

Upper Barwon River Macroinvertebrate Sampling Report 2019-2022

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1. Introduction

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

The survey determined a baseline for ongoing monitoring of the Barwon River as part of a remediation plan required by a section 78 Ministerial Notice by:

- Assessing the spatial extent of surface water effects resulting for acidic discharge from Boundary Creek in the Barwon River,
- Determining if acidic discharge from Boundary Creek has affected sediment in the Barwon River and if so, the spatial extent and depth of accumulation, and;
- Assess the potential impact of acidic discharge from Big Swamp at Yeodene on the macroinvertebrate community structure in Boundary Creek and the Barwon River.

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

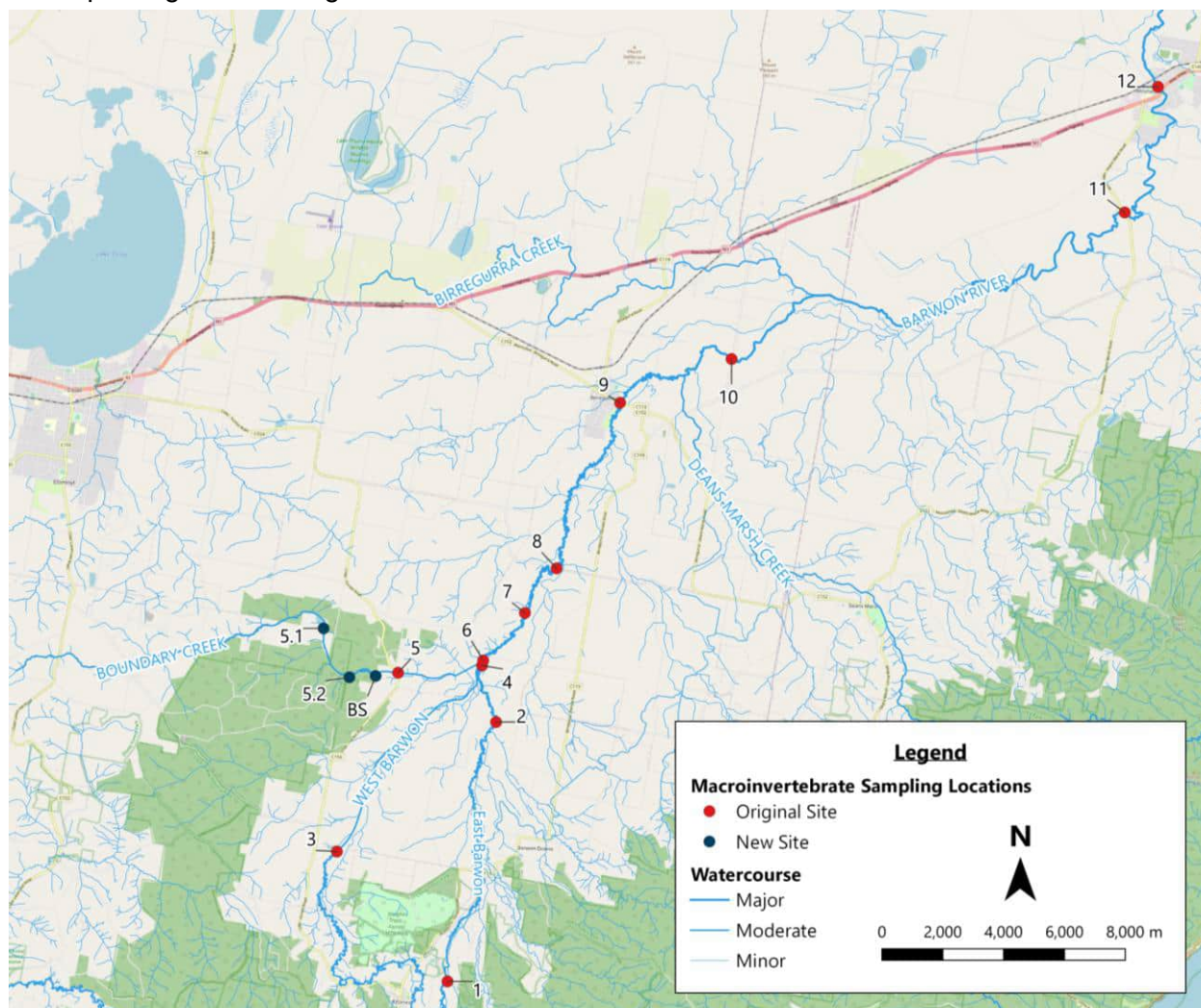
The objective of this report is to provide an overview of the ecological condition of Boundary Creek and the upper Barwon River and the impact, if any, of Big Swamp and Boundary Creek on the Barwon River.

1.3. Summary

Barwon Water has committed to continuing water quality and macroinvertebrate sampling along the Barwon River and within Boundary Creek over the following two years during the Boundary Creek remediation works. Sampling biannually will give 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, the Barwon River is in very good condition at a number of 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 2019, Autumn 2020, Spring 2020, Autumn 2021, Spring 2021 and Autumn 2022. A further 3 sites were surveyed on Boundary Creek and in Big Swamp along with the original twelve in Autumn 2022.



■ **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.**

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, one site in Big Swamp and eight sites are on the mainstem 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 @ 7 Bridges Road	Upstream	-38.474669	143.689396
4	Barwon River 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
BS	Big Swamp @ eastern end	Big Swamp	-38.422270	143.702076

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 9th and 10th November, 2021. 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 or fencing or 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 4 below give an indication of the conditions at the time of sampling.

■ **Table 2: In-situ water quality data- Spring 2019, Autumn 2020, Spring 2020, Autumn 2021, Spring 2021, Autumn 2022.**

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
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
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
Site 4 Barwon River 100m upstream of Boundary Creek confluence	Spring 19	17.9	7.4	575	664	9.15	96.4	10	8.01
	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
Site 5	Spring 19	12.1	3.94	777	1030	7.43	67.6	0	2.92

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)
Boundary Creek@ Colac-Forrest Road	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
Site 6 Barwon River 100m downstream of Boundary Creek confluence	Spring 19	14.4	7.34	608	756	7.3	71.3	10	9.43
	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
	Spring 21	16.7	7.48	262.2	310.8	6.20	66.3	30	18.5
Site 7 Barwon River @ north boundary of plantation	Autumn 22	12.4	7.25	477	628	9.38	88.1	35	12.5
	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 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
Site 9 Barwon River @ Birregurra	Autumn 21	11.0	6.74	255.8	350.3	7.10	64.2	25	12.4
	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 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
Site 10	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
	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
Site 10	Spring 19	14.6	7.9	1252	1561	8.1	86.1	15	18

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	Autumn 20	16.2	5.56	511	613	3.96	40.2	15	19.2
	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
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
Site 12 Barwon River@ Princes Hwy bridge, Winchelsea	Autumn 22	12.4	7.46	1369	1805	7.02	65.3	70	16.2
	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
Site 5.1 Boundary Creek downstream of McDonalds Dam	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
Site 5.2 Boundary Creek upstream of Big Swamp	Autumn 22	13.2	6.81	461	694	6.23	59.5	35	3.29
Site BS Big Swamp eastern end	Autumn 22	8.9	6.72	410	592	10.18	87.2	30	5.07
	Autumn 22	9.6	5.48	656	929	19.4	2.20	10	20.1

The metal and acidity loads emanating from Big Swamp and Boundary Creek appear to be highly variable and most likely linked to flows through Big Swamp. Noting that the pH values in the Barwon River downstream of the confluence with Boundary Creek appear unaffected by the low pH in Boundary Creek reflects the Barwon's good buffering capacity. The Barwon River pH values lie predominantly within the ecologically optimum range of 6.5 to 8.5. Conductivity was consistently higher at all sites than most previous sampling events, similar to concentrations recorded during the first sampling event in Spring 2019. Dissolved oxygen levels are typical for the lower flows often seen in Autumn and the low levels in Big Swamp at Site BS are consistent for wetlands.

- 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
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	<0.001	<0.001	<0.001	0.006
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
Site 4 Barwon River 100m upstream of Boundary Creek confluence	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
	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	<0.0001	<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
Site 5	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

Site	Waterway	Sampling event	Filtered Metal Concentration (mg/L)											
			Aluminium	Antimony	Arsenic (total)	Cadmium	Chromium (total)	Copper	Iron	Lead	Manganese	Mercury	Selenium	Silver
Boundary Creek@ Colac-Forrest Road	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
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
	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
Site 7 Barwon River @ north boundary of plantation	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 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
Site 8 Barwon River @ Colac- Lorne Road	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 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
Site 9 Barwon River @ Birregurra	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 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
Site 9 Barwon River @ Birregurra	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

Site Waterway	Sampling event	Filtered Metal Concentration (mg/L)												
		Aluminium	Antimony	Arsenic (total)	Cadmium	Chromium (total)	Copper	Iron	Lead	Manganese	Mercury	Selenium	Silver	Zinc
Site 10 Barwon River @ Conns Lane	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
	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
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
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
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
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
Site BS 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

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

Aluminium concentrations in Autumn 2022 are within ANZECC guideline levels at sites below the Boundary Creek confluence (Sites 6-12), reduced from Spring 2021 concentrations. Whilst Aluminium concentrations were higher in Big Swamp (Site BS) than above the swamp (Site 5.1 and 5.2), they were lower than at Site 5, below Big Swamp. Arsenic concentrations were the highest they have been over the past three years at Site 5 (Boundary Creek at Colac-Forrest Road), exceeding the ANZECC guideline levels but concentrations are below detectable levels in the Barwon River downstream of the Boundary Creek confluence (Sites 6-12). Copper concentrations exceed ANZECC guideline levels within Big Swamp (Site BS) but were undetectable in Boundary Creek at Site 5. Iron concentrations in Autumn 2022 at Site 5 (51mg/L) were similar to that detected in Autumn 2021 (50mg/L) and were similar to that detected in Big Swamp (48mg/L). Zinc concentrations exceed ANZECC guidelines in Autumn 2022 at Site 1 (East Barwon at Kents Road) and most sites along the West/ main branch of the Barwon River (Sites 3, 4, 6, 8, 9, 10, 11, 12) in addition to Site 5 on Boundary Creek and in Big Swamp (Site BS). The iron oxyhydroxide floc that was observed on vegetation at Site 6 (immediately downstream of the Boundary Creek confluence) in Autumn 2021 was not present in Autumn 2022, possibly because low flows meant that the slow flow areas where material would settle was not inundated but also the filterable iron concentrations at the site were significantly less than those reported in Autumn 2021 (Table 3).

3.2. Macroinvertebrates

Biotic indices such as AusRivAS, SIGNAL2, EPT (Ephemeroptera, 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). 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 2022 is in Appendix 2.

AusRivAS scores and bands (Table 3) 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).

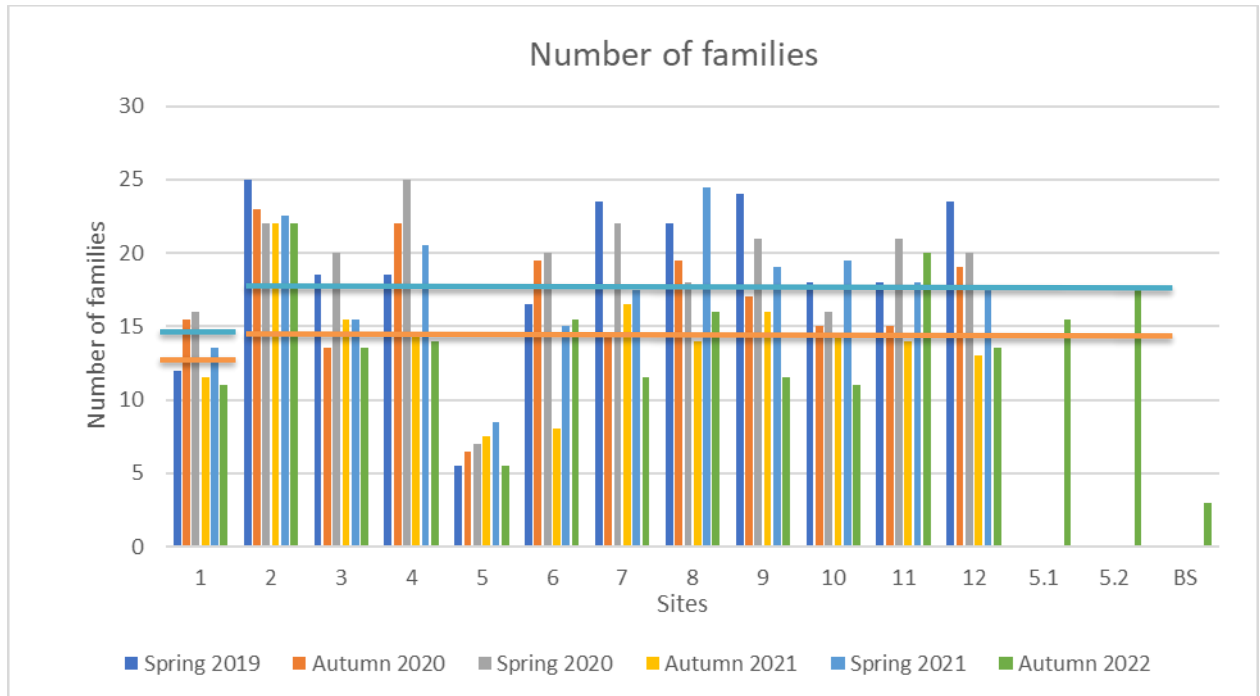
The EPT score indicates the number of families that are sensitive to pollution that are present at the site with a low score usually indicating that there has been some type of disturbance. Together, these scores give a good picture of the health of the waterway at a site and potentially what is causing 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 Yaugher) 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. Site BS is a wetland site and as such objectives have not been applied to this site.

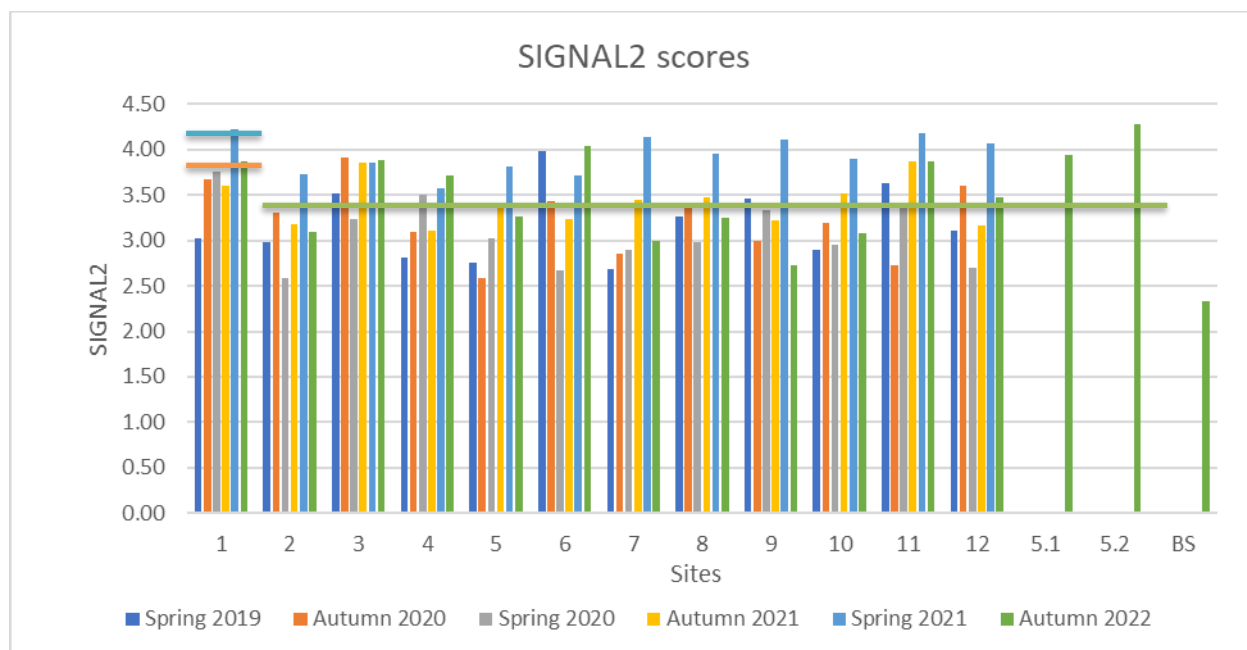
■ **Table 5: Environmental Quality Objectives for Biological Indicators, edge habitat (VGG, 2021)**

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.**

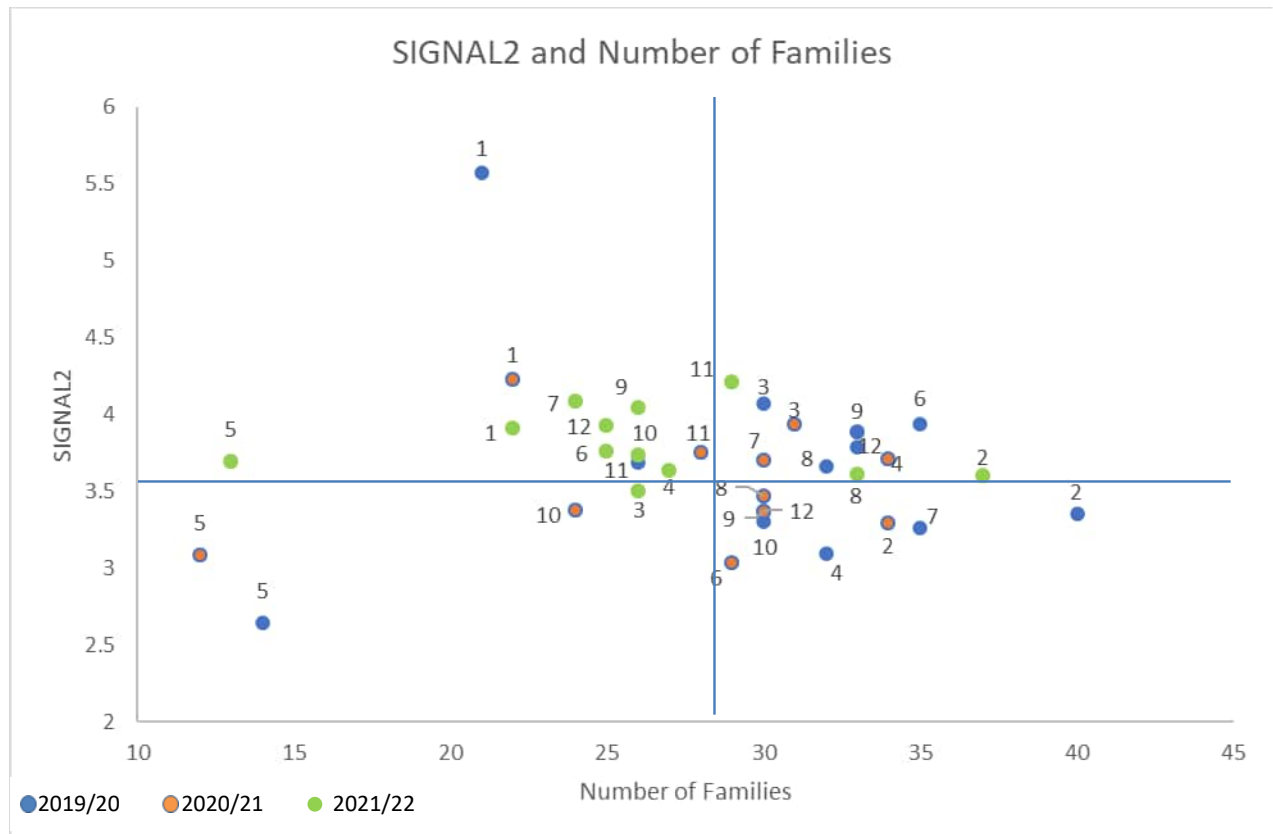
Figure 2 shows that the East Barwon River at Dewings Bridge Road (Site 2) is the only site to consistently meet the objectives for Number of Families. In addition, the new site, Site 5.2 on Boundary Creek immediately above Big Swamp, and Site 11 were the only other sites to meet the Number of Families objective in Autumn 2022. There are no consistent patterns along the waterways over time but it is interesting to note that Boundary Creek above Big Swamp (Sites 5.1 and 5.2) have comparable numbers of families present to sites on the Barwon River.



- **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 whilst none of the sites consistently meet the objectives for SIGNAL2, 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 five of the six sampling events. Boundary Creek at Colac-Forrest Road (Site 5) met the SIGNAL2 objectives during the Spring 2021 sampling event when pH was at its most neutral (6.05 pH units). The two Boundary Creek sites upstream of Big Swamp recorded amongst the highest SIGNAL2 scores of the study.

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.

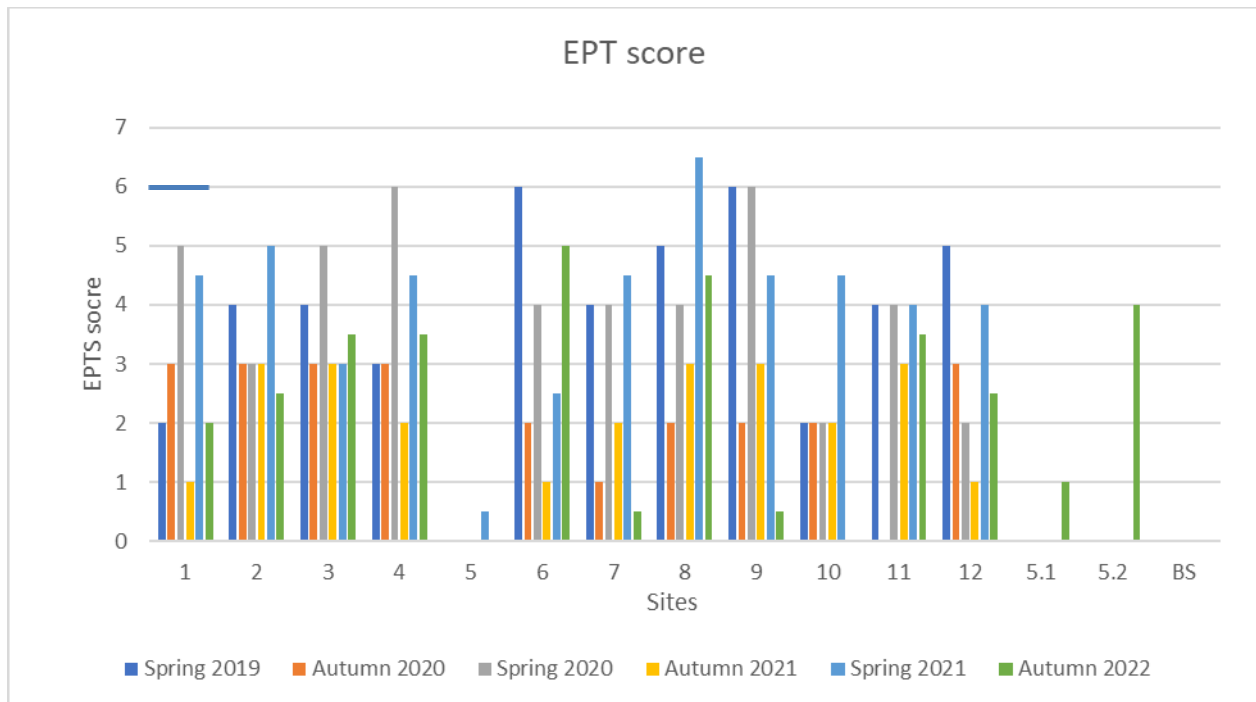


■ **Figure 4: SIGNAL2 index plotted against number of families recorded for each site combined over season for three years.**

Figure 4 above shows that for most sites, above and below the Boundary Creek/ Barwon River confluence, there was a shift to the upper left quadrant with fewer families being present but not a corresponding shift to fewer pollution sensitive taxa. Sites in this quadrant are often subject to toxic pollution such as heavy metals or low pH or harsh physical conditions (Chessman, 2003). The cause of the shift is not clear but is unlikely to be due to Boundary Creek impacts as sites above and below the confluence were affected.

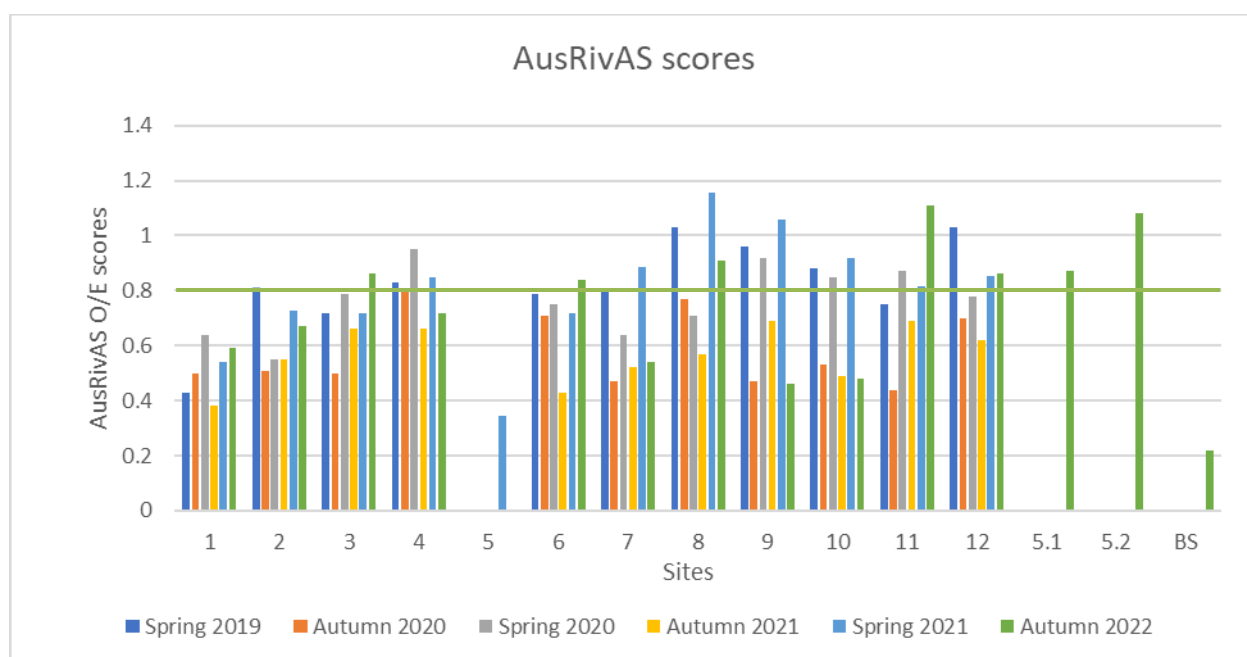
The two uppermost sites on the Barwon River tributaries, Site 1 (East Barwon at Kents Road) and Site 3 (West Barwon at Seven Bridges Road) show different patterns to the majority of the sites. The river has been extensively modified during willow removal works at Site 1 during the 2021/22 summer with the number of families remaining stable but the SIGNAL2 score has declined over the study period. The SIGNAL2 score has also declined over time at Site 3 and the number of families present has reduced by five families between 2020/21 and 2021/22.

The pollution sensitive Ephemeroptera, Plecoptera and Tricoptera (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 (Ephemoptera, 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 sites such as Site 9 at Birregurra have good numbers of these taxa present in Spring and that in Spring 2021, Site 8 at Colac-Lorne Road had the highest number of EPT taxa present over the three years.



■ **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 4 (upstream of Boundary confluence), 9 (Birregurra) and 10 (Conns Lane) meet AusRivAS objectives during every Spring sampling events over the three years. AusRivAS objectives were met in both the latest Spring and Autumn sampling events at Sites 8 (Colac-Lorne Road), 11 (Winchelsea-Deans Marsh Road), and 12 (Winchelsea). The two new sites on Boundary Creek above Big Swamp (Site 5.1 and 5.2) both met objectives and the site in Big Swamp recorded the lowest score whilst Site 5 was once again outside the experience of the model in Autumn, presumably due to the low alkalinity at this site.

■ **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
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
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

Site Waterway	Season	Number of Families	SIGNAL2 Index score	EPT Index score	AusRivAS Band	Number of objectives met
	Autumn 22	X	✓	N/A	✓	2
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
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
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
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
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
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
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 11	Spring 19	X	✓	N/A	X	1
	Autumn 20	X	X	N/A	X	0

Site Waterway	Season	Number of Families	SIGNAL2 Index score	EPT Index score	AusRivAS Band	Number of objectives met
Barwon River @Winchelsea- Deans Marsh Road	Spring 20	✓	✓	N/A	✓	3
	Autumn 21	X	✓	N/A	X	1
	Spring 21	X	✓	N/A	✓	2
	Autumn 22	✓	✓	N/A	✓	3
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
Site 5.1 Boundary Creek downstream of McDonalds Dam	Autumn 22	X	✓	N/A	✓	2
Site 5.2 Boundary Creek upstream of Big Swamp	Autumn 22	✓	✓	N/A	✓	3
Site BS Big Swamp eastern end	Autumn 22	N/A	N/A	N/A	N/A	N/A

To have met Biological Objectives for a sampling event, objectives for all of the indices must be met (VGG, 2021). This occurred once at Site 8 (Colac-Lorne Road) in Spring 2021, once at Site 9 (Birregurra) in Spring 2019, once at Site 12 (Winchelsea) in Spring 2021 and once at Site 5.2 (Boundary Creek immediately upstream of Big Swamp) during the only sampling event in Autumn 2022. Site 4 (upstream of the confluence) and Site 11 (Winchelsea-Deans Marsh) have met objectives twice out of the six times sampled, in Spring 2020 and Spring 2021 at Site 4, and Spring 2020 and Autumn 2022 at Site 11. Objectives are not applicable to the site within Big Swamp as it is a wetland rather than a flowing waterway (biological assemblages did not meet objectives regardless of the waterbody).

Site 5.1, downstream of McDonalds Dam was surveyed in Autumn 2015 as part of an assessment of the condition of Boundary Creek by Jacobs Australia and Austral Research and Consulting (2015). Just over half of the macroinvertebrate families were different between Autumn 2015 and Autumn 2022 but the majority of those different families were single individuals and whilst the number of families reduced from 21 in 2015 to 16 in 2022, the SIGNAL2 score went up from 3.65 in 2015 to 3.94 in 2022.

Sampling macroinvertebrates in Big Swamp (Site BS) partially filled a data gap in this project although only one accessible site contained water and a sample was only taken during one event (Autumn 2022). 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. Only three taxa were collected at the site; Chironomid larvae (non biting midges), Culicid larvae (mosquitos), and Dytiscid adults (diving beetles). All three taxa are very tolerant of pollution or harsh conditions and were found at other sites within the catchment.

4. Discussion

The metal and acidity loads in the lower reaches of Boundary Creek downstream of Big Swamp continue to be highly variable. This is reflective of the acidification and mobilisation processes occurring as a result of the acid sulfate soils and the seasonal flow regime, despite the use of supplementary flows to maintain minimum flows in Boundary Creek. Under acidic conditions aluminium and iron have the potential to form insoluble flocs which can smother vegetation and clog gills of aquatic organisms although flow will dislodge this floc as was observed in Autumn 2021 at Site 6 below the confluence with Boundary Creek. Zinc also exceeds the ANZECC guidelines and is mobilised within the catchment probably in response to acidic conditions. Macroinvertebrate community composition is comparable in Boundary Creek above Big Swamp, if not better, to that found in the upper Barwon River but continues to be poor downstream of the swamp at Site 5. That said, ecological health at Site 5 has shown improvements over time, potentially bolstered by the increase in pH despite the reduction in quality in Autumn 2022 after a peak in Spring 2021. This is consistent with the findings of the hydrogeochemical modelling report which indicates ‘the risks to the Barwon River are highest in May and June, when discharge from Boundary Creek contains higher concentrations of parameters of concern and flows from the creek begin to increase’ (Jacobs 2021).

The effects on Barwon River’s water quality from Boundary Creek inflows are of very limited downstream effect. The buffering capacity of the river combined with its larger discharge mean pH shows 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 at least once in the last three years and Sites 8, 11 and 12 meeting all three EPA biological objectives during either spring or autumn in the last 12 months reflecting the ability of the Barwon River to absorb catchment impacts on water quality or habitat condition.

Boundary Creek is in very good condition upstream of Big Swamp and appears to be in a good position to provide recolonisation via drift or aerial dispersal to the downstream wetlands and waterways provided water quality can be improved. 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 but declined in Autumn 2022. While this corresponded with a lower pH, this pattern was evident at many sites during this last sampling round, likely indicating a regional rather than local influence.

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.

The addition of a site on Boundary Creek upstream of Big Swamp will give a measure of what could be expected downstream of the wetland should water quality conditions improve. Site 5.1 is most similar to Site 5 with regard to instream habitat and therefore would be a logical addition to the sampling regime. The number of sites sampled on the Barwon River could be reduced to Site 4 (above the confluence with Boundary Creek), and Sites 6, 7, 8 and 9 (Birregurra) as any impact on the Barwon River from Boundary Creek past this point has not been observed since monitoring commenced in 2019. Surveys conducted during wet periods such as during Spring 2021 showed the extent of connection between Boundary Creek and the Barwon River via overland flow and wetlands around Site 4. For this reason and safety issues associated with crossing Boundary Creek to access Site 4, consideration should be given to moving Site 4 further upstream just below the West Branch/ East Branch Barwon confluence. The site would need to be accessed from the east bank and would require the cooperation of adjacent landholders. An annual survey, perhaps during Spring to maximise wetted habitat could be conducted in Big Swamp but this is unlikely to assist in determining the effect of Boundary Creek/ Big Swamp on the upper 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

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 dominate the riparian zone and are growing within the stream channel. 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 is a homogenous channel with very little riparian zone and submerged macrophytes. The banks were either disturbed bare earth with some grasses beginning to establish or rip rap and not unexpectedly for such extensive and recent works, the river was more turbid than previously observed. Stock now appear excluded from the waterway and all woody weeds have been removed within the vicinity of the site.

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

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

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. 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 100m upstream of Boundary Creek 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

The Barwon River 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

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 and Autumn 2022. The riparian zone is wide and a mix of native and exotic vegetation except the ground cover which is dominated by *Convolvulus* sp. and pasture grasses. 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 Creek 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

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. 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

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

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

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. Rakali footprints are evident in the soft sediment edge during many of the sampling events. 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

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 and 2022. 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

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

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

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 none 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

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. 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 BS- Big Swamp eastern end



Site BS1: upstream Autumn 2022



Site BS1: downstream Autumn 2022

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.

Appendix 2:

Autumn 2022

	1A	1B	2A	2B	3A	3B	4A	4B	5.1A	5.1B	5.2A	5.2B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	BS2
Aeshnidae			1	2																					1				
Atyidae			1	2	2		3	7							1	9	3	16		1	3	11	8	15	2	8		2	
Baetidae			4	4	4		1	7							15	23			2	2					2		12	4	
Belostomatidae				1																1									
Caenidae																1													
Calamoceratidae																				1					2	1			
Ceinae			6	2	2		5	3			5	11					8	10		2	7	1	1	2		3	1		
Ceratopogonidae																					2	1							
Chironominae	3	2	1	10	7	3	5	12	28	30	3	1	10	2	8	2	1	1	3	13			1		2	9	13	5	59
Coenagrionidae			15	23	1		7	8								2	2	9	7	26	4	10		2	2	4	1	1	
Corduliidae									1									1											
Corixidae	19	28		6	17	7	19	6		1					1		7	25	22	5	5	15	3	5		1	6	3	
Crambidae			1	3	1											1									1	1			
Culicidae													14	9															9
Dixidae			4	1					1	4	19	41											2						
Dugesidae			7	15	1												15	15	4	4	18	7	6	2	11	14	1	12	
Dytiscidae			1	4						1		1	5	2															2
Ecnomidae								1										1							1				
Elmidae																										1			
Glossophoniidae				1																1								1	
Gripopterygidae											3	1																	
Gyrinidae			3	1			3	1							2	10	1		2					1	4	4	1		
Hydraenidae				1		2																							
Hydrobiidae	2	8							2	6	4	4																	
Hydrobiosidae															1	1													
Hydrophilidae		1	1	1						1														1					
Hydropsychidae																											1		

Hydroptilidae	1	1		1	3	2						7			5	8			8	2											
Janiridae										1															1						
Leptoceridae	12		11	9	18	27	6	16	2	6	14	16			21	13			11	22	1				1	1	2	6			
Leptophlebiidae		7			4	1	1	2			1	5			1				1	1				1							
Lestidae																			1												
Lymnaeidae				1			1		1		1	1			1	1			1					2							
Mesoveliidae																					1	1									
Mites		2			2	6		1	2	23	3	6				1	1	1			3	8	6	15	5	4	1	17			
Naucoridae				1																	1										
Notonectidae		2	3				1	1		1	2	11					4		2	2						2					
Notonemouridae												3																			
Oligochaeta			2	2			1		2	7	2				9	2			2		1	1	1		1	2					
Orthocladiinae	8	3	2	4	3	1	1	3		1	2	2	1		9	2	1	2	1				1	1	2	2	6	1			
Paramelitidae			1	3				1		1	1							1													
Perthiidae			1													1															
Physidae	3	1	4	1	9	1			2	3	16	5			1		2	4	4	3	1	1		1	7	15	10	18			
Pleidae				1																											
Scirtidae sp.	1								1				1	2										1	1						
Simuliidae	12	1					1		4	2	3				3	3								1							
Sphaeriidae									5	4																					
Tanypodinae	1	4			2	1					1	1							1					1	3	2	1				
Telephlebiidae												1																			
Tipulidae									1																						
Veliidae					3	14			2	5	1	2	1	3		1		2			1		1	5	3	7	2	1			