Reducing stormwater pollution in the Werribee catchment

Sources Impacts and solutions

2020

Bridging Troubled Waters

Linking community groups with pollution tracking technology

2018 - 2020

Disclosure Statement

Bio2Lab Pty Ltd acknowledges that some of the recommendations made herein (particularly regarding monitoring of industrial pollutants) could be construed as in the interest of the company, as Bio2Lab provides such services and stands to gain financially if an employment opportunity should arise. In light of this, all possible efforts have been made to ensure impartiality in all recommendations and discussions provided. Bio2Lab does not promote their business practices in this document, nor one technology or supplier over another. The advice they put forward in this document is therefore meant to be taken as general in nature. It is also acknowledged that the company will only participate in any possible future action that may be taken in this space if the process of involvement is deemed to be fair, unbiased and based on merit.

Citation

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Acknowledgements

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We acknowledge the Traditional Owners of the land on which this investigation took place. We pay our respects to their Elders, past and present, and the Aboriginal Elders of other communities.

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Executive Summary

This report, for the first time, provides stakeholders and the public with an easily accessible ecological report card of waterways in the Werribee Catchment, while also identifying the priority pollutants and catchments requiring further investigations by the appropriate authorities. It also sets environmental baseline targets which can be used to measure changes in waterway condition over time - critical in assessing the success of environmental education and enforcement programs and in the development of waterway management strategies. It is anticipated that this approach could be further refined and used as a cost-effective, standardised waterway assessment template for waterway managers and other community groups across Australia.

This approach, which essentially identifies high risk sub-catchments for priority action, can assist in targeting where funds and resources are directed to improve the environmental, social and economic sustainability of urbanised catchments. Establishing environmental baseline targets will allow changes in waterway condition to be independently monitored and assessed, with the results feeding back into adaptive management programs. By incorporating adaptive management approaches into local environmental strategies will allow best practice environmental management to be implemented as technologies develop and environmental health outcomes change over time.

Results showed clearly that the Werribee catchment requires urgent environmental management strategies that tackles stormwater pollution. The impacts on local biota are real and will continue to cause decline unless waterway managers, councils, industry and the community addresses stormwater pollution. Results from the hotspot investigation clearly showed that education and awareness, coupled with enforcement actions can change business practices and reduce stormwater pollution to our waterways. This should prompt further investigation by the relevant authorities to clarify the major sources of contaminants of concern, and put in place strategies to reduce or stop ongoing discharges from reaching the Werribee River and other associated creeks.

Initiating comprehensive, integrated and sustained environmental education and enforcement programs actively supported by both local government and the environmental regulator should form the basis of on-going stormwater reduction strategies. One of the outcomes from this investigation is the establishment of environmental baseline targets which can be used to measure changes in waterway condition over time. Coupling integrated stormwater programs with on-going independent pollution monitoring of receiving waters would allow the success of these programs to be assessed. To further build public confidence in and support for the program, the monitoring data must be publicly available, readily accessible, and easy to understand by both business and the general public.

It is hoped that results from this project will initiate integrated stormwater education and awareness programs, with local governments, environmental regulators and waterway managers leading the way. Using the voices of community groups such as the Werribee River Association will provide for more effective communication with those that matter - the general public and industry.

Introduction

With the expansion of urban landscapes, maintaining the ecological condition of waterways becomes increasingly difficult. Altered flow regimes and increases in stormwater pollution can cause significant stress to local biota. In particular, trace metals, pesticides and hydrocarbons can all enter aquatic environments via stormwater runoff and accumulate within local sediments. This can lead to contaminated ecosystems and loss of biodiversity. Reducing pollution inputs to urban aquatic ecosystems is a key challenge facing water managers as urban landscapes expand. For waterway management strategies to be effective, it is vital to identify priority stressors, their sources, and impacts on aquatic systems.

Aquatic macroinvertebrates are popular biological indicators globally, because they are abundant and diverse, and can be sensitive to changes in sediment and water quality, flow regime and habitat conditions. Therefore, the responses of biological communities - or of individual organisms - can be monitored to indicate effects on the ecosystem. The presence or absence of certain species at particular locations can indicate, for example, whether habitat or water quality have changed. In Australia, the Stream Invertebrate Grade Number Average Level (SIGNAL), Ephemeroptera, Plecoptera and Trichoptera (EPT) and number of families are simple biotic indices used to assess the biological condition of rivers and streams in Australia.

One of the most effective ways to reduce the ecological impact of stormwater pollution on waterway biota is to prevent the pollution in the first place, and one of the best ways to achieve this is through targeted stormwater education, awareness and sometimes enforcement programs. Often, it may only be one or two premises in a catchment that are generating the majority of the pollutants reaching local waterways. Identifying high risk catchments and premises that are generating the bulk of the pollutant loads is critical when designing targeted education and enforcement programs at a regional scale. Unfortunately, due to extreme variability in stormwater flow rates and pollution concentrations, accurate characterization of pollution sources using traditional water sampling techniques is usually either cost-prohibitive or ineffective.

To overcome these issues, passive samplers specifically designed to accumulate contaminants over extended periods of time can be used. Stormwater passive samplers are devices deployed into stormwater drains that continuously accumulate contaminants over an extended period of time, providing a time-weighted average concentration for the monitoring period. This approach is ideal for detecting pulse pollution events that would otherwise be missed, and is a cost-effective way to characterize hydrophobic contaminants in stormwater simultaneously across catchments. Results can quickly identify pollution hot-spots within a catchment, thereby providing stormwater managers and environmental authorities with targeted areas to undertake compliance and education programs.

This project aims to reduce threats to Port Phillip Bay health by determining sources and impacts of pollution in the Werribee catchment using smart stormwater solutions, biological assessments and leveraging of community partnerships. Identifying priority sources of pollution will help local government, EPA, Melbourne Water, and the community better target education and enforcement campaigns. Collaboration between all these stakeholders is critical to improve the condition of our urban waterways by reducing water pollution. The collection of baseline stormwater pollution profiles and sediment and biological quality information will also form the basis for evaluating long term success of the program.

Figure 1 Microplastics found in the Werribee River at Maltby Bypass

The Werribee Catchment

The Werribee catchment region spans a vast geographic area of around 2,500 Km^2, west of Melbourne (Figure 3). Landuse in the catchment comprises a patchwork of some of Victoria's most distinctive landscapes. From agricultural plains and expansive native grasslands to natural forests and vibrant urban centres. Numerous rivers and creeks traverse the landscape, all which provide important habitat for an enormous range of species (Figure 6). The Werribee River, alongside other waterways such as the Lerderderg River and Skeleton Creek also provide ecological, economical, social and cultural values to the community. The headwaters of the Werribee and Lerderderg rivers in particular are recognised as sites of international and state geomorphological significance. Their landscapes provide breeding habitat for a range of species including the peregrine falcon and the wedge-tailed eagle[1].

Numerous ecological values important to the catchment are currently at risk from urban growth and agricultural activities (Table 1[1]). In particular, the decline in platypus populations in the upper and middle reaches of the catchment requires significant investment in habitat improvement and flow stabilisation. To some extent, this is now happening. Agricultural activities in the catchment have left the Werribee River highly flow stressed due to diversions for the supply of irrigation water to Bacchus Marsh and Werribee.[2] To improve the system, the river receives environmental flows to protect and increase fish populations, stabilise platypus and macroinvertebrate populations, while generally increasing the health of the river.

Figure 2 Collecting sediment in the Werribee River in Werribee South

Table 1 Werribee subcatchments, key values and current condition[1]

Sub catchment	Key value	Current condition
Upper and Middle	Platypus	Very Low
	Fish	High
	Frogs	Moderate
	Birds	Low
	Vegetation	Moderate
	Macroinvertebrate	Moderate
	Amenity	Moderate
Lowland Systems	Platypus	Very Low
	Fish	High
	Frogs	Moderate
	Birds	High*
	Vegetation	Low
	Macroinvertebrate	Moderate
	Amenity	Moderate
Skeleton and Kororoit system	Platypus	Not present
	Fish	Moderate
	Frogs	High
	Birds	Low
	Vegetation	Low
	Macroinvertebrate	Low
	Amenity	Moderate

1. https://www.melbournewater.com.au/water/health-and-monitoring/river-health-and-monitoring/werribee-catchment

2. Mackintosh, T. J. (2018) Our Werribee River - A water quality analysis report, prepared for the Werribee River Association

Current Werribee subcatchment pressures[1]

Upper and Middle

The greatest challenge facing waterway health in this subcatchment is the impact of urban growth and agriculture, which will continue to affect water quality.

Werribee and Little River lowlands

The greatest challenge facing waterway health in this subcatchment is the impact of urban growth and the need to balance environmental and economic outcomes.

Skeleton and Kororoit Creek

The greatest challenge facing waterway health in this subcatchment is urbanisation, industrial activity and balancing social and environmental outcomes

Monitoring aquatic ecosystems

Environmental health indicators

Environmental health indicators are defined as physical, chemical, biological and socio-economic measures that represent key elements of an ecosystem. Aquatic ecosystem health indicators can be broadly divided into three categories:

- Physico-chemical indicators
- Biological indicators
- Habitat indicators

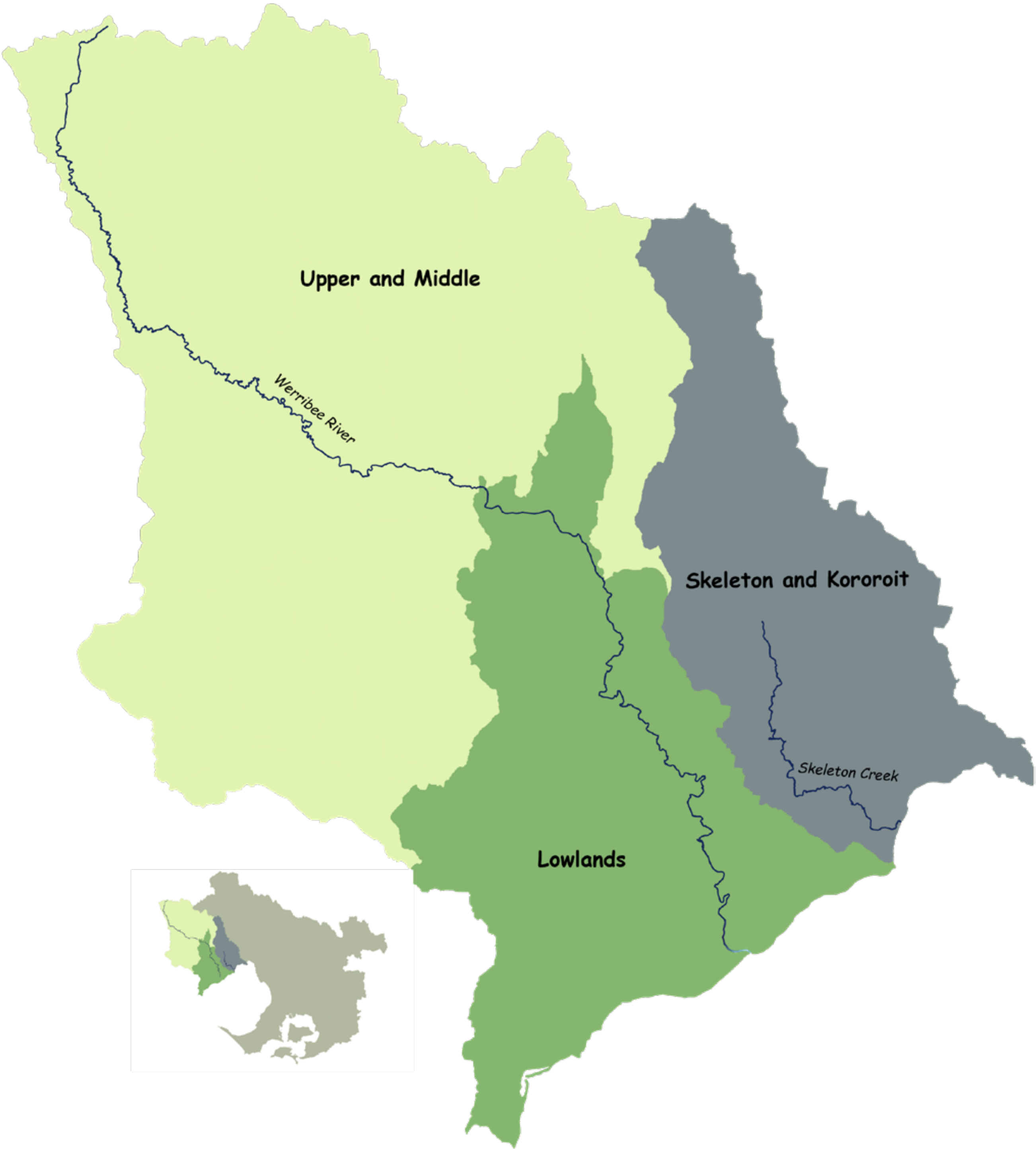


Figure 3 The Werribee catchment showing the 3 main subcatchments

Physico-chemical indicators

Physico-chemical indicators are the environmental quality indicators which most people are familiar. Parameters include dissolved oxygen, pH, temperature, electrical conductivity and nutrients (nitrogen and phosphorus) (Box 2). They can also include measures of toxicants such as insecticides, herbicides and metals. Environmental quality indicators provide a 'snapshot' of environmental conditions at the moment samples are taken, yet often fail to detect pulse pollution events, and only provide limited information on the extent that pollutants are actually impacting local biota[1]. To assess the ecology of a system, we need to turn to biological monitoring.

Biological indicators

Biological monitoring involves directly assessing the health of aquatic, providing a more holistic indication of the condition of a waterway. Because biota often live at a site for long periods of time, they can reflect environmental changes caused by pollution events and / or more subtle changes to land use.

Macroinvertebrate indices

In Australia, to monitor and assess aquatic ecosystem condition, broad-scale rapid biological monitoring approaches based on aquatic macroinvertebrates are

Figure 4 Steve Marshall from Bio2lab sorting macroinvertebrates collected from the Werribee River at the fishladder near Werribee Mansion.

1. CSIRO (1999) Urban stormwater : best practice environmental management guidelines.

Australia's great environmental challenge

As populations grow, the need for additional housing and other infrastructure such as roads puts pressure on our natural ecosystems. Population growth also tends to be most concentrated in the outer suburbs, with around 20,000 new dwellings built each year in Melbourne's major greenfield sites. The flow on effect from increased urbanisation is an ongoing impact to the environment, in particular pollution associated with urban and industrial land use activities (Table 2).

Stormwater pollution is one of Australia's greatest environmental challenges, driven by the continual expansion of urban landscapes across the country. Increased urbanisation increasingly involves the transformation of pervious landscapes into impervious landscapes. As land becomes more impervious, rain runoff must be managed through stormwater systems, which increases the efficiency of water transport to receiving environments such as local waterways. However, increases in stormwater often leads to significant impacts on the health of aquatic habitats[1].

Table 2 Effects of stormwater on waterway ecology and system processes

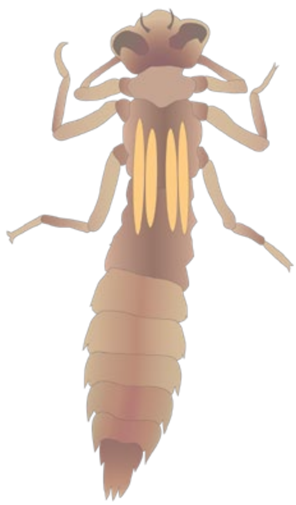
Increased stormwater	Flooding	Habitat loss	Loss of wildlife	Contamination	Erosion
Increased peak flow	✓	✓			✓
Increased volume	✓	✓			✓
Sediment load changes	✓		✓		✓
Pollution			✓	✓	

1. Pervious landscapes such as parklands and natural habitat allow water to filter and pass through into the top-soil. Impervious landscapes such as roads, roofs and concrete paths prevent water from passing through into the top soil. Rain that falls on these hard surfaces is directed into stormwater drains to prevent flooding.

The primary problem with water entering waterways from hard surfaces or drains is the contamination often associated with those hard surfaces. Runoff can pick up pollutants such as heavy metals, oils, nutrients and litter from these surfaces. These pollutants inevitably end up in our creeks, rivers and wetlands, and ultimately the bay and marine environments. As stormwater is rarely filtered, it is very difficult to stop pollutants from harming wildlife and degrading local waterways. Even when it is not raining, human activities such as machinery wash downs, inappropriate disposal of waste into stormwater drains, garden watering, and car washing can all contribute to what is known as dry-weather flows. While dry-weather flows carry much lower volumes of water than rain events, they often have very high pollutant concentrations. This is especially true in areas associated with industrial and mechanical processing and manufacturing industries.

The importance of sediment

Sediment is essential in maintaining the health of aquatic ecosystems. They play a critical role in maintaining an enormous variety of species that are central to fundamental processes at local and global scales. The 175,000 or so organisms associated with freshwater sediments all play important roles in the many ecological processes that keep freshwater clean and healthy[2].



Over time, pollutants generated from catchments and transported to receiving environments via stormwater often accumulate in aquatic sediments. Pollutants in sediments can adversely affect the overlying water column and can be re-suspended during storm events, facilitating entry of contaminants into the food chain (Simpson et al, 2005). Trace metals in particular, due to their highly toxic effect, long residence time and bioavailability are a risk to sediment dwelling biota, and potentially to human health. Because pollutants such as heavy metals

2 Palmer, M., et al (1997). "Biodiversity and ecosystem processes in freshwater sediment." Ambio 26: 571-577

tend to persist in the environment, waterway managers can use them as a marker for waterways under pressure from poorly managed urbanisation. Since sediment quality has a well-established link to ecological health, this also provides an insight into the potential impact of pollution on the health of the local aquatic ecosystem.

Figure 5 Maltby bypass stormwater outlet

commonly used. Macroinvertebrate data is generally interpreted using several metrics. These include the SIGNAL (Stream Invertebrate Grade Number – Average Level) biotic index score, the number of key families, the total number of families and the EPT index (number of Ephemeroptera, Plecoptera and Trichoptera families) score.

Habitat indicators

Habitat indicators include both riparian and in-stream habitats. Riparian indicators include waterway width, percentage shading and flora species composition, while in-stream indicators include the extent of scouring, erosion and presence of woody habitat.

> **Box 2 Stormwater Objectives**
>
> Suspended solids - 80% retention of the typical urban annual load
>
> Total phosphorus - 45 per cent retention of the typical urban annual load
>
> Total nitrogen - 45 per cent retention of the typical urban annual load
>
> Litter - 70 per cent retention of typical urban annual load
>
> Flows - maintain discharges for the 1.5 year ARI at pre-development levels.

Stormwater management

In 1999, Urban stormwater: best practice environmental management guidelines (BEPM) provides a toolbox to meet the needs of those planning, designing and/or managing urban land uses or stormwater systems. The BPEM establishes stormwater quality objectives to assist in determining the level of stormwater management required to meet the State Environment Protection Policy (Waters) (SEPP) objectives. The SEPP is a statutory policy under section 16 of the Environment Protection Act 1970 that identifies the beneficial uses of Victoria's waterways.

SEPP (Waters) requires measures to be implemented to control the environmental impact of stormwater pollution. The BPEM sets best-practice performance objectives for urban stormwater to help meet the policy's requirements (Box 2).

Under the current Victorian Planning Provisions, it is now compulsory for residential, industrial, commercial and public developments to design and manage urban stormwater management systems to meet current BPEM objectives. However, often stormwater strategies only focus on how to manage stormwater pollutants more effectively', rather than 'how to reduce the generation of pollutants in the first place'. For instance, Water Sensitive Urban Design (WSUD) forms the basis of most stormwater strategies across Australia. There are many benefits of incorporating WSUD into urban landscapes, including enhanced aesthetics, reduced erosion from peak flows, reductions in nutrients reaching the bay and enhanced natural environments that the community can enjoy. Yet, toxicant levels in Melbourne's major waterways continue to increase (Sharley et al 2015). And while State Environment Protection Policies require stormwater quality treatment be undertaken, pollution reduction targets for heavy metals, hydrocarbons and pesticides are nonexistent.

Critically, while wetlands can play a role in filtering stormwater and slowing its entry into receiving waters, this merely delays the transport of pollution and does nothing to stop it at the source. In addition, Sharley et al (2012) showed that around 40% of stormwater wetlands across Melbourne were contaminated, resulting in significant increases in the cost of maintaining wetland assets (dredging and disposal of contaminated sediment) while also increasing the ecological risk to wildlife (potential to be ecological traps - highly attractive to wildlife but with toxic implications).

Education and Awareness

People are often unaware that their everyday activities can impact on stormwater quality and result in ecological stress to local aquatic biota . Once aware and informed of simple solutions that reduce or avoid the generation of stormwater pollution, you will more likely see a change in people's behaviour. Environmental education is the catalyst for change, and while critical to achieving stormwater best practice, it is often overlooked as an effective tool to improve stormwater quality and waterways.

Figure 6 Landuse in the Werribee Catchment

Figure 7 Example of a stormwater education poster that can be used to provide passive education to the community and businesses.

Stormwater pollution from residential, industrial and commercial areas is the cumulative result of many individual choices throughout the catchment. The placement of infographic signage (see Figure 7 as an example) in areas highly frequented by local business workers (out the front of local cafes) or local residents (at sporting ovals or schools) may provide an effective medium to provide passive education about the impact of stormwater pollution on the local environment and may help to create behaviour changes which result in cleaner stormwater.

Project components

There are 4 major components to the project:

- Werribee River sediment quality monitoring program
- Stormwater pollution profiling program
- Environmental education and biological monitoring program
- Drone program to identify litter hotspots

Methods

Werribee River sediment quality monitoring program

Surface sediments were collected at 17 sites across the Werribee Catchment (Table 3) using standard methods developed by (Sharp and Sharley 2012) in 2018 and 2019. Persistent contaminants commonly found in stormwater, including: heavy metals (arsenic, cadmium, copper, chromium, nickel, lead, zinc) and oils (as total petroleum hydrocarbons or TPH) were analysed for at a NATA accredited laboratory. Contaminant concentrations were compared with the SEPP Waters and National Sediment Quality Guidelines (Simpson *et al* 2013). Results were compared to the Default Guideline Value (DGV) and the Guideline Value High (GV-H). Contaminants in urban stream sediments should not exceed the DGV, while GV-H is the upper limit above which direct toxicity to aquatic biota becomes likely.

We combined individual contaminant concentrations into a mean sediment quality index (Figure 8) to facilitate interpretation and communication of sediment quality data to both catchment managers and the wider community (Figure 8).

Stormwater pollution profiling program

Bio2Lab deployed passive samplers at major drain outlets or tributaries in both 2018 and 2019. The 2018 program profiled drains throughout the catchment, while the 2019 program profiled a high risk catchment identified in the 2018 program. Passive samplers provide a time-integrated assessment of pollution. For an explanation of how passive sampling works (see Figure 10). Once deployed, the samplers (StormScouts) are exposed to stormwater 7 days a week 24 hours a day. Over the deployment period (14 days), they continue to accumulate pollutants such as heavy metals and oils. After samplers are collected, new samplers are deployed. The collected samplers are sent to a NATA accreditetd Laboratory for analysis. We converted contaminant concentrations into a simple colour-coded metrics based on concentrations detected (Figure 8). Each sampling round consisted of three sampling events.

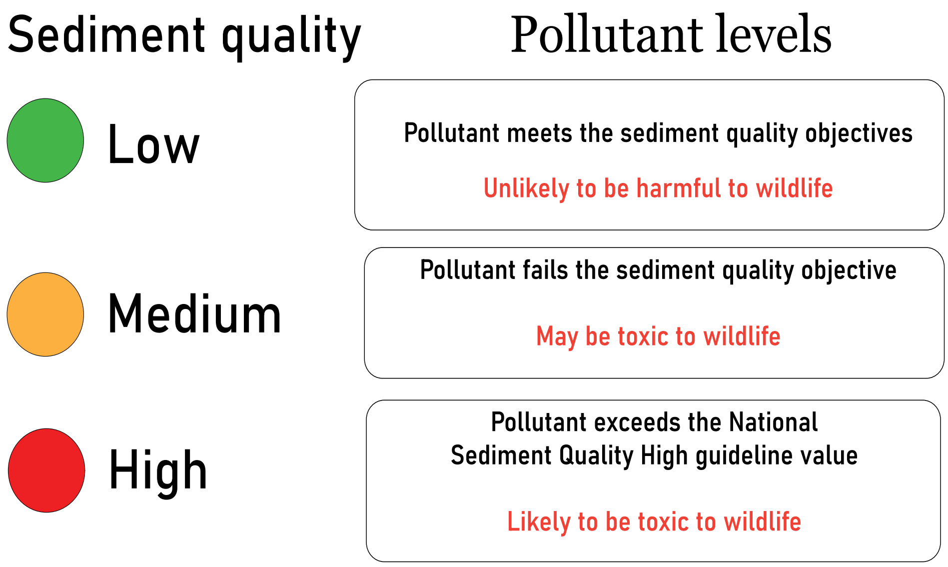


Figure 8 Sediment quality index based on average pollutant concentrations detected

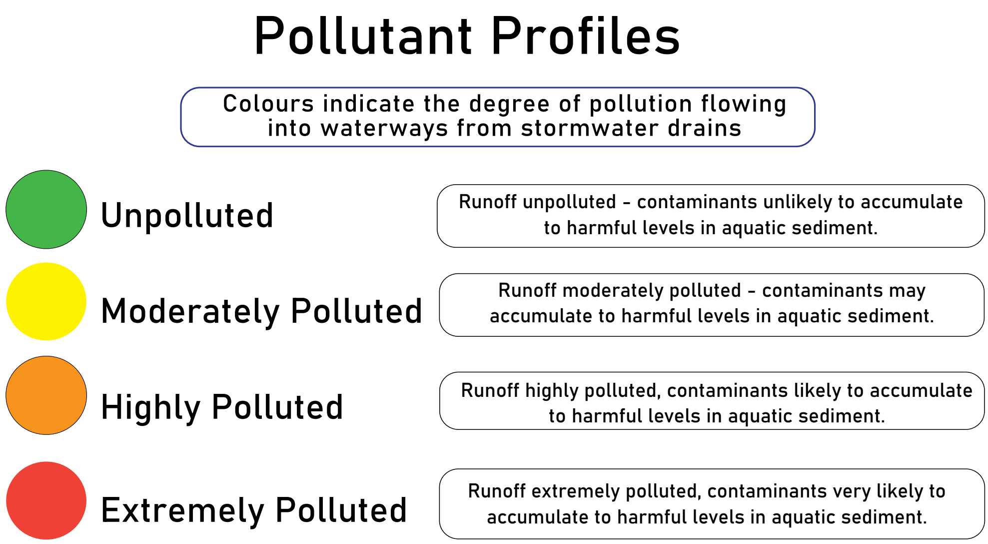


Figure 9 Stormwater pollution index based on average pollutant concentrations detected

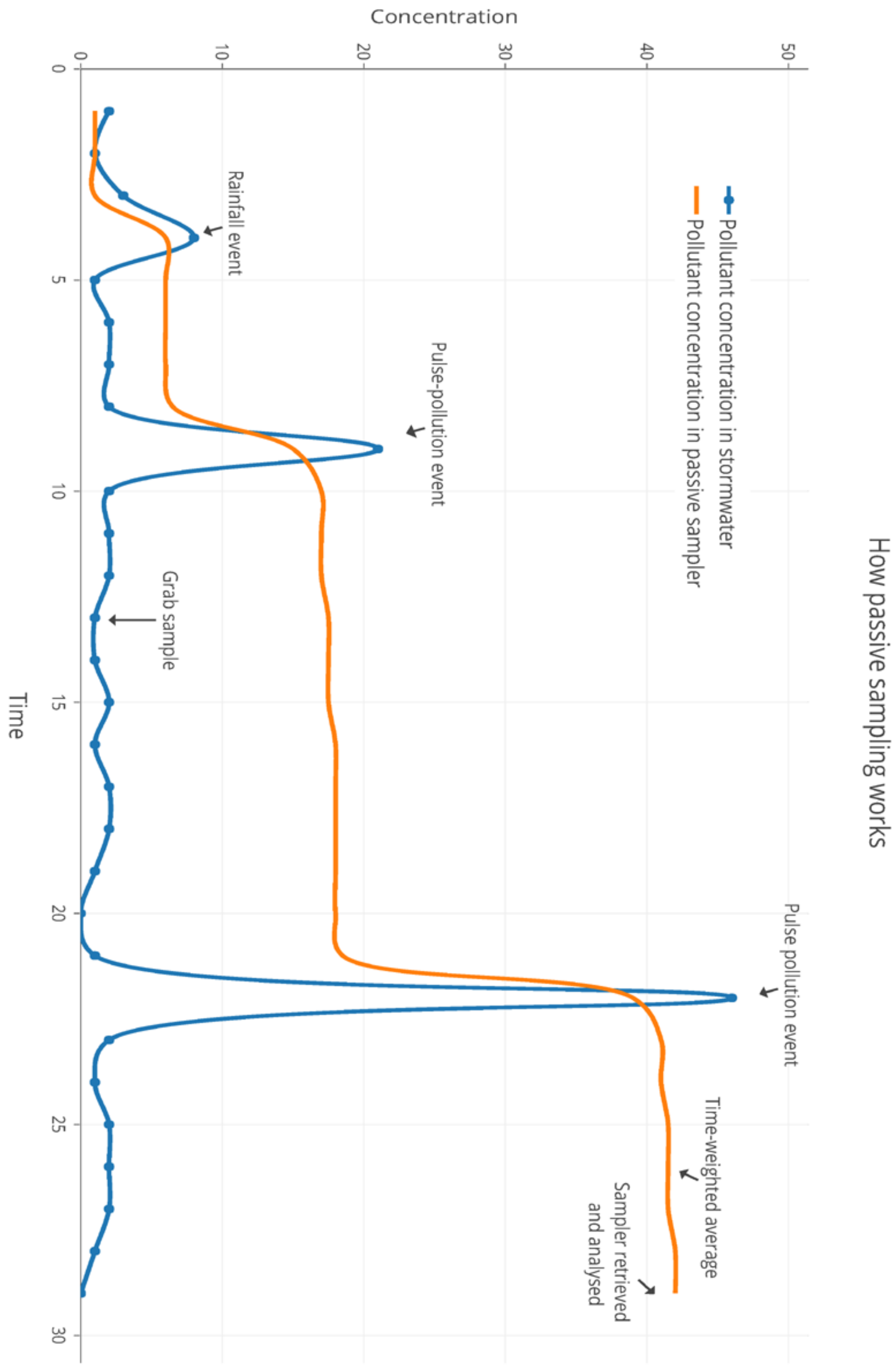


Figure 10 How passive sampling detects pulse pollution events

Environmental education program

To increase the community awareness about stormwater pollution and the impact on waterway health, numerous environmental education and awareness projects were initiated. Training and support programs were developed to introduce and teach basic biological, river quality and litter surveys to the general community. This involved recruiting volunteers to assist with the macroinvertebrate and water quality assessments throughout the project. In addition, the training and support programs were extended into local schools. For the macroinvertebrate monitoring, the Agreed Level Taxonomy methodology used by Melbourne Water's Waterwatch Program was used. Water quality parameters such as electrical conductivity and pH were also collected at each site. To extend the program, Werribee River Association collaborated with Melbourne Water to deliver the River Detectives program to schools in the west. Activities included excursions to the Werribee River, Skeleton Creek and Davis Creek to sample for macroinvertebrates and assess water quality. Delivery of incursions occurred where schools were unable to access transport.

Figure 11 Teaching kids about testing water quality and explaining the reasons why we monitor pollutants.

Drone program to identify litter hotspots

Litter pollution continues to be a major problem in urban areas. Over the last few years, there has been renewed emphasis on reducing the amount of litter reaching our local waterways, estuaries and bays - with the ABC TV show 'the War on Waste' raising awareness of the impact our everyday activities can have on our environment. In addition, research into the accumulation of micro-plastics and its impact on local wildlife is gaining momentum. Across Australia, there are many groups and organisations such as 'Beach Patrol' and "Little Heroes" helping to keep trash from our waterways or actively clean it up if it ends up there. Increasing the efficiencies of litter cleanups by identifying litter hotspots prior to any action will save time and resources. In addition, building up a database of known litter hotspots and their sources will allow more targeted action in the future and assist in state-wide litter reduction strategies.

Figure 12 A new stormwater wetland connected to Edgars Creek in Nth Epping

Drone technology and associated spatial mapping services continues to rapidly advance. Today, drones, are safer, more sophisticated and when coupled with advanced software for both flying and analysing results, makes them a powerful tool in precision mapping and object detection.

The aim of this project was to trial drone technologies and the advancement in precision mapping and real-time spatial analysis to rapidly identify litter hotspots and start to determine the major litter sources in the Werribee catchment.

Results

Sediment quality monitoring

Sediment was collected from 17 locations throughout the Werribee Catchment (Table 3, Figure 13). Collections took place in both 2018 and 2109. Results displayed here provide a summary of current sediment quality at each site. As expected, sediment quality from Bunding Rd - the reference site (W1), located in the Wombat State forest was good with only moderate pollution detected (Figure 15), This was primarily driven by a slight increase in nickel concentrations in 2019 compared to 2018 (Figure 15).

Werribee River

Sediment pollution levels in the Werribee River varied throughout the catchment (Figure 14). Most of the Werribee River sites located in the urban and industrial areas of Werribee failed environmental objectives in both years (Figure 15), with the exception being Tesron Court (W6), which only failed guidelines in the second year for oils (Figure 15). Sediment pollution levels at Cobbledicks Ford (W2) situated in the lower agricultural regions of the catchment decreased in 2019 due to lower TPH levels (Figure 15). In general, the results suggest that pollution levels in the Werribee River slightly decreased in 2019 compared to 2018, although decreases were site-specific. In both years, oils, zinc and nickel were the primary contaminants of concern, with copper lead and chromium rarely exceeding sediment quality guidelines in the Werribee River. This suggests that pollution is likely to be originating from diffuse sources such as roads, where we know runoff often contain high levels of zinc and oils generated from cars and trucks. One or more contaminants exceeded the GV-H at 3 locations - W6, W7 and W8. This suggested that the industrial area in Werribee, north of the Maltby Bypass is a potential pollution hotspot (Figure 16). Pollution tracking results also suggested that this area was a high risk for heavy metal and hydrocarbon (oils) stormwater pollution.

Figure 13 Sediment collection sites

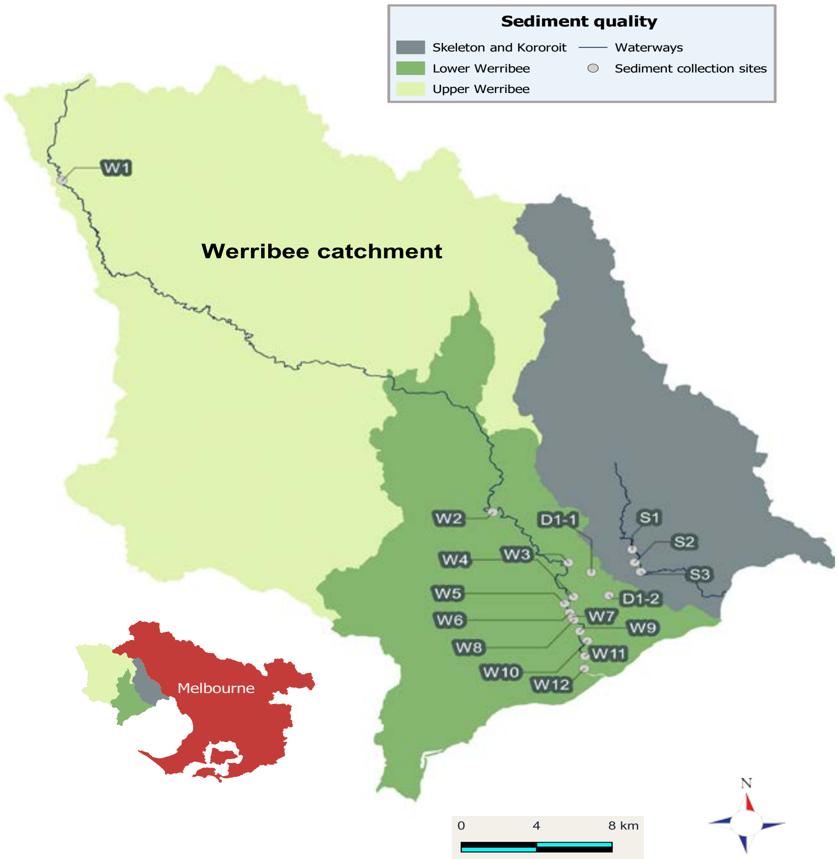


Table 3 Sediment quality sites

Site Code	Site Name
W1	Werribee R at Bunding Rd
W2	Werribee R at Cobbledicks Ford
W3	Werribee River at Riverside Drive
W4	Werribee River ds Cottrell St
W5	Werribee R at Bungies Hole
W6	Werribee R ds Tesron Ct Drain
W7	Werribee R ds Maltby Bypass Drain
W8	Werribee River at Werribee Zoo
W9	Werribee R at Fishladder
W10	Werribee R at K-Rd Cliffs
W11	Werribee R ds Masons
W12	Werribee R ds Cutriss Rd Drain
D1-1	D1 Drain at Heaths Rd
D1-2	D1 Drain at Sneydes Rd
S1	Skeleton Ck at Waterside Cl
S2	Skeleton Ck at Rosslare Ct
S3	Skeleton Ck us Princess Fwy

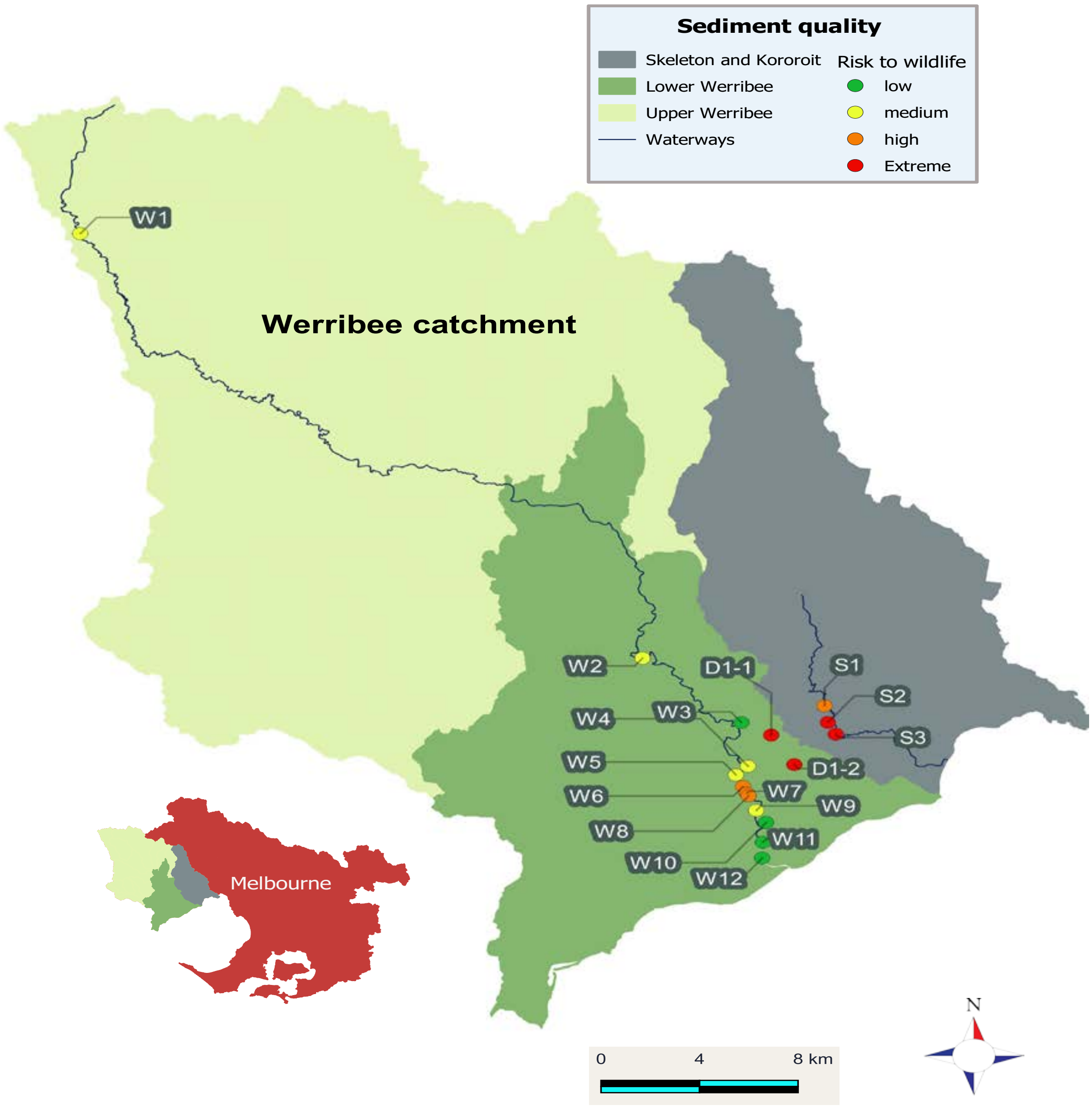


Figure 14 Pollution levels in sediment at the 17 sites assessed in the Werribee, Skeleton and D1 catchments.

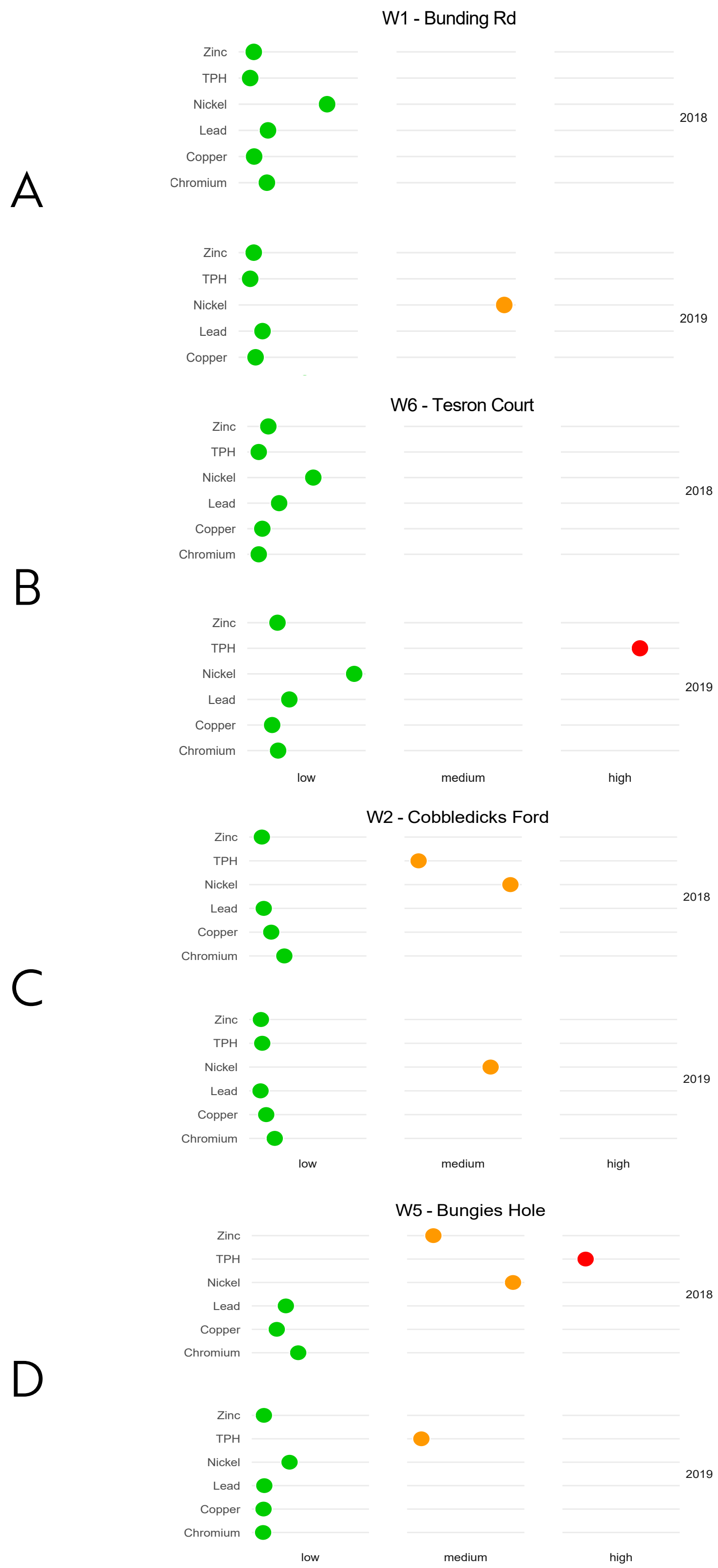


Figure 15 Pollution levels at A - Bunding Rd, B - Tesron Court, C - Cobbledicks Ford and D - Bungies Hole. Colours represent the level of pollution.

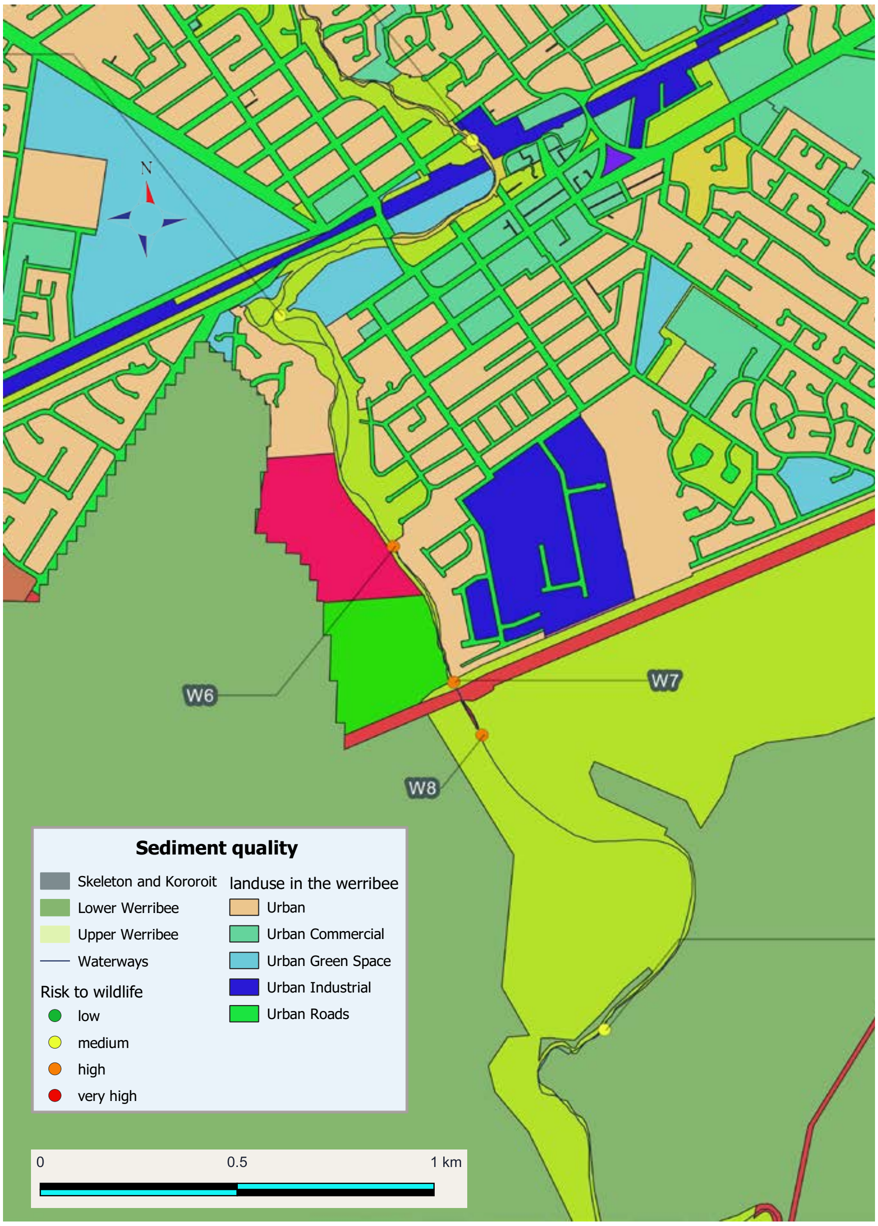


Figure 16 Werribee River landuse and pollution levels in sediment

Skeleton Creek

Sediment pollution varied in the urban areas of Skeleton Creek. Pollution levels were generally high at all sites, with zinc, nickel and TPH (oils) all at levels above State environmental sediment quality guidelines (Figure 18). Total Petroleum Hydrocarbon (TPH) and zinc levels were extremely high at all three sites, posing a significant risk to local wildlife such as platypuses and fish. It was evident that stormwater pollution increased in 2019 compared to 2018 at sites S2 and S3 (Figure 17). However, it is unclear as to where the contaminants may be originating, with landuse predominantly urban residential throughout the Skeleton Creek catchment (Figure 18). However, S3 is located downstream of a major industrial area (Figure 18), and was consistently one of the most contaminated sites surveyed in this study. All contaminants except for Chromium were found to be above State DV-G thresholds, suggesting localised point-source pollution hotspots are likely.

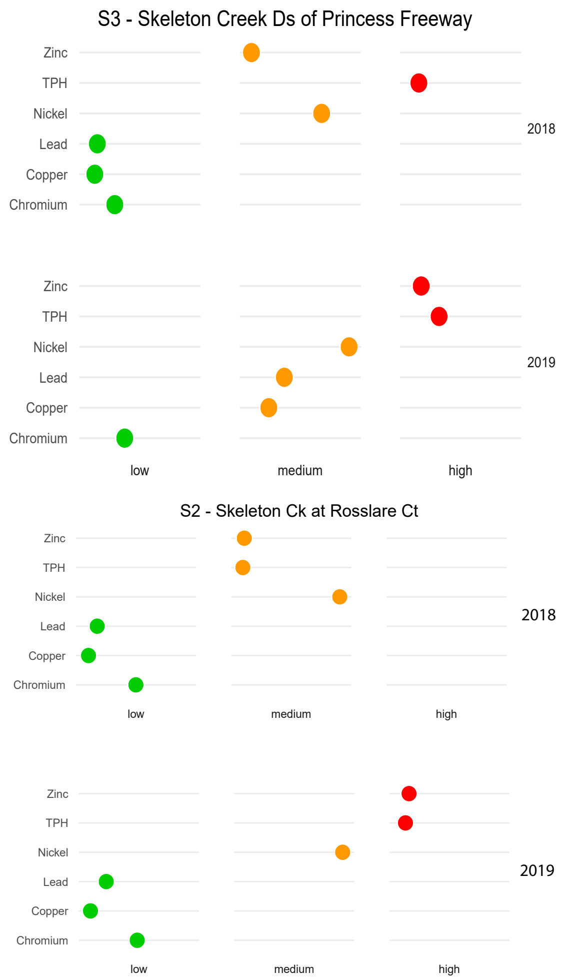


Figure 17 Sediment quality in Skeleton Creek and pollution levels at Princess St and Rosslare Court

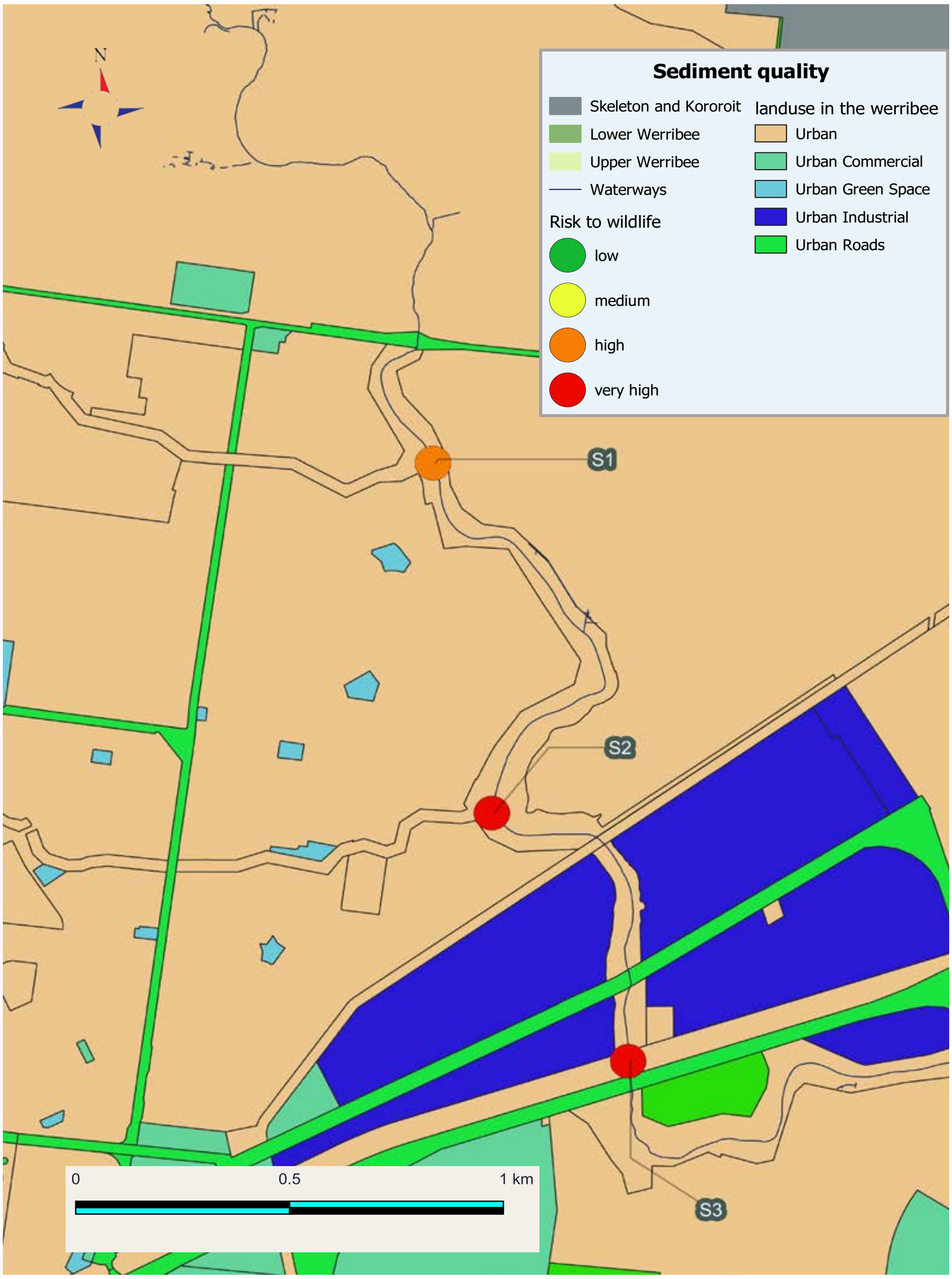


Figure 18 Skeleton Creek landuse map and pollution levels in sediment

Results also strongly suggest that aquatic biota populations living in sediment in this area are likely to be extremely impacted, resulting in high mortality and population level changes.

D1 Drain

Both sediment sites in the D1 catchment were highly polluted, with nickel exceeding the DGV and TPH, and zinc exceeding the GV-H at both sites in both years (Figure 19). The catchment is primarily residential with some highly concentrated commercial activities (Figure 19). Heavy vehicle traffic in the commercial areas is a common source of moderate copper, zinc and TPH pollution, but the very high levels at Heaths Rd are unusual and should be investigated further.

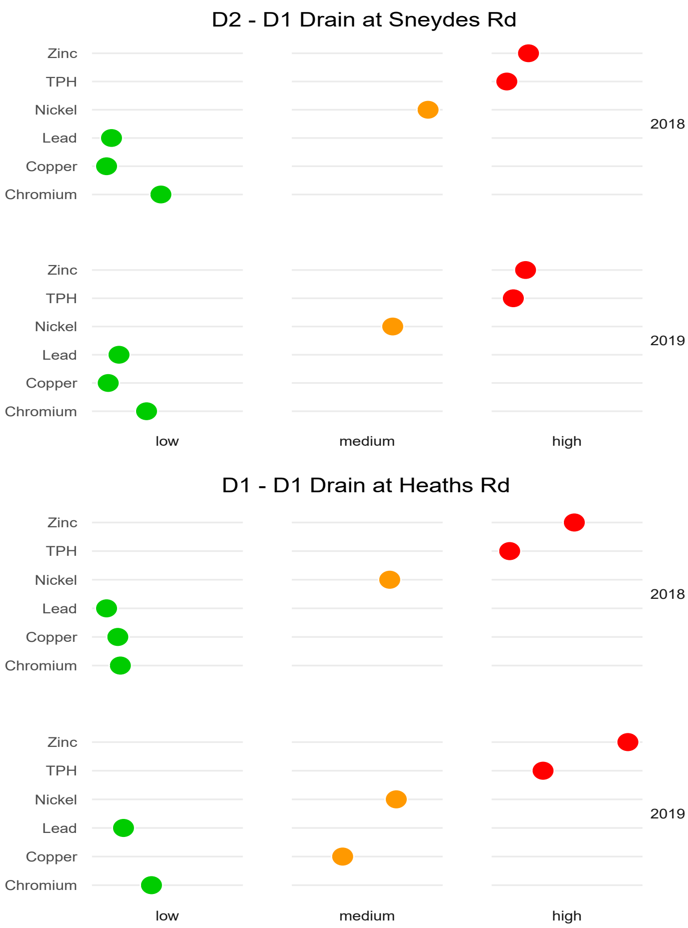


Figure 19 Sediment quality in D1 Drain and pollution levels at Heaths and Sneydes Rd.

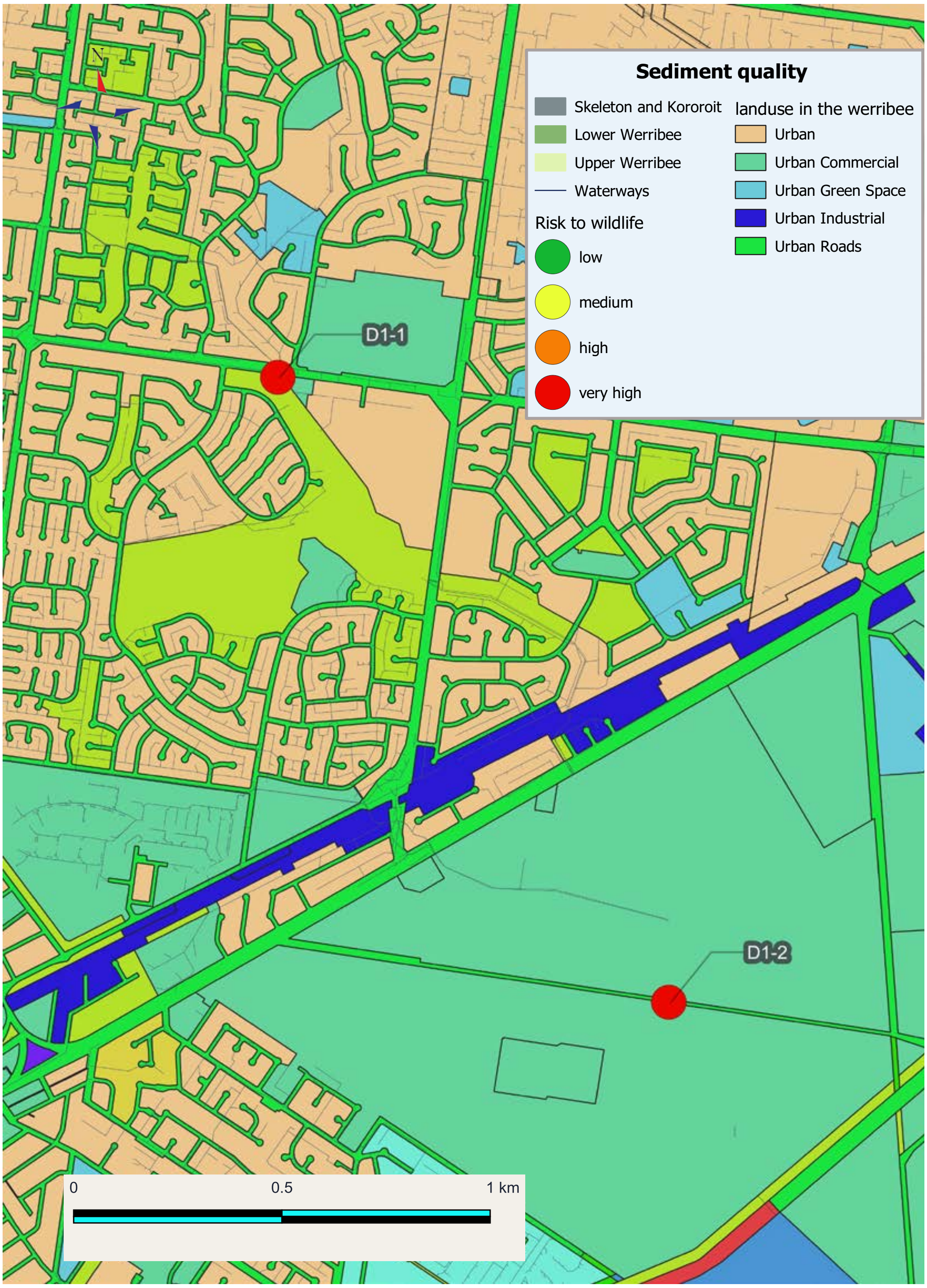


Figure 20 keleton Creek landuse map and pollution levels in sediment

Sediments can adversely affect the water quality of waterways and can be resuspended during storm events, facilitating the entry of contaminants into the food chain (Simpson et al 2005). Trace metals in particular, due to their highly toxic effect, long residence time and bioavailability, pose a risk to benthic organisms, and potentially to human health (Bryan and Langston, 1992). Long-term monitoring of surface sediments provides critical information on temporal trends of trace metal pollution in waterways, thereby improving the risk assessment process (Sharley et al 2016).

The sediment monitoring program was effective at identifying areas in the catchment likely to be impacting the aquatic biota, and the major contaminants of concern. The outcomes of this study show how sediment quality monitoring can be an effective assessment tool providing policy makers and management agencies with critical information for incorporation into environmental management frameworks. See appendix 1 for all of the site-specific sediment quality results.

Figure 21 Sediment acccumulated at Bungies Hole below the weir.

Bryan, G., Langston, W., 1992. Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environ. Pollut. 76, 89-131.

Sharley, D. J., S. M. Sharp, S. Bourgues and V. J. Pettigrove (2016). Detecting long-term temporal trends in sediment-bound trace metals from urbanised catchments. Environmental Pollution 219: 705-713.

Simpson, S., Batley, G.E., Chariton, A.A., Stauber, J.L., King, C.K., Chapman, J., Hyne, R.V., Gale, S.A., Roach, A.C., Maher, W.A., 2005. Handbook for Sediment Quality Assessment. CSIRO, Bangor, NSW

Stormwater pollution profiling

In 2018, Stormwater pollution profiles were developed for 15 catchments: nine connected to the Werribee River; three associated with Skeleton Creek and three with the D1 drain (Figure 22). All sites varied in their stormwater pollution profiles, but run-off from all catchments was at least moderately polluted with oils and metals (Figure 22).

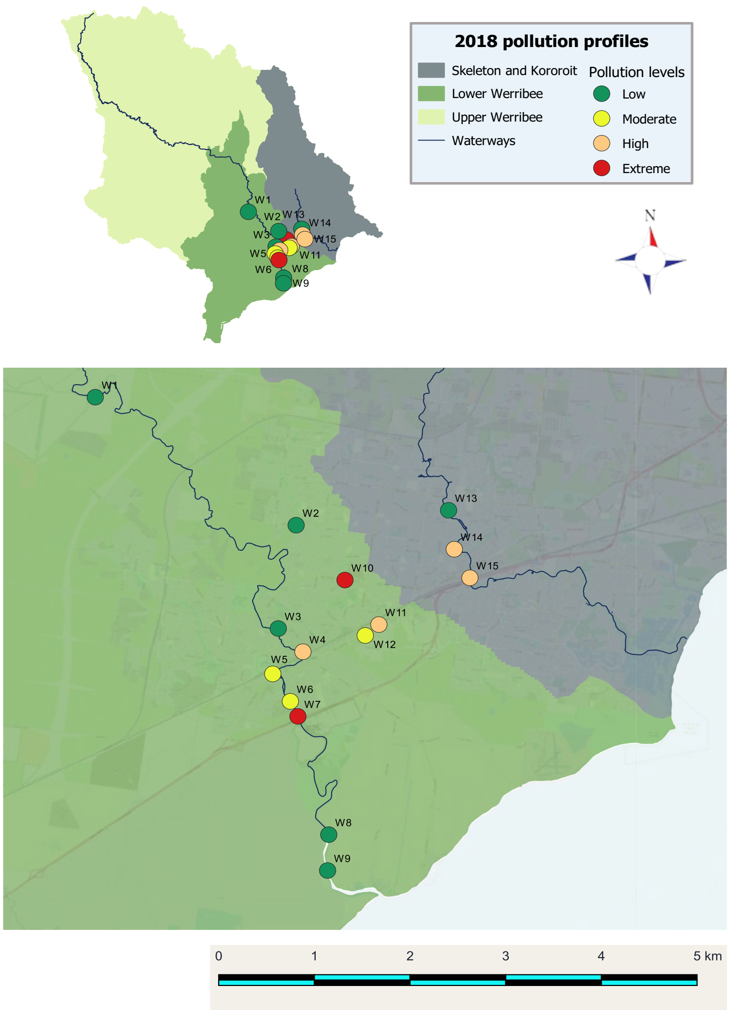
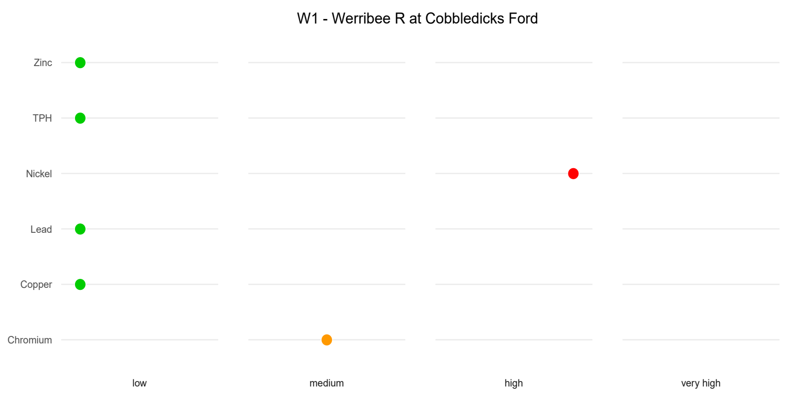


Figure 22 Stormwater Pollution profiles across both the Werribee and Skeleton Creek catchments.

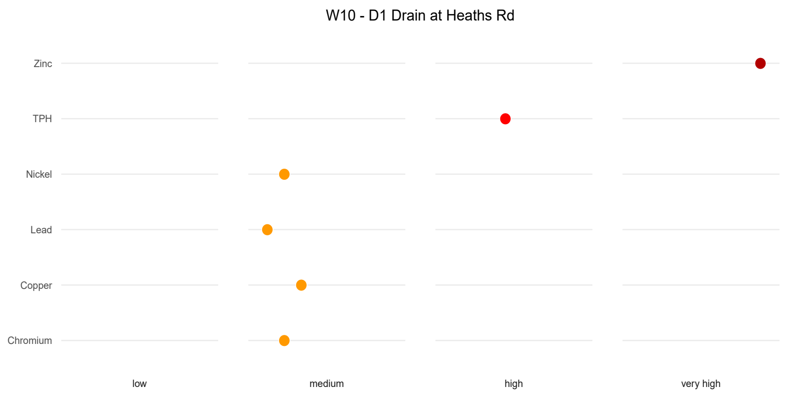
Figure 23 StormScout sampler

Figure 24 Typical stormwater drain where stormscous are deployed

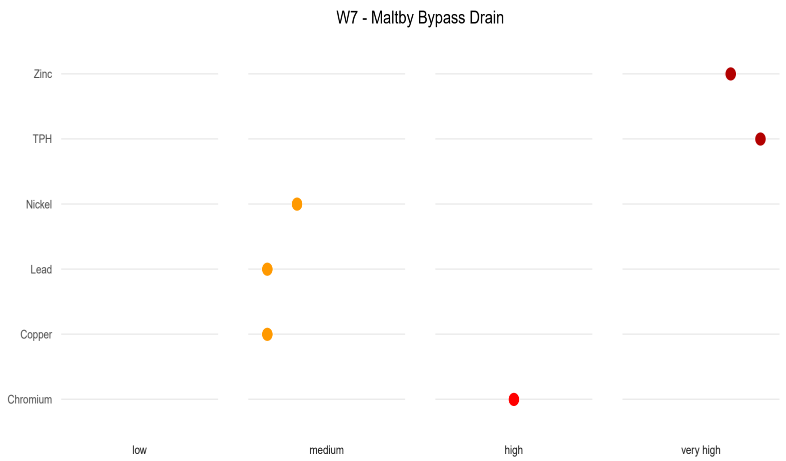
Pollution profiles indicated that contaminant levels were highly linked to local landuse. It was clear that urban and industrial activities increased pollution to local waterways. Whereas peri-urban areas with a large proportion of parklands, open space and natural areas were found to generate very low levels of pollution (see below figures).



Cobbledicks Ford, Mount Cottrell is located in a Peri-urban / agricultural area north of Werribee. Both Chromium and nickel were elevated, but this could be due to the basalt soils in the area. This site was categorised as having low pollution levels.



All metals were elevated at D1 Drain at Heaths Rd, Hoppers Crossing. Both TPH and Zinc were found at very high levels, which can be explained by the associated commercial-urban catchment. This site was categorised as having very high pollution levels.



All metals were elevated in sediments from the Werribee River at the point where stormwater from the Maltby Bypass industrial precinct enters the river. TPH Zinc and chromium concentrations were high to very high. This was the most polluted site due to the associated industrial activities in the catchment. This site was categorised as having very high pollution levels.

Hotspot investigation

Due to the very high levels of pollution being generated in the Maltby industrial catchment, a further pollution hotspot investigation was initiated. Ten sites in the Maltby Bypass industrial catchment where chosen to deploy StormScouts for a further three weeks. This investigation was initiated to locate where the high pollution was being generated (Figure 25). It was clear that high levels of pollution was being generated from a local area associated with site H4 in Lock Ave, Werribee (Figure 25).

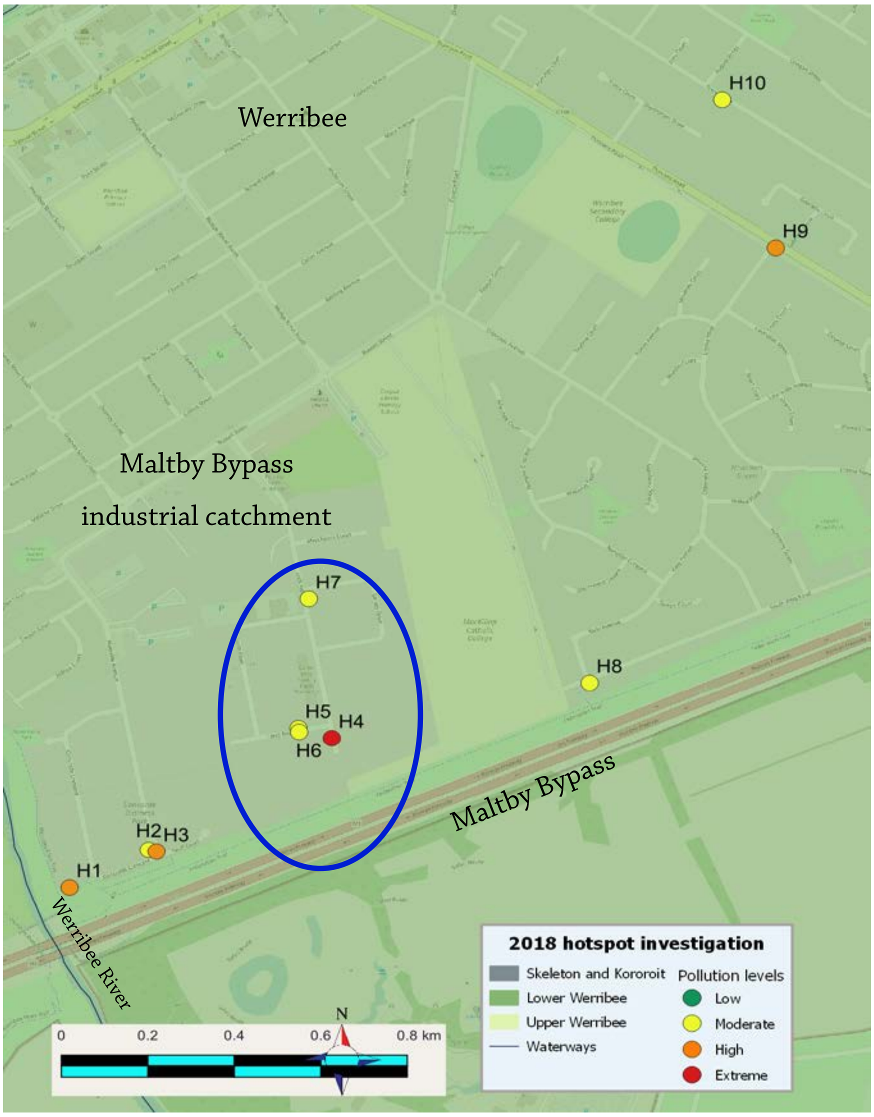


Figure 25 Hotspot investigation area

EPA / WRA Engagement and Enforcement Program

Given the very high to extreme levels of pollution being generated from the catchment associated with Site H4, the local OPLE and WRA officers designed an education and enforcement program to engage with local businesses on stormwater best practice. Letters were hand delivered to local businesses explaining how extreme level of pollution was being generated from local activities. They also explained that EPA would conduct formal investigations if there was not any improvement in stormwater quality after six months (Figure 26).

WERRIBEE RIVER ASSOCIATION

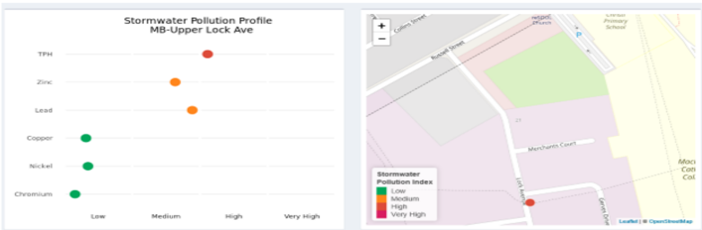
EPA VICTORIA | Environment Protection Authority Victoria

Dear Business Owner / Manager

Re: Pollution of stormwater entering Werribee River

The Werribee River Association (WRivA) is a local not-for-profit organisation, which works with the community to improve the health of the Werribee River. We have been conducting a project to find where contaminants are entering the Werribee River.

The monitoring has revealed that the stormwater coming from the northern section of Lock Avenue (including Merchants Court and the northern section of Gerves Court) is high in Total Petroleum Hydrocarbons (TPH) and contains moderate levels of zinc and lead.



WERRIBEE RIVER ASSOCIATION

EPA VICTORIA | Environment Protection Authority Victoria

Werribee River Association is therefore partnering with the Victorian EPA to provide education and information to businesses such as yours. Please make sure that all your employees follow requirements in the attached guidelines.

Your willingness to participate in this program is very much appreciated.

We will be undertaking further testing of the stormwater drain in the next six months and will let you know the results if interested. If further testing shows that hydrocarbons and metal levels continue to be high EPA will be undertaking formal inspections of premises in this area.

If you have any further questions or would like some advice please feel free to contact Teresa Mackintosh on 0432 478 033 or teresa.mackintosh@werribeeriver.org.au; or Michelle Walker at michelle.walker@epa.vic.gov.au.

The Werribee River is a valuable natural asset, providing an important habitat for many animals and plants. Reducing pollution from stormwater inputs into the river, will help us protect this important waterway for generations to come.

Figure 26 Business education material sent to businesses in the Maltby Industrial area. Developed by Werribee River Association and EPA Victoria

It was evident that the Engagement and Enforcement Program was successful at reducing local stormwater pollution. There was a significant reduction of all contaminants six months after the program ended (Figure 27 and Figure 28). It is likely that the door-door education and enforcement campaign had a positive impact on stormwater management in the area, resulting in reductions of pollutants being discharged off-site into stormwater drains. In our experience, education programs can have strong short- to mid-term benefits. Annual education and enforcement programs are recommended over the next 2-3 years, with biennial programs recommended going forwards to reinforce the positive results from this program.

Before education After education

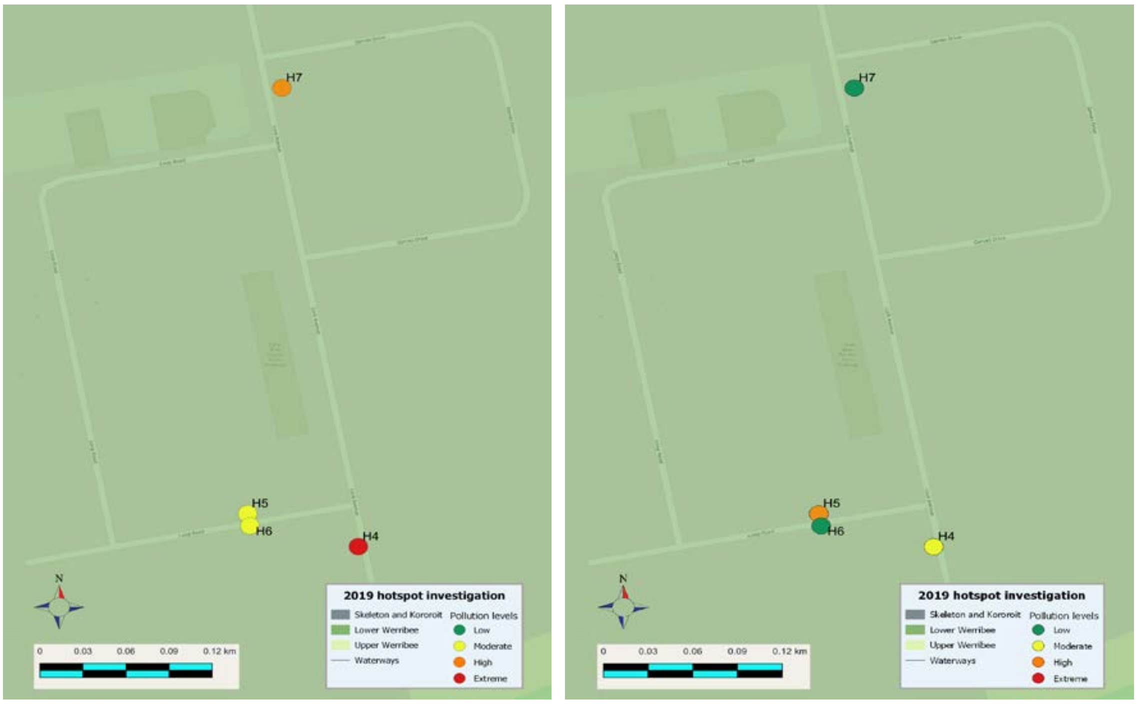


Figure 27 Stormwater pollution levels at sites in the Maltby Industrial area before and after an education and enforcement program was carried out by EPA Victoria and the Werribee River Association

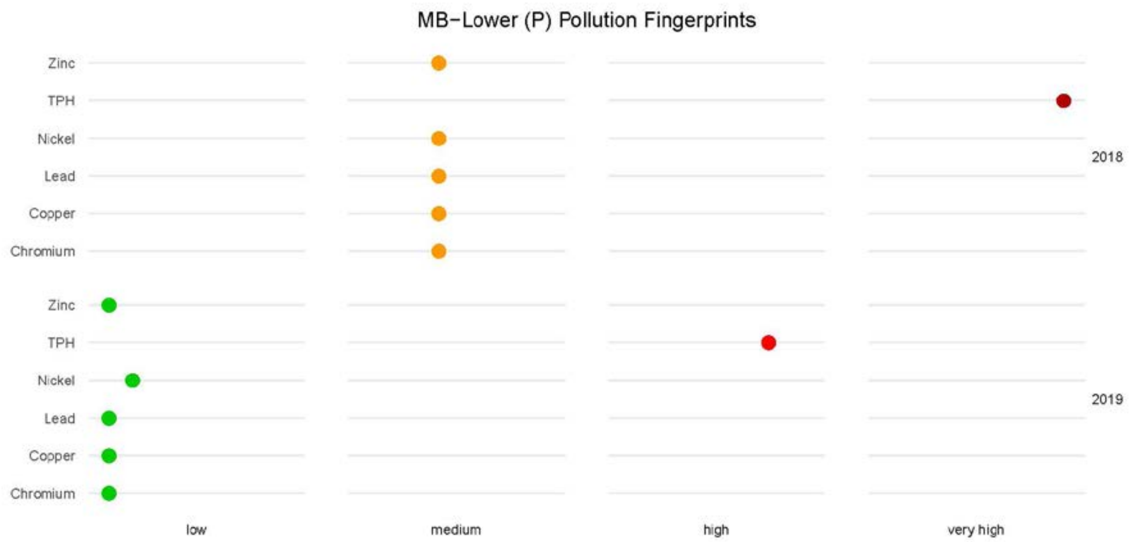


Figure 28 Stormwater pollution profuiles at the bottom of the Maltby Industrial catchment in 2018 and 2019. Notice the significant reduction in pollution levels following the monitoring and education and enforcement programs.

One site (H5) did see increases in pollution after the education and enforcement program (Figure 29). This pollution was linked to poor business practices and illegal discharges from one business in the area. EPA was notified of the pollution event and enforcement action commenced. A pollution abatement notice was issued to the business.

Figure 29 Pollution discharging from a local business in the Maltby industrial area. The pollution event was reported to EPA which resulted in action being taken to mitigate the impacts downstream.

Biological monitoring

To assess the condition of the Werribee River and Skeleton Creek, a biological monitoring program was set up. This involved the collection of macroinvertebrates from 12 sites. Nine sites along the Werribee River and three sites along Skeleton Creek (Figure 31). The sites were selected to provide additional information to the sediment monitoring program and to some extent the pollution profiling program. Over the course of the project, five sampling events took place.

In general, SIGNAL scores were consistently below State Environmental Protection guideline thresholds. Based on both SIGNAL and diversity scores, Cobbledicks Ford was the healthiest site in the catchment , followed by the reference site in the Wombat State Forest. There was also a clear link between waterway health and urban land use, with a deterioration in the health of aquatic ecosystems as urban activities increased (Figure 32). It is very likely that the high pollution levels and deterioration in catchment health is driving changes in local food webs, impacting important fauna such as platypuses, fish and birds(Figure 33).

Figure 30 Steve Marshall collecting macroinvetrebrates from the Fish Ladder near Werribee Mansion.

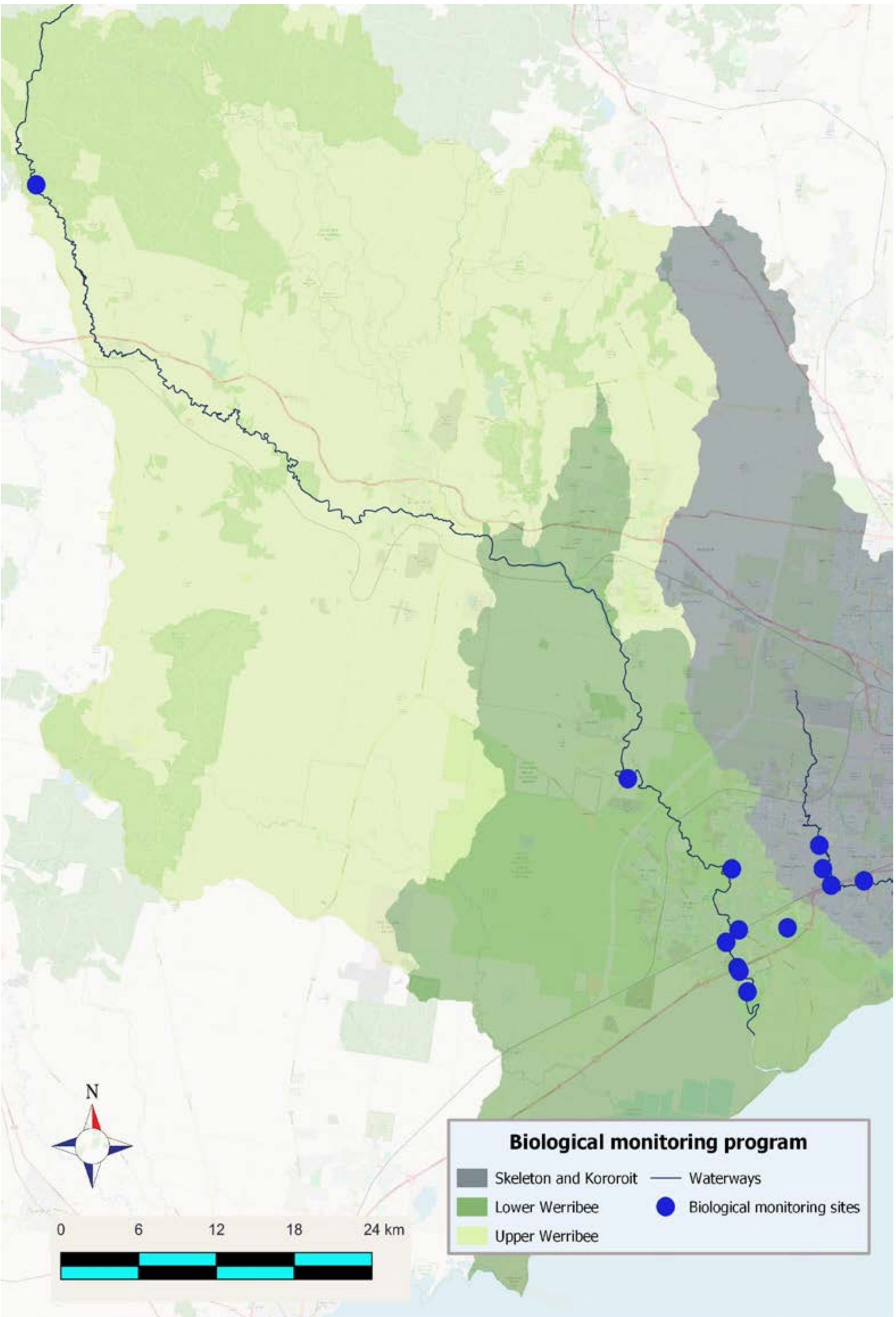
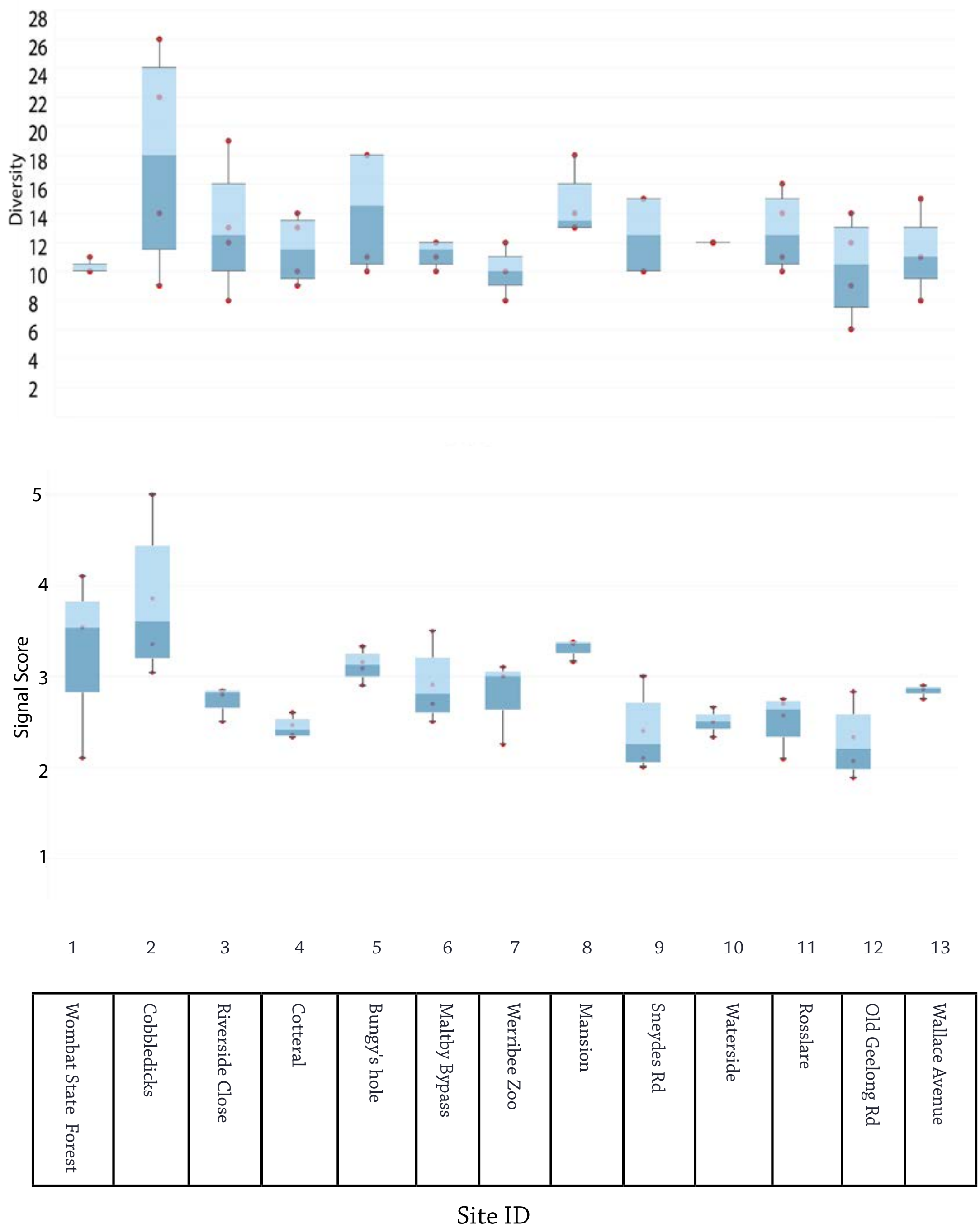


Figure 31 Biological monitoring sites

Figure 32 Figure Diversty and SIGNAL score boxplots summarising the results from the five macroinvertebrate sampling rounds sampling rounds (2018-2020)



Foodweb impacts

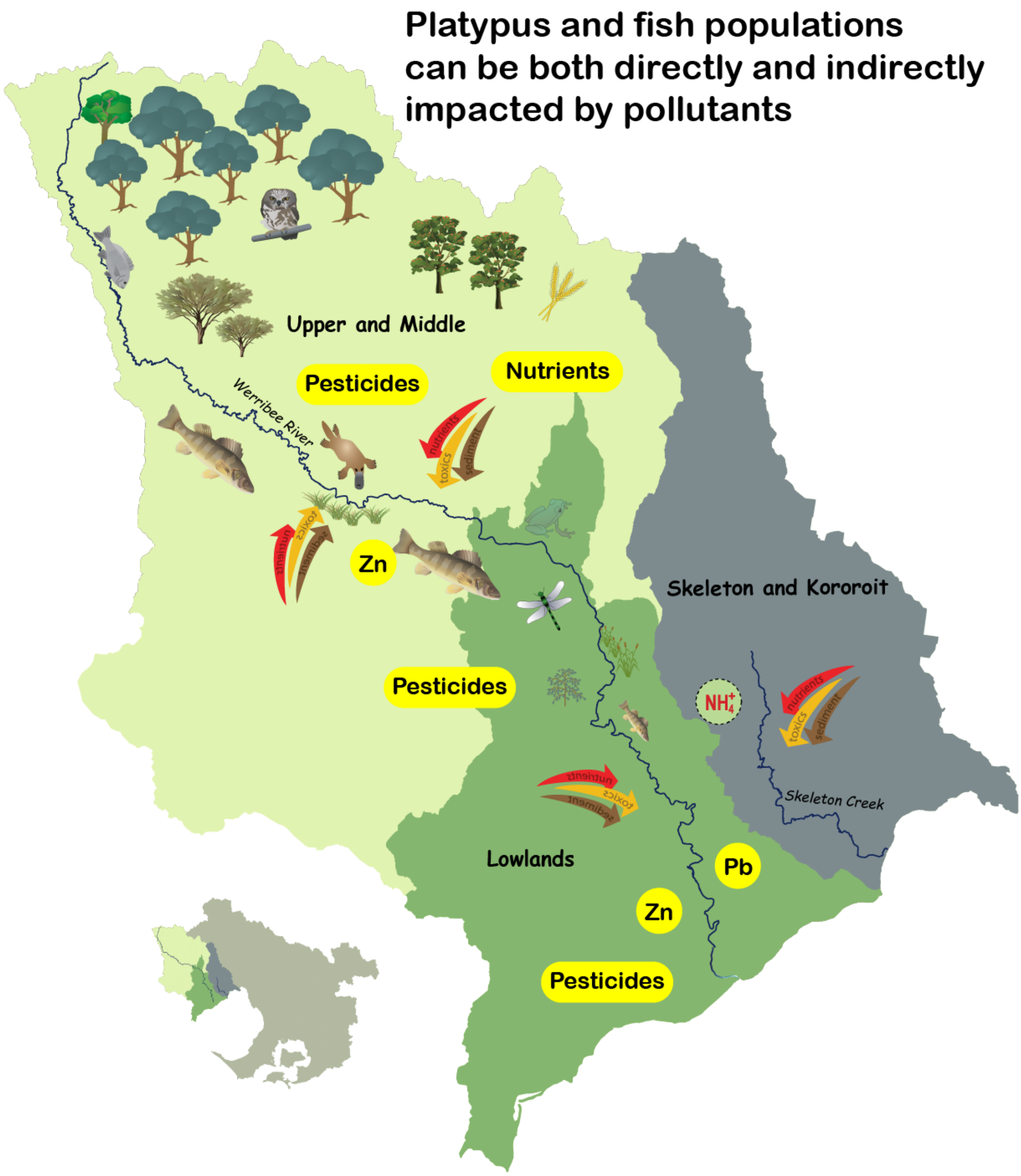


Figure 33 Foodweb impacts driven by catchment activities and pollutants.

Education and Awareness programs

One of the most important aspects of this project was to better develop stormwater education and awarness programs. The programs aimed to provide local communities with the necessary information to reduce the amount of pollution entering stormwater infrastructure and improving local waterways and aquatic ecosystems. The program targeted a number of different groups, including primary school level students, community members and businesses in high risk areas. One of the ways it was decided to engage with local communtiy members was to initiate biological monitoring training programs. The program recruited volunteers to not only help with macroinvertebrate collection, sorting and identification, but in the process gain valuable experience in monitoring local wildlife for the assessment of waterway condition. The program recruited 51 volunteers over the project period (Figure 34).

It is widely known that environmental education and awarness programs aimed at school students have the best chance of long-term success. This project conducted school incursions to give students unique learning experiences in how the natural world works and the ecolgical balance required to keep natural systems from collapsing. The incusions usually inloved taking students to nearbuy waterways and wetlands to show them how to collect, sort and identif local aquatic insects, measure water quality and score habitat quality. Integrating these results, students were able to see how variations in water quality and pollution levels can impact on the health of wildlife, especually insect and invetrebrate populations. In total, the project visited 15 schools. while some were one time incursions, some schools set-up monthly incursions.

Importantly, the project developed realtionships with numerous groups and associations, which are still active today. Some of the groups include Wyndham Council, EPA Victoria (OPLE program), Melbourne Water, DELWP, Werribee Open Range Zoo, Yarra River Keeper, Development Victoria, Sustainability Victoria, Wathaurung Traditional Owners Aboriginal Corporation and Nature West. The links developed throughout this project will provide opportunties to develop other collaborative projects with the aim to improve the health of waterways in the Werribee Catchment and reduce pollution in Port Phillip Bay for years to come.

The overall impact of this project on raising awareness about how stormwater can reduce the health of aqautic environments in the Werribee catchment and Port Phillip Bay can not be underestimated.

Figure 34 Summary statistics from the education and engagement program

Drone litter mapping

The use of a drone to identify and map litter hotspots prior to on-ground actions is likely to improve the efficacy of litter reduction programs. A trial was conducted to assess the use of drones to safely identify litter hotspots. Five locations were identified for the trial. Each planned mission had a number of parameters required to input into the flight program to ensure the drone captured enough photos from the site to build an orthomosaic photo of the area being surveyed. Photos were uploaded into photogrammetry software to build the model, which produced a georeferenced TIFF file for litter identification and counting. Once the litter was identified and counted, the data was analysed through Kernel Density Estimation to produce detailed heat-maps of where the litter hotspots are for each survey area.

The results demonstrate how drone mapping can provide a way to identify litter hotspots along waterways in a safe and timely manner prior to litter collection events by identifying where participants should be focusing their attention.

Figure 35 3D model of Skeleton Creek running pararell to Pilatus Cres. The model was generated using 400 orthomosaic images taken using the drone

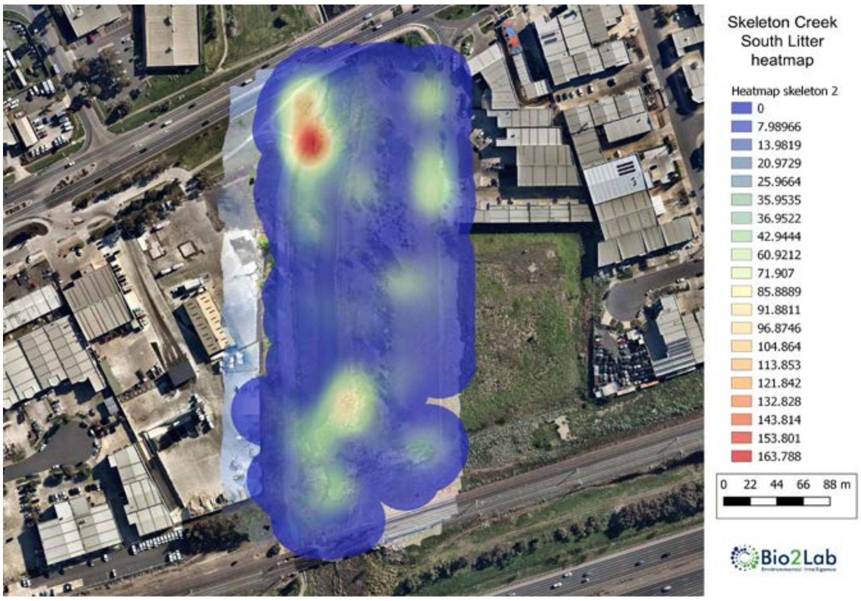
Prior to this investigation, the use of drones to identify litter hotspots in Melbourne was scarce. A study that assessed stormwater outlets along an urban creek showed that it was more cost-effective, safe and more rapid at identifying litter than on-ground searching techniques (Sharley 2017). In particular, the ability to pick up litter types from drone footage was as accurate as on-ground searching, but 75% faster. Although, the study showed that current resolution limitations only allow litter around 5cm or bigger to be accurately identified, as camera capabilities increase, we expect this to come down. Although counting and identifying microplastcs would always require ground-based monitoring. Advances in artificial intelligence and real-time object detection monitoring provides new ways to safely and accurately count and distinguish litter hotspots over large areas. In particular change detection allows managers to better understand the causes of litter hotspots, enabling better on-ground mitigation. It was clear that litter accumulated in hotspots than disperse randomly throughout local environments (Figure 37). This provides opportunities to increase the efficiency of on-ground litter reduction activities, as participants can target these areas, providing a safer working environment.

It is also evident that new construction sites are a primary source of large amounts of litter. It was clear that the waste materials associated with new builds such as waffle pods, plastic wrapping, timber, plasterboard tended to eventually find its way to waterways where they accumulate in vegetation before making its way to the bay and marine environments. When we analysed litter data from drone footage along a waterway in Point Cook adjacent to a new housing development we found that the construction site was contributing 50-60 times more litter than developed areas (Figure 38). For instance, when we analysed the 26 Ha site, over 770 individual pieces of litter adjacent to the construction site were identified, compared to 15 individual pieces of litter on the other side of the waterway where there was no construction (Figure 38). The movement of litter from construction sites, especially those adjacent to waterways needs to be better controlled to stop the accumulation of litter in waterways (Figure 36). This requires coordinated action by developers, builders, local governments, and industry bodies.

In general, stormwater outlets were the biggest conveyance of litter to aquatic environments, especially drains associated with new construction sites. While the accumulation of large amounts of litter is likely to be detrimental to the health of the biota associated with these ecosystems, it does provide opportunities to quickly remove this litter through targeted litter reduction strategies.

Drones also provide a unique perspective, providing opportunity for waterway managers to better understand litter dynamics. Large scale drone mapping which can cover 100 Ha or more per flying run, with real-time processing provides the community, industry and managers with a new set of tools for managing aquatic litter pollution. While Covid-19 restrictions prevented the project from integrating a real-time litter hotpot map with a community litter reduction event, it is recommended that this be trialled after restrictions are lifted.

Figure 36 Photos of litter scattered and accumulated throughout the construction site adjacent to Skeleton Creek.


Skeleton Creek
South Litter
heatmap
Heatmap skeleton 2
0
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20.9729
25.9664
35.9535
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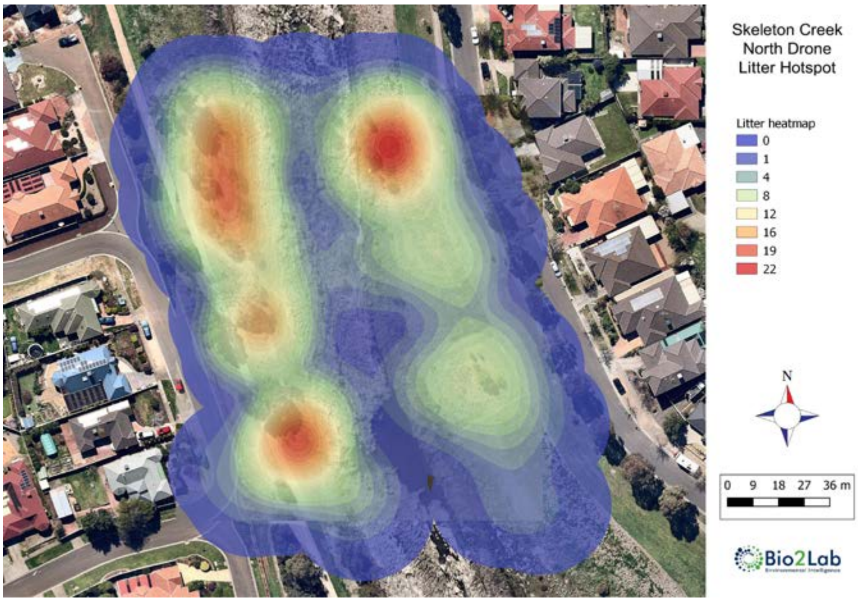
Skeleton Creek
North Drone
Litter Hotspot
Litter heatmap
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Bio2Lab


Davis Creek
Drone Litter
Hotspot Trial
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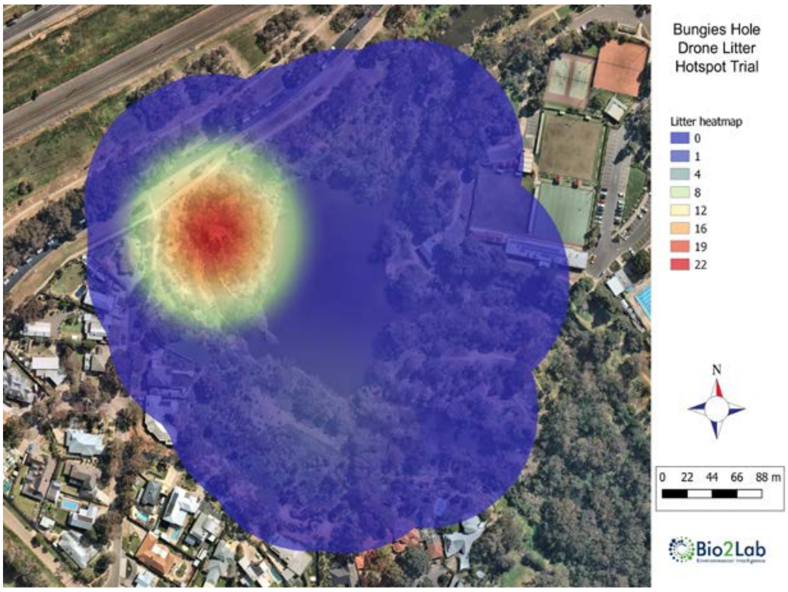
Bio2Lab



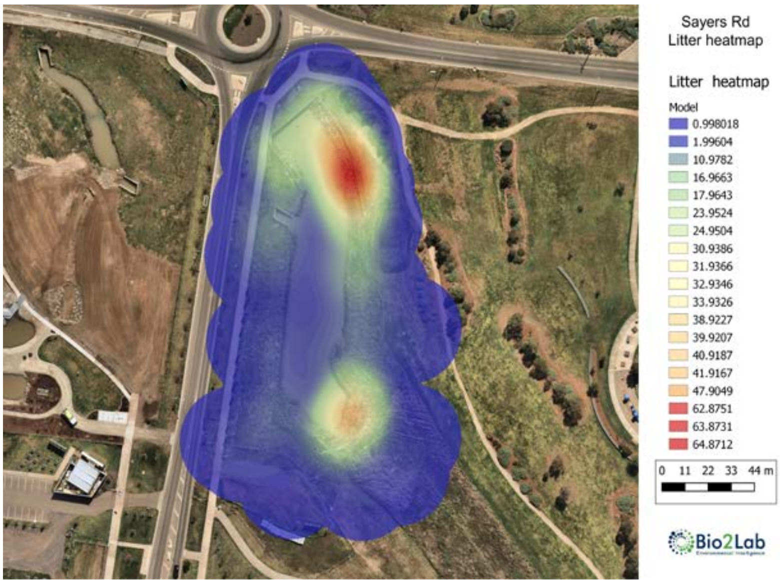


Figure 37 Litter hotspot identified by processing drone footage at five locations in the Werribee River and Skeleton Creek catchments.

Litter analysis

Litter analysis using orthomosaic mapping clearly showed the impact of new construction sites on litter accumulation in adjacent waterways when compared to areas already developed on the other side of the waterway. The photo also clearly shows the large amounts of litter scattered and piled up throughout the construction sites.

On the northern side of the skeleton creek adjacent to the construction sites there were over 760 pieces of litter detected compared to 15 pieces on the other side. The area analysed was 26 Ha.

Figure 38 A processed Orthomosaic photo of Skeleton Creek adjacent to Pilatus. Red dots represent individual pieces of litter identified through post-processing of the image.

Next steps

This program clearly found that the Werribee catchment requires urgent environmental management strategies that tackles stormwater pollution. The impacts to local biota is real and will continue to decline unless waterway managers, councils, industry and the community addresses stormwater pollution. Results from the hotspot investigation clearly showed that education and awareness, coupled with enforcement actions can change business practices and reduce stormwater pollution to our waterways. This should prompt further investigation by the relevant authorities to clarify the major sources of contaminants of concern, and put in place strategies to reduce or stop ongoing discharges from reaching the Werribee River and other associated creeks. Initiating comprehensive, integrated and sustained environmental education and enforcement programs actively supported by both local government and the environmental regulator should form the basis of on-going stormwater reduction strategies. One of the outcomes from this investigation is the establishment of environmental baseline targets which can be used to measure changes in waterway condition over time. Coupling integrated stormwater programs with on-going independent pollution monitoring of receiving waters would allow the success of these programs to be assessed. To further build public confidence in and support for the program, the monitoring data must be publicly available, readily accessible, and easy to understand by both business and the general public.

Stormwater pollution from residential, industrial and commercial areas is the cumulative result of many individual choices throughout the catchment. People are often unaware that their choices around many activities can impact the quality of stormwater. Once aware of simple solutions that reduce or avoid stormwater pollution, people are likely to make better choices. Infographic signage similar to the examples provided in Figure 7 which highlights the sources and impacts of pollution while also identifying simple solutions should be placed in areas highly frequented by local business workers (out the front of local cafes) or local residents (at sporting ovals or schools), as a way to provide passive education about the impact of stormwater pollution on the local environment.

Stormwater pollution will never cease to exist, but reducing it to below levels likely to cause harm to local wild life should be the ultimate aim. The only way to do this is to engage the whole community across multiple platforms; school programs, community events, online initiatives, door-door education and giving volunteers access to hands on education packages all have a place in raising awareness about stormwater. This multi-level engagement is likely to be far more effective than an isolated program targeted solely at business activities. Creating awareness of where stormwater comes from, where it ends up, and how it can impact local wildlife and potentially our own health will drive conscious changes in the workplace and at home.

A

B

C

D

Figure 39 (A) Steve Marshall and Venessa Nguyen sort macroinvertebrates at the Hogans Rd Site in Hoppers Crossing, (B) Teresa Macintosh gives a presentation at the Port Phillip Bay Forum held at the Melbouren Convention Centre in 2019, (C) Dave Sharley teaching the kids from Carranballac P-9 College about life in our wetlands and how to conduct biological monitoring and assess water quality at the Boardwalk Boulevard Wetlands in Point Cook, (D) Teresa Mackintosh, Liam Coombes and Steve Marshall during a macroinvertebrate survey at Hogan Road in Hoppers Crossing.

Summary

In 2018, the Werribee River Association was awarded a grant to address the issue of stormwater pollution and the associated impacts on the health of the Werribee River and other local creeks. The project, "bridging troubled waters" aimed to design and implement a number of scientifically rigorous and targeted investigations to highlight the problem of uncontrolled stormwater pollution. Using the latest in stormwater pollution monitoring technology and industry standard sediment and biological monitoring techniques, the results formed the basis of integrated education and awareness campaigns across the catchment.

This report, for the first time, provides stakeholders and the public with an easily accessible ecological report card of waterways in the Werribee Catchment, while also identifying the priority pollutants and catchments requiring further investigations by the appropriate authorities. It also sets environmental baseline targets which can be used to measure changes in waterway condition over time - critical in assessing the success of environmental education and enforcement programs and in the development of waterway management strategies. It is also anticipated that the approach used here could be further refined and used as a cost-effective, standardised waterway assessment template for waterway managers and other community groups across Australia.

The approach used, which essentially identifies high risk sub-catchments for priority action can assist in targeting where funds and resources are directed to improve the environmental, social and economic sustainability of urbanised catchments. By establishing environmental baseline targets will allow changes in waterway condition to be independently monitored and assessed, with the results feeding back into adaptive management programs. By incorporating adaptive management approaches into local environmental strategies will allow best practice environmental management to be implemented as technologies develop and environmental health outcomes change over time.

It is hoped that results from this project will initiate integrated stormwater education and awareness programs, with local governments, environmental regulators and waterway managers leading the way. Using the voices of community groups such as the Werribee River Association will provide for more effective communication with those that matter - the general public and industry.

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