

Upper Barwon River Macroinvertebrate Sampling Report 2019-2023

- Final
- July 2023

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Document history and status

Revision	Date issued	Reviewed by	Approved by
Draft	15/06/2023	Kylie Iervasi	Dion Iervasi
Draft	23/06/2023	Will McCance	Kylie Iervasi
Final	14/07/2023	Kylie Iervasi	Kylie Iervasi

Printed:	17 July 2023
Last saved:	17 July 2023 03:08 PM
File name:	
Author:	Kylie Iervasi
Project manager:	Kylie Iervasi
Name of organisation:	Barwon Water
Name of project:	Barwon River/ Boundary Creek Survey
Name of document:	Upper Barwon River Macroinvertebrate Sampling Report 2019-2023
Document version:	Final
Project number:	

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1. Introduction

Austral Research and Consulting (Austral) were contracted by Barwon Water in Spring 2019 to undertake an investigation into the ecological condition of the upper Barwon River with regard to the extent of impact of low pH inflows from Boundary Creek.

The initial surveys determined a baseline for ongoing monitoring of the Barwon River as part of a remediation plan required by a section 78 Ministerial Notice and twice yearly monitoring is now carried out on sites along both the Upper Barwon River and Boundary Creek including Big Swamp.

1.1. Background

Studies have confirmed that historic groundwater extraction from the Barwon Downs borefield to boost Geelong's water supply in conjunction with a dry climate led to reductions in flows in lower Boundary Creek (Jacobs, 2017), an increased occurrence of wet-dry cycling and a decrease in groundwater levels. These factors led to the oxidation of naturally occurring acid sulfate soils in Big Swamp, thus releasing acid into the system and lowering the pH. This process has led to the discharge of acidity into the lower reaches of Boundary Creek, which flows into the Barwon River approximately 3.7 km downstream of Big Swamp.

A community and stakeholder working group was established in 2018 to develop a remediation plan for Big Swamp and Boundary Creek and the Boundary Creek, Big Swamp and Surrounding Environment - Remediation and Environmental Protection Plan (REPP) (Barwon Water, 2020) was released in December 2019 and updated in February 2020.

1.2. Objectives

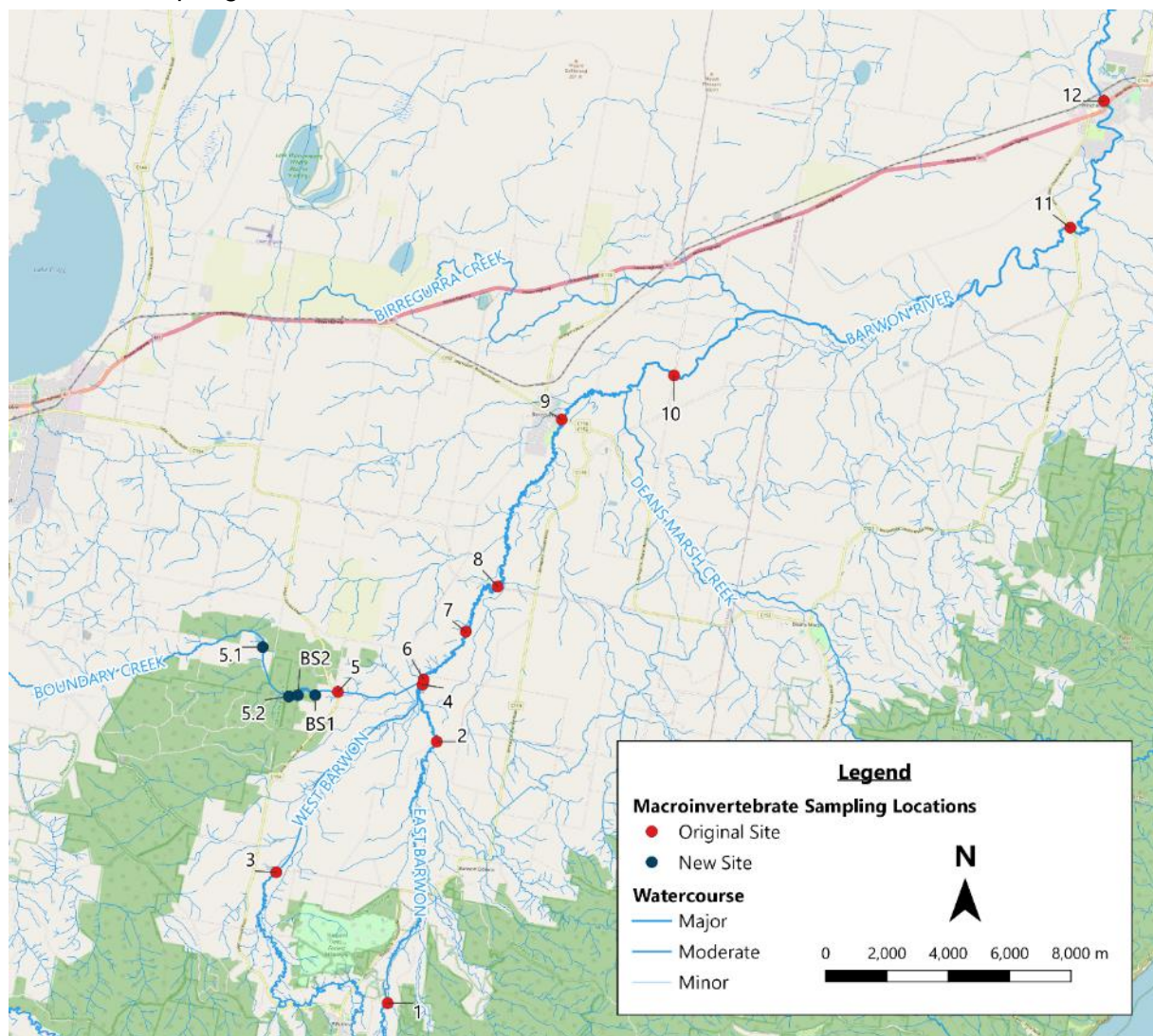
The objective of this report is to provide an overview of the ecological condition of Boundary Creek (including where it flows through Big Swamp) and the upper Barwon River.

1.3. Summary

As part of the REPP, Barwon Water has committed to continuing water quality and macroinvertebrate sampling along the Barwon River and within Boundary Creek to identify any changes in the conditions and assess the effectiveness of the remedial actions. Sampling biannually gives an indication of any impacts during higher flow (Spring) and lower flow (Autumn) conditions and will give an indication as to whether metals and altered pH are being mobilised and affecting the river system. The latest results indicate that whilst Boundary Creek is still being impacted by water quality from Big Swamp, metal concentrations and pH levels are improving, and the Barwon River continues to be in very good condition at most sites downstream of the Boundary Creek confluence.

2. Methods

A total of twelve sites were surveyed along East Barwon, West Barwon, and Barwon Rivers in addition to Boundary Creek (Figure 1) in Spring and Autumn in 2019 to 2023. A further four sites were surveyed on Boundary Creek and in Big Swamp along with the original twelve sites in Autumn 2022, Spring 2022 and Autumn 2023.



- **Figure 1: Barwon River and Boundary Creek (base map from Open Street Map).** Red markers are original sites, blue are new sites added in Autumn 2022. Big Swamp east (BS1) was sampled in Autumn and Spring 2022 and Autumn 2023 and Big Swamp west (BS2) in Spring 2022 and Autumn 2023.

2.1. Site Selection

Sites were selected in consultation with Barwon Water to best give an indication of the impact of water coming from Big Swamp on Boundary Creek and particularly the Barwon River. Two sites are on the East Barwon River, one site is on the West Barwon River, three sites are on Boundary Creek, two sites in Big Swamp (west site is intermittently dry) and eight sites are on the mainstem of the Barwon River. They incorporate existing Waterwatch sites, upstream sites that are unimpacted by Boundary Creek (sites 1-4) and sites focused on any impacts from Boundary Creek (Table 1).

- **Table 1: Site locations, descriptions and approximate distance from Boundary Creek/ Barwon River confluence.**

Site no.	Site description	Distance from Boundary Creek conf.	Latitude	Longitude
1	East Barwon River @ Kents Road	Upstream	-38.512196	143.732530
2	East Barwon River @ Dewings Bridge Road	Upstream	-38.434878	143.747933
3	West Barwon River @ Seven Bridges Road	Upstream	-38.474669	143.689396
4	Barwon River 50-100m u/s of Boundary Ck conf.	Upstream	-38.418236	143.742025
5	Boundary Creek @ Colac-Forrest Road	Boundary Creek	-38.421122	143.710475
6	Barwon River 100m d/s of Boundary conf.	100m	-38.416717	143.742383
7	Barwon River @ north boundary of plantation	3.7km	-38.402291	143.757554
8	Barwon River @ Colac-Lorne Road	7.5km	-38.388771	143.768956
9	Barwon River @ Birregurra	17.6km	-38.339105	143.790971
10	Barwon River @ Conns Lane	21.7km	-38.325134	143.832385
11	Barwon River @ Winchelsea- Deans Marsh Road	42.4km	-38.278018	143.978382
12	Barwon River @ Princes Hwy bridge, Winchelsea	50.6km	-38.240445	143.989326
5.1	Boundary Creek @ d/s McDonalds Dam	Boundary Creek	-38.408599	143.681938
5.2	Boundary Creek @ u/s Big Swamp	Boundary Creek	-38.422875	143.692198
BS1	Big Swamp @ eastern end	Big Swamp	-38.422270	143.702076
BS2	Big Swamp @ western end	Big Swamp	-38.423042	143.695382

In Autumn 2023 the location of Site 4 was changed due to access issues resulting in sampling being conducted on the opposite bank, closer to the confluence with Boundary Creek. This will likely remain the site location unless other access can be arranged.

2.2. Sampling methodology

Macroinvertebrates and *in situ* water quality, vegetation, site descriptions and photos were collected with specific sampling methods detailed below.

2.2.1. In-situ water quality

In-situ water quality parameters were measured at each site including dissolved oxygen (mg/L), temperature (°C), specific conductivity (µS/cm) and pH using a YSI ProPlus water quality meter. Turbidity (NTU) and alkalinity (mg/L) were measured using HACH meters and test kits respectively.

2.2.2. Metals in water

Water samples were collected for metals analysis, field filtered using 0.45µm membrane filter, using bottles containing Nitric Acid (HNO₃) preservative and kept refrigerated prior to delivery to the NATA accredited ALS Laboratory.

2.2.3. Macroinvertebrates

Macroinvertebrates were collected at each site and photos and site assessment sheets were completed as per Victorian EPA guidelines (EPA Victoria, 2021). In the absence of riffle habitats, two edge samples (labelled A and B) were collected (EPA Victoria, 2021) using a 250µm mesh dip net to sample ten metres of representative habitat at two locations at each site on the 18th and 19th April, 2023. The contents of the net were placed into a white tray to be picked through for 30 minutes with the aim of picking over 100 animals into 70% ethanol for later identification to family level following the Rapid Bioassessment Methodology for Rivers and Streams (EPA Victoria, 2021). Macroinvertebrates were identified in the laboratory in accordance with the guidelines; to class for Oligochaeta and Mites, chironomids to sub-family and all other taxa to family except those that are not included in EPA Victoria biotic calculations (EPA Victoria, 2021).

2.2.4. Site descriptions

EPA Victoria field sampling and habitat assessment sheets were filled out at each site and site photos taken (EPA Victoria, 2021). This information has been summarised in Appendix 1. The reported habitat parameter score is not expected to change over the short term unless works have been undertaken at the site such as riparian revegetation, fencing, large woody debris introduction or the site is experiencing changes in flow such as drought conditions.

3. Results

3.1. Water Quality

The *in situ* water quality information in Table 2 below gives an indication of the conditions at the time of sampling.

■ **Table 2: In-situ water quality data- Spring 2019 to Autumn 2023**

Site Waterway	Season	Temp. (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm@25°C)	Dissolved oxygen (DO) (mg/L)	DO %	Alkalinity (mg/L)	Turbidity (NTU)
Site 1 East Barwon River@ Kents Road	Spring 19	13.2	6.2	186.7	240	13.07	123	5	9.09
	Autumn 20	14	8.67	161.8	210.2	4.42	47.5	5	2.6
	Spring 20	16.0	7.2	123.7	149.5	7.79	80.1	35	2.88
	Autumn 21	10.6	6.5	93.5	129.0	7.59	68.7	25	8.5
	Spring 21	12.2	6.59	120.5	159.7	9.92	94.2	30	5.86
	Autumn 22	12.0	6.96	209.7	279.3	8.40	77.7	30	26.2
	Spring 22	14.5	7.62	178.5	223.4	3.64	35.7	25	6.97
	Autumn 23	13.6	7.23	150.5	193.0	5.56	54.1	35	4.68
Site 2 East Barwon River @ Dewings Bridge Road	Spring 19	15.5	6.3	544	664	6.8	66.8	10	9.97
	Autumn 20	16	7.71	180.7	218.2	5.85	59.9	10	9.49
	Spring 20	16.2	7.6	272.0	327.3	10.86	110.4	55	9.35
	Autumn 21	11.2	6.58	228.9	311.8	8.21	74.2	35	8.2
	Spring 21	16.6	6.65	220.1	245.4	9.02	94.5	40	7.88
	Autumn 22	14.5	6.53	387.7	484.1	12.54	120.9	45	12.9
	Spring 22	13.4	7.63	250.4	321.7	3.30	31.8	35	18.3
	Autumn 23	17.2	7.35	276.6	326.2	4.47	47.1	45	10.2
Site 3 West Barwon River@ Seven Bridges Road	Spring 19	14.7	5.26	473.4	590.6	7.3	73.5	10	16.3
	Autumn 20	14.4	8.23	179.6	224.0	4.45	42.9	10	3.28
	Spring 20	12.7	7.1	195.2	255.0	6.12	56.3	50	5.58
	Autumn 21	9.7	7.3	165.1	233.4	7.21	63.9	30	3.65
	Spring 21	14.7	6.73	179.1	221.1	6.63	66.4	35	3.54
	Autumn 22	10.6	7.02	240.7	331.5	7.49	67.5	30	3.43
	Spring 22	12.5	7.51	256.6	336.7	3.01	28.3	40	12.7
	Autumn 23	14.8	6.56	196.7	245.0	4.80	47.4	35	4.29
Site 4	Spring 19	17.9	7.4	575	664	9.15	96.4	10	8.01

Site Waterway	Season	Temp. (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm@25°C)	Dissolved oxygen (DO) (mg/L)	DO %	Alkalinity (mg/L)	Turbidity (NTU)
Barwon River 50-100m upstream of Boundary Creek confluence	Autumn 20	17	6.60	211.2	248.4	6.08	64.3	10	41.5
	Spring 20	14.1	7.4	248.1	326.1	8.25	80.5	55	17.7
	Autumn 21	10.8	7.03	224.3	308.7	7.96	71.2	35	14.2
	Spring 21	17.3	6.88	242.3	277.4	8.06	83.5	45	12.6
	Autumn 22	13.6	7.31	423.4	541.6	9.73	93.5	45	30.5
	Spring 22	Site not accessible due to high water							
	Autumn 23	16.2	6.91	370	444.7	4.91	50	40	12.6
Site 5.1 Boundary Creek downstream of McDonalds Dam	Autumn 22	13.2	6.81	461	694	6.23	59.5	35	3.29
	Spring 22	14.6	7.35	290.9	361.8	3.27	32.2	40	14.2
	Autumn 23	14.4	6.69	369.6	463.6	5.53	54.2	20	12.5
Site 5.2 Boundary Creek upstream of Big Swamp	Autumn 22	8.9	6.72	410	592	10.18	87.2	30	5.07
	Spring 22	14.0	6.63	280.8	355.8	3.68	35.8	40	13.8
	Autumn 23	13.3	7.14	354.8	457.3	5.26	50.4	20	10.1
Site BS2 Big Swamp western end	Spring 22	14.7	5.87	272.2	338.4	2.06	20.6	20	9.64
	Autumn 23	13.9	5.38	334.1	424.2	3.24	31.2	10	3.97
Site BS1 Big Swamp eastern end	Autumn 22	9.6	5.48	656	929	2.2	22.5	10	20.1
	Spring 22	13.7	6.30	306.4	390.3	2.90	28.0	30	26.9
	Autumn 23	13.6	5.87	491.6	384.5	3.13	30.2	20	17.4
Site 5 Boundary Creek@ Colac-Forrest Road	Spring 19	12.1	3.94	777	1030	7.43	67.6	0	2.92
	Autumn 20	10.4	4.05	680	944	2.05	18.5	0	260
	Spring 20	12.9	3.1	614	798	5.31	50.6	0	6.82
	Autumn 21	10.0	4.0	286.6	401.2	8.76	76.8	20	35.7
	Spring 21	14.6	6.05	364.5	453.7	8.10	87.7	20	75.3
	Autumn 22	10.4	4.75	830	1152	7.37	66.2	0	22.3
	Spring 22	13.9	6.02	328.4	416.5	3.69	35.2	20	36.9
	Autumn 23	13.3	5.49	386	497.1	4.14	39.2	10	42.0
	Spring 19	14.4	7.34	608	756	7.3	71.3	10	9.43
Site 6 Barwon River 100m downstream of Boundary Creek confluence	Autumn 20	15.8	6.88	207.7	250.6	6.58	66.1	10	31.7
	Spring 20	13.9	7.0	298.5	378.8	6.88	67.1	50	12.2
	Autumn 21	10.9	7.19	254.2	347.7	7.03	62.9	25	20.6

Site Waterway	Season	Temp. (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm@25°C)	Dissolved oxygen (DO) (mg/L)	DO %	Alkalinity (mg/L)	Turbidity (NTU)
Site 7 Barwon River @ north boundary of plantation	Spring 21	16.7	7.48	262.2	310.8	6.20	66.3	30	18.5
	Autumn 22	12.4	7.25	477	628	9.38	88.1	35	12.5
	Spring 22	15.2	6.20	304.8	374.6	3.67	35.9	30	18.1
	Autumn 23	16.8	6.90	398	472	4.15	43.0	35	11.8
	Spring 19	13.4	7.9	599	770	7.2	71.7	5	10
	Autumn 20	15.4	6.46	207.9	256.2	7.46	75.6	5	21.8
	Spring 20	14.2	7.1	276.6	348.2	7.15	69.7	45	13.6
	Autumn 21	10.7	7.14	258.1	354.6	6.78	61.9	20	17.9
Site 8 Barwon River @ Colac-Lorne Road	Spring 21	15.7	7.62	254.2	309.0	6.72	68.5	45	12.87
	Autumn 22	14.5	7.04	510	637	9.09	91.7	35	12.9
	Spring 22	13.3	7.95	304.7	392.6	3.67	35.3	35	21.7
	Autumn 23	16.5	6.92	386	459	3.68	45.9	30	19.7
	Spring 19	16.2	7.8	660	795	8.8	87.9	10	13.5
	Autumn 20	15.9	6.79	234.8	284.8	3.22	32	10	5.13
	Spring 20	16.3	7.3	286.3	344.2	6.55	67.7	50	5.61
	Autumn 21	11.0	6.74	255.8	350.3	7.10	64.2	25	12.4
Site 9 Barwon River @ Birregurra	Spring 21	16.9	7.35	244.3	255.7	6.75	70.4	35	13.0
	Autumn 22	13.7	7.21	552	701	6.14	59.1	35	4.04
	Spring 22	14.0	7.69	322.1	407.4	3.33	32.6	40	20.9
	Autumn 23	15.5	6.89	449	368	3.58	36.0	35	15.1
	Spring 19	15.4	7.8	1049	1288	9.7	98	15	16.6
	Autumn 20	16.2	6.79	494.4	600.6	6.65	69.8	15	11.1
	Spring 20	16.7	7.5	477.8	568.1	8.28	86.6	25	16.2
	Autumn 21	10.0	7.62	372.9	523.3	7.69	67.0	40	23.7
Site 10	Spring 21	16.8	7.15	366.0	437.5	7.61	77.5	45	32.4
	Autumn 22	14.1	7.56	1115	1412	9.88	92.7	55	9.25
	Spring 22	16.0	6.63	574	694	4.24	43.0	45	65.9
	Autumn 23	15.2	7.28	810	996	3.92	39.1	40	19.0
	Spring 19	14.6	7.9	1252	1561	8.1	86.1	15	18
	Autumn 20	16.2	5.56	511	613	3.96	40.2	15	19.2

Site Waterway	Season	Temp. (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm@25°C)	Dissolved oxygen (DO) (mg/L)	DO %	Alkalinity (mg/L)	Turbidity (NTU)
Barwon River @Conns Lane	Spring 20	15.6	7.5	756	920	7.45	76.2	75	22.2
	Autumn 21	11.1	7.14	372.5	506.5	9.03	81.5	40	33.7
	Spring 21	16.8	7.29	276.3	461.3	8.05	84.7	45	19.9
	Autumn 22	14.5	7.44	1399	1119	7.09	67.5	60	19.5
	Spring 22	15.6	6.78	643	783	3.80	37.7	50	58.5
	Autumn 23	14.9	7.39	901	1117	4.85	47.8	60	29.1
Site 11 Barwon River @Winchelsea- Deans Marsh Road	Spring 19	13	7.9	1707	2227	9.23	87	15	26.1
	Autumn 20	15.6	6.26	762	929	3.62	35.2	15	13.3
	Spring 20	15.5	7.6	863	1054	6.28	64.7	75	13.7
	Autumn 21	11.0	6.82	401.9	548.8	8.35	74.1	40	31.5
	Spring 21	16.5	7.39	444.1	589.3	7.34	75.6	45	21.1
	Autumn 22	12.4	7.46	1369	1805	7.02	65.3	70	16.2
	Spring 22	14.6	8.25	1563	1950	5.02	49.7	85	81.0
	Autumn 23	14.5	7.42	733	919	4.92	48.1	55	33.7
Site 12 Barwon River@ Princes Hwy bridge, Winchelsea	Spring 19	12.4	8	1788	2364	8.4	82.1	15	19.9
	Autumn 20	15.9	6.69	924	1117	5.25	54.5	15	20.7
	Spring 20	15.0	7.6	1048	847	6.25	62.8	85	17.1
	Autumn 21	10.8	6.93	466.1	639.8	8.18	72.7	40	31.2
	Spring 21	17.1	7.61	733	622	7.06	79.3	50	19.6
	Autumn 22	13.8	7.48	1737	2209	6.54	63.2	80	9.71
	Spring 22	15.5	8.06	1528	1868	3.66	36.9	85	85.5
	Autumn 23	14.5	7.37	797	997	7.85	76.5	75	24.9

Autumn typically has lower pH than in spring as was the case in Autumn 2023. Big Swamp (Sites BS1&2) and Boundary Creek downstream of the swamp (Site 5) recorded pH levels between 5 and 6 but pH levels in the Barwon River (Sites 6 and beyond) were similar to the Barwon River sites upstream. Conductivity in Autumn 2023 was mostly lower than Autumn 2022 but higher than Autumn 2021.

- Table 3: Metal results (0.45µm filtered) for freshwater samples (mg/L) and Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2019). In all but two instances the 95% level of species protection is applied as is recommended for slightly to moderately disturbed ecosystems. Shaded cells indicate exceedance of guideline values.

Site Waterway	Sampling event	Filtered Metal Concentration (mg/L)												
		Aluminium	Antimony	Arsenic (total)	Cadmium	Chromium (total)	Copper	Iron	Lead	Manganese	Mercury	Selenium	Silver	Zinc
Toxicant default guideline values		0.055 (>6.5pH) 0.8# (<6.5pH)	0.009#	AsIII 0.024 AsV 0.013	0.0002	CrIII 0.0003 CrVI 0.001	0.0014	-	0.0034	1.9	0.00006^	0.005^	0.00005	0.008
Site 1 East Barwon River@ Kents Road	Spring 19	< 0.05*	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.33	< 0.001	0.04	< 0.0001	< 0.001	< 0.005	0.032
	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.21	< 0.001	0.007	< 0.0001	< 0.001	< 0.005	< 0.005
	Summer21	0.06	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.68	< 0.001	< 0.005	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.04	<0.001	<0.001	<0.0002	<0.001	<0.001	0.35	<0.001	0.046	<0.0001	<0.001	<0.001	0.002
	Spring 21	0.03	<0.001	<0.001	<0.0002	<0.001	<0.001	0.21	<0.001	0.015	<0.0001	<0.001	<0.001	<0.001
	Autumn 22	0.02	0.008	<0.001	<0.0002	<0.001	<0.001	0.42	<0.001	0.31	<0.0001	<0.001	<0.001	0.009
	Spring 22	0.03	<0.001	<0.001	<0.0002	<0.001	<0.001	0.34	<0.001	0.031	<0.0001	<0.001	<0.001	0.005
	Autumn 23	<0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.24	<0.001	0.052	<0.0001	<0.001	<0.001	0.004
Site 2 East Barwon River@ Dewings Bridge Road	Spring 19	< 0.05*	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.4	< 0.001	0.15	< 0.0001	< 0.001	< 0.005	0.008
	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.08	< 0.001	0.037	< 0.0001	0.001	< 0.005	< 0.005
	Summer21	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.22	< 0.001	0.006	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.19	<0.001	0.057	<0.0001	<0.001	<0.001	0.005
	Spring 21	0.02	<0.001	<0.001	<0.0002	<0.001	<0.001	0.30	<0.001	0.010	<0.0001	<0.001	<0.001	0.004
	Autumn 22	<0.01	0.006	<0.001	<0.0002	<0.001	<0.001	0.10	<0.001	0.028	<0.0001	<0.001	<0.001	0.006
	Spring 22	0.02	<0.001	<0.001	<0.0002	<0.0001	<0.001	0.51	<0.001	0.063	<0.0001	<0.001	<0.001	0.004
	Autumn 23	<0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.11	<0.001	0.040	<0.0001	<0.001	<0.001	0.005
Site 3 West Barwon River@ Seven Bridges Road	Spring 19	< 0.05*	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.31	< 0.001	0.31	< 0.0001	< 0.001	< 0.005	0.051
	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	< 0.05	0.004	0.015	< 0.0001	< 0.001	< 0.005	< 0.005
	Summer21	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.09	< 0.001	0.12	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.21	<0.001	0.035	<0.0001	<0.001	<0.001	0.006
	Spring 21	0.03	<0.001	<0.001	<0.0002	<0.001	<0.001	0.65	<0.001	0.005	<0.0001	<0.001	<0.001	0.007
	Autumn 22	<0.01	0.004	<0.001	<0.0002	<0.001	<0.001	0.13	<0.001	0.081	<0.0001	<0.001	<0.001	0.014
	Spring 22	0.06	<0.001	<0.001	<0.0002	<0.001	0.003	1.1	<0.001	0.34	<0.0001	<0.001	<0.001	0.015
	Autumn 23	<0.01	<0.001	<0.001	<0.0002	<0.001	0.001	0.12	0.010	0.067	<0.0001	<0.001	<0.001	0.014
Site 4	Spring 19	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.33	< 0.001	0.15	< 0.0001	< 0.001	< 0.005	0.017

Site Waterway	Sampling event	Filtered Metal Concentration (mg/L)												
		Aluminium	Antimony	Arsenic (total)	Cadmium	Chromium (total)	Copper	Iron	Lead	Manganese	Mercury	Selenium	Silver	Zinc
Barwon River 100m upstream of Boundary Creek confluence	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.14	< 0.001	0.35	< 0.0001	< 0.001	< 0.005	< 0.005
	Summer21	<0.05	< 0.005	< 0.001	<0.0002	< 0.001	< 0.001	0.33	< 0.001	0.019	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.19	<0.001	0.06	<0.00010.2	<0.001	<0.001	0.002
	Spring 21	0.03	<0.001	<0.001	<0.0002	<0.001	<0.001	0.71	<0.001	0.008	<0.0001	<0.001	<0.001	0.011
	Autumn 22	<0.01	0.003	<0.001	<0.0002	<0.00	0.001	0.05	<0.001	0.095	<0.0001	<0.001	<0.001	0.014
	Spring 22	Site not accessible due to high water												
	Autumn 23	<0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.10	<0.001	0.13	<0.0001	<0.001	<0.001	0.006
Site 5.1 Boundary Creek downstream of McDonalds Dam	Autumn 22	<0.01	0.002	<0.001	<0.0002	<0.001	<0.001	0.39	<0.001	0.015	<0.0001	<0.001	<0.001	0.007
	Spring 22	0.19	<0.001	0.001	<0.0002	<0.001	<0.001	2.8	0.001	0.25	<0.0001	<0.001	<0.001	0.004
	Autumn 23	0.02	<0.001	<0.001	<0.0002	<0.001	<0.001	0.37	<0.001	0.070	<0.0001	<0.001	<0.001	0.006
Site 5.2 Boundary Creek upstream of Big Swamp	Autumn 22	0.01	0.002	0.001	<0.0002	<0.001	<0.001	0.59	<0.001	0.019	<0.0001	<0.001	<0.001	0.007
	Spring 22	0.20	<0.001	0.001	<0.0002	<0.001	<0.001	2.4	<0.001	0.046	<0.0001	<0.001	<0.001	0.004
	Autumn 23	0.02	<0.001	<0.001	<0.0002	<0.001	<0.001	0.43	<0.001	0.030	<0.0001	<0.001	<0.001	0.004
Site BS2 Big Swamp western end	Autumn 23	0.09*	<0.001	0.002	<0.0002	<0.001	<0.001	2.0	<0.001	0.019	<0.0001	<0.001	<0.001	0.016
Site BS1 Big Swamp eastern end	Autumn 22	0.26*	<0.001	0.003	<0.0002	0.001	0.002	48	<0.001	0.024	<0.0001	<0.001	<0.001	0.023
	Autumn 23	0.31*	<0.001	0.003	<0.0002	0.001	<0.001	31	<0.001	0.018	<0.0001	<0.001	<0.001	0.016
Site 5 Boundary Creek@ Colac-Forrest Road	Spring 19	10*	< 0.005	< 0.001	0.0002	< 0.001	< 0.001	5.4	< 0.001	0.06	< 0.0001	< 0.001	< 0.005	0.34
	Autumn20	< 0.05*	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	17	< 0.001	0.18	< 0.0001	< 0.001	< 0.005	0.015
	Summer21	7.2*	< 0.005	0.001	<0.0002	0.001	< 0.001	40	< 0.001	0.061	< 0.0001	0.001	< 0.005	0.23
	Autumn21	1.6*	<0.001	0.004	<0.0002	<0.001	0.005	50	<0.001	0.024	<0.0001	0.003	<0.001	0.08
	Spring 21	1.2*	<0.001	<0.0002	<0.0002	<0.001	<0.001	1.3	<0.001	0.034	<0.0001	<0.001	<0.001	0.11
	Autumn 22	1.2*	0.003	0.006	<0.0002	<0.001	<0.001	51	0.003	0.042	<0.0001	0.001	<0.001	0.10
	Spring 22	1.2*	<0.001	0.004	<0.0002	0.002	<0.001	20	<0.001	0.030	<0.0001	0.001	<0.001	0.052
	Autumn 23	0.40*	<0.001	0.003	<0.002	0.002	<0.001	29	<0.001	0.027	<0.0001	<0.001	<0.001	0.059
Site 6 Barwon River 100m downstream of Boundary Creek confluence	Spring 19	0.09	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.13	< 0.001	0.17	< 0.0001	< 0.001	< 0.005	0.057
	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.17	< 0.001	0.16	< 0.0001	< 0.001	< 0.005	< 0.005
	Summer21	<0.05	< 0.005	< 0.001	<0.0002	< 0.001	< 0.001	0.69	< 0.001	0.29	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.07	<0.001	<0.001	<0.0002	<0.001	<0.001	2	<0.001	0.069	<0.0001	<0.001	<0.001	0.012

Site	Waterway	Sampling event	Filtered Metal Concentration (mg/L)											
			Aluminium	Antimony	Arsenic (total)	Cadmium	Chromium (total)	Copper	Iron	Lead	Manganese	Mercury	Selenium	Silver
	Spring 21	0.06	<0.001	<0.001	<0.0002	<0.001	0.001	1.3	<0.001	0.010	<0.0001	<0.0001	<0.001	0.016
	Autumn 22	0.02	0.002	<0.001	<0.0002	<0.001	<0.001	0.19	<0.001	0.11	<0.0001	<0.001	<0.001	0.014
	Spring 22	0.11	<0.001	<0.001	<0.0002	<0.001	<0.001	1.8	<0.001	0.13	<0.0001	<0.001	<0.001	0.006
	Autumn 23	0.02	<0.001	<0.001	<0.0002	<0.001	<0.001	0.27	<0.001	0.13	<0.0001	<0.001	<0.001	0.009
Site 7 Barwon River @ north boundary of plantation	Spring 19	0.07	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.15	< 0.001	0.08	< 0.0001	< 0.001	< 0.005	0.013
	Autumn20	< 0.05*	< 0.005	< 0.001	< 0.0002	< 0.001	0.001	0.09	< 0.001	0.01	< 0.0001	< 0.001	< 0.005	0.006
	Summer21	0.06	< 0.005	< 0.001	<0.0002	< 0.001	< 0.001	0.37	< 0.001	0.023	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.07	<0.001	<0.001	<0.0002	<0.001	<0.001	0.61	<0.001	0.072	<0.0001	<0.001	<0.001	0.009
	Spring 21	0.05	<0.001	<0.001	<0.0002	<0.001	0.002	1.2	<0.001	0.005	<0.0001	<0.001	<0.001	0.040
	Autumn 22	0.01	0.002	<0.001	<0.0002	<0.001	<0.001	0.05	<0.001	0.14	<0.0001	<0.001	<0.001	0.008
	Spring 22	0.10	<0.001	0.001	<0.0002	<0.001	<0.001	1.9	<0.001	0.086	<0.0001	<0.001	<0.001	0.006
	Autumn 23	0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.17	<0.001	0.14	<0.0001	<0.001	<0.001	0.007
Site 8 Barwon River @ Colac- Lorne Road	Spring 19	0.1	< 0.005	< 0.001	< 0.0002	< 0.001	0.001	0.23	< 0.001	0.066	< 0.0001	< 0.001	< 0.005	0.015
	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	< 0.05	< 0.001	< 0.005	< 0.0001	< 0.001	< 0.005	< 0.005
	Summer21	<0.05	< 0.005	< 0.001	<0.0002	< 0.001	<0.001	0.24	< 0.001	<0.005	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.04	<0.001	<0.001	<0.0002	<0.001	<0.001	0.33	<0.001	0.031	<0.0001	<0.001	<0.001	0.005
	Spring 21	0.05	<0.001	<0.001	<0.0002	<0.001	<0.001	1.2	<0.001	0.021	<0.0001	<0.001	<0.001	0.012
	Autumn 22	<0.01	0.001	<0.001	<0.0002	<0.001	<0.001	0.04	<0.001	0.052	<0.0001	<0.001	<0.001	0.012
	Spring 22	0.09	<0.001	<0.001	<0.0002	<0.001	<0.001	1.8	<0.001	0.13	<0.0001	<0.001	<0.001	0.006
	Autumn 23	<0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.07	<0.001	0.12	<0.0001	<0.001	<0.001	0.005
Site 9 Barwon River @ Birregurra	Spring 19	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.22	< 0.001	0.098	< 0.0001	< 0.001	< 0.005	0.01
	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	< 0.05	< 0.001	0.016	< 0.0001	< 0.001	< 0.005	< 0.005
	Summer21	<0.05	< 0.005	< 0.001	<0.0002	< 0.001	< 0.001	0.37	< 0.001	0.037	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.02	<0.001	<0.001	<0.0002	<0.001	<0.001	0.24	<0.001	0.038	<0.0001	<0.001	<0.001	0.004
	Spring 21	0.04	<0.001	<0.001	<0.0002	<0.001	<0.001	0.99	<0.001	0.011	<0.0001	<0.001	<0.001	0.006
	Autumn 22	<0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.02	<0.001	0.10	<0.0001	<0.001	<0.001	0.013
	Spring 22	0.05	<0.001	0.001	<0.0002	<0.001	0.001	1.4	<0.001	0.13	<0.0001	<0.001	<0.001	0.004
	Autumn 23	<0.01	<0.001	<0.001	<0.0002	<0.001	<0.001	0.02	<0.001	0.13	<0.0001	<0.001	<0.001	0.004
Site 10	Spring 19	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.22	< 0.001	0.09	< 0.0001	< 0.001	< 0.005	< 0.005

Site	Sampling event	Filtered Metal Concentration (mg/L)												
		Aluminium	Antimony	Arsenic (total)	Cadmium	Chromium (total)	Copper	Iron	Lead	Manganese	Mercury	Selenium	Silver	Zinc
Barwon River @ Conns Lane	Autumn20	< 0.05*	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	< 0.05	< 0.001	0.027	< 0.0001	< 0.001	< 0.005	0.008
	Summer21	0.09	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.6	< 0.001	0.045	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.02	< 0.001	< 0.001	< 0.0002	< 0.001	< 0.001	0.25	< 0.001	0.025	< 0.0001	< 0.001	< 0.001	0.005
	Spring 21	0.04	< 0.001	< 0.001	< 0.0002	< 0.001	< 0.001	1.2	< 0.001	0.012	< 0.0001	< 0.001	< 0.001	0.004
	Autumn 22	< 0.01	0.003	< 0.001	< 0.0002	< 0.001	< 0.001	0.03	< 0.001	0.12	< 0.0001	< 0.001	0.003	0.012
	Spring 22	0.06	< 0.001	0.001	< 0.0002	< 0.001	0.001	1.3	< 0.001	0.096	< 0.0001	< 0.001	< 0.001	0.004
	Autumn 23	< 0.01	< 0.001	< 0.001	< 0.0002	< 0.001	< 0.001	0.02	< 0.001	0.13	< 0.0001	< 0.001	< 0.001	0.005
Site 11 Barwon River @ Winchelsea- Deans Marsh Road	Spring 19	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.42	< 0.001	0.1	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn20	< 0.05*	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	< 0.05	< 0.001	0.082	< 0.0001	< 0.001	< 0.005	< 0.005
	Summer21	0.16	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	1.4	< 0.001	0.028	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.03	< 0.001	< 0.001	< 0.0002	< 0.001	< 0.001	0.18	< 0.001	0.032	< 0.0001	< 0.001	< 0.001	0.003
	Spring 21	0.04	< 0.001	0.001	< 0.0002	< 0.001	0.001	1.1	< 0.001	0.025	< 0.0001	< 0.001	< 0.001	0.003
	Autumn 22	< 0.01	0.001	< 0.001	< 0.0002	< 0.001	< 0.001	0.03	< 0.001	0.12	< 0.0001	< 0.001	< 0.001	0.010
	Spring 22	0.03	< 0.001	0.002	< 0.0002	< 0.001	0.002	1.0	< 0.001	0.11	< 0.0001	< 0.001	< 0.001	0.003
Autumn 23	< 0.01	< 0.001	< 0.001	< 0.0002	< 0.001	< 0.001	0.02	< 0.001	0.11	< 0.0001	< 0.001	< 0.001	0.004	
Site 12 Barwon River @ Princes Hwy bridge, Winchelsea	Spring 19	0.07	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	0.56	< 0.001	0.1	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn20	< 0.05	< 0.005	< 0.001	< 0.0002	< 0.001	< 0.001	< 0.05	< 0.001	0.044	< 0.0001	< 0.001	< 0.005	0.015
	Summer21	0.27	< 0.005	0.001	< 0.0002	< 0.001	0.001	1.7	< 0.001	0.049	< 0.0001	< 0.001	< 0.005	< 0.005
	Autumn21	0.02	< 0.001	< 0.001	< 0.0002	< 0.001	< 0.001	0.19	< 0.001	0.03	< 0.0001	< 0.001	< 0.001	< 0.001
	Spring 21	0.04	< 0.001	0.001	< 0.0002	< 0.001	0.001	1.0	< 0.001	0.021	< 0.0001	< 0.001	< 0.001	0.003
	Autumn 22	< 0.01	< 0.001	< 0.001	< 0.0002	< 0.001	0.007	0.04	< 0.001	0.11	< 0.0001	< 0.001	< 0.001	0.013
	Spring 22	0.03	< 0.001	0.002	< 0.0002	< 0.001	0.001	1.0	< 0.001	0.10	< 0.0001	< 0.001	< 0.001	0.003
Autumn 23	< 0.01	< 0.001	< 0.001	< 0.0002	< 0.001	< 0.001	0.03	< 0.001	0.12	< 0.0001	< 0.001	< 0.001	0.006	

level of species protection unknown

* Aluminium results where pH is <6.5

^ 99% species protection level to account for the bioaccumulating nature of this toxicant

Shaded exceeds guideline values

Lead and zinc concentrations in Autumn 2023 are elevated and exceeding ANZECC guideline levels at Site 3 on the West Barwon River at Seven Bridges Road which is above the confluence with Boundary Creek. Zinc also exceeds guidelines within Big Swamp (Sites BS1 and BS2 and at Site 5 on Boundary Creek below the swamp but not at any other sites downstream of the Boundary Creek/Barwon River confluence. Iron concentrations increase along Boundary Creek from 2mg/L at the western edge of Big Swamp to around 30mg/L at the eastern edge and Colac- Forrest Road. Despite iron floc smothering instream vegetation at Site 6 on the Barwon River, iron concentrations in the river had reduced to 0.27mg/L and were back to levels similar to upstream of Boundary Creek by Site 8 at the Colac-Lorne Road.

3.2. Macroinvertebrates

Biotic indices such as AusRivAS, SIGNAL2, EPT (Ephemoptera, Plecoptera, Trichoptera) and taxa richness (number of families) scores were calculated in accordance with EPA Victoria biological indicators (EPA Victoria, 2004). EPA Victoria released their updated guidelines for the rapid bioassessment of rivers in 2021 which ties in with the Environmental Reference Standards (ERS) ((Victorian Government Gazette (VGG), 2021), formally SEPP-Waters) and are presented in Table 5. The main change in the objectives contained within the ERS (VGG, 2021) is that they are split into Seasons so that concurrent seasons do not need to be sampled in order for objectives to be applied. Other changes include removing SIGNAL scores and instead using SIGNAL2 scores. Also, individual edge sample scores are calculated and the average reported rather than combining families and reporting as a single sample when a riffle is not present.

A list of macroinvertebrate families found at each site in Autumn 2023 is in Appendix 2.

AusRivAS scores and bands (Table 4) are considered to give the most accurate assessment of the health of a site as the program compares the test site to a number of reference sites that have similar physical and chemical characteristics but are relatively free of environmental impacts. The score indicates how many macroinvertebrate families were found compared to those found at reference sites. The statewide model for edge habitat for each season was applied to these samples.

■ **Table 4: AusRivAS Bands, Observed/Expected scores and descriptions for edge models (AusRivAS Macroinvertebrate Predictive Modelling Version 3.2.2)**

Band	OE 50 score		Description
	Spring	Autumn	
X	1.20+	1.20+	More biologically diverse than reference sites
A	0.81-1.19	0.81-1.19	Reference condition
B	0.43-0.80	0.42-0.80	Significantly impaired
C	0.05-0.42	0.03-0.41	Severely impaired
D	0-0.04	0-0.02	Extremely impaired

SIGNAL2 is a biotic index based on the tolerance or intolerance of biota (macroinvertebrates) to water pollution. Sites with high scores are likely to have low nutrient, salinity and turbidity levels and high oxygen levels but its accuracy in identifying toxicants is less certain (EPA Victoria, 2021).

The EPT score indicates the number of families that are sensitive to pollution that are present at the site with a low score usually indicating that there has been some type of disturbance. Together, these scores give a good picture of the health of the waterway at a site and potentially what is causing any disturbance.

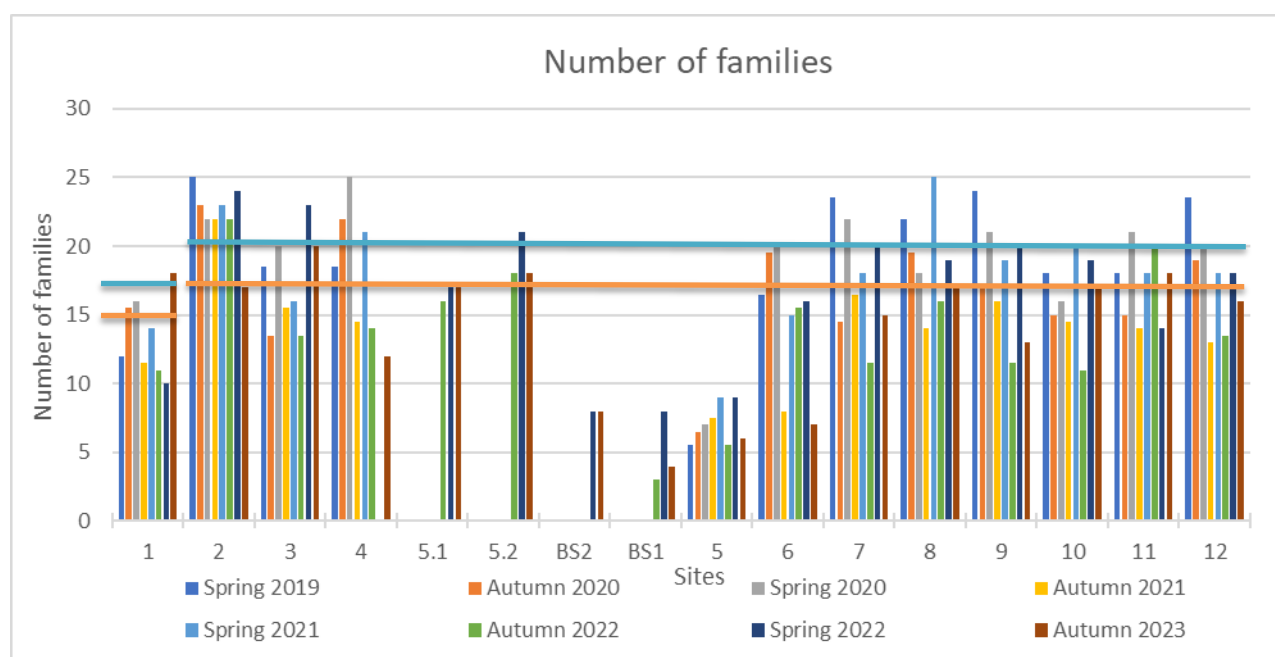
Taxa richness, measured by the number of macroinvertebrate families collected, can give a good overview of the health of a waterway. High numbers are associated with diverse habitats present at

the site but can also be influenced by mild nutrient enrichment which can increase the food supply. The score can be combined with SIGNAL2 scores as in Figure 4 to help interpret results.

The study area crosses two biological regions. Site 1 (East Barwon River at Yaughner) is in Uplands B; characterised by upland reaches in the Otway Ranges where there is some clearing for forestry, grazing and some intensive agriculture. Sites 2 to 12 are in Central Foothills and Coastal Plains; incorporating the lower reaches of the Barwon River where the region has been substantially cleared for intensive agriculture (EPA Victoria, 2004). The ecological values of Site 1 following the recent willow removal, streambank modification, and riparian clearing works upstream of, and at, the site are more consistent with the other sites within this study and therefore consideration should be given to applying the Central Foothills and Coastal Plains objectives. Sites BS1 and BS2 are wetland sites with input from Boundary Creek and as such objectives may not be relevant.

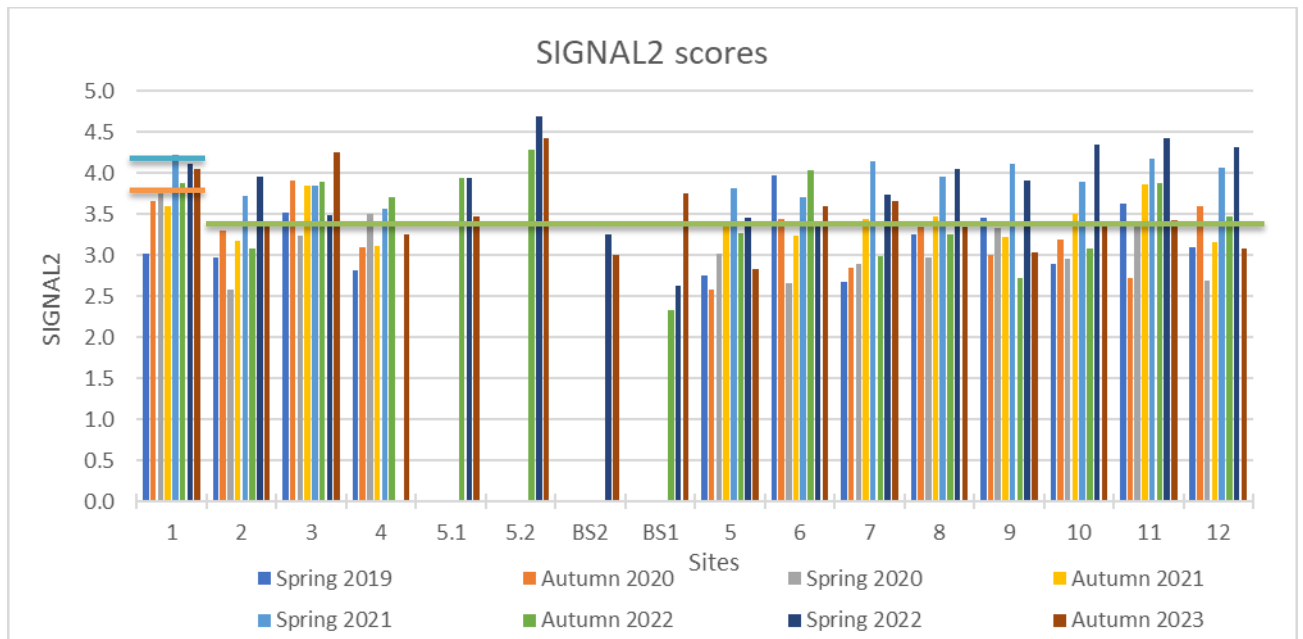
■ **Table 5: Environmental Quality Objectives for Biological Indicators, edge habitat (VGG, 2021)**

Objective	Season	Number of Families	SIGNAL2 Index score	EPT Index score	AusRivAS Band
Uplands B	Autumn	15	3.8	N/A	A
	Spring	17	4.2	6	A
Central Foothills & Coastal Plains	Autumn	17	3.4	N/A	A
	Spring	20	3.4	N/A	A



■ **Figure 2: Number of families found in edge habitats in the Barwon River and Boundary Creek. Blue line denotes Spring objective and orange line denotes Autumn objective.**

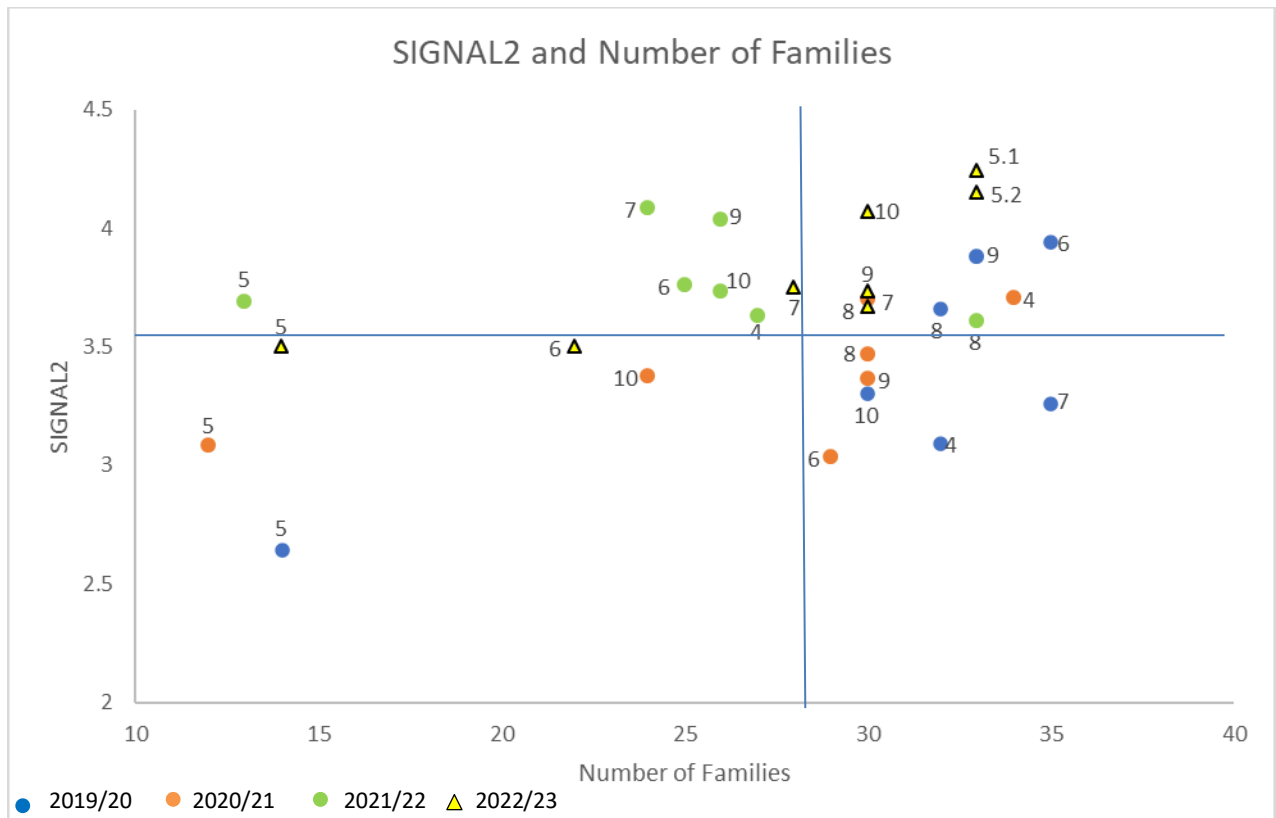
Figure 2 shows that the East Barwon River at Dewings Bridge Road (Site 2) and Boundary Creek above Big Swamp (Site 5.2) are the only sites to consistently meet the objectives for Number of Families. In addition, Sites 1, 3, 8, 10 and 11 on the Barwon River and Site 5.1 on Boundary Creek also met the Number of Families objective in Autumn 2022. There are no consistent patterns along the waterways over time but it is interesting to note that Site 1 on the Barwon River appears to be recovering from the willow removal works and the Boundary Creek sites above Big Swamp (Sites 5.1 and 5.2) have comparable numbers of families present to sites on the Barwon River. Site BS1 at the downstream edge of Big Swamp had the least number of families present in Autumn 2023.



■ **Figure 3: SIGNAL2 index scores from edge habitats in the Barwon River and Boundary Creek. Blue line denotes Spring objective and orange line denotes Autumn objective for Uplands B objectives and green line denotes both Spring and Autumn objective for Central Hills and Coastal Plains objective.**

Figure 3 shows that the two new sites on Boundary Creek upstream of Big Swamp have met the objectives for SIGNAL2 on each of the three sampling occasions with Site 5.2 immediately above the swamp recording the second highest score in Autumn 2023 of all sampling events. Site 3 on the West Barwon River at Seven Bridges Road and Site 11 on the Barwon River upstream of Winchelsea have met objectives during seven of the eight sampling events.

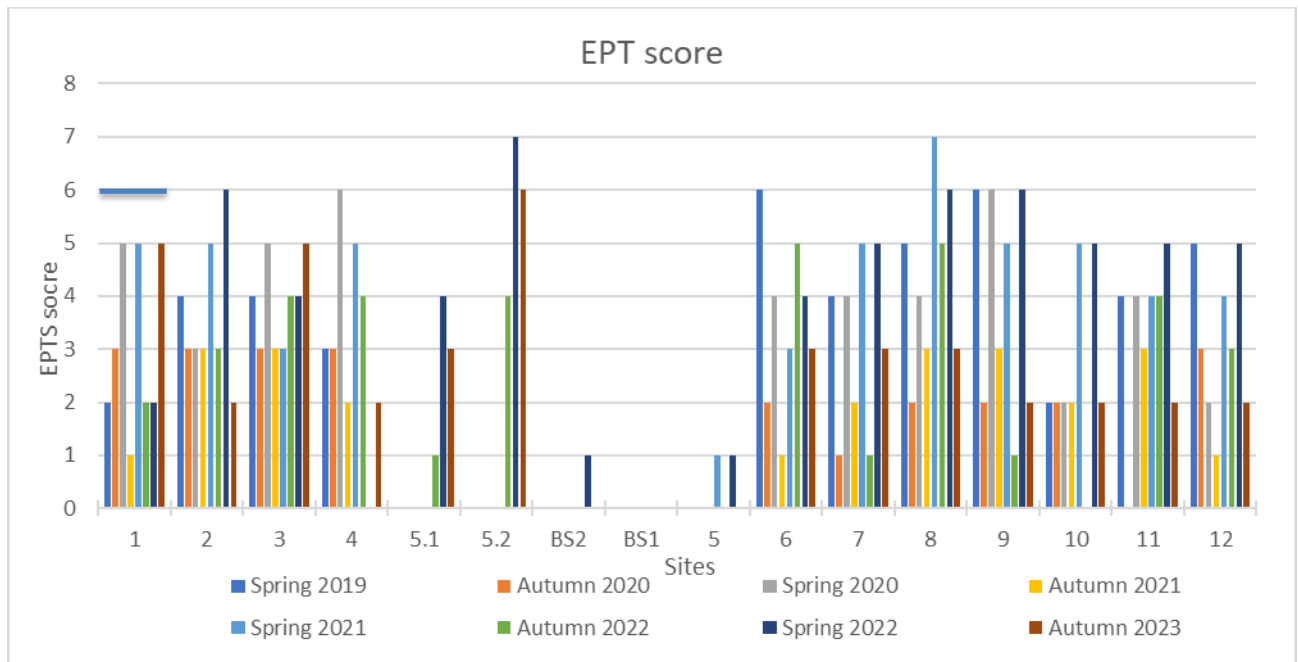
Whilst SIGNAL2 scores give an indication of water quality in the river from which the sample was collected, combining the score with the richness score (how many different macroinvertebrate families are present), can provide an indication of the types of pollution and other physical and chemical factors that are affecting the macroinvertebrate community. This is shown in the plot in Figure 4 where quadrant boundaries are defined according to Chessman (2003) with the top right quadrant (Quadrant 1) containing the healthiest sites. As all sites are subject to human disturbance, those sites that met or were close to meeting EPA biological objectives for number of families and SIGNAL scores were included in Quadrant 1 and a cross check of which sites had the most EPT families (Figure 5) confirmed the quadrant borders using 2019/20 data.



■ **Figure 4: SIGNAL2 index plotted against number of families recorded for sites 4 to 10 combined over season for four years.**

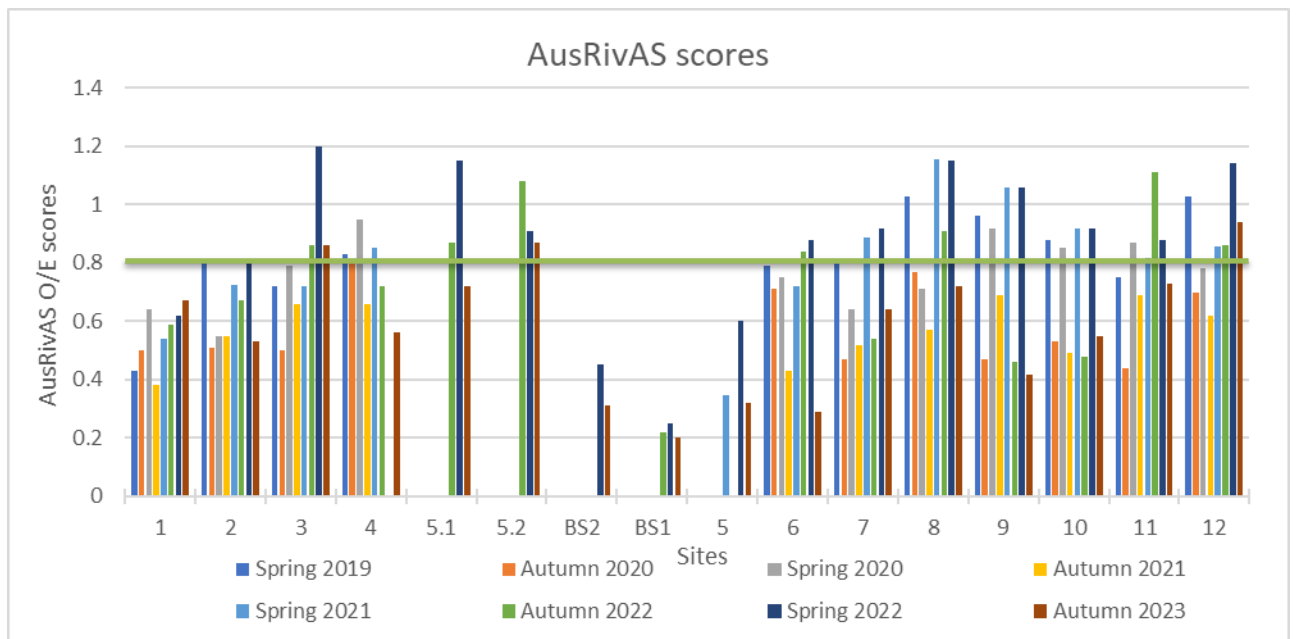
Only sites 4 to 10 have been shown in Figure 4 above as the graph was becoming increasingly difficult to interpret with the increased number of data points over the years. Site 4 in 2022/23 has not been shown as it was only sampled in one season (Autumn). Site 5 on Boundary Creek at Colac-Forrest Road continues to show improvement in the last two years compared to the first two years of sampling. Site 6 on the Barwon River immediately below the Boundary Creek confluence continues to report a fluctuation in macroinvertebrate communities, exhibiting a long-term decline over the monitoring period however this does not correlate with a corresponding decline in water quality or SIGNAL score. Site 7 was losing diversity along with Site 6 but that trend has reversed this last year. Site 8 at the Colac-Lorne Road is the most consistent with three of the four years in the top left quadrant where habitat and water quality is typically favourable. Sites 9 and 10 at Birregurra and Conns Lane both improved in the past year with Site 10 returning to the same number of families as in 2019/20 but with a higher sensitivity score.

The pollution sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) macroinvertebrate families are seldom found in waterways within the Cleared Hills and Coastal Plains region, therefore no objectives have been set but have been reported in Figure 5 below.



■ **Figure 5: EPT (Ephemeroptera, Plecoptera, Tricoptera families) index scores from edge habitats in the Barwon River and Boundary Creek. There is only a Spring objective for Uplands B region (blue line).**

Whilst the number of pollution sensitive taxa present (EPT score) does not have an objective for many of the sites in this study, Figure 5 shows that Site 5.2 on Boundary Creek above Big Swamp recorded the highest number of EPT taxa in 2022/23 and that sites such as Site 8 at Colac-Lorne Road and Site 9 at Birregurra have good numbers of these taxa present during most Spring sampling events.



■ **Figure 6: AusRivAS observed vs expected (O/E) scores from edge habitats in the Barwon River, Boundary Creek and Big Swamp. Green line denotes both Spring and Autumn objective (Band A).**

Sites 9 (Birregurra) and 10 (Conns Lane) meet AusRivAS objectives during every Spring sampling event over the four years (Figure 6). AusRivAS objectives were met in both the latest Spring and Autumn sampling events at Site 3 (Seven Bridges Road), Site 5.2 (Boundary Creek above Big Swamp) and Site 12 (Winchelsea). Site 5 recorded its highest AusRivAS score in Spring 2022.

To have met Biological Objectives for a sampling event, objectives for all of the indices must be met (VGG, 2021). In the past year (Spring 2022 and Autumn 2023), Site 3 at Seven Bridges Road and Site 5.2 on Boundary Creek immediately above Big Swamp met the Biological Objectives. Site 2 (Dewings Bridge Road), Site 7 (downstream of the pine plantation), and Site 9 (Birregurra) met biological objectives only in Spring (2022) (Table 6).

■ **Table 6: Environmental Quality Objectives met over season and year for edge habitat (VGG, 2021). Shaded green signifies all relevant objectives are met for that sampling event.**

Site Waterway	Season	Number of Families	SIGNAL2 Index score	EPT Index score	AusRivAS Band	Number of objectives met
Site 1 East Barwon River@ Kents Road	Spring 19	X	X	X	X	0
	Autumn 20	✓	X	X	X	1
	Spring 20	X	X	X	X	0
	Autumn 21	X	X	X	X	0
	Spring 21	X	✓	X	X	1
	Autumn 22	X	✓	X	X	1
	Spring 22	X	X	X	X	0
	Autumn 23	✓	✓	X	X	2
Site 2 East Barwon River @ Dewings Bridge Road	Spring 19	✓	X	N/A	✓	2
	Autumn 20	✓	X	N/A	X	1
	Spring 20	✓	X	N/A	X	1
	Autumn 21	✓	X	N/A	X	1
	Spring 21	✓	✓	N/A	X	2
	Autumn 22	✓	X	N/A	X	1
	Spring 22	✓	✓	N/A	✓	3
	Autumn 23	✓	✓	N/A	X	2
Site 3 West Barwon River@ Seven Bridges Road	Spring 19	X	✓	N/A	X	1
	Autumn 20	X	✓	N/A	X	1
	Spring 20	✓	X	N/A	X	1
	Autumn 21	X	✓	N/A	X	1
	Spring 21	X	✓	N/A	X	1
	Autumn 22	X	✓	N/A	✓	2
	Spring 22	✓	✓	N/A	✓	3
	Autumn 23	✓	✓	N/A	✓	3
Site 4 Barwon River 100m upstream of Boundary Creek confluence	Spring 19	X	X	N/A	✓	1
	Autumn 20	✓	X	N/A	X	1
	Spring 20	✓	✓	N/A	✓	3
	Autumn 21	X	X	N/A	X	0
	Spring 21	✓	✓	N/A	✓	3
	Autumn 22	X	✓	N/A	X	1
	Spring 22	N/A	N/A	N/A	N/A	-
	Autumn 23	X	X	N/A	X	0
Site 5.1 Boundary Creek downstream of McDonalds Dam	Autumn 22	X	✓	N/A	✓	2
	Spring 22	X	✓	N/A	✓	2
	Autumn 23	✓	✓	N/A	X	2
Site 5.2 Boundary Creek upstream of Big Swamp	Autumn 22	✓	✓	N/A	✓	3
	Spring 22	✓	✓	N/A	✓	3
	Autumn 23	✓	✓	N/A	✓	3

Site Waterway	Season	Number of Families	SIGNAL2 Index score	EPT Index score	AusRivAS Band	Number of objectives met
Site 5 Boundary Creek@ Colac-Forrest Road	Spring 19	X	X	N/A	X	0
	Autumn 20	X	X	N/A	X	0
	Spring 20	X	X	N/A	X	0
	Autumn 21	X	✓	N/A	X	1
	Spring 21	X	✓	N/A	X	1
	Autumn 22	X	X	N/A	X	0
	Spring 22	X	✓	N/A	X	1
	Autumn 23	X	X	N/A	X	0
Site 6 Barwon River 100m downstream of Boundary Creek confluence	Spring 19	X	✓	N/A	X	1
	Autumn 20	✓	✓	N/A	X	2
	Spring 20	✓	X	N/A	X	1
	Autumn 21	X	X	N/A	X	0
	Spring 21	X	✓	N/A	X	1
	Autumn 22	X	✓	N/A	✓	2
	Spring 22	X	✓	N/A	✓	2
	Autumn 23	X	✓	N/A	X	1
Site 7 Barwon River @ north boundary of plantation	Spring 19	✓	X	N/A	X	1
	Autumn 20	X	X	N/A	X	0
	Spring 20	✓	X	N/A	X	1
	Autumn 21	✓	✓	N/A	X	2
	Spring 21	X	✓	N/A	✓	1
	Autumn 22	X	X	N/A	X	0
	Spring 22	✓	✓	N/A	✓	3
	Autumn 23	X	✓	N/A	X	1
Site 8 Barwon River @ Colac-Lorne Road	Spring 19	✓	X	N/A	✓	2
	Autumn 20	✓	✓	N/A	X	2
	Spring 20	X	X	N/A	X	0
	Autumn 21	X	✓	N/A	X	1
	Spring 21	✓	✓	N/A	✓	3
	Autumn 22	X	X	N/A	X	0
	Spring 22	X	✓	N/A	✓	2
	Autumn 23	✓	✓	N/A	X	2
Site 9 Barwon River @ Birregurra	Spring 19	✓	✓	N/A	✓	3
	Autumn 20	✓	X	N/A	X	1
	Spring 20	✓	X	N/A	✓	2
	Autumn 21	X	X	N/A	X	0
	Spring 21	X	✓	N/A	✓	2
	Autumn 22	X	X	N/A	X	0
	Spring 22	✓	✓	N/A	✓	3
	Autumn 23	X	X	N/A	X	0
Site 10 Barwon River @Conns Lane	Spring 19	X	X	N/A	✓	1
	Autumn 20	X	X	N/A	X	0
	Spring 20	X	X	N/A	✓	1
	Autumn 21	X	✓	N/A	X	1
	Spring 21	X	✓	N/A	✓	2
	Autumn 22	X	X	N/A	X	0

Site Waterway	Season	Number of Families	SIGNAL2 Index score	EPT Index score	AusRivAS Band	Number of objectives met
Site 11 Barwon River @Winchelsea- Deans Marsh Road	Spring 22	X	✓	N/A	✓	2
	Autumn 23	✓	✓	N/A	X	2
	Spring 19	X	✓	N/A	X	1
	Autumn 20	X	X	N/A	X	0
	Spring 20	✓	✓	N/A	✓	3
	Autumn 21	X	✓	N/A	X	1
	Spring 21	X	✓	N/A	✓	2
	Autumn 22	✓	✓	N/A	✓	3
	Spring 22	X	✓	N/A	✓	2
	Autumn 23	✓	✓	N/A	X	2
Site 12 Barwon River@ Princes Hwy bridge, Winchelsea	Spring 19	✓	X	N/A	✓	2
	Autumn 20	✓	✓	N/A	X	2
	Spring 20	✓	X	N/A	X	1
	Autumn 21	X	X	N/A	X	0
	Spring 21	✓	✓	N/A	✓	3
	Autumn 22	X	✓	N/A	✓	2
	Spring 22	X	✓	N/A	✓	2
	Autumn 23	X	X	N/A	✓	1

Macroinvertebrates in Big Swamp (Sites BS1 and BS2) continue to be sampled to fill a data gap in this project. Wetland macroinvertebrates assemblages are often made up of mobile species that can cope with wetting and drying phases, therefore the taxa that are collected during one sampling event may not be indicative of what may be present at a later date. Taxa are similar between the two Big Swamp sites and Site 5 downstream of the swamp and two taxa, Nepidae (Needle bugs) and Koonungidae were only found at those sites. Nepids typically occur in wetlands and *Koonunga* are found in waterbodies associated with groundwater springs (Gooderham & Tsyrin, 2002). Neither are sensitive taxa.

4. Discussion

Boundary Creek water quality remains poor downstream of Big Swamp (Site 5) although pH levels do appear to be improving since initial investigations in 2019/2020. Metals still appear to be being mobilised due to the low pH but Aluminium concentrations were the lowest in three years in Autumn 2023, no longer exceeding species protection levels and concentrations of all other metals were reduced during the 2022/23 year. Zinc still exceeds the ANZECC guidelines at Site 5 but not at Site 6 within the Barwon River. Ecological health at Site 5 has shown improvements over time, potentially bolstered by the increase in pH. Metal concentrations increase along Big Swamp but only exceed ANZECC guidelines for Zinc.

The effects on Barwon River's water quality from Boundary Creek inflows are of limited downstream effect. The buffering capacity of the river combined with its larger discharge result in pH showing little difference at sites above and below the confluence of the two streams (i.e. mixing and dilution are efficient). Overall, stream health as measured by macroinvertebrate community composition is good downstream of the confluence with sites identified as reference condition (AusRivAS Band A) at all downstream sites in Spring 2022 reflecting the ability of the Barwon River to absorb catchment impacts on water quality or habitat condition. Sites 7 and 9 met all three EPA biological objectives during Spring 2022. Site 6 immediately below the confluence of Boundary Creek recorded the lowest number of families in the past year and a lower AusRivAS score in Autumn 2023 than Site 5 in Boundary Creek. Iron floc observed at this location may be driving this local scale decline as this can smother in stream habitat and prevent regeneration.

Boundary Creek is in very good condition upstream of Big Swamp and will provide recolonisation via drift or aerial dispersal to the downstream wetlands and waterways provided water quality can be improved in the remainder of Boundary Creek. The ecological health of Boundary Creek downstream of Big Swamp at Site 5 (Colac-Forrest Road) had been steadily improving over the past three years, meeting SIGNAL2 objectives in Autumn 2021 and Spring 2021 and Spring 2022.

4.1. Recommendations

Continued sampling of metals in the water along the Barwon River during the Boundary Creek remediation works should give an indication of whether they are being mobilised by the low pH water coming into the system. Whilst the updated biological sampling guidelines and associated objectives allows for only one season to be sampled, the variability seen in macroinvertebrate community composition between seasons suggests that biannual macroinvertebrate sampling in Autumn and Spring during the Boundary Creek remediation works will give the most accurate assessment of the health of Boundary Creek and the Barwon River.

5. References

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Appendix 1:

5.1. Site 1- East Barwon River@ Kents Road



Site 1: upstream Spring 2019



Site 1: downstream Spring 2019



Site 1: upstream Autumn 2020



Site 1: downstream Autumn 2020



Site 1: upstream Spring 2020



Site 1: upstream Spring 2020



Site 1: upstream Autumn 2021



Site 1: downstream Autumn 2021



Site 1: upstream Spring 2021



Site 1: downstream Spring 2021



Site 1: upstream Autumn 2022



Site 1: downstream Autumn 2022



Site 1: upstream Spring 2022



Site 1: downstream Spring 2022



Site 1: upstream Autumn 2023



Site 1: downstream Autumn 2023

Prior to the willow removal and river realignment in early 2022, the East Barwon River at Kents Road had diverse habitat with large deep pools and some riffle/ run areas. These runs had dried to trickles in Autumn 2020 but were flowing well in Spring and Autumn 2021. The average stream width was eight meters and bank full but had contracted to five meters in Autumn 2020. Willows dominated the riparian zone and were growing within the stream channel prior to removal. The substrate was a mix of clay and silt with a number of aquatic macrophytes growing in the margins and shallow pool areas. The majority of the riparian zone was exotic vegetation, dominated by blackberries (possibly poisoned in Summer 20/21), willows and pasture grass. One larval fish has been collected as bycatch during macroinvertebrate sampling. A concurrent snapshot study by EnviroDNA (2019) found evidence of platypus at this site.

Following the works in January to April 2022 (Barwon Water, 2022), the East Barwon River at Kents Road was a homogenous channel with very little riparian zone and submerged macrophytes. The banks had healed in areas in Spring 2022 from the disturbed bare earth or rip rap that was evident in Autumn 2022. Stock now appear excluded from the waterway and all woody weeds have been removed within the vicinity of the site. Most of the banks were vegetated in Autumn 2023 and aquatic vegetation was beginning to be established although there appeared to be a highly mobile silty substrate that may easily smother submerged macrophytes. Filamentous algae was abundant in Autumn 2023.

Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gives this site a score of 74 out of 140 in 2019 and a downgraded score of 57 out of 140 in 2022 due to the recent works. It is expected that this score will improve following the planned revegetation works and ongoing stock exclusion.

5.2. Site 2- East Barwon River@ Dewings Bridge Road



Site 2: upstream Spring 2019



Site 2: downstream Spring 2019



Site 2: upstream Autumn 2020



Site 2: downstream Autumn 2020



Site 2: upstream Spring 2020



Site 2: downstream Spring 2020



Site 2: upstream Autumn 2021



Site 2: downstream Autumn 2021



Site 2: upstream Spring 2021



Site 2: downstream Spring 2021



Site 2: upstream Autumn 2022



Site 2: downstream Autumn 2022



Site 2: Upstream Spring 2022



Site 2: Downstream Spring 2022



Site 2: upstream Autumn 2023



Site 2: downstream Autumn 2023

The East Barwon at Dewings Bridge Road consists of a slow flowing channel with extensive backwaters. There is very little riparian zone present but a number of submerged and emergent macrophytes provide good habitat for macroinvertebrates and fish. One larval fish was found in the sample net in Autumn 2020, three pygmy perch in Spring 2020 and a pygmy perch in Spring 2021. The substrate is a mix of clay and silt with some sand. The average stream width at this site was seven meters and was bank full during both Spring and Autumn sampling. The majority of the riparian zone is pasture grass with stock access on both sides. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 59 out of 140 and increased to 70 out of 140, primarily due to the gradual reduction in erosional scars and the increase in submerged and emergent macrophyte beds, despite the constant stock access. Removing stock access and establishing riparian vegetation will improve the health of this site significantly.

5.3. Site 3- West Barwon River@ Seven Bridges Road



Site 3: upstream Spring 2019



Site 3: downstream Spring 2019



Site 3: upstream Autumn 2020



Site 3: downstream Autumn 2020



Site 3: upstream Spring 2020



Site 3: downstream Spring 2020



Site 3: upstream Autumn 2021



Site 3: downstream Autumn 2021



Site 3: upstream Spring 2021



Site 3: downstream Spring 2021



Site 3: upstream Autumn 2022



Site 3: downstream Autumn 2022



Spring 2022



Spring 2022



Site 3:upstream Autumn 2023



Site 3: downstream Autumn 2023

The West Barwon River at Seven Bridges Road has large deep pools with a number of backwaters. The average stream width at this site is seven meters, narrow at the top of the surveyed reach and widening into a large pool near the bridge. The substrate is clay and silt mixed with 20% sand. There are some macrophytes present along with trailing bank vegetation, roots and instream large woody debris (primarily willow branches). Willows dominate the riparian zone a mix of shrubs and native and pasture grasses in the understory. Usual access to the river was blocked in Autumn 2023 by a ground nest European Wasps, one of a number of sites that had nests. Four larval fish were collected as bycatch during macroinvertebrate sampling in Spring 2019. One mountain galaxias, one common galaxias, one pygmy perch and a laval galaxias were collected in Spring 2020 and another galaxias in Spring 2021. A number of pygmy perch were collected in Autumn 2022. A concurrent snapshot study by EnviroDNA (2019) found evidence of platypus at this site in Spring 2019. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 85 out of 140 in 2019 and this has remained steady over the three years of the study.

5.4. Site 4- Barwon River 50-100m upstream of Boundary Ck confluence



Site 4: upstream Spring 2019



Site 4: downstream Spring 2019



Site 4: upstream Autumn 2020



Site 4: downstream Autumn 2020



Site 4: upstream Spring 2020



Site 4: downstream Spring 2020



Site 4: upstream Autumn 2021



Site 4: downstream Autumn 2021



Site 4: upstream Spring 2021



Site 4: downstream Spring 2021



Site 4: upstream Autumn 2022



Site 4: downstream Autumn 2022



Site 4: Upstream Autumn 2023, new site



Site 4: downstream Autumn 2023, new site

Site 4 was moved in Autumn 2023 from 100 meters upstream of the confluence with Boundary Creek to 50 meters upstream of the confluence and sampled from the opposite site. The primary difference is that the Barwon River is narrower at this point and has larger beds of *Juncus*. The Barwon River 50-100 meters upstream of the Boundary Creek confluence is a large slow flowing channel with shallow side sections that support a number of macrophyte beds. The average stream width at this site is nine meters. The substrate is clay and black silt with some large woody debris and filamentous algae present in addition to the macrophytes. *Juncus*, *Typha*, *Triglochin* and *Polygonum* species are all present instream though riparian vegetation is limited to some isolated trees, a narrow native plantation and pasture grass with stock access. The introduced *Gambusia* (mosquito fish) were collected as bycatch during macroinvertebrate sampling in Spring 2019, Autumn 2021 and Autumn 2022 and a pygmy perch sampled in Spring 2021. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 79 out of 140 in 2019 and an increased score of 99 due to the establishment of more aquatic macrophytes and healed erosion. Fencing and revegetation of the left side of the river to a similar standard as the right side would see further improvements to the health of the river.

5.5. Site 5- Boundary Creek @ Colac- Forrest Road



Site 5: upstream Spring 2019



Site 5: downstream Spring 2019



Site 5: upstream Autumn 2020



Site 5: downstream Autumn 2020



Site 5: upstream Spring 2020



Site 5: downstream Spring 2020



Site 5: upstream Autumn 2021



Site 5: downstream Autumn 2021



Site 5: upstream Spring 2021



Site 5: downstream Spring 2021



Site 5: upstream Autumn 2022



Site 5: downstream Autumn 2022



Spring 2022



Spring 2022



Site 5: upstream Autumn 2023



Site 5: downstream Autumn 2023

Boundary Creek at Colac- Forrest Road has a mix of large deep pools, a large shallow pool at the bridge and shallow runs. It has been bank full with an average stream width of four meters, narrow at the top of the surveyed reach and widening into a large pool upstream of the bridge during each sampling event excepting during Autumn 2020 sampling when the creek had contracted to a pool approximately 4 meters long by 2.5 meters wide. During this time the pooled water was stagnant, with low oxygen concentrations and very high turbidity. The substrate is a mix of cobble, pebble, gravel, sand, clay and silt. There are no macrophytes but there was some filamentous algae in Spring 2019, (absent since) and trailing bank vegetation present. Foam was present at the top of the reach in Spring 2020, Autumn 2021, Spring 2021, Autumn 2022 and Spring 2022. The riparian zone is wide and a mix of native and exotic vegetation except the ground cover which is dominated by *Convolvulus* sp. which has taken over the pasture grass. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams has remained steady at 81 out of 140 between 2019 and 2022 and is likely to remain so until conditions allow aquatic vegetation to establish and the riparian vegetation is improved.

5.6. Site 6- Barwon River 100m downstream of Boundary Ck confluence



Site 6: upstream Spring 2019



Site 6 : downstream Spring 2019



Site 6: upstream Autumn 2020



Site 6: downstream Autumn 2020



Site 6: upstream Spring 2020



Site 6 : downstream Spring 2020



Site 6: upstream Autumn 2021



Site 6: downstream Autumn 2021



Site 6: upstream Spring 2021



Site 6: downstream Spring 2021



Site 6: upstream Autumn 2022



Site 6: downstream Autumn 2022



Spring 2022



Spring 2022



Site 6: upstream Autumn 2023



Site 6: downstream Autumn 2023

The Barwon River 100 meters downstream of the Boundary Creek confluence is a narrow deep channel with wide shallow edges dominated by grasses and aquatic macrophytes. The average stream width at this site is five meters and was bank full in Spring 2019, Spring 2020, Autumn 2021 and Spring 2021 and had contracted to a narrow (1-2 meter) channel in Autumn 2020 and Autumn 2022. There is a narrow channel at the top of the surveyed reach, narrowing to a confined channel downstream. The river had contracted to the main channel but remained flowing, leaving the fringes to dry out in Autumn 2020 and Autumn 2022. The substrate consists of clay and silt usually with filamentous algae tangled through the macrophyte beds but in Autumn 2021 and Spring 2021 the macrophyte beds were covered in a smothering floc that was easily disturbed, forming a thick plume. This plume appeared to be absent in Autumn 2022 but this could have been due to the absence of slow flowing areas where floc would be able to settle. The iron floc was back in Autumn 2023, smothering most of the instream habitat. Macrophyte species are varied with *Triglochin*, *Polygonum*, *Phragmites*, and *Juncus* species all present in addition to trailing grasses. Four different fish species have been collected at this site as bycatch; southern pygmy perch, smelt and a galaxid in Autumn 2020, gambusia and southern pygmy perch in Spring 2020. The riparian zone is limited to grasses and scattered native trees and shrubs with stock access to the site. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 70 out of 140 in 2019 and a very similar score of 71 in 2022. As with all sites that have unrestricted stock access, the health of this site would be improved by fencing and revegetating the river on both sides.

5.7. Site 7- Barwon River @ north boundary of plantation



Site 7: upstream Spring 2019



Site 7: downstream Spring 2019



Site 7: upstream Autumn 2020



Site 7: downstream Autumn 2020



Site 7: upstream Spring 2020



Site 7: downstream Spring 2020



Site 7: upstream Autumn 2021



Site 7: downstream Autumn 2021



Site 7: upstream Spring 2021



Site 7: downstream Spring 2021



Site 7: upstream Autumn 2022



Site 7: downstream Autumn 2022



Spring 2022



Spring 2022



Site 7: upstream Autumn 2023



Site 7: downstream Autumn 2023

The Barwon River adjacent to the northern boundary of the pine plantation has a large deep channel with any shallow areas dominated by beds of *Phragmites*. The average stream width at this site is seven meters. The substrate is clay and silt. In addition to the *Phragmites* beds there are beds of *Triglochin*, and scattered *Polygonum*, *Juncus* and other grasses. The riparian zone has a good mix of trees, shrubs and understory with a majority of native trees and shrubs. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 90 out of 140 in 2019 and increased to 104 in 2022 primarily due to continued improvements in riparian and instream macrophyte condition.

5.8. Site 8- Barwon River @ Colac- Lorne Road



Site 8: upstream Spring 2019



Site 8: downstream Spring 2019



Site 8: upstream Autumn 2020



Site 8: downstream Autumn 2020



Site 8: upstream Spring 2020



Site 8: downstream Spring 2020



Site 8: upstream Autumn 2021



Site 8: downstream Autumn 2021



Site 8: upstream Spring 2021



Site 8: downstream Spring 2021



Site 8: upstream Autumn 2022



Site 8: downstream Autumn 2022



Spring 2022



Spring 2022



Site 8: upstream Autumn 2023



Site 8: downstream Autumn 2023

The Barwon River at Colac- Lorne Road has large deep pools with a shallow areas at the sides and willow trees growing in the channel with some substrate exposed when the river level is low. The average stream width at this site is eight meters with a predominantly clay and silt substrate mixed with some sand. There are beds of *Triglochin* and *Phragmites* in addition to trailing grasses and large willows. The riparian zone consists of willow trees, pasture grasses and blackberries and allows stock access. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gives this site a score of 69 out of 140 in 2019 and a similar score of 73 in 2022.

5.9. Site 9- Barwon River @ Birregurra



Site 9: upstream Spring 2019



Site 9: downstream Spring 2019



Site 9: upstream Autumn 2020



Site 9: downstream Autumn 2020



Site 9: upstream Spring 2020



Site 9: downstream Spring 2020



Site 9: upstream Autumn 2021



Site 9: downstream Autumn 2021



Site 9: upstream Spring 2021



Site 9: downstream Spring 2021



Site 9: upstream Autumn 2022



Site 9: downstream Autumn 2022



Spring 2022



Spring 2022



Site 9: upstream Autumn 2023



Site 9: downstream Autumn 2023

The Barwon River at Birregurra consists of a large deep slow flowing pool. The average stream width at this site is five meters with steep clay banks. The substrate is clay and silt with willow roots, some snags and *Triglochin* beds scattered along the edges of the channel and establishing well over time. There were willow removal works and replanting of the riparian zone in Spring 2019 in amongst the pasture grass and blackberry groundcover. The riparian zone is established and growing well although follow up ground cover weed management may be required with blackberries becoming established in Autumn 2023. Rakali footprints were evident in the soft sediment edge during many of the sampling events in 2019 and 2020. Introduced mosquitofish (*Gambusia sp.*) were bycatch in Autumn 2022. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 67 out of 140 in 2019 but has increased to 98 in 2022, primarily due to the successful reintroduction of the riparian zone following large scale willow removal.

5.10. Site 10- Barwon River @ Conns Lane



Site 10: upstream Spring 2019



Site 10: downstream Spring 2019



Site 10: upstream Autumn 2020



Site 10: downstream Autumn 2020



Site 10: upstream Spring 2020



Site 10: downstream Spring 2020



Site 10: upstream Autumn 2021



Site 10: downstream Autumn 2021



Site 10: upstream Spring 2021



Site 10: downstream Spring 2021



Site 10: upstream Autumn 2022



Site 10: downstream Autumn 2022



Spring 2022



Spring 2022



Site 10: upstream Autumn 2023



Site 10: downstream Autumn 2023

The Barwon River at Conns Lane has large deep pools with some small deep backwaters and a narrow deep run at the top of the reach. The average stream width at this site is six meters. The substrate is clay and silt mixed with some sand and gravel. *Phragmites* beds line the channel and there are isolated patches of *Triglochin* in addition to *Polygonum* and trailing grasses along the waters edge. The trailing and shallow vegetation contained filamentous algae in Autumn 2021, 2022 and 2023. Larval fish and gambusia were collected in the macroinvertebrate net in Spring 2020 and gambusia were plentiful in Autumn 2021 though not in Spring 2021. The riparian zone consists of a native revegetation project that is more successful on the right side than the left. Exotic trees are re-establishing on the left side and pasture grass dominates. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 98 out of 140 in 2019 and a similar score of 101 in 2022.

5.11. Site 11- Barwon River@ Winchelsea- Deans Marsh Road



Site 11: upstream Spring 2019



Site 11: downstream Spring 2019



Site 11: upstream Autumn 2020



Site 11: downstream Autumn 2020



Site 11: upstream Spring 2020



Site 11: downstream Spring 2020



Site 11: upstream Autumn 2021



Site 11: downstream Autumn 2021



Site 11: upstream Spring 2021



Site 11: downstream Spring 2021



Site 11: upstream Autumn 2022



Site 11: downstream Autumn 2022



Spring 2022



Spring 2022



Site 11: upstream Autumn 2023



Site 11: downstream Autumn 2023

The Barwon River at Winchelsea- Deans Marsh Road has large deep pools with a shallow run at the top of the reach. The average stream width at this site is five meters and the substrate is clay and silt mixed with some sand and gravel. *Triglochin* is growing in the shallow areas of the channel and there are roots, large woody debris and trailing grasses. The riparian zone is predominately native trees and understory with a mix of grasses as groundcover. Rakali footprints were spotted at the waters edge in Spring 2019. The height and force of a flood between Autumn 2021 and Spring 2021 sampling can be seen in the upstream Spring 2021 photo of the log wedged in the forked tree in the left foreground. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 90 out of 140 in 2019 and the similar but slightly higher score of 98 in 2022 with the introduction of more woody debris into the channel following the 2021 floods and the continuing growth of riparian vegetation.

5.12. Site 12- Barwon River @ Princes Hwy bridge, Winchelsea



Site 12: upstream Spring 2019



Site 12: downstream Spring 2019



Site 12: upstream Autumn 2020



Site 12: downstream Autumn 2020



Site 12: upstream Spring 2020



Site 12: downstream Spring 2020



Site 12: upstream Autumn 2021



Site 12: downstream Autumn 2021



Site 12: upstream Spring 2021



Site 12: downstream Spring 2021



Site 12: upstream Autumn 2022



Site 12: downstream Autumn 2022



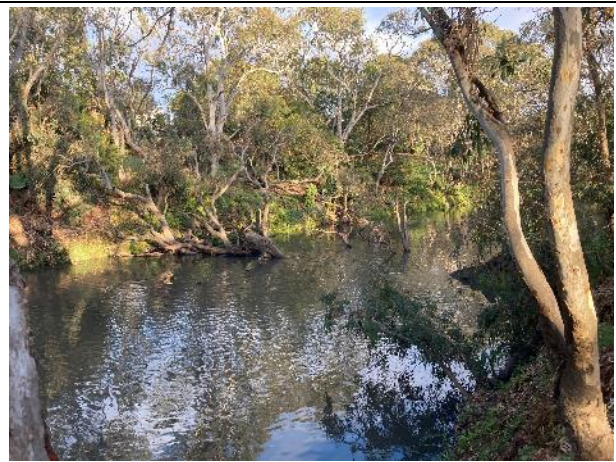
Spring 2022



Spring 2022



Site 12: upstream Autumn 2023



Site 12: downstream Autumn 2023

The Barwon River at Winchelsea has large deep pools with a large shallow pool at the top of the reach. The average stream width at this site is twelve meters. The substrate is clay and silt mixed with sand and some gravel. In addition to the *Phragmites* beds at the top of the reach and along some edges there are also patches of *Triglochin*. Large woody debris, trailing grasses and emergent vegetation such as *Polygonum* are also present. Riparian vegetation is predominantly native with many established eucalypts and groundcover is pasture grass. A concurrent snapshot study by EnviroDNA (2019) in Spring found evidence of platypus at this site. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 88 out of 140 in 2019 and a similar score of 91 in 2022.

5.13. Site 5.1- Boundary Creek downstream of McDonalds Dam



Site 5.1: upstream Autumn 2022



Site 5.1: downstream Autumn 2022



Spring 2022



Spring 2022



Site 5.1: upstream Autumn 2023



Site 5.1: downstream Autumn 2023

Site 5.1 on Boundary Creek was added to the current sampling regime to replicate the site sampled by Austral in 2014/2015 for Jacobs (2017) and give some context to the health of Boundary Creek upstream of Big Swamp. Boundary Creek below McDonalds Dam is between 3 and 4 meters wide with a mix of deep pools, shallower pools and artificial riffle areas from the culvert/ bridge. There were isolated patches of aquatic macrophytes in 2014 but non were present in 2022. Whilst large trees are a feature of the riparian zone, live blackberries and bare ground where they have been poisoned, dominate. Intensive agriculture exists outside of the riparian zone. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 87 out of 140 in 2014 and a similar score of 91 in 2022.

5.14. Site 5.2- Boundary Creek upstream of Big Swamp



Site 5.2: upstream Autumn 2022



Site 5.2: downstream Autumn 2022



Spring 2022



Spring 2022



Site 5.2: upstream Autumn 2023



Site 5.2: downstream Autumn 2023

Site 5.2 on Boundary Creek was added to the current sampling regime to give additional information on the biological health of Boundary Creek upstream of Big Swamp. Boundary Creek is between 1 and 2 meters wide either side of the vehicle crossing and is very different to all other sites sampled with a mix of large and small, deep and shallow pools and runs. There are extensive areas of macrophytes including Triglochin, Ranunculus and Cyperus beds and isolated patches of Alisma and Juncus. The riparian zone is extensive consisting of predominantly, if not totally, native species. Pool deepening works close to the gauge were in progress at the time of sampling in Autumn 2023, as is evident by the silt and rock in the downstream picture. Overall analysis of the health of the waterway using EPA habitat parameters for Low Gradient Streams gave this site a score of 130 out of 140, the highest of any in this study.

5.15. Site BS1- Big Swamp eastern end



Site BS1: upstream Autumn 2022



Site BS1: downstream Autumn 2022



Spring 2022



Spring 2022



Site BS1: upstream Autumn 2023



Site BS1: downstream Autumn 2023

Site BS1 in Big Swamp was added to the current sampling regime to give additional information on the condition of Big Swamp. The water level was shallow and was slowly flowing around the extensive amount of large woody debris and beds of Giant Rush and scattered sedges and rushes such as *Gahnia* and *Cyperus*. There was a high amount of iron floc present on the substrate.

5.16. Site BS2- Big Swamp western end



Site BS2: upstream Spring 2022



Site BS2: downstream Spring 2022



Site BS2: upstream Autumn 2023



Site BS2: downstream Autumn 2023

Site BS2 in Big Swamp was dry in Autumn 2022 and whilst was holding water in Spring 2022 and Autumn 2023, water at this site is primarily standing not flowing as it is at Site BS1. Vegetation appears to be all native with an excellent riparian zone. Vegetation is similar to Site BS1 with beds of Giant Rush and scattered sedges and rushes such as *Gahnia* and *Cyperus* but without the extensive large woody debris. This site also has floating mats and submerged decaying mats of algae amongst the vegetation.

Appendix 2:

Autumn 2023 Macroinvertebrates

	1A	1B	2A	2B	3A	3B	4A	4B	5.1A	5.1B	5.2A	5.2B	BS2	BS1	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	
Ancylidae																									1				3	5	
Atriplectididae						1						1																			
Atyidae	1	2	2	1	1		3	4											6	9	7	2	8	6	5	9	6	4	1	1	
Baetidae	17	7									1						3	2		1							5	6	1		
Calamoceratidae				1	2	2					1	4									2										
Ceinidae			2	1	1		3	6	7	10	1	1			1				1	2	7		3	8	6	1		1	2	4	
Chironominae	3	16	3	2	1	16	12	6	1	4	7	2		17	3	12	1		2	6	8	19	4			1	25	8	18	11	
Coenagrionidae			1	3	5	6	2	2											1	7	6	2	1	3	5	2	4	3	3	19	
Corduliidae					2	3																									
Corixidae	6	6	23	12	4	8	6	12	5	1								2	4	7	19	21	6	14	2	1	5	12	4	12	
Crambidae																											2	1			
Culicidae	11								2	5				8	13	5															
Dixidae	1		1	1	2						4	6	2	2		1									4	7					
Dugesiiidae	1	4	1	3					6	6			10		1	3			10	12	2	2	19	12	5	1	4	1			
Dytiscidae		1	1		1	1			1				1		2	4															
Elmidae																				1											
Empididae																			1												
Glossiphoniidae											1	2											1								
Gripopterygidae												1																			
Gyrinidae			1	2				1												2	2	1	2	3			2	2	1	1	5
Hydraenidae												1		1									1				2				
Hydridae																														1	
Hydrobiidae	9	11			3	1			4	5	9	1	2																2		
Hydrobiosidae	6	3																													
Hydrochidae				2				1																							
Hydrometridae																							1		1	1					
Hydrophilidae								1													1						2				
Hydroptilidae	12	7			2	1	4	3	6	2	2	8					1	1	5	7	8	7	5	7	2						

	1A	1B	2A	2B	3A	3B	4A	4B	5.1A	5.1B	5.2A	5.2B	BS2	BS1	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B
Janiridae									1							1											1			
Koonungidae													4																	
Leptoceridae	14	10	24	6	35	22	23	32	5	12	18	17						3	13	1	24	11		1	2	1	15	2	7	4
Leptophlebiidae		3		1	2	11			1		8	5								2	1									
Lestidae																						1								1
Lymnaeidae																	1								2	1				
Megapodagrionidae					3																									
Mesoveliidae																						3	1							
Mites	1		8		2	12		7	2		5	1							9	2	1		23	18	9	3	6	16	3	9
Naucoridae				3																			5							
Nepidae													1																	
Notonectidae				3			1				1	1	2							2		1						1	2	3
Oligochaeta	1	4	2	1	1	2	2		4			1						1				1							1	
Orthoclaudiinae	9	11			1	7	9	3	1	1	2	6	1		1		4	1	1	1	6	7			2	1	1	2		1
Paramelitidae			1		2				2	1	1														3	1		1		
Perthiidae			1															1												
Physidae	5	4	1	2	20	16		1	9	11	3	2							3		1	3	5		2	1	8	11	12	17
Planorbidae					1												2													
Pleidae				1																										
Simuliidae	12	1				1				15											1	1					1	3		
Sphaeriidae		1							2	2																				
Stratiomyidae			3																1		1		1			2				
Tanypodinae	1	3			1				3	2	3	1										1			1		4	4	1	
Telephlebiidae					2						1																			
Tipulidae	1				1			1																						
Veliidae					9					4		2							2			1	1			5	19		13	1