Good	0.0120	229	0.0229	1.1430	2.49
111	Wairuna at Millar Road	Poor	0.0594	919	0.1326	1.3960	14.48
112	Waitahuna at Tweeds Bridge	Good	0.0130	365	0.0159	0.1489	3.50
113 *	Waitati at Mt Cargill Road	Excellent	0.0035	190	0.0081	0.0982	1.34
114	Waiwera at Maws Farm	Poor	0.0179	330	0.0403	1.0500	2.90



Figure 2 Kaikorai Stream

## Water quality results

Table 4: Water quality results for Group 2 sites. The orange cells show where the 80<sup>th</sup> percentile below median flow exceeded the Schedule 15 limits and targets. Sites with an ‘\*’ have been monitored for less than five years, therefore the grade is interim. Sites monitored by NIWA are shown with an ‘N’.

Site #	Name	Grade	NH4-N mg/l	E.Coli cfu/100ml	DRP mg/l	NNN mg/l	Turb NTU
	<b>Schedule 15 limit or target</b>		<b>0.1</b>	<b>260</b>	<b>0.01</b>	<b>0.075</b>	<b>5</b>
3 *	Akatore Creek at Akatore Creek Road	Fair	0.0079	251	0.0058	0.4760	14.36
4 *	Arrow at Morven Ferry Road	Good	0.0025	66	0.0017	0.1134	3.36
5	Awamoko at SH83	Poor	0.0132	579	0.0844	0.6990	1.96
6	Bannockburn at Lake Dunstan	Excellent	0.0041	132	0.0062	0.0014	3.86
7	Benger burn at SH8	Poor	0.0141	373	0.0162	0.2830	1.42
11	Cardrona at Mt Barker	Good	0.0047	162	0.0030	0.0753	1.89
14 N	Clutha at Luggate Br.	Excellent	0.0068	4	0.0005	0.0428	1.09
15 N	Clutha at Millers Flat	Excellent	0.0040	33	0.0009	0.0442	3.30
16	Contour Channel at No. 4 Bridge	Poor	0.0702	883	0.0371	0.2880	6.94
20	Deep Stream at SH87	Excellent	0.0035	227	0.0038	0.0018	0.87
22	Dunstan Creek at Beattie Road	Good	0.0046	169	0.0040	0.1005	1.15
23 *	Fraser at Old Man Range	Excellent	0.0025	13	0.0031	0.0116	0.49
25	Hawea at Camphill Bridge	Excellent	0.0023	9	0.0030	0.0200	0.60
27 *	Hills Creek at SH85	Fair	0.0025	438	0.0037	0.1315	1.44
31 *	Kakaho Creek at SH1	Fair	0.0771	195	0.0543	0.1843	4.42
32	Kakanui at Clifton Falls Bridge	Good	0.0034	699	0.0028	0.0595	0.40
33	Kakanui at McCones	Good	0.0080	133	0.0033	0.7150	0.50
34	Kauru at Ewings	Excellent	0.0042	202	0.0033	0.0265	0.34
35	Kawarau at Chards (NIWA)	Excellent	0.0130	13	0.0020	0.0282	4.38
36	Kye Burn at SH85 Bridge	Good	0.0040	212	0.0047	0.1031	1.17
47	Lindis at Ardgour Road	Good	0.0052	161	0.0030	0.0935	1.43
48	Lindis at Lindis Peak	Excellent	0.0036	108	0.0040	0.0191	1.84
51	Luggate Creek at SH6 Bridge	Good	0.0037	181	0.0109	0.0070	1.30
54	Manuherikia at Blackstone Hill	Excellent	0.0040	232	0.0050	0.0059	4.61
55	Manuherikia at Galloway	Fair	0.0070	300	0.0186	0.0625	2.55
56	Manuherikia at Ophir	Poor	0.0171	729	0.0303	0.1378	3.56
57 *	Manuherikia downstream of Fork	Excellent	0.0025	39	0.0060	0.0039	0.35



Figure 3. Arrow River

## Water quality results

Table 4 continued: Water quality results for Group 2 sites. The orange cells show where the 80<sup>th</sup> percentile below median flow exceeded the Schedule 15 limits and targets. Sites with '\*' have been monitored for less than five years, therefore the grade is interim. Sites monitored by NIWA are shown with an 'N'. Sites with '\*\*\*' were originally monitored by NIWA before ORC took on the sampling responsibility. \*\*\*There is an exemption for turbidity for the Shotover.

Site #	Name	Grade	NH4-N mg/l	E.Coli cfu/100ml	DRP mg/l	NNN mg/l	Turb NTU
			<b>0.1</b>	<b>260</b>	<b>0.01</b>	<b>0.075</b>	<b>5</b>
	<b>Schedule 15 limit or target</b>						
59 *	Meggat Burn at Berwick Road	Poor	0.0110	448	0.0103	0.1200	3.65
60	Mill Creek at Fish Trap	Fair	0.0150	313	0.0060	0.4300	4.10
62	Nenthorn at Mt Stoker Road	Good	0.0077	219	0.0174	0.0031	1.67
63	Nevis at Wentworth Station	Excellent	0.0027	65	0.0045	0.0026	0.94
64 *	Oamaru Creek at SH1	Poor	0.0219	613	0.3900	0.6920	3.04
67 *	Pleasant at Patterson Road Ford	Good	0.0080	72	0.0034	0.0250	6.23
69	Pomahaka at Glenken	Good	0.0050	318	0.0083	0.0313	1.58
70 *	Poolburn at Cob Cottage	Poor	0.0117	359	0.0570	0.1098	2.45
73 *	Quartz Reef Creek at SH8	Excellent	0.0025	220	0.0025	0.0123	2.80
75 *	Roaring Meg at SH6	Excellent	0.0025	48	0.0081	0.0295	0.94
77	Shag at Craig Road	Good	0.0043	98	0.0039	0.1449	0.71
78	Shag at Goodwood Pump	Good	0.0087	226	0.0059	0.2870	0.73
79 N	Shotover at Bowens Peak	Excellent	0.0042	7	0.0003	0.0164	4.81
80	Silverstream at Taieri Depot	Fair	0.0205	579	0.0082	0.7540	0.91
81 *	Silverstream at Three Mile Hill Road	Excellent	0.0025	69	0.0024	0.0234	0.83
82 ***	Sutton Stream at SH87	Good	0.0045	609	0.0075	0.0102	1.58
84	Taieri at Allanton Bridge	Fair	0.0175	508	0.0099	0.0774	3.97
85	Taieri at Linnburn Runs Road	Good	0.0050	296	0.0039	0.0043	1.54
86 ***	Taieri at Outram	Good	0.0065	112	0.0112	0.0495	2.10
87	Taieri at Stonehenge	Excellent	0.0060	144	0.0080	0.0149	1.51
88	Taieri at Sutton	Fair	0.0071	821	0.0123	0.0632	3.86
89 ***	Taieri at Tiroiti	Good	0.0070	181	0.0221	0.0630	4.01
90	Taieri at Waipiata	Fair	0.0100	303	0.0363	0.0466	3.51
91 *	Teviot at Bridge Huts Road	Excellent	0.0051	109	0.0015	0.0075	4.23
93	Thomsons Creek at SH85	Poor	0.0259	1920	0.0982	0.3490	7.81
98	Trotters Creek at Mathesons	Fair	0.0376	312	0.0043	0.4870	2.98
101 *	Upper Cardrona at Tuohys Gully Road	Excellent	0.0025	237	0.0010	0.0185	1.57
102 *	Upper Pomahaka at Aitchison Runs Road	Excellent	0.0025	92	0.0064	0.0212	0.87
103 *	Upper Shag at SH85 Culvert	Excellent	0.0030	115	0.0023	0.0410	0.29
104	Waianakarua at Browns	Fair	0.0050	337	0.0034	0.3750	0.42
105 *	Waianakarua at South Branch SH1	Good	0.0057	218	0.0018	0.6170	0.36
106	Waiareka Creek at Taipo Road	Poor	0.0125	492	0.2550	0.9250	2.45
107	Waikouaiti at Confluence d/s	Excellent	0.0046	79	0.0045	0.0642	1.20
110	Waipori at Waipori Falls Reserve	Excellent	0.0057	34	0.0033	0.0561	1.73
115 *	Whare Creek at Whare Flat Road	Excellent	0.0025	37	0.0029	0.0445	1.26

## Water quality results

**Table 5: Group 3 sites showing water quality results. The orange cells show where the 80<sup>th</sup> percentile below median flow exceeded the Schedule 15 limits and targets. Sites with an ‘\*’ have been monitored for less than five years, therefore the grade is interim. Sites monitored by NIWA are shown with an ‘N’. \*\*\*There is an exemption for turbidity for the Dart and Matukituki**

Site #	Name	Grade	NH4-N	E.Coli	DRP	NNN	Turb
			mg/l	cfu/100ml	mg/l	mg/l	NTU
	<b>Schedule 15 limit or target</b>		<b>0.01</b>	<b>50</b>	<b>0.005</b>	<b>0.075</b>	<b>3</b>
1 *	12 Mile Creek at Glen-Queenstown Rd	Excellent	0.0025	6	0.0027	0.0059	0.26
2 *	25 Mile Creek at Glen-Queenstown Rd	Excellent	0.0025	6	0.0028	0.0061	0.27
9 *	Buckler Burn at Glen-Queenstown Rd	Excellent	0.0025	5	0.0018	0.0311	2.28
10 *	Bullock Creek at Dunmore Street	Fair	0.0025	846	0.0015	0.7650	0.49
17 *	Craig Burn at SH6	Good	0.0025	55	0.0033	0.0086	0.95
19	Dart at The Hillocks	Good	0.0039	9	0.0030	0.0357	10.76
21 *	Dundas Creek at Mill Flat	Excellent	0.0025	2	0.0029	0.0410	0.55
24 *	Greenstone at Greenstone Station Road	Excellent	0.0025	22	0.0019	0.0221	0.48
28 *	Horn Creek at Queenstown Bay	Poor	0.0145	318	0.0096	0.1655	3.35
29 *	Invincible Creek at Rees Valley Road	Excellent	0.0025	2	0.0007	0.0104	1.77
45 *	Leaping Burn at Wanaka Mt Aspiring Rd	Good	0.0013	196	0.0015	0.0300	0.57
53 *	Makarora at Makarora	Excellent	0.0025	28	0.0022	0.0594	1.47
58	Matukituki at West Wanaka	Fair	0.0093	34	0.0040	0.0803	3.16
61 *	Motatapu at Wanaka Mt Aspiring Road	Excellent	0.0025	31	0.0010	0.0436	1.14
66 *	Ox Burn at Rees Valley Road	Good	0.0025	6	0.0019	0.0260	4.61
71 *	Precipice Creek at Glenorchy Paradise Rd	Excellent	0.0025	15	0.0017	0.0094	0.54
72 *	Quartz Creek at Maungawera Valley Road	Fair	0.0025	89	0.0027	0.1392	0.51
74 *	Rees at Glenorchy Paradise Road Bridge	Good	0.0025	10	0.0018	0.0176	10.01
76 *	Scott Creek at Routeburn Road	Excellent	0.0025	11	0.0021	0.0317	0.75
92 *	The Neck Creek at Meads Road	Excellent	0.0025	10	0.0019	0.0066	0.42
94 *	Timaru at Peter Muir Bridge	Good	0.0013	7	0.0050	0.0154	24.90
100 *	Turner Creek at Kinloch Road	Excellent	0.0025	9	0.0024	0.0531	0.28

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

Site #	Name	Grade	NH4-N	E.Coli	Turb	TP	TN
			mg/L	cfu/100ml	NTU	mg/L	mg/L
	<b>Schedule 15 limit or target</b>		<b>0.1</b>	<b>126</b>	<b>3.00</b>	<b>0.0330</b>	<b>0.5500</b>
39	Lake Hayes	Good	0.0423	3	3.68	0.0536	0.4260
40	Lake Onslow	Excellent	0.0075	11	4.95	0.0270	0.3000
41	Lake Tuakitoto	Poor	0.0760	125	8.91	0.1494	1.4370
42	Lake Waihola	Poor	0.0240	97	17.55	0.0776	0.6400

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

Site #	Name	Grade	NH4-N	E.Coli	Turb	TP	TN
			mg/L	cfu/100ml	NTU	mg/L	mg/L
	<b>Schedule 15 limit or target</b>		<b>0.01</b>	<b>10</b>	<b>3.00</b>	<b>0.0050</b>	<b>0.1000</b>
37	Lake Dunstan	Good	0.0039	9	1.08	0.0060	0.0946
38	Lake Hawea	Excellent	0.0025	0.5	0.72	0.0015	0.0400
43	Lake Wakatipu	Excellent	0.0025	0.5	0.61	0.0020	0.0645
44	Lake Wanaka	Excellent	0.0013	0.5	0.53	0.0020	0.0630

## Water quality results

Table 8 shows the variation in water quality grades over the years. In 2016-2021 69% of the SoE sites are classified as having 'excellent' or 'good' water quality. Most of the sites with 'excellent' river water quality were in Central Otago and the upper Clutha. In these areas, 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.

**Table 8: Summary of results showing variation in water quality grades across three five year periods.**

RIVERS	2014-19	2015-20	2016-21	LAKES	2014-19	2015-20	2016-21
Excellent	37	37	41	Excellent	3	3	4
Good	32	34	32	Good	2	3	2
Fair	18	19	17	Fair	0	0	0
Poor	19	16	17	Poor	3	2	2
TOTAL	106	106	107	TOTAL	8	8	8

Compared to 2021-2021 water quality results, 98 sites retained the same grade, eight sites improved by one grade, one site improved by two grades and eight sites degraded by one grade.

In Group 1, four sites (of 23) had 'excellent' water quality (Clutha Mata/Au at Balclutha, Blackcleugh Burn, Maclennan River and Waitati River); eight had 'good' water quality (Catlins River, Pomahaka River at Burkes, Tahakopa River, Tokomairiro at Lisnatunny, Tokomairiro at West Branch Bridge, Tuapeka River and Waipahi River); four had 'fair' water quality, and 7 sites had 'poor' water quality. The sites graded 'poor' included the tributaries of the Pomahaka River, Dunedin urban streams, the Waiwera River. Schedule 15 limits were most often exceeded for *E. coli* and NNN.

For Group 2, 22 sites (out of 61) had 'excellent' water quality. Most of these were upper catchment sites spread widely across Otago, including the Taieri, Manuherekia, Pomahaka, Lindis and Waikouaiti in the Taieri and Clutha river catchments. Eighteen sites had 'good' water quality, twelve had 'fair' water quality, and another nine were classified as 'poor' water quality. The parameter that most often exceeded the Schedule 15 limit in this category was NNN.

Of the 23 sites in Group 3, 15 had 'excellent' water quality, six had 'good' water quality, one site had 'fair' water quality, and one site (Horn Creek) had 'poor' water quality. Horn Creek was the only site in Otago to exceed the Schedule 15 limit for ammoniacal nitrogen. Water quality grades for Timaru Creek, the Dart River and the Buckler Burn improved, while Quartz Creek dropped from good to fair.

For Group 4 lake sites, Lake Hayes had 'good' water quality, Lake Onslow had 'excellent' water quality, and Lake Tuakitoto and Lake Waihola had 'poor' water quality. All but Onslow exceeded Schedule 15 limits for turbidity total phosphorus (TP). None of the Group 4 lakes exceeded the *E. coli* limit.

The lake sites in Group 5 sites had excellent water quality, except for Lake Dunstan which recorded total phosphorus above the Schedule 15 limit.

## Macroinvertebrates (NPSFM 2020, Appendix 2B, Tables 14 and 15)

Macroinvertebrates are important in streams and rivers because they aid ecosystem processes and provide food for fish and some birds. As macroinvertebrates have a relatively long lifespan, they are good indicators of environmental conditions over a prolonged period.

Macroinvertebrates are included in the NPSFM 2020 as attributes requiring an action plan (NPSFM 2020, Appendix 2B, Tables 14-15). The NPSFM has attribute states for Macroinvertebrate Community Index (MCI) score; Quantitative Macroinvertebrate Community Index (QMCI) score and Macroinvertebrate Average Score Per Metric (ASPM). ORC has traditionally monitored SQMCI.

NPSFM 2020 macroinvertebrate attribute bands are shown in Table 9 and macroinvertebrate results are shown in Table 10.

**Macroinvertebrate Community Index (MCI):** The MCI is based on the tolerance or sensitivity of species (taxa) to organic pollution and nutrient enrichment. For example, mayflies, stoneflies and caddis flies are generally sensitive to pollution. They are only abundant in clean and healthy streams, whereas worms and snails are more tolerant and found in polluted streams. Most benthic invertebrate taxa have been assigned a tolerance value ranging from 1 (very tolerant) to 10 (very sensitive). Higher MCI scores indicate better stream conditions at the sampled site. Table 11 shows that *MCI scores were highest at the Dart, Blackcleugh Burn and Arrow River and lowest in the Kaikorai Stream, Oamaru Creek and Waipahi at Waipahi.*

**Semi-Quantitative Macroinvertebrate Community Index (QMCI):** A more cost-effective variant of the QMCI is called the Semi-Quantitative Macroinvertebrate Community Index, or SQMCI (Stark 1998). The SQMCI uses a five-point scale of coded abundances (i.e., Rare, Common, Abundant, Very Abundant, Very Very Abundant). This index produces values very similar to the QMCI. The SQMCI uses the same tolerance scores as the MCI but uses the relative abundance of macroinvertebrates to determine an index of stream health. The SQMCI is considered more sensitive to subtle changes in water quality and stream health because it shows changes in the relative proportions of different species rather than the presence or absence. SQMCI scores range from 0 to 10. Table 11 shows that *SQMCI scores were highest at 12 Mile Creek, Manuherekia at Galloway and the Dart River and lowest in the Kaikorai Stream, Kakanui River at McCones and the Silverstream.*

**Average Score Per Metric (ASPM):** The ASPM index aggregates three other metrics that are averaged to indicate stream health. The component metrics are the MCI, the richness of Ephemeroptera, Plecoptera and Trichoptera (EPT taxa) and %EPT abundance. Table 11 shows that *ASPM scores were highest in Dunstan Creek, Manuherekia at Galloway and the Arrow River and lowest in the Kaikorai Stream, Oamaru Creek and Silver Stream.*



Smooth Cased Caddis - Olinga caddis larve construct smooth mobile cases that lack sand grains



Deleatidium Mayfly. Single, leaf-like gills.

### Figure 4 Common Invertebrates

(<https://www.landcareresearch.co.nz>)



## Macroinvertebrate results

Table 9: Macroinvertebrate NPSFM 2020, Appendix 2B, Table 14/15

	Macroinvertebrate Community Index (MCI) score; Quantitative Macroinvertebrate Community Index (QMCI) score		
	Description	QMCI	MCI
A	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.	≥6.5	≥130
B	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat	≥5.5 and <6.5	≥110 and <130
C	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or moderate alteration of the natural flow regime or habitat.	≥4.5 and <5.5	≥90 and <110
	National bottom line	4.5	90
D	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat	<4.5	<90

	Macroinvertebrate Average Score Per Metric (ASPM)	
	Description	ASPM
A	Macroinvertebrate communities have high ecological integrity, similar to that expected in reference conditions.	≥6.5
B	Macroinvertebrate communities have mild-to-moderate loss of ecological integrity.	≥5.5 and <6.5
C	Macroinvertebrate communities have moderate-to severe loss of ecological integrity.	≥4.5 and <5.5
	National bottom line	4.5
D	Macroinvertebrate communities have severe loss of ecological integrity.	<4.5

Table 10: Median macroinvertebrate results, taken from five years of monitoring between 2016 to 2021. Results at sites marked with an "\*" are interim as they have been monitored for less than five years.

Site	MCI 5 year median	SQMCI 5 year median	ASPM 5 year median
12 Mile Creek at Glenorchy Queenstown Road*	112.50	7.45	0.56
25 Mile Creek at Glenorchy Queenstown Road*	110.83	4.01	0.43
Akatore Creek at Akatore Creek Road*	100.77	6.15	0.48
Arrow at Morven Ferry Road*	121.05	6.33	0.57
Blackcleugh Burn at Rongahere Road*	124.44	5.79	0.56
Bullock Creek at Dunmore Street Footbridge*	102.00	4.80	0.37
Cardrona at Mt Barker	104.44	3.91	0.46
Dart at The Hillocks*	125.14	7.29	0.56
Dunstan Creek at Beattie Road	120.00	7.22	0.65
Greenstone at Greenstone Station Road*	116.36	6.23	0.56
Kaikorai Stream at Brighton Road	68.00	2.15	0.13
Kakanui at McCones	87.69	3.10	0.31
Kye Burn at SH85 Bridge	102.73	6.70	0.52
Lindis at Ardgour Road	102.00	4.77	0.42
Luggate Creek at SH6 Bridge	106.32	5.52	0.50
Manuherikia at Blackstone Hill	100.00	5.67	0.53
Manuherikia at Galloway*	105.26	7.37	0.57
Manuherikia River at Ophir*	110.26	5.93	0.54
Matukituki at West Wanaka Station*	107.50	6.94	0.36
Motatapu at Wanaka Mt Aspiring Road*	111.11	5.98	0.54
Oamaru Creek at SH1*	81.11	4.23	0.19
Owaka at Katea Road*	93.85	4.31	0.52
Precipice Creek at Glenorchy Paradise Road*	110.91	4.55	0.39
Shag at Goodwood Pump	87.62	5.43	0.41
Silverstream at Taieri Depot	90.43	3.25	0.28
Tahakopa at Tahakopa*	107.14	5.43	0.56
The Neck Creek at Meads Road*	108.75	5.17	0.45
Tokomairiro at West Branch Bridge	104.67	5.52	0.53
Turner Creek at Kinloch Road*	117.50	3.44	0.39
Upper Pomahaka at Aitchison Runs Road*	116.36	5.72	0.56
Waianakarua at Browns	106.09	5.74	0.50
Waipahi at Waipahi	84.62	4.57	0.30
Waitahuna at Tweeds Bridge	100.00	5.64	0.49

## Periphyton (Chlorophyll *a*) (NPSFM 2020, Appendix 2A, Table 2)

Chlorophyll-*a* (Chl<sub>a</sub>) is a common method for estimating stream periphyton biomass because all types of algae contain Chl<sub>a</sub>, this metric reflects the total amount of live algae in a sample. The trophic state of a water body is the amount of living material (biomass) that it supports. The NPSFM 2020 specifies attributes for trophic state based periphyton biomass in rivers (Table 11). Chl<sub>a</sub> is the measure of biomass that the NOF periphyton attributes are based on, and the results are shown in Table 12.

The periphyton monitoring programme includes 34 sites sampled monthly between February 2019 and June 2021. Periphyton sampling was undertaken with one composite sample collected from each site. Samples were collected using the Quantitative Method 1b (QM-1b) described by the Ministry for the Environment (Biggs and Kilroy 2000). A stone was randomly chosen at 20 points from each site, and a predetermined area of the stone surface was scrubbed with a small brush into a tray and rinsed with river water. The scrubblings from the 20 stones were pooled and transferred to a sample container using river water. The total chlorophyll *a* was calculated using a standard formula (Biggs and Kilroy, 2000) and scaled to the number of milligrams of chlorophyll *a* per m<sup>2</sup> of the stream bed.

The 28 months of monitoring falls short of the 3 years required by the NPSFM. The results presented in Table 13 are therefore interim. Of the sites monitored, 16 sites had negligible nutrient enrichment and met the A band requirements, ten sites had low nutrient enrichment and were band B, three sites had moderate nutrient enrichment and met were band C, and five sites fell below the national bottom line with 8% of samples exceeding 200 mg chl-*a*/m<sup>2</sup> reflecting high nutrient enrichment.

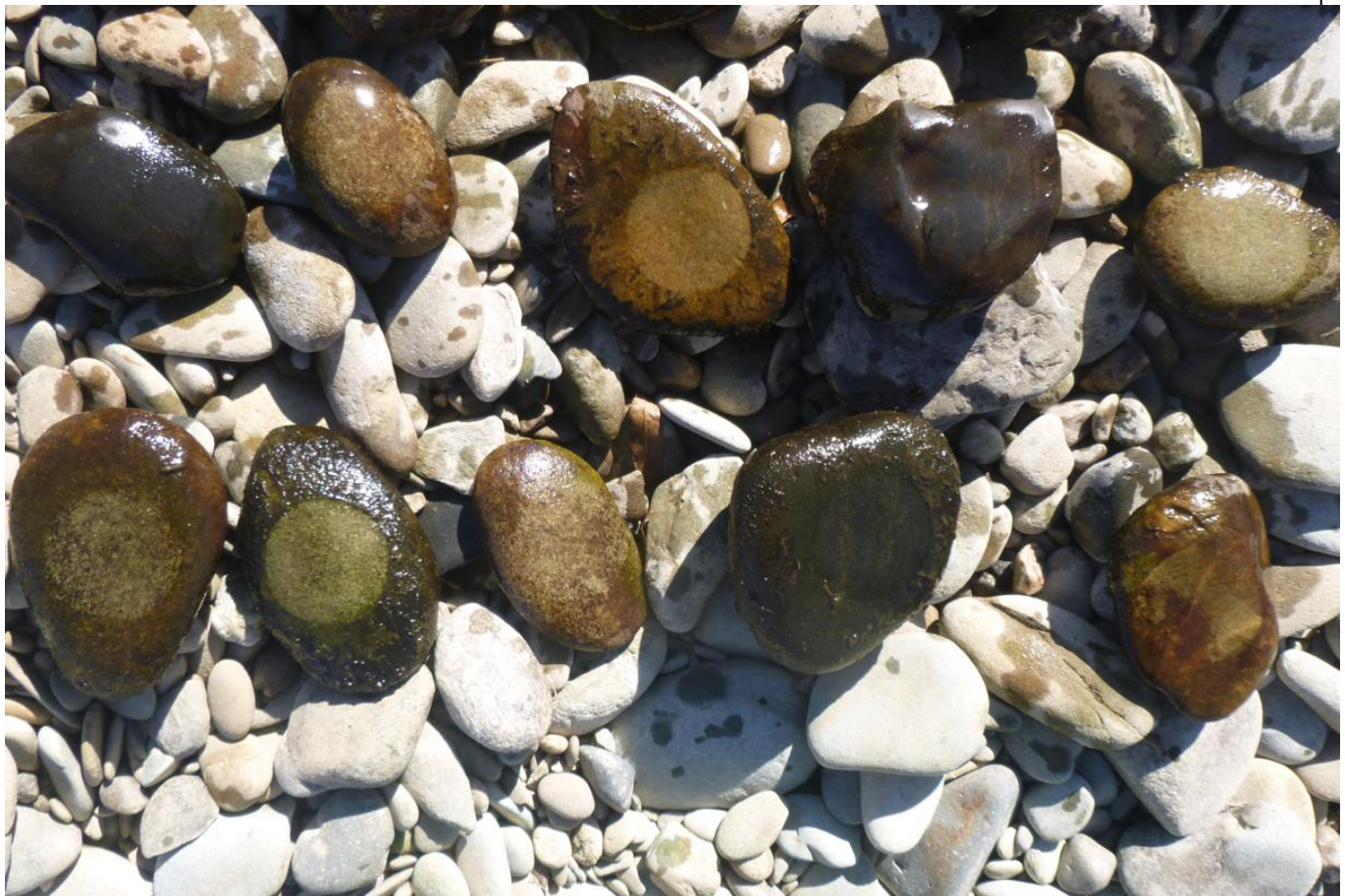


Figure 5 Scrubbed stones – Kakanui at McCones

## Periphyton (Chlorophyll *a*) results

Table 11: Periphyton trophic state NPSFM 2020, Appendix 2A, Table 2

	mg chl-a/m <sup>2</sup> (milligrams chlorophyll-a per square metre)	
	Description	Numeric attribute state
A	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.	≤50
B	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat	>50 and ≤120
C	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or moderate alteration of the natural flow regime or habitat.	>120 and ≤200
	National bottom line	200
D	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat	>200

Table 12: Attribute bands for Periphyton, based on chlorophyll *a* average score (mg per m<sup>2</sup>) at each site for months monitored between February 2019 and June 2021

Site	# samples	Attribute Band	Exceeded no more than 8% of samples			
			% samples ≤50 mg chl-a/m <sup>2</sup>	% samples >50 - ≤120 mg chl-a/m <sup>2</sup>	% samples >120 - ≤200 mg chl-a/m <sup>2</sup>	% samples >200 mg chl-a/m <sup>2</sup>
12 Mile Creek at Glen-Queenstown ad	28	A	100	0	0	0
25 Mile Creek at Glen-Queenstown Rd	28	A	100	0	0	0
Akatore Creek at Creek Road	26	B	73	19	0	8
Arrow River at Arrow Gorge Track	27	A	100	0	0	0
Arrow River at Morven Ferry Road	23	A	96	4	0	0
Blackcleugh Burn at Rongahere Road	25	B	88	8	0	0
Bullock Creek at Dunmore Street	27	B	70	26	0	4
Cardrona River at Mt Barker	25	A	100	0	0	0
Dart River at The Hillocks	22	A	100	0	0	0
Dunstan Creek at Beattie Road	24	A	96	4	0	0
Greenstone River at Greenstone Station Rd	28	A	100	0	0	0
Kaikorai Stream at Brighton Road	26	D	4	23	15	58
Kakanui River at McCones	25	D	12	20	24	44
Kye Burn at SH85 Bridge	22	A	95	5	0	0
Lindis River at Ardgour Road	21	B	57	38	5	0
Luggate Creek at SH6 Bridge	27	B	81	19	0	0
Manuherikia River at Blackstone Hill	21	B	81	14	5	0
Manuherikia River at Galloway	25	B	84	12	4	0
Manuherikia River at Ophir	24	B	83	13	4	0
Matukituki River at West Wanaka	24	A	96	4	0	0
Motatapu River at Wanaka Mt Aspiring Road	26	A	92	8	0	0
Oamaru Creek at SH1	27	D	0	11	26	63
Owaka River at Katea Road	21	C	48	33	19	0
Precipice Creek at Glenorchy Paradise Road	28	A	100	0	0	0
Shag River at Goodwood Pump	27	D	26	26	33	15
Silver Stream at Taieri Depot	26	C	50	38	12	0
Tahakopa River at Tahakopa	22	A	95	5	0	0
The Neck Creek at Meads Road	26	A	96	4	0	0
Tokomairaro River at West Branch Bridge	25	B	88	4	8	0
Turner Creek at Kinloch Road	28	B	86	14	0	0
Upper Pomahaka River at Aitchisons Run Rd	24	A	100	0	0	0
Waianakarua River at Browns	27	D	44	22	22	11
Waipahi River at Waipahi	19	C	84	5	11	0
Waitahuna River at Tweeds Bridge	22	A	95	5	0	0

## Phytoplankton (Chlorophyll *a*) (NPSFM 2020, Appendix 2A, Table 1)

Phytoplankton is a key limnological variable for measurement because it represents a large proportion of the total energy available to the food webs of many lakes. Chlorophyll *a* concentration in the water is a measure of phytoplankton biomass and can be a robust indicator of nutrient enrichment. The NPSFM 2020 specifies attributes for trophic state based phytoplankton biomass in lakes (Table 13). Chl<sub>a</sub> is the measure of biomass that the NOF periphyton attributes are based on, and the results are shown in Table 14.

Phytoplankton is monitored monthly as part of ORC's lake monitoring programme. The results are presented in Table 15. Of the sites monitored, nine had negligible nutrient enrichment and met the A band requirements, Lake Hayes met the 'C' band for the annual median value, but was below the national bottom line for the annual maximum value, indicating that the lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes. Both Lake Waihola and Lake Tuakitoto met the 'B' band for the annual median chlorophyll *a* value and the 'C' band for the annual maximum chlorophyll *a* value.

## Phytoplankton (Chlorophyll *a*) results

**Table 13: Phytoplankton trophic state NPSFM 2020, Appendix 2A, Table 1**

		mg chl- <i>a</i> / m <sup>3</sup> (milligrams chlorophyll- <i>a</i> per cubic metre)	
	Description	Annual Median	Annual Maximum
A	Lake ecological communities are healthy and resilient, similar to natural reference conditions.	≥2	≥10
B	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions	>2 and ≤5	>10 and ≤25
C	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.	>5 and ≤12	>25 and ≤60
	National bottom line	12	60
D	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	>12	>60

**Table 14: Attribute bands for Phytoplankton, based on chlorophyll *a* average score (mg per m<sup>2</sup>) at each site**

Site	#samples	Annual median		Annual maximum	
		Median	Grade	Maximum	Grade
Lake Dunstan at Dead Mans Point	12	0.450	A	1.800	A
Lake Hawea South Open Water 10m	11	0.001	A	0.770	A
Lake Hayes at Mid Lake 10m	12	8.537	C	94.000	D
Lake Onslow at Boat Ramp	11	0.008	A	4.100	A
Lake Tuakitoto at Outlet	12	4.550	B	34.000	C
Lake Waihola at Waihola Mid	4	4.600	B	27.000	C
Lake Wakatipu at Frankton Arm 10m	12	0.186	A	6.000	A
Lake Wakatipu at Queenstown Bay 10m	12	0.256	A	1.200	A
Lake Wakatipu Open Water 10m	10	0.001	A	0.002	A
Lake Wanaka at Glendu Bay 10m	12	0.241	A	0.920	A
Lake Wanaka at Roy's Bay 10m	12	0.206	A	1.100	A
Lake Wanaka Open Water 10m	12	0.261	A	0.890	A

## Deposited Sediment (NPSFM 2020, Appendix 2B, Table 16)

Excess sediment directly affects the health of a waterway, decreasing its mauri or life-supporting capacity. Deposited fine sediment occurs naturally in the beds of rivers and streams. It usually enters a stream because of terrestrial weathering processes or bank erosion and in-stream fluvial processes. Because sediment is naturally transported longitudinally through a river network, its state at any given point will be influenced by climate, geology, topography, and current velocity. Human activities can affect this natural sediment cycle by accelerating sediment delivery to streams and increasing the quantity of smaller particle sizes. The effect of excess in-stream sedimentation is recognised as a major impact of changing land use on river health. In particular, sediment alters the physical habitat by clogging interstitial spaces used as refugia by benthic invertebrates and fish, altering food resources, and removing sites used for egg-laying. As such, sediment can affect the diversity and composition of biotic communities. Excess sediment can also affect the aesthetic appeal of rivers and streams for human recreation.

The sediment cover assessment programme comprised 35 sites sampled monthly. The indicator score is the percentage cover of the streambed in a run habitat determined by the instream visual method, SAM2, as defined in Clapcott *et al.*, 2011.

The NPSFM 2020 specifies attributes for deposited fine sediment (Table 15). The 24 months of monitoring falls short of the five years required by the NPSFM. The results presented in Table 16 are therefore interim. Each site was graded according to its median score over 24 months and its deposited sediment class (NPSFM, 2020 Table 24).

All sites obtained an A grade, other than the Matukituki River (C grade), the Tahakopa River (B grade), the Waitahuna River (B grade) and the Waipahi River at Waipahi (B grade)

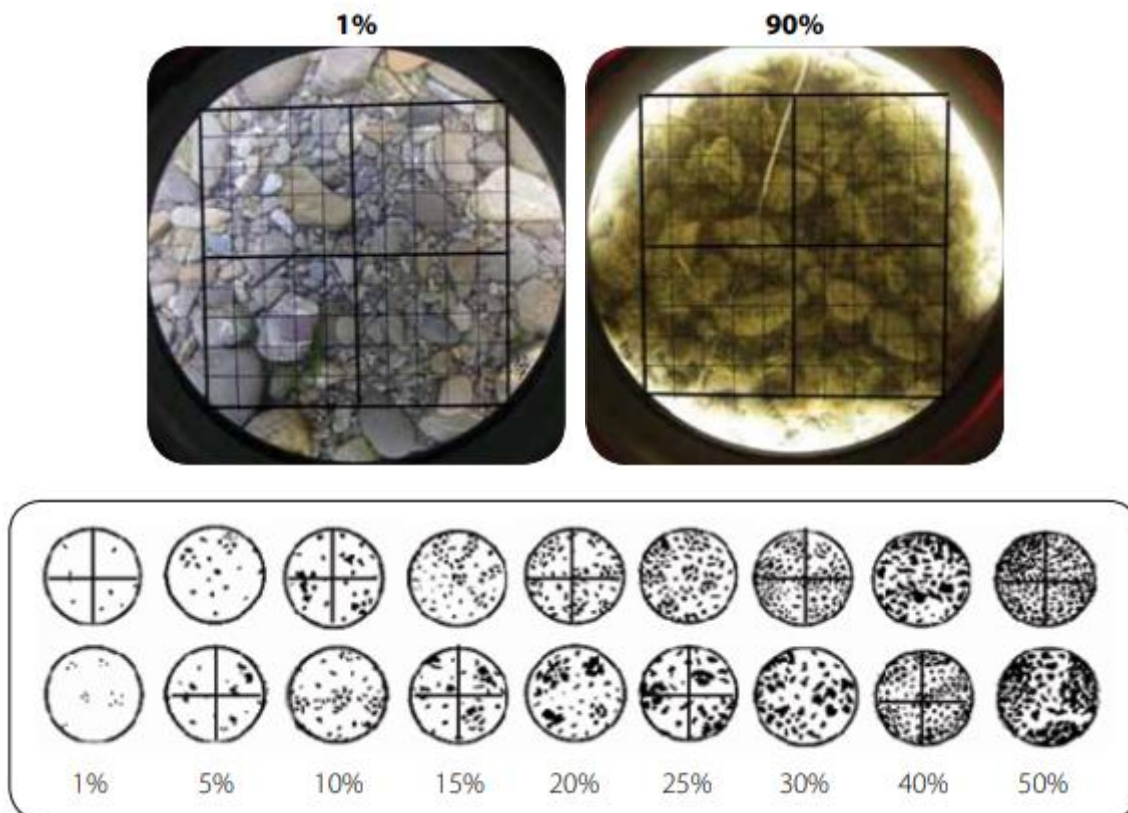


Figure 6. Real examples of percent cover of sediment on the streambed as seen through an underwater viewer and examples of percent cover of sediment on the streambed as seen through an underwater viewer (Clapcott *et.al.*, 2011)

## Deposited sediment results

**Table 15: Deposited fine sediment NPSFM 2020, Appendix 2B, Table 16**

	Description	% fine sediment cover			
		Numeric attribute state by deposited sediment class			
		1	2	3	4
A	Minimal impact of deposited fine sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.	≤7	≤10	≤9	≤13
B	Low to moderate impact of deposited fine sediment on instream biota. Abundance of sensitive macroinvertebrate species may be reduced	>7 and ≤14	>10 and ≤19	>9 and ≤18	>13 and ≤19
C	Moderate to high impact of deposited fine sediment on instream biota. Sensitive macroinvertebrate species may be lost.	>14 and ≤21	>19 and ≤29	>18 and ≤27	>19 and ≤27
	National bottom line	21	29	27	27
D	High impact of deposited fine sediment on instream biota. Ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.	>21	>29	>27	>27

**Table 16: Deposited sediment median result and interim grade at each site, for months monitored between July 2019 and June 2021.**

Site	# samples	Deposited Sediment Class (NPSFM)	Median % fine sediment cover
12 Mile Creek at Glenorchy Queenstown Road	20	4	0.25
25 Mile Creek at Glenorchy Queenstown Road	20	4	3.25
Akatore Creek at Akatore Creek Road	19	3	1.75
Arrow at Morven Ferry Road	16	3	0.00
Arrow River at Arrow Gorge Track	20	3	5.75
Blackcleugh Burn at Rongahere Road	15	4	0.65
Bullock Creek at Dunmore Street Footbridge	19	3	4.48
Cardrona at Mt Barker	17	2	3.63
Dart at The Hillocks	12	4	0.20
Dunstan Creek at Beattie Road	18	4	3.10
Greenstone at Greenstone Station Road	20	4	0.00
Kaikorai Stream at Brighton Road	19	3	0.00
Kakanui at McCones	18	2	0.00
Kye Burn at SH85 Bridge	16	2	6.13
Lindis at Ardgour Road	13	2	0.50
Luggate Creek at SH6 Bridge	18	4	0.00
Manuherikia at Blackstone Hill	15	2	5.05
Manuherikia at Galloway	12	2	0.55
Manuherikia at Ophir	13	2	2.40
Matukituki at West Wanaka Station	15	4	16.88
Motatapu at Wanaka Mt Aspiring Road	17	4	4.50
Oamaru Creek at SH1	19	3	0.10
Owaka at Katea Road	12	2	2.00
Precipice Creek at Glenorchy Paradise Road	19	4	3.05
Shag at Goodwood Pump	19	2	0.33
Silverstream at Taieri Depot	19	2	4.50
Tahakopa at Tahakopa	13	2	10.35
The Neck Creek at Meads Road	19	4	2.38
Tokomairiro at West Branch Bridge	17	2	1.63
Turner Creek at Kinloch Road	20	4	0.50
Upper Pomahaka at Aitchison Runs Road	16	4	1.35
Waianakarua at Browns	19	2	0.00
Waipahi at Waipahi	13	3	8.75
Waitahuna at Tweeds Bridge	14	2	8.00

## Ecological Processes (NPSFM 2020, Appendix 2B, Table 21)

The NPS-FM 2020 introduced ecosystem metabolism (gross primary production and ecosystem respiration) as an action-planning attribute to assess the ecological processes component of the compulsory ecosystem health value in rivers. To measure ecosystem metabolism, the NPS-FM requires the deployment of a logger to continuously record dissolved oxygen and temperature for at least 7 days during the summer period. In the ecosystem health framework (Clapcott *et al.*, 2018), alternative measures of ecological processes are recommended, including a cotton strip assay (CSA). The CSA provides an estimate of organic matter processing and is less resource intensive to measure than ecosystem metabolism. However, the same as for ecosystem metabolism, there are currently no national guideline values (within the NPS-FM) for assessing ecological processes using this method. Cawthron explored the development of attribute bands for ORC to support the application of the CSA as an alternative action planning attribute (Wagenhoff *et al.*, 2020), the attribute bands are shown in Table 17.

Otago Regional Council initially deployed strips in February 2020, but because strips could not be retrieved due to Covid-19 restrictions, no data was generated. The assay was repeated in May–June 2020, when cotton strips were deployed for an average of 28 days at 34 sites. The 34 sites were spread across the FMUs.

Results are shown in Table 18. Of the 34 sites, three sites achieved an A band (Motatapu River, Silverstream and Waianakarua River), five sites a B band (Bullock Creek, Cardrona River, Dunstan Creek, Manuherekia at Blackstone Hill and The Neck Creek), ten sites a C band and the remaining sites were below the national bottom line, achieving a D band.



Figure 7. Cotton strip deployment, Tahakopa River, Catlins

## Ecological processes results

**Table 17 Interim organic matter processing attribute table for regional and national application.**

Percent cotton tensile strength loss per degree day (%CTSL dd-1 )		
	Description	Numeric attribute state
A	River ecological processes are healthy and resilient, like natural reference conditions.	$\leq 0.12$
B	River ecological processes are slightly impacted by nutrient levels that are elevated above natural reference conditions and/or by altered flows/habitat due to land use impacts	$>0.12$ and $\leq 0.24$
C	River ecological processes are moderately impacted by nutrient levels that are elevated above natural reference conditions and/or by altered flows/habitat due to land use impacts.	$>0.24$ and $\leq 0.37$
	National bottom line	0.37
D	River ecological processes are unhealthy and significantly impacted by nutrient levels that are elevated above natural reference conditions and/or by altered flows/habitat due to land use impacts.	$>0.37$

**Table 18 Percent cotton tensile strength loss per degree day (%CTSL dd -1) May-June 2020.**

Site	%ctsl/dd	Site	%ctsl/dd
12 Mile Creek at Glenorchy Queenstown Road	0.357	Motatapu at Wanaka Mt Aspiring Road	0.118
25 Mile Creek at Glenorchy Queenstown Road	0.563	Oamaru Creek at SH1	0.454
Akatore Creek at Akatore Creek Road	0.501	Owaka at Katea Road	0.554
Arrow at Morven Ferry Road	0.250	Precipice Creek at Glenorchy Paradise Road	0.297
Arrow River at Arrow Gorge Track	0.244	Shag at Goodwood Pump	0.413
Blackcleugh Burn at Rongahere Road	0.616	Silverstream at Taieri Depot	0.117
Buckler Burn at Glenorchy Queenstown Road	0.342	Tahakopa at Tahakopa	0.475
Bullock Creek at Dunmore Street Footbridge	0.209	Taieri at Outram	0.557
Cardrona at Mt Barker	0.169	Taieri at Sutton	0.400
Dart at The Hillocks	0.422	Taieri at Waipiata	0.735
Dunstan Creek at Beattie Road	0.232	The Neck Creek at Meads Road	0.262
Greenstone at Greenstone Station Road	0.405	Tokomairiro at West Branch Bridge	0.473
Luggate Creek at SH6 Bridge	0.319	Turner Creek at Kinloch Road	0.361
Manuherikia at Blackstone Hill	0.195	Upper Pomahaka at Aitchison Runs Road	0.271
Manuherikia at Galloway	0.374	Waianakarua at Browns	0.094
Manuherikia at Ophir	0.625	Waipahi at Waipahi	0.374
Matukituki at West Wanaka Station	0.276	Waitahuna at Tweeds Bridge	0.526



## References

Biggs, B., Kilroy, C. (2000) New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams. NIWA Client Report. Report no., 116 pp

Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M. and Death, R.G. (2011) Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute, Nelson, New Zealand.

Clapcott J, Young R, Sinner J, Wilcox M, Storey R, Quinn J, Daughney C, Canning A, 2018. Freshwater biophysical ecosystem health framework. Prepared for Ministry for the Environment. Cawthron Report No. 3194. 89 p. plus appendices.

NZ Government, 2020. National Policy Statement for Freshwater Management 2020

Otago Regional Council, 2004. Regional Plan: Water for Otago. Dunedin: Otago Regional Council

Wagenhoff A, Clapcott J, Goodwin E 2021. Thresholds to inform the setting of numeric targets for managing ecosystem health of Otago streams and rivers. Prepared for Otago Regional Council. Cawthron Report No. 3626. 54 p. plus appendices.