



Environmental Report

Kawana Sewage Treatment Plant Environmental Investigation

Prepared for:

Unitywater

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Contents

Summary	i
1 Introduction and Scope	1
1.1 Scope of this Report	2
2 Background	5
2.1 The Sewage Treatment Plant	5
2.2 The Receiving Environment	5
2.3 MBBR Carriers	7
2.4 Plastics	8
2.5 Degradation	8
2.6 High Density Polyethylene	9
2.7 Size Classes	10
3 Laboratory Analysis of Microplastic Particles	11
4 Assessment of Material Collected on the 2mm Effluent Screens	13
5 Assessment of MBBR Plastic Media in Effluent and Comparison to Microplastics Entering the STP	16
6 Assessment of Loss in Mass of In-Service MBBR Plastic Media	18
7 Assessment of Mechanical Degradation Testing of MBBR Plastic Media	19
8 Assessment of MBBR Plastic Media Chemical Breakdown	21
9 Dispersion Modelling	22
10 Assessment of Visual Recreational Amenity, during Ambient Conditions and following a Wet Weather Event	29
11 Assessment of Plastic in Aquatic Ecosystems	30
11.1 Collection of Water and Sediment in the River During a Wet Weather Release	30
11.2 Collection of Biota in the River During Dry Weather Conditions	30

11.3 Collection of Water, Sediment and Biota from Near the Ocean Diffuser	31
12 Summary, Discussion and Conclusions	33
13 References	40
Appendix A Notice to conduct or commission an environmental evaluation, 14 December 2021	
Appendix B SAQP	
Appendix C SAQP P1: Assessment of material collected on the 2mm effluent screens	
Appendix D SAQP P2, P3 & P7: Assessment of MBBR plastic media in effluent and comparison to microplastics entering the STP	
Appendix E SAQP P5: Assessment of loss in mass of in-service MBBR plastic media	
Appendix F SAQP P6: Assessment of mechanical degradation testing of MBBR plastic media	
Appendix G SAQP P7: Assessment of MBBR plastic media chemical breakdown	
Appendix H Dispersion Modelling	
Appendix I SAQP E1 to E6: Assessment of visual recreational amenity, during ambient conditions and following a wet weather event	
Appendix J SAQP E7 to E12: Assessment of background plastic in ocean water and sediment	
Appendix K SAQP E19 to E22: Assessment of plastic in river water and sediment, following a wet weather event	
Appendix L SAQP E23 to E32: Assessment of plastic in biota in the river	
Appendix M SAQP E27 & E28: Assessment of plastic on oceanic fish and other invertebrates	
Appendix N Statutory Declarations	

Tables

Table 1.1	EE Requirements and corresponding section and appendix of this report.	2
Table 2.1	Classes of plastics that are commonly encountered in the marine environment.	8
Table 3.1	Example of types of polymer classified by the FTIR spectroscopy .	11
Table 12.1	EE Requirements and corresponding section and appendix of this report.	36

Figures

Figure 2.1	Location of the Kawana STP ocean outfall release point (W1) and the release point in the Mooloolah River (W3).	6
Figure 2.2	Unused MBBR carriers.	7
Figure 2.3	Broken down MBBR carriers.	7
Figure 4.1	Average daily volume of plastic media collected from the effluent screening system	14
Figure 4.2	Relationship of Screenings Volume and STP Inflow for Daily Flows Exceeding ADWF	15
Figure 5.1	Sampling points within the STP.	16
Figure 7.1	Rate of mechanical degradation of MBBR plastic media from rotary tumbler testing with 'medium' rocks as grinding media.	20
Figure 9.1	Predicted distribution of maximum sedimented particles within the Mooloolah River – Scenario 1	23
Figure 9.2	Predicted distribution of maximum sedimented particles within the Mooloolah River – Scenario 2	24
Figure 9.3	Predicted distribution of maximum sedimented particles within the Mooloolah River – Scenario 3	25
Figure 9.4	Predicted distribution of maximum sedimented particles within the Pacific Ocean – Scenario 1 (Caloundra to Mooloolaba)	26

Figure 9.5	Predicted distribution of maximum sedimented particles within the Pacific Ocean – Scenario 2 (Caloundra to Mooloolaba)	27
Figure 9.6	Predicted distribution of maximum sedimented particles within the Pacific Ocean – Scenario 3 (Caloundra to Mooloolaba)	28

Summary

Unitywater owns and operates the Kawana Sewerage Treatment Plant (STP), a large STP designed for treatment of up to 200,000 equivalent persons. The main bioreactor of the plant uses a moving bed biofilm reactor (MBBR) process where millions of plastic carriers or media are maintained in the liquid sewage suspension by mechanical mixing and large quantities of air bubbles. Biofilm growing on each of the carriers provides the capability to reduce pollutant loads, such as ammonia, from the incoming sewage. The treated wastewater is discharged to the ocean via an outfall pipeline running approximately 1 km offshore from Wyanda Park, Kawana (release point W1) and in times of high rainfall, effluent is also discharged to the Mooloolah River adjacent to the STP (release point W3).

On 14 December 2021, Unitywater was issued a Notice to conduct or commission an environmental evaluation (an EE) by the Chief Executive Officer of the Department of Environment and Science, with respect to the activities of the Kawana Sewerage Treatment Plant. Specifically the EE was issued to investigate the discovery of MBBR plastic media within the receiving waters of the Kawana STP and potential release of plastic media from the degradation of MBBR carriers within the Kawana STP. This report presents a summary of significant results from investigations completed as part of the requirements of the EE and Sampling and Analysis Quality Plan (SAQP).

Samples collected as part of the SAQP were analysed by the University of Newcastle. The colour and shape of the microplastic particles was determined using a microscope, and the polymer type characterised using advanced FTIR (Fourier transform infrared) spectroscopy. The spectra of the microplastic particles in each sample were compared to a global polymer library and the laboratories database, a percentage match calculated, and the polymer composition of the particle was estimated. Where the polymer type of a particle was determined to be 'black polyethylene', it was considered that the particle could potentially have originated from the MBBR carriers. No other polymer types could originate from the MBBR carriers.

The investigations completed as part of the requirements of the EE and SAQP identified:

- Mechanical degradation has had a noticeable impact on the condition of MBBR carriers within the Kawana STP, with MBBR carriers within the plant visually worn.
- The degradation of the MBBR plastic media occurs via two mechanisms: loss due to wear which is relatively constant, and loss due to breakage which has increased since the MBBR media was put into service. The loss due to wear is estimated to be 24 kg/day, which is not captured by the effluent screens. The loss in MBBR plastic media due to breakage which is captured in the effluent screens is currently 4.8 kg/day (~30 L/day).

- The rate of mechanical degradation due to wear is estimated to remain relatively consistent until the structural integrity of the MBBR carriers is compromised and there is breakage.
- Degradation is highest within the anoxic tanks where there is mechanical mixing. There is no evidence that the MBBR carriers used within the Kawana STP are susceptible to degradation from UV exposure or exposure to chemicals typically found in sewage influent.
- The current 2 mm effluent screening system collects most of the broken MBBR plastic media that is greater than 2 mm prior to release. For microplastics in the effluent smaller than 2 mm, most (average of 45.3 particles per survey) were in the size fraction $\leq 63-11 \mu\text{m}$, with <1 particle per survey larger than $500 \mu\text{m}$. Black polyethylene particles, that may have originated from the MBBR particles, comprised between 23.9% and 93.3% of the particles.
- Despite there being a greater number of small particles, most of the mass of plastic particles released in the effluent was comprised of large particles.
- The mass of black polyethylene particles released in the effluent after the screens was highly variable, ranging from 0.5 kg to 87.5 kg per day over the monitoring period. On average, 24 kg/day (17,520 kg over 2 years) was estimated to be released in the effluent after the screens, and 3.73 kg/day was estimated to be released in biosolids.
- As no black polyethylene particles were recorded in the 6 influent samples, it is likely that most of the black polyethylene particles released from the STP are from the degradation of MBBR carriers in the plant.
- There was no distinct relationship between STP inflow and the volume of plastic media (macro and microplastic) that accumulated on the screen,
- Large increases in the volume of MBBR plastic media collected on the effluent screens can mostly be attributed to specific events, such as high flows and new mixers. While the amount of breakage of MBBR plastic media has varied over the last 2 years, results from the last 6-months suggest breakage may be increasing over time.
- Alternative MBBR carriers, such as those supplied by Warden Biomedica, had a consistently lower rate of wear from mechanical degradation than the Hel-X carriers used at the Kawana STP, with no evidence of breakage in the Warden Biomedica for the 70 days of experimentation. This suggests that alternate MBBR carriers may be more appropriate for the conditions experienced within the Kawana STP.
- Prior to this investigation, MBBR plastic media released from the Kawana STP were observed and collected from beaches inshore of the ocean release point. Following

retrofitting of the effluent screening system, the beaches inshore of the ocean release have been surveyed each month (December 2021 to May 2022), and the Mooloolah River in March 2022. One MBBR plastic media particle was recorded in these surveys, on the beach inshore of the ocean release point. That is, there is not a significant impact on the visual recreational amenities of coastal waters or the Mooloolah River from the release of MBBR plastic media particles from the Kawana STP via the Pacific Ocean Outfall or the Mooloolah River Overflow outfall.

- Similarly, few black polyethylene particles (that may include MBBR particles) were found in biota, water or sediment in the receiving environment at locations where dispersion modelling indicated concentrations would be highest.
- Specifically, in samples from the Mooloolah River, there were:
 - no black polyethylene particles (that may include MBBR particles) in surface water or sediment.
 - microplastics particles in surface water, sediment and biota at all sites, with the exception of oysters at the mouth of the estuary, and
 - some black polyethylene particles (that may include MBBR particles) in one oyster and one prawn sample from the mid-estuary.
- In samples from the ocean, there were:
 - black polyethylene particles (that may include MBBR particles) in the surface water and bottom water near the diffuser, and in one of the shrimp samples from near the diffuser
 - no black polyethylene particles in the sediment near the diffuser nor inshore of the diffuser on the beach
 - on average, 0.24 plastic microparticles per cubic metre (m^{-3}) of seawater, and
 - no more than 0.02 particles m^{-3} of black polyethylene (that may include MBBR particles) in surface or bottom water i.e. while black polyethylene particles (that may include MBBR particles) were detected in ocean water, they comprised a small proportion of the total number of plastic microparticles.

1 Introduction and Scope

On 14 December 2021, Unitywater was issued a Notice (Appendix A) to conduct or commission an environmental evaluation (an EE) by the Chief Executive Officer of the Department of Environment and Science (the department), with respect to the activities of the Kawana Sewage Treatment Plant (the STP), Main Drive Bokarina, WLD, 4575. Unitywater is authorised to undertake Environmentally Relevant Activity (ERA) 63-(1)(g) Sewage treatment >100,000 Equivalent Persons (EP) at these premises under the conditions of EPPR00869113 (the EA). The EE issued on 14 December 2021 superseded an EE issued on 27 October 2021.

The grounds for issuing the EE on 14 December 2021, and the requirements of the EE are detailed in the Notice (Appendix A).

The background for issuing the EE can be summarised as:

- The Kawana STP has been recently upgraded and now the main bioreactor uses moving bed biofilm reactor (MBBR).
- Unitywater contracted Monadelphous (MEPL) to construct the MBBR system.
- MEPL acted under Unitywater's EA during this work.
- Plastic carriers are used in the MBBR.
- Biofilms on the carriers reduce pollutant loads from incoming sewage.
- In January 2020 it was identified that small quantities of broken MBBR carriers may be discharged in the effluent.
- In January 2020 Unitywater inspected the beaches adjacent to W1 and reported some MBBR plastic media on the beach.
- In September 2020, November 2020, March 2021 and April 2021 Unitywater notified the department some more media had been released. The releases in September and November 2020 were to the ocean via release point W1 1 km offshore of Warana at approximately 20 m depth, while the one in March 2021 was via release point W3 in the Mooloolah River.
- After these events Unitywater inspected the beach and removed MBBR plastic.
- Unitywater has provided advice that known releases of plastic media >2 mm to the marine environment from the STP are estimated to be between 5 and 10 litres.

- Unitywater has advised that they currently do not have an estimate of the volume of degraded plastic media <2 mm released through the screens to the receiving environment.

Unitywater installed 2 mm screens to prevent releases of MBBR carriers, however in wet weather, these screens foul quickly, and broken MBBR carriers may be released. Unitywater is investigating further options to address this issue.

1.1 Scope of this Report

This report presents information collected as part of the requirements of the EE. Details of methods used, results and discussion are presented in the Appendices, and a summary of the significant results are presented in the main body of this report (Table 1.1).

Table 1.1 EE Requirements and corresponding section and appendix of this report.

EE Requirement	Section	Appendix
3. By 28 February 2022 the AQP engaged in requirement 1 must design and commence implementing, a Sampling and Analysis Quality Plan (SAQP) that is representative for all reasonably foreseeable hydraulic operational scenarios expected to occur during the operation of the MBBR and that:		
a. Proposes a size of MBBR plastic media which can be accurately collected, distinguished from other plastic sources in the influent and measured, and define why this size of MBBR plastic media to be sampled is proposed.	5	D
b. Assesses the breakdown rate of the MBBR plastic media in the MBBR due to existing mechanical forces as currently configured (such as collision with infrastructure, other media and abrasion with sediment in influent) and chemical breakdown processes(including that caused by ultraviolet UV degradation of the	4, 7 and 8	C, F and G

EE Requirement	Section	Appendix
plastic and exposure to chemicals in the sewage influent).		
c. Determines the percentage of broken MBBR plastic media within the MBBR in a way which determines if the percent rate of breaking media is increasing or decreasing over time.	4	C
d. Determines the size distribution of the resultant breakdown plastic media with specific reference to current containment controls (i.e. 2 mm screen aperture).	4	C
e. Determines the current volume of plastic media being released from the STP via release points W1 and W3, as referenced in the EA.	5	E
4. The AQP must implement the SAQP and undertake analysis and interpretation of the data obtained to estimate the volume and size distribution of MBBR plastic media released over a range of hydraulic scenarios, and over the proposed lifespan of existing MBBR plastic media.	5	D

In addition to the requirements listed in the Notice, Unitywater is undertaking additional investigations. These investigations are listed in the SAQP (Appendix B) and summarised in this report. They comprise:

- assessing the amount of microplastics entering the STP, to provide a comparison with the loss of mass of MBBR carriers

- dispersion modelling of MBBR plastic media estimated to be released to the environment for $\leq 2\text{mm}$ and $\geq 2\text{mm}$ MBBR plastic media particles from release point W1 and release point W3, as referenced in the EA
- visual assessment of plastic washed on to land, at potentially impacted sites and at control sites, in both ambient conditions and after an event
- the amount of plastic in ocean water and sediment, near W1 and at control sites, and the contribution of MBBR media
- the amount of plastic in water and sediment following a rainfall event¹, at potentially impacted sites in the Mooloolah River and at control sites in the Maroochy River, and the contribution of MBBR media
- the amount of plastic potentially available for human consumption and in biota at potentially impacted sites in the Mooloolah River and at control sites in the Maroochy River, and the contribution of MBBR media
- the amount of plastic in finfish and potentially edible invertebrates in the vicinity of the ocean outfall and at a control site, and the contribution of MBBR media.

The appointed AQPS are:

- Carol Conacher of frc environmental: Environmental Investigations (Appendix J, K, L and M)
- Ed Beling of Intrawater: Dispersion Modelling (Appendix H), and
- Chris Conway of Hunter H2O: Development of SAQP and oversight of experimental work at Kawana STP (Oversight of work completed for Appendix C, D, E, F, G and I).

Unitywater is submitting monthly reports to the Department. This report addresses items 3 to 6 of the requirements in the Notice, and summarises results of the additional investigations listed above and in the SAQP.

2 Background

2.1 The Sewage Treatment Plant

Unitywater owns and operates several sewage treatment plants (STP's) on the Sunshine Coast. Kawana STP located at Main Drive, Birtinya, is one of the largest and has been identified as a future centralised treatment facility with possible future loads of up to 600,000 equivalent persons. The STP is currently designed for a treatment capacity of 200,000 EP. The main bioreactor of the plant uses a moving bed biofilm reactor (MBBR) process where millions of plastic carriers or media are maintained in the liquid sewage suspension by mechanical mixing and large quantities of air bubbles.

The bioreactor has 4 separate compartments with screens mounted in the head wall between each, that are designed to retain the plastic carriers in each compartment. Biofilm growing on each of the carriers provides the capability to reduce pollutant loads, such as ammonia, from the incoming sewage. The treated wastewater is discharged to the ocean via an outfall pipeline running approximately 1 km offshore from Wyanda Park, Kawana (release point W1) and in times of high rainfall, effluent is also discharged to the Mooloolah River adjacent to the STP (release point W3).

2.2 The Receiving Environment

The Kawana STP predominantly releases into the Pacific Ocean via a diffuser at W1, with releases to the Mooloolah River under specific conditions at W3 (Figure 2.1).

The diffuser at W1 is approximately 1 km offshore of Kawana. The diffuser and surrounding pipes at W1 serves as an artificial reef supporting diverse communities of algae, hard and soft corals, sponges, ascidians, and hydrozoans, with a variety of reef fish. Nearby habitats of rocky reef and bare sand are dominated by algae, hard and soft coral, and sponges. The habitats in the vicinity of the ocean outfall do not provide habitat critical to the survival or reproduction of any threatened aquatic species that may be present in the area (frc environmental 2014).

The outfall in the river (W3) is in the upper reaches of the estuary, with nearby vegetation consisting of riparian vegetation and mangroves (*Bruguiera gymnorhiza* and mixed mangrove forests). Fish communities in the river are anticipated to be typical of estuaries in south east Queensland with urbanised foreshores, with opportunistic species such as bream likely dominating (Yabsley et al. 2018).

The habitats of the receiving environment are further described in Appendices L and M.

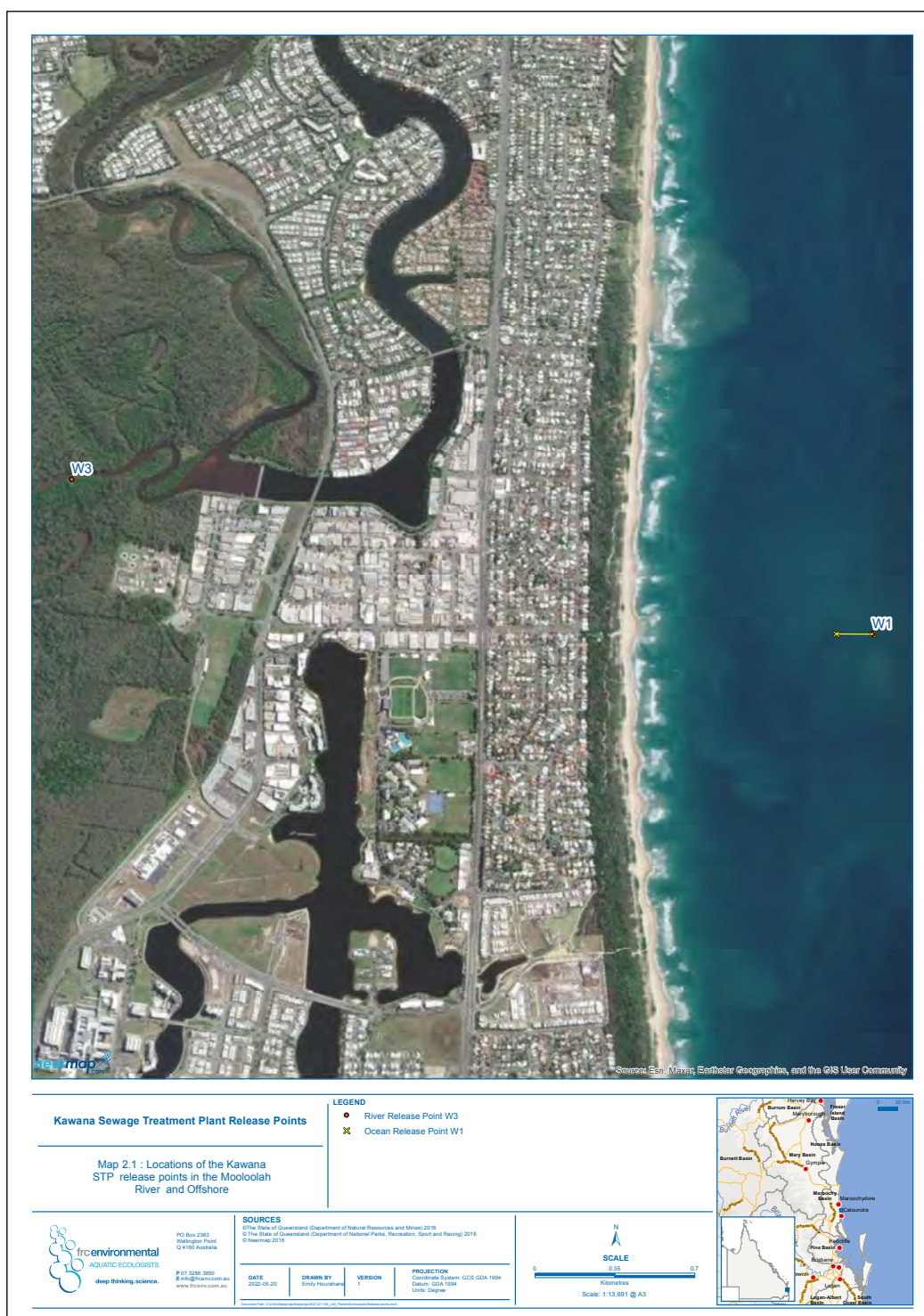


Figure 2.1 Location of the Kawana STP ocean outfall release point (W1) and the release point in the Mooloolah River (W3).

2.3 MBBR Carriers

The moving bed biofilm reactor (MBBR) is a compact treatment alternative to conventional activated sludge reactors for the treatment of municipal and industrial wastewater. In MBBR systems the biomass is grown as biofilm on small special plastic carrier elements which move around in the reactor known as MBBR carriers (Figure 2.2 and Figure 2.3). There was reported to be more than 1200 MBBR wastewater treatment plants worldwide in 2014 (Biswas et al. 2014).

MBBR carriers are primarily made from high density polyethylene (HDPE) and are extremely persistent within the marine environment due to the lack of UV visible chromophores which resist photo-oxidative degradation.



Figure 2.2 Unused MBBR carriers.



Figure 2.3 Broken down MBBR carriers.

2.4 Plastics

Plastics are high molecular weight polymers that are combined with additives during production to produce a versatile, durable, light weight yet extremely strong and persistent product. Further, the strong polymeric carbon-carbon double bonds and additional production additives prohibit biodegradation, thus plastics remain in the environment for thousands of years fragmenting into progressively smaller pieces e.g., to microplastics (Biamis et al. 2021). Primary microplastics are intentionally manufactured for applications such as resin pellets and microbeads in personal care products (i.e. cosmetics). They can also be generated through items containing plastic in synthetic clothing and car tyres during use. Secondary sources of microplastics are caused by the degradation and weathering of larger plastic debris on land or sea resulting in a reduced structural integrity (Coyle et al. 2020). There are several main classes of plastics which are globally produced in large quantities and end up within the marine environment (Table 2.1).

Table 2.1 Classes of plastics that are commonly encountered in the marine environment.

Plastic Class		Specific Gravity	Products
Low-density polyethylene	LDPE	0.91 – 0.93	Plastic bags, six-pack rings, bottles, netting, drinking straws, microbeads
High-density polyethylene	HDPE	0.94	Commercial products, milk jugs
Polypropylene	PP	0.85 – 0.83	Rope, bottle caps, netting
Polystyrene	PS	1.05	Plastic utensils, milk containers
Foamed Polystyrene	-	-	Floats, bait boxes, cups
Nylon	PA	-	Fishing gear (netting and traps)
Thermoplastic Polyester	PET	1.37	Beverage bottles
Poly(vinyl chloride)	PVC	1.38	Plastic film, bottles, cups
Cellulose Acetate	CA	-	Cigarette filters

2.5 Degradation

The increasing global production and use of plastics has led to an accumulation of plastic litter in the ocean. Characteristics such as low density, good mechanical properties and low cost allow for successful use of plastics in industries and everyday life but the high durability leads to persistence of the synthetic polymers in the marine environment where they cause harm due to leaching of chemical additives and the accumulation of pollutants.

There are four main types of plastic degradation:

- solar UV-induced photodegradation reactions
- thermal reactions including thermo-oxidation
- hydrolysis of the polymer, and
- microbial biodegradation.

In diverse marine habitats, including beaches, the sea surface, water column, and seafloor, plastics are exposed to different environmental conditions that either accelerate or decelerate their physical, chemical and biological degradation. Degradation occurs primarily through solar UV-radiation induced photo oxidation reactions and is, thus, most intensive in photic environments such as the sea surface and on beaches (Andrady 2015). The rate of degradation is temperature-dependent resulting in considerable deceleration of the processes in seawater. Below the photic zone in the water column, plastics degrade very slowly resulting in high persistence of plastic litter, especially at the seafloor. Initial exposure of plastic results in the formation of a surface biofilm (Lobelle & Cunliffe 2011) that is rapidly colonized by algae and other marine biota, including encrusting organisms, that increase the density of the plastic causing it to sink in seawater (Thangavelu & Subramani 2016). Of the five classes of the commonly used plastics (or commodity thermoplastics), polyethylenes (PE) and polypropylenes (PP) as well as the expanded form of polystyrene or polystyrene foam (EPS) are less dense than sea water and float (Andrady 2011).

2.6 High Density Polyethylene

High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a thermoplastic polymer produced from the monomer ethylene. It is sometimes called "alkathene" or "polythene". With a high strength-to-density ratio, HDPE is used in the production of plastic bottles, corrosion-resistant piping, geomembranes and plastic lumber. HDPE is commonly recycled, and has the number "2" as its resin identification code. As one of the most versatile plastic materials around, HDPE plastic is used in a wide variety of applications, including plastic bottles, milk jugs, shampoo bottles, bleach bottles, cutting boards, and piping. Known for its outstanding tensile strength and large strength-to-density ratio, HDPE plastic has a high-impact resistance and melting point.

Polyethylene constitutes to the largest percent of total global plastics (38%), and HDPE represents 17% with LDPE 21% respectively (Andrady 2011). HDPE although the most latent, degrades slowly in the marine environment as opposed to other plastics. Primarily

due to the lack of UV visible chromophores which resist photo-oxidative degradation (Chamas et al. 2020).

2.7 Size Classes

Marine plastic debris comes in various classes and constitute unintentionally produced nanoparticles that are derived from the breakdown of microplastics (<5 mm), which in turn are derived from mesoplastics (>5.0 mm) and macroplastics (greater than a few centimetres) (Andrady 2011; Cole & Galloway 2015; Iwasakia et al. 2017).

The density of the plastic particles will determine bioavailability in the water column; hence the type of plastic ingested may vary between organisms. Planktivores, filter feeders and suspension feeders inhabiting the upper water column are likely to encounter positively buoyant, low-density plastics, such as polyethylene (specific gravity 0.91e0.94), on the sea surface (Wright et al. 2013).

The particle size of MBBR plastic media that was assessed in this EE was selected specifically for this investigation, and based on microplastic particle sizes previously found within environmental samples of the region, literature reviews and suitable standards and industry practices. Although a review of the literature identified a range of suitable particles sizes (typically 100 micron to 1 mm), a lower limit of 11 microns was selected based on the laboratory capabilities of the laboratory selected (University of Newcastle).

For the assessment of particles obtained from the STP effluent screens, standard soil and mineral sieve sizes were used. As the effluent screens have a 2 mm aperture and the MBBR carriers are 13 mm in length (unbroken), sieve sizes from 1.18 mm to 9.5 mm were used to grade the material gathered from the effluent screens.

3 Laboratory Analysis of Microplastic Particles

The laboratory analysis of microplastic particles is presented in Attachment 4 of Appendix D. In summary:

- Samples that were high in organic content were heat digested using Fenton reagent.
- The digested samples were then sieved to separate microplastics of different particle sizes.
- The microplastics were then microscopically examined to determine colour and shape.
- Particles were characterised using advanced FTIR (Fourier transform infrared) spectroscopy. When infrared radiation is passed through a sample, some radiation is absorbed by the sample. The spectrum of absorbed light represents a 'fingerprint' of the molecular structure of the sample.
- The spectra of the microplastic particles in each sample were compared to a global polymer library and the laboratories database, a percentage match calculated, and the composition of the particle was estimated.
- The composition of the particles were classified into polymer types e.g. Table 3.1.

Table 3.1 Example of types of polymer classified by the FTIR spectroscopy .

Abbr.	Polymer Type
PVC	Polyvinyl Chloride
PET	Polyethylene terephthalate
PVA	Polyvinyl alcohol
PS	Polystyrene
PP	Polypropylene
SBCo	Styrene butadiene copolymer
PVB	Polyvinyl butyral
PA	Polyamide
PE-Chl	Chlorinated polyethylene
PE	Polyethylene
Black PE	Black polyethylene

Fragments that were black, and had the polymer type of 'black polyethylene' may have originated from MBBR plastic media.

Samples could not be directly compared to the plastic in MBBR carriers due to:

- the very small size of the microparticles
- the small number per sample
- the MBBR carriers are made from recycled plastic, and consequently don't have a unique spectral signature
- plastic particles in the environment chemically degrade and consequently the signature of a particle from an MBBR carrier would degrade.

4 Assessment of Material Collected on the 2mm Effluent Screens

The breakdown of MBBR plastic media at Kawana STP was investigated by assessing the volume and material characteristics of plastic media caught by the 2 mm effluent screening systems.

The assessment addressed the:

- breakdown rate of MBBR plastic media due to existing mechanical forces (as currently configured)
- percentage of broken MBBR plastic media within the MBBR over time to determine the rate of breakage, and
- size distribution of plastic media with specific reference to the current 2 mm effluent screening system.

Plastic media that had accumulated on the effluent screens was collected fortnightly from February 2020 to May 2022. The bulk volume of all plastic media removed was recorded. The size and material types was also assessed for a subsample of each collection, with materials visually classified as MBBR plastic, plastic other than MBBR media or non-plastics.

This investigation is comprehensively presented in Appendix C and summarised below.

The volume of plastic media collected from the screening system had three distinct phases (Figure 4.1):

- Phase 1 (February 2020- October 2020): little accumulation of plastic media on the screening system until September 2020 when the installation of a new anoxic mixer increased degradation of the MBBR material, causing a sudden increase in plastic material collected until October 2020.
- Phase 2 (October 2020 – August 2021): a gradual decrease in the volume of damaged media accumulating on the screens following the installation of a new anoxic mixer in October 2020.
- Phase 3 (August 2021 – May 2022): a gradual increase in the volume collected, coinciding with the commissioning of a new clarifier skimming system and increased flows through the Kawana STP during wet weather.

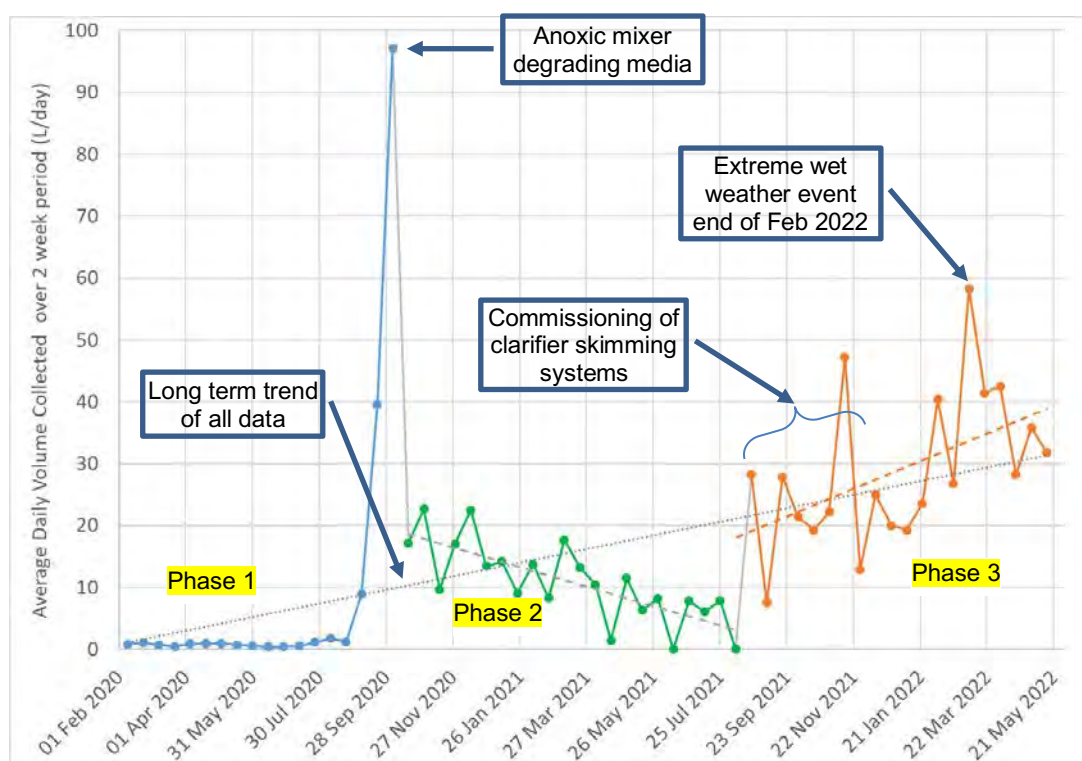


Figure 4.1 Average daily volume of plastic media collected from the effluent screening system

There was no distinct relationship between STP inflow and the volume of plastic media accumulated on the screen, however there was a distinct relationship between the volume of plastic media accumulated on the screen and the daily flows that exceed the average dry weather flow (ADWF) (Figure 4.2). This suggests that broken MBBR plastic media within the bioreactor may require a certain level of hydraulic force (i.e. flows greater than the ADWF) to flush material through to the effluent screening system, particularly larger media particles that might otherwise be retained by screens inside the bioreactor.

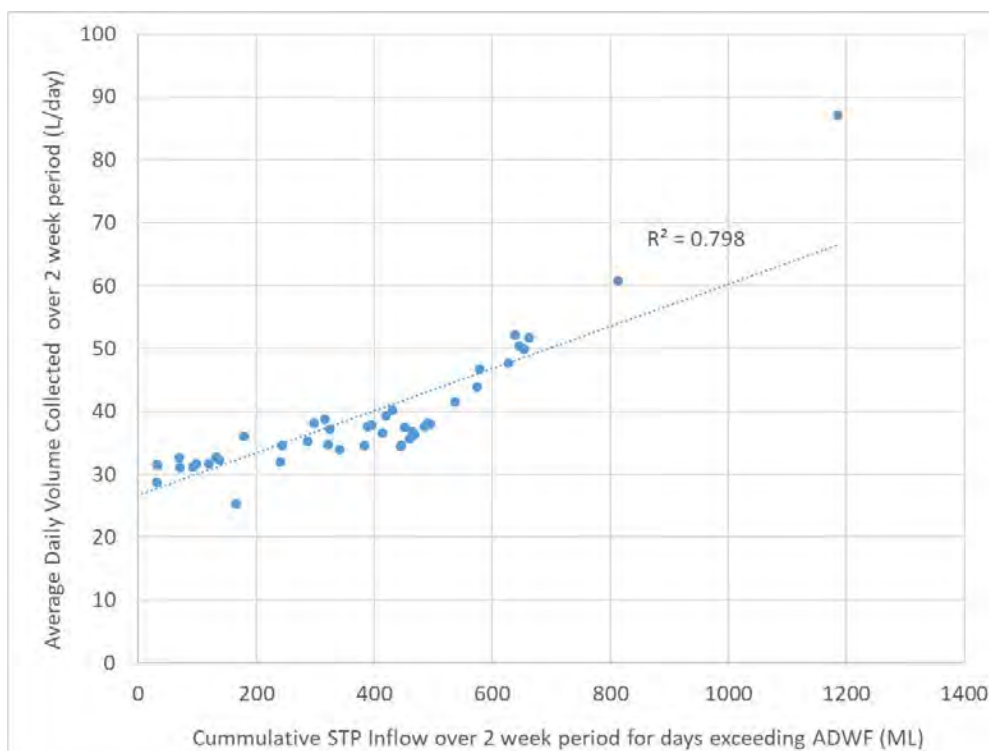


Figure 4.2 Relationship of Screenings Volume and STP Inflow for Daily Flows Exceeding ADWF

The size distribution of plastic media collected on the effluent screening system indicates that once the MBBR plastic media breaks (i.e. loses a quarter section), it is quickly flushed out of the MBBR bioreactor with minimal degradation.

Although changes in the volume of MBBR plastic media collected on the effluent screens can be attributed to specific events, such as high flows and new mixers, results from the last 6-months suggest the amount of breakage of MBBR plastic media may be increasing over time.

5 Assessment of MBBR Plastic Media in Effluent and Comparison to Microplastics Entering the STP

Microplastic particles in effluent from the Kawana STP plant were investigated to determine the total amount of microplastic particles, and what proportion were black polyethylene that may have originated from MBBR carriers.

A liquid effluent sample was collected each month for 6 months during dry weather conditions, and a further sample collected during a wet weather event at the end of February 2022. In addition, the influent, MBBR feed, MBBR discharge, effluent, and biosolids were sampled on 6 separate days during dry weather conditions (Figure 5.1).

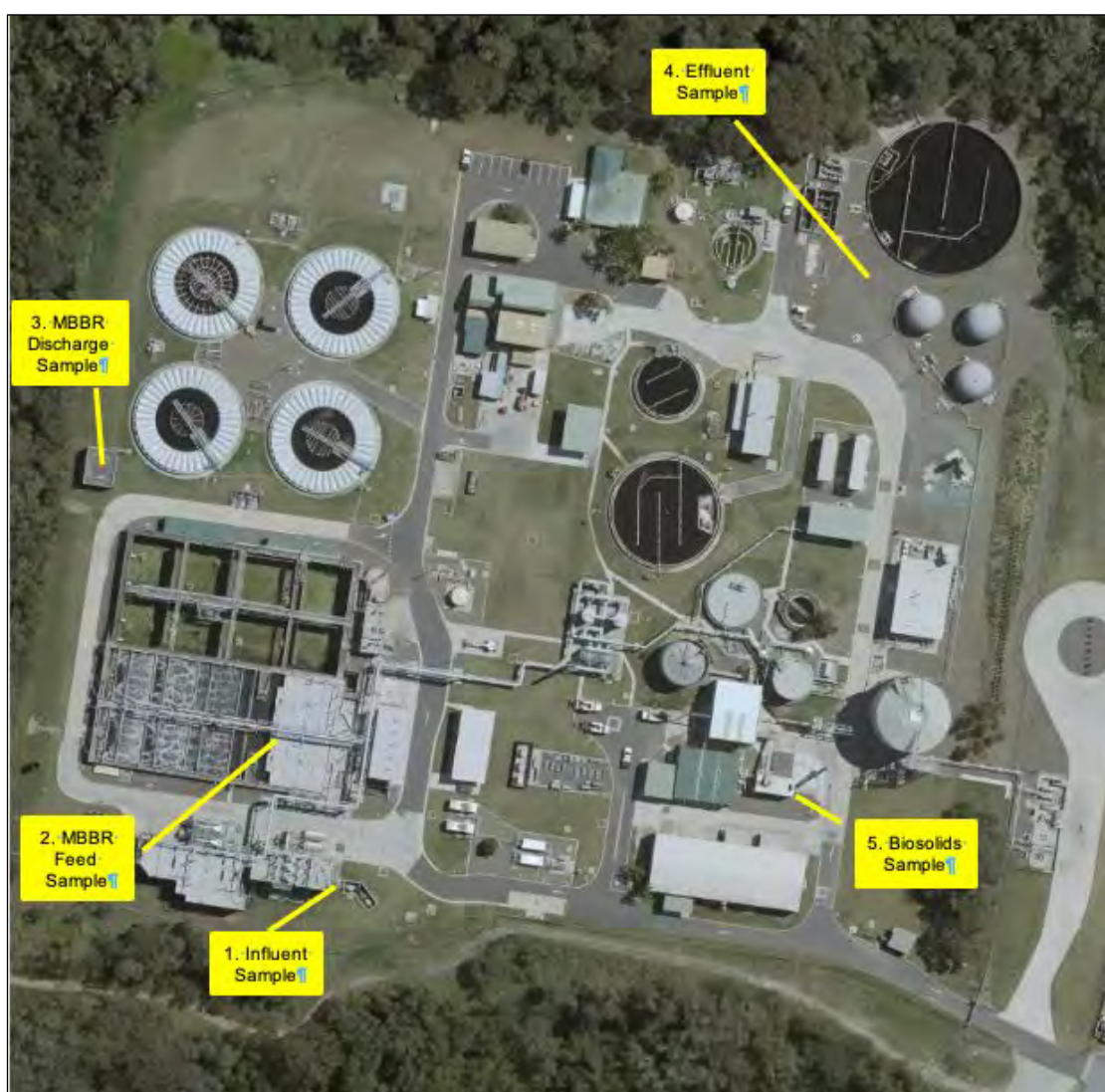


Figure 5.1 Sampling points within the STP.

This investigation is comprehensively presented in Appendix D. In summary:

- There were no black polyethylene particles in the influent samples, or in the MBBR feed (once sources of contamination were removed).
- The mass of black polyethylene particles released in the effluent after the screens was highly variable, ranging from 0.5 kg to 87.5 kg per day over the monitoring period.
- On average, the mass release of black polyethylene particles in the effluent was estimated to be 24 kg/day, or 17,520 kg over 2 years of operating.
- On average, the mass release of black polyethylene particles in the biosolids was estimated to be 3.73 kg/day, or 2,725kg over 2 years of operating.
- These results generally coincide with the estimated loss in mass calculated in Section 5 (Appendix E)
- The average concentration of microplastic particles was 20.8 microplastic particles per litre of effluent.
- Between 24% and 93% of these particles were black polyethylene and likely to have originated from the degradation of MBBR plastic media in the plant.
- There was no correlation between STP inflow and the concentration of microplastics, or the percentage of particles that were black polyethylene.
- During dry weather flows, most microplastic particles that were detected in the effluent were over 11 µm and less than 125 µm, with most black polyethylene particles between 11 and 63 µm.
- During wet weather flows, most microplastic particles that were detected in the effluent were between 11 and 63 µm.

6 Assessment of Loss in Mass of In-Service MBBR Plastic Media

The wear of plastic MBBR carriers used at Kawana STP was investigated to determine if there is likely to have been any loss in mass after the carriers have been in-service for approximately 2 years.

Samples of MBBR carriers were collected from the anoxic and first aeration zones of both MBBR bioreactors, and the biofilm removed. The mass of these MBBR carriers was compared to the mass of two sets of unused carriers².

This investigation is comprehensively presented in Appendix E. In summary:

- The carriers from the anoxic tanks were on average 10% and 6% lighter than the two sets of unused carriers.
- The carriers from the aeration tanks were on average 6% and 3% lighter than the two sets of unused carriers.
- The decrease in mass is likely due to wear of the carriers in service, which is supported by visual examination of the in-service carriers. However, this assessment is based on the assumption that the carriers used in the analysis are representative of the carriers that were first put into service.
- Considering the MBBR carriers have been in-service at Kawana STP for approximately 2 years, achieving a 25-year design life normally expected of MBBR carriers would be challenging if this current rate of degradation continues.

² The unused carriers used for this assessment were from a different batch to the MBBR carriers first put into service at the Kawana STP. Due to differences in size and composition between batches, the impact of manufacturing variances is unknown.

7 Assessment of Mechanical Degradation Testing of MBBR Plastic Media

The mechanical degradation of plastic MBBR carriers used at Kawana STP (Hel-X carriers) was investigated to determine the breakdown rate of MBBR plastic media due to existing mechanical forces. The mechanical degradation of alternate HDPE carriers (Warden Biomedia) was also investigated for comparison.

Samples of plastic MBBR carriers were experimentally exposed to mechanical wear within rotary tumblers containing grinding media, plastic MBBR carriers and water. A range of grinding media was trialled, with 'medium' and 'large' rocks producing results that most resembled the wear and breakage observed within the Kawana STP.

This investigation is comprehensively presented in Appendix F. In summary:

- there was a noticeable increase in the rate of mechanical degradation of the Hel-X carriers, once the carriers started to show signs of breakage (Figure 7.1)
- MBBR carriers within the Kawana STP are likely to experience a similar increase in mechanical degradation, however there is uncertainty when this may occur, and
- Warden Biomedia carriers had a consistently lower rate of wear from mechanical degradation than the Hel-X carriers, with no evidence of breakage in the Warden Biomedia throughout the experiment (Figure 7.1).

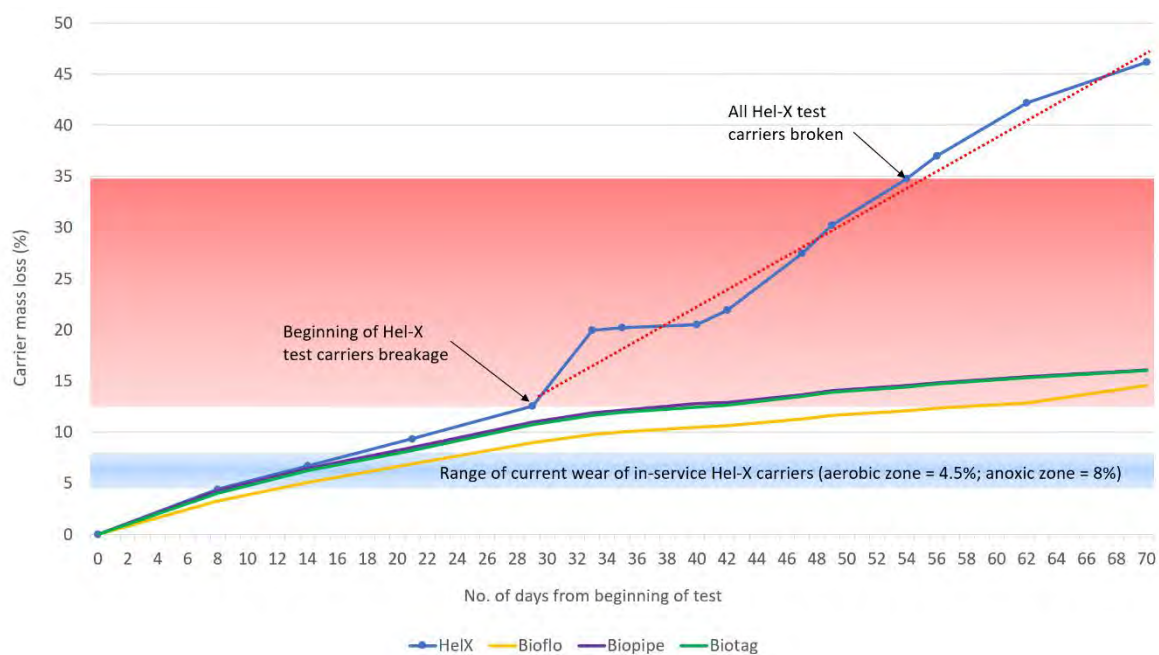


Figure 7.1 Rate of mechanical degradation of MBBR plastic media from rotary tumbler testing with 'medium' rocks as grinding media.

8 Assessment of MBBR Plastic Media Chemical Breakdown

Plastic MBBR carriers from the Kawana STP were microscopically investigated for signs of degradation from UV damage or chemicals likely to be present at the Kawana STP. The objective was to determine if UV exposure or chemical degradation have a significant role in the loss of plastic media from the Kawana STP.

This investigation is comprehensively presented in Appendix G. In summary, the microscopic examination did not identify any signs of degradation from UV or chemical exposure on plastic MBBR carriers from the Kawana STP.

9 Dispersion Modelling

Dispersion modelling was used to investigate how particles from the Kawana STP's Moving Bed Biofilm Reactor (MBBR) may potentially be released and transported in the waters surrounding the diffuser offshore of Kawana Beach (W1) and downstream of the outfall in the Mooloolah River (W3).

Results from preliminary modelling were used to inform the design of the Environmental Evaluation's Sampling and Analysis Quality Plan by identifying potential zones of particle accumulation in the environment, thus predicting the likely destination for media released from the Kawana STP. This was confirmed by the final modelling.

Twelve months were simulated, with 3 potential release scenarios:

- Scenario 1 (baseline dry weather scenario): discharge of MBBR particles < 2 mm where these smaller particles pass through the effluent basket screens.
- Scenario 2 (unforeseen dry weather scenario): undetected release of a portion of all sizes of MBBR particles due to undetected damage to the basket screens.
- Scenario 3 (wet weather scenario): overtopping of the basket screens during an extreme wet weather event and associated release to both the Pacific Ocean and Mooloolah River outfalls. Although no longer possible with the current configuration of effluent basket screens, this scenario investigated the potential dispersion of particles from the previous plant configuration.

The results of the scenarios are presented spatially as distributions of maximum sedimented/deposited mass concentrations calculated over the simulation period, with results of the modelling described in detail in Appendix H. In summary:

Mooloolah River – Release from Mooloolah River Overflow Outfall

- Both dry weather scenarios (Scenario 1 and 2) indicate there would be an accumulation of particles at (Figure 9.1):
 - A – The reach downstream of Release Point W3 and upstream of Parrearra Weir
 - B – Mid estuarine reaches near the Brightwater Eastern Conservation Area, and
 - C – Foreshore areas between Mooloolah Island and Minyama Island.

- The model indicated the potential for a greater accumulation in location “A”, immediately following a release event. These particles may be retained here until the following wet weather event which effectively flushes them downstream.
- Further downstream the predicted areas of accumulation “B” and “C” appear to predominantly correlate with intertidal zones along the mid-estuarine riverbanks and the more artificially developed foreshores in the lower estuary.
- Particle distribution in the wet weather scenario (Scenario 3; Figure 9.3) was similar to the dry weather scenarios, but with a greater accumulation near the Parrearra Weir.

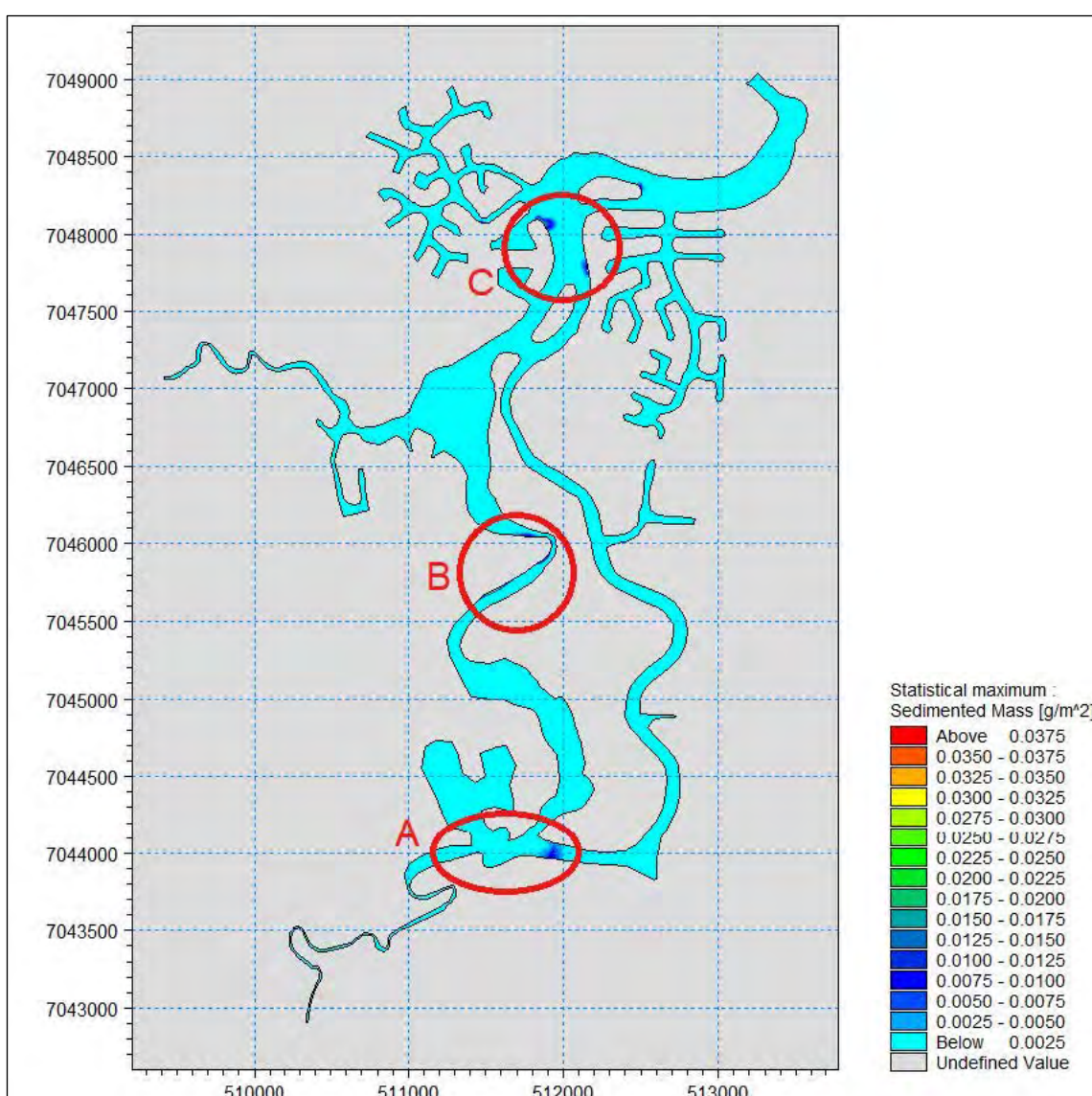


Figure 9.1 Predicted distribution of maximum sedimented particles within the Mooloolah River – Scenario 1

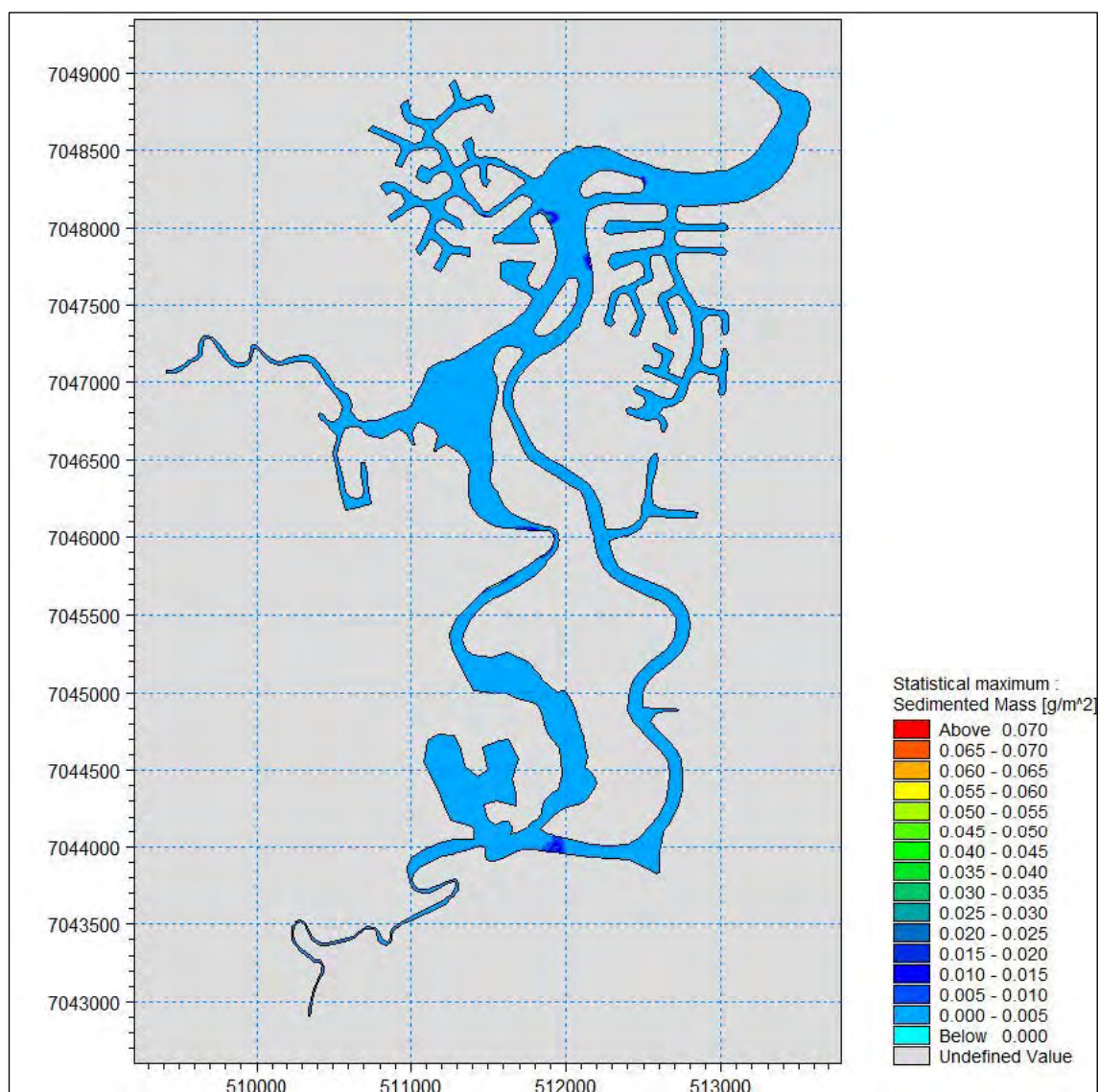


Figure 9.2 Predicted distribution of maximum sedimented particles within the Mooloolah River – Scenario 2

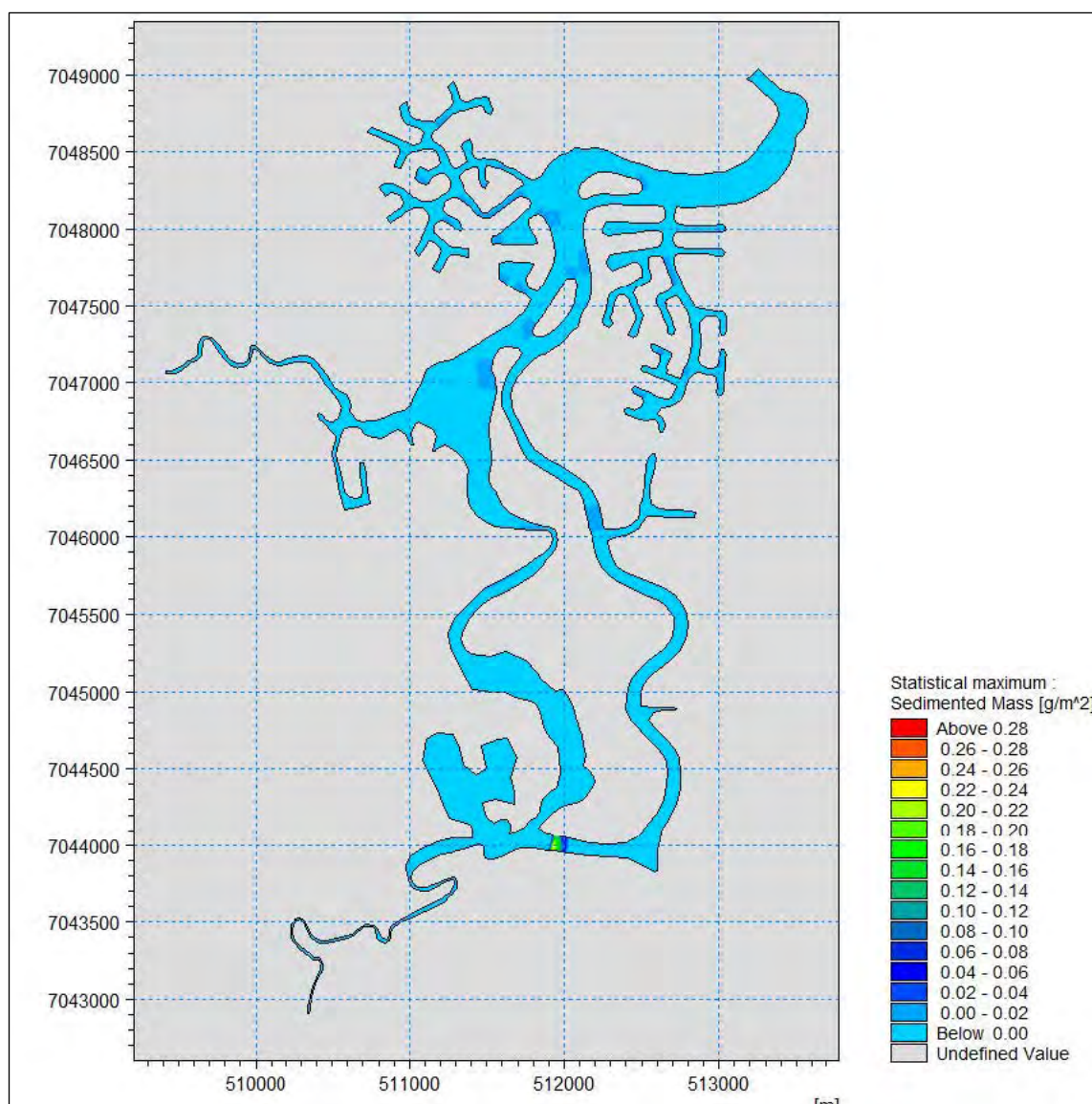


Figure 9.3 Predicted distribution of maximum sedimented particles within the Mooloolah River – Scenario 3

Pacific Ocean – Release from Kawana Beach Outfall

- In each scenario, particles accumulated on the beaches between Currimundi Lake in the south, and the Point Cartwright headland in the north, with concentrations highest between Wyanda Drive and Currawan Street (Figure 9.4–Figure 9.6)
- In the wet weather scenario (Scenario 3; Figure 9.6) there was a more southerly accumulation on the foreshore, demonstrating the effect of high flows on buoyant media.

In the dry weather scenarios, the distribution of particles was primarily influenced by northerly winds, a southward tidal stream and an easterly wave climate.

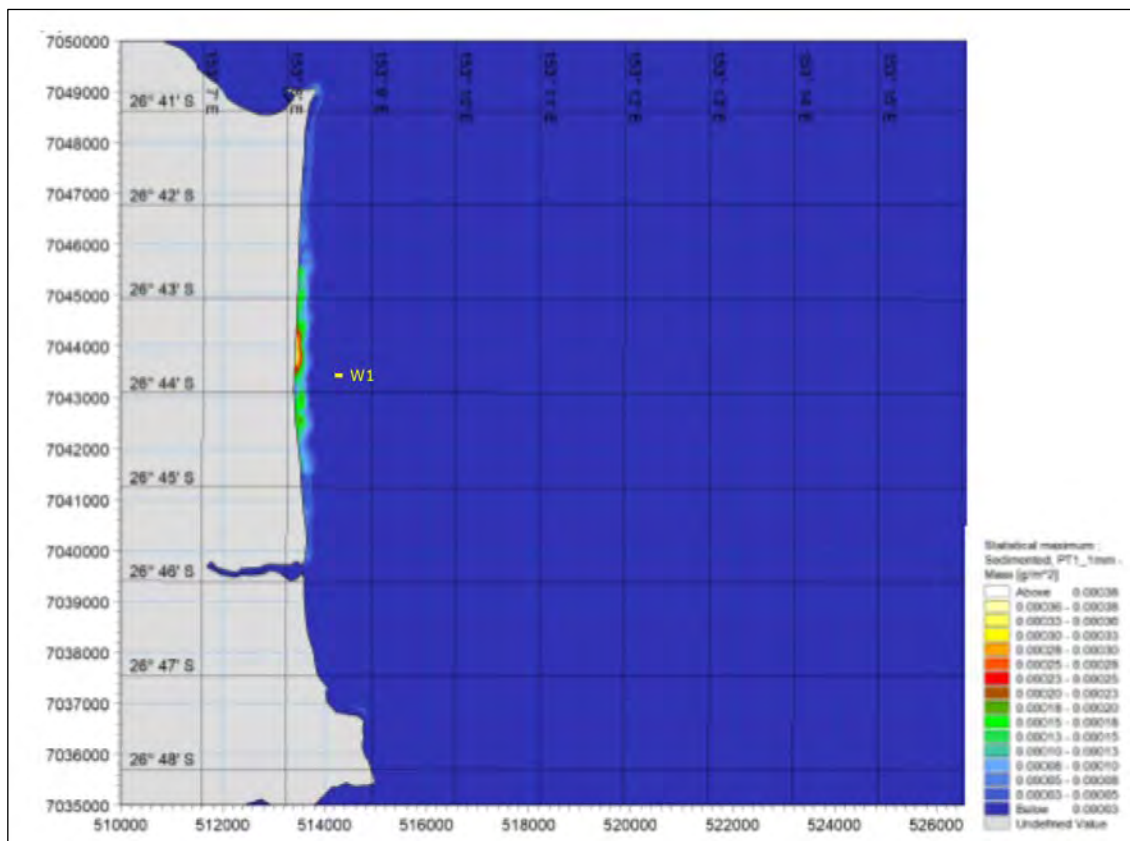


Figure 9.4 Predicted distribution of maximum sedimented particles within the Pacific Ocean – Scenario 1 (Caloundra to Mooloolaba)

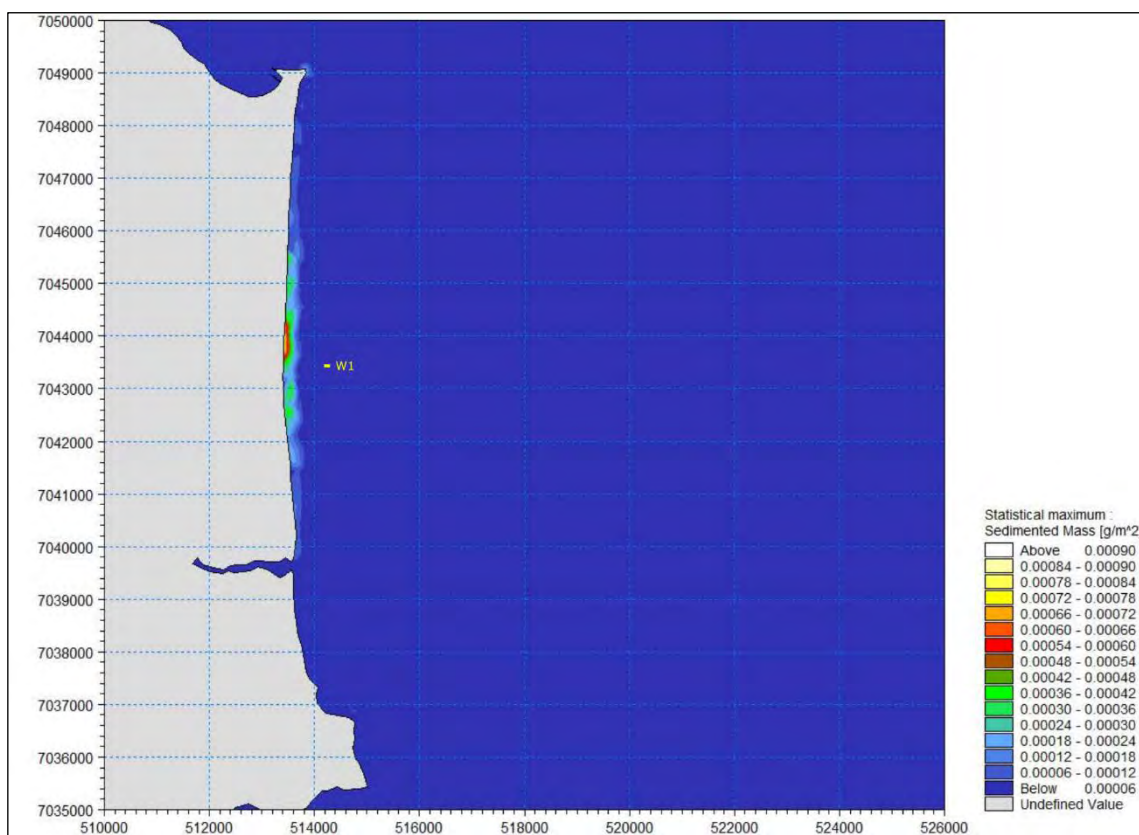


Figure 9.5 Predicted distribution of maximum sedimented particles within the Pacific Ocean – Scenario 2 (Caloundra to Mooloolaba)

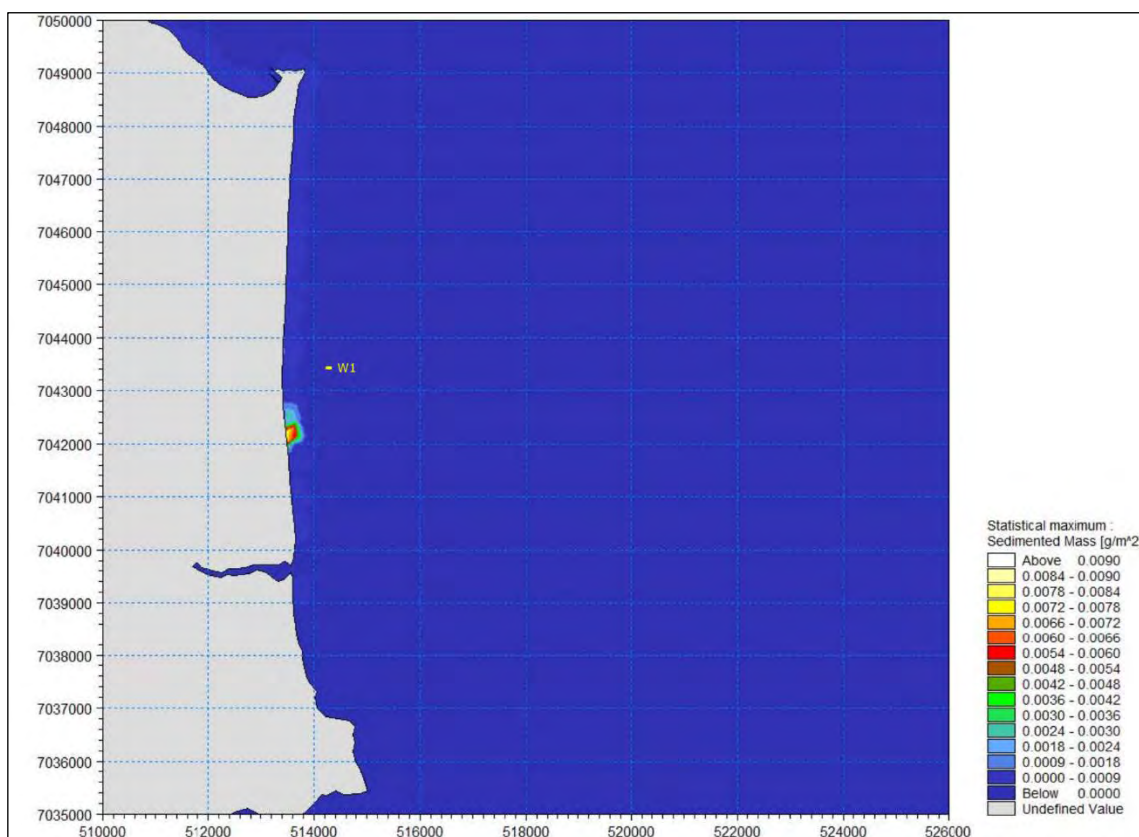


Figure 9.6 Predicted distribution of maximum sedimented particles within the Pacific Ocean – Scenario 3 (Caloundra to Mooloolaba)

10 Assessment of Visual Recreational Amenity, during Ambient Conditions and following a Wet Weather Event

Microplastic particles deposited on land adjacent to waterways and beaches were investigated to assess the potential impact from plastic MBBR carrier particles released from the Kawana STP on areas of recreation amenities.

Beach samples were collected monthly from December 2021 to May 2022 from 3 sites at Kawana Beach (identified as North, Central and South) and one site at Coolum Beach (as a control), with 3 transects sampled at each site (i.e. total of 54 monthly samples from Kawana Beach and 18 from Coolum Beach). An additional wet weather sampling event was completed in early March 2022 following the extreme wet weather event in February 2022.

River samples were collected from 5 sites along the banks of the Mooloolah River following the extreme wet weather event (early March 2022), with 3 transects sampled at each site (i.e. total of 15 samples).

Sites on Kawana Beach and along the Mooloolah River were selected based on preliminary dispersion modelling results outlined in Appendix H. Sampling at each site involved collected debris that could be identified as non-natural and having plastic appearance.

This investigation is comprehensively presented in Appendix I. In summary:

- material collected on Kawana Beach and Coolum Beach predominantly consisted of hard microplastic particles
- one piece of MBBR plastic media was found in all of the surveys
- the piece of MBBR plastic media was found on Kawana Beach, in January 2022, and consequently:
- there is no evidence of a significant impact on the visual recreational amenities of coastal waters or the Mooloolah River from the release of MBBR plastic media particles from the Kawana STP via the Pacific Ocean Outfall or Mooloolah River Overflow outfall.

11 Assessment of Plastic in Aquatic Ecosystems

11.1 Collection of Water and Sediment in the River During a Wet Weather Release

On 24 February 2022, water and sediment were sampled in the river during a wet weather release of treated effluent into the Mooloolah River from W3. In this survey, surface water was sampled at three sites downstream of W3 and at an upstream control site by towing a circular plankton net. Sediment was also collected from upstream, near W3 and at downstream sites. Samples were sent to the laboratory and analysed for microplastic particles and Black polyethylene particles. This investigation is comprehensively presented in Appendix K. In summary:

- black polyethylene particles were not found in surface water or sediment samples in the Mooloolah River, and
- all surface water and sediment samples had microplastics, most of fragment shape.

11.2 Collection of Biota in the River During Dry Weather Conditions

On 22 - 25 March 2022 river biota was collected at 3 sites along the Mooloolah River and 3 equivalent sites in the Maroochy River. Two samples of filter feeding invertebrates (oysters), other invertebrates, and fin fish (e.g. mullet, flathead, bream) were collected from each site. On average, 16 filter feeding invertebrates, 30 other invertebrates and 19 fin fish were collected from each site. Samples were sent to the laboratory and analysed for microplastic particles and Black polyethylene particles.

This investigation is comprehensively presented in Appendix L. In summary:

- There were microplastic particles in biota throughout the Mooloolah estuary, with the exception of oysters at the mouth of the estuary.
- Black polyethylene particles, that may have originated from MBBR carriers, were found at one site in the River, where dispersion modelling indicated particles from the release at W3 were likely to accumulate.
- Black polyethylene particles, that may have originated from MBBR carriers, were found in one oyster sample (comprised of 13 oysters) and one prawn sample (comprised of 12 prawns) at this site, with no black polyethylene particles found in the remaining samples from the same site (comprised of 12 oysters or 19 prawns) .

- 9 out of 11 microplastic particles in oysters from the mid estuary site were identified as black polyethylene fragments, which may have originated from MBBR carriers.
- Oysters are filter feeders that bioaccumulate contaminants, and consequently it is likely that the oysters in this sample bioaccumulated these particles.

11.3 Collection of Water, Sediment and Biota from Near the Ocean Diffuser

In April 2022, during dry weather flows, biota, water and sediment samples were collected from near the diffuser at ocean outfall (W1) and from a control site near Raper Shoal.

In addition, sediment samples were collected near the high tide mark inshore of the diffuser, and at a control site on Coolum Beach.

These investigations are comprehensively presented in Appendices J and M. In summary:

- Near the diffuser:
 - there were black polyethylene particles, that may have originated from MBBR carriers, in the shrimp sample, one of two surface water samples and bottom water samples
 - there were no black polyethylene particles in the fish or prawn samples at the diffuser
 - there were no black polyethylene particles in the sediment near the diffuser, nor in sediment near the high tide mark inshore of the diffuser, and
 - there were microplastic particles in all biota, water and sediment samples.

On average, there were 0.24 microplastic collected per cubic metre (m^{-3}) of seawater, with black polyethylene particles (that may have originated from MBBR carriers) comprising no more than 0.02 particles m^{-3} .

- Shrimp from the control site at Raper Shoal did not have any black polyethylene particles in their tissue, although one sample did have other microplastics.
- There were no black polyethylene particles in the water or sediment at the control site near Raper Shoals.
- There were no black polyethylene particles in the sediment collected at the high tide mark inshore of the diffuser or from the control site.

- While one of the prawn samples, the limpet and the gastrointestinal tract of the dragonet sample from near diffuser contained microplastics, none contained black polyethylene particles that may have originated from MBBR carriers.

That is, while there were black polyethylene particles (that may have originated from the MBBR carriers) in water and biota near the diffuser, they were a very small proportion of all the microplastic particles.

There were no black polyethylene particles (that may have originated from the MBBR carriers) in any of the sediment samples.

12 Summary, Discussion and Conclusions

In summary:

- Mechanical degradation has had a noticeable impact on the condition of MBBR carriers within the Kawana STP, with MBBR carriers within the plant visually worn.
- There is no evidence that the MBBR carriers used within the Kawana STP are susceptible to degradation from UV exposure or exposure to chemicals typically found in sewage influent.
- The degradation of the MBBR plastic media occurs via two mechanisms. Loss due to wear which is relatively constant, and loss due to breakage which has increased since the MBBR media was put into service. The loss due to wear is estimated to be 24 kg/day which is not captured by the effluent screens. The loss in MBBR plastic media due to breakage which is captured in the effluent screens is currently 4.8 kg/day (~30 L/day)
- The rate of mechanical degradation due to wear is estimated to remain relatively consistent until the structural integrity of the MBBR carriers is compromised and breakage occurs. Degradation is highest within the anoxic tanks where mechanical mixing occurs.
- The current 2 mm effluent screening system collects most of the broken MBBR plastic media that is greater than 2 mm prior to release. For microplastics in the effluent smaller than 2 mm, most (average of 45.3 particles per survey) were in the size fraction $\leq 63-11 \mu\text{m}$, with <1 particle per survey larger than $500 \mu\text{m}$. Black polyethylene particles, that may have originated from the MBBR particles, comprised between 23.9% and 93.3% of the particles.
- Despite there being a greater number of small particles, most of the mass of plastic particles released in the effluent was comprised of large particles.
- The mass of black polyethylene particles released in the effluent after the screens was highly variable, ranging from 0.5 kg to 87.5 kg per day over the monitoring period. On average, 24 kg/day (17,520 kg over 2 years) was estimated to be released in the effluent after the screens, and 3.73 kg/day was estimated to be released in biosolids.
- As no black polyethylene particles were recorded in the 6 influent samples, it is likely that most of the black polyethylene particles released from the STP are from the degradation of MBBR carriers in the plant.
- There was no distinct relationship between STP inflow and the volume of plastic media (macro and microplastic) that accumulated on the screen,

- Large increases in the volume of MBBR plastic media collected on the effluent screens can mostly be attributed to specific events, such as high flows and new mixers. While the amount of breakage of MBBR plastic media has varied over the last 2 years, results from the last 6-months suggest breakage may be increasing over time.
- Alternative MBBR carriers, such as those supplied by Warden Biomedia, had a consistently lower rate of wear from mechanical degradation than the Hel-X carriers used at the Kawana STP, with no evidence of breakage in the Warden Biomedia for the 70 days of experimentation. This suggests that alternate MBBR carriers may be more appropriate for the conditions experienced within the Kawana STP.
- Prior to this investigation, MBBR plastic media released from the Kawana STP were observed and collected from beaches inshore of the ocean release point. Following retrofitting of the effluent screening system, the beaches inshore of the ocean release have been surveyed each month (December 2021 to May 2022), and the Mooloolah River in March 2022. Of the 1200 microplastic particles collected on the beach inshore of the ocean release point, one MBBR plastic media particle was recorded, with no MBBR plastic media collected within the Mooloolah River. That is, there is not a significant impact on the visual recreational amenities of coastal waters or the Mooloolah River from the release of MBBR plastic media particles from the Kawana STP via the Pacific Ocean Outfall or the Mooloolah River Overflow outfall.
- Similarly, few black polyethylene particles (that may include MBBR particles) were found in biota, water or sediment in the receiving environment at locations where dispersion modelling indicated concentrations would be highest.
- Specifically, in samples from the Mooloolah River, there were:
 - no black polyethylene particles (that may include MBBR particles) in surface water or sediment.
 - microplastics particles in surface water, sediment and biota at all sites, with the exception of oysters at the mouth of the estuary, and
 - some black polyethylene particles (that may include MBBR particles) in one oyster and one prawn sample from the mid-estuary.
- In samples from the ocean, there were:
 - black polyethylene particles (that may include MBBR particles) in the surface water and bottom water near the diffuser, and in one of the shrimp samples from near the diffuser
 - no black polyethylene particles in the sediment near the diffuser nor inshore of the diffuser on the beach

- on average, 0.24 plastic microparticles per cubic metre (m³) of seawater, and
- no more than 0.02 particles m⁻³ of black polyethylene (that may include MBBR particles) in surface or bottom water i.e. while black polyethylene particles (that may include MBBR particles) were detected in ocean water, they comprised a small proportion of the total number of plastic microparticles.

Responses to each of the EE requirements are provided in Table 12.1.

Table 12.1 EE Requirements and corresponding section and appendix of this report.

EE Requirement	Response
3. By 28 February 2022 the AQP engaged in requirement 1 must design and commence implementing, a Sampling and Analysis Quality Plan (SAQP) that is representative for all reasonably foreseeable hydraulic operational scenarios expected to occur during the operation of the MBBR and that:	
a. Proposes a size of MBBR plastic media which can be accurately collected, distinguished from other plastic sources in the influent and measured, and define why this size of MBBR plastic media to be sampled is proposed.	The particle size of MBBR plastic media that was assessed in this EE was selected specifically for this investigation, and based on microplastic particle sizes previously found within environmental samples of the region, literature reviews and suitable standards and industry practices. Although a review of the literature identified a range of suitable particles sizes (typically 100 micron to 1 mm), a lower limit of 11 microns was selected based on the laboratory capabilities of the laboratory selected (University of Newcastle). For the assessment of particles obtained from the STP effluent screens, standard soil and mineral screen sizes were used. As the effluent screens have a 2 mm aperture and the MBBR carriers are 13 mm in length (unbroken), assessment was completed on using screen sizes from 1.18 mm to 9.5 mm.
b. Assesses the breakdown rate of the MBBR plastic media in the MBBR due to existing mechanical forces as currently configured (such as collision with infrastructure, other media and abrasion with sediment in influent) and chemical breakdown processes (including that caused by ultraviolet UV degradation of the plastic and exposure to chemicals in the sewage influent).	The breakdown rate of the MBBR plastic media is considered in two parts. Loss due to wear which is relatively constant, and loss due to breakage which has increased since being put into service. The loss due to wear is estimated to be 24 kg/day which is not captured by the effluent screens. The loss in MBBR plastic media due to breakage which is captured in the effluent screens is currently 4.8 kg/day (~30 L/day). There is no evidence that the MBBR carriers used within the Kawana STP are susceptible to degradation from UV exposure or exposure to chemicals typically found in sewage influent.

EE Requirement	Response
c. Determines the percentage of broken MBBR plastic media within the MBBR in a way which determines if the percent rate of breaking media is increasing or decreasing over time.	It was not possible to determine the percentage of broken MBBR plastic media within the MBBR. Figure 4.1 was used to assess if the rate of breakage of MBBR plastic media was increasing or decreasing over time. While the rate of media collected in the effluent screens has fluctuated over time due to broken mixers and wet weather flows, the amount of media captured since installation has grown from 1 L/week to the current rate of 200 L/week.
d. Determines the size distribution of the resultant breakdown plastic media with specific reference to current containment controls (i.e. 2 mm screen aperture).	Within the Kawana STP, broken MBBR carriers are estimated thought to be quickly flushed out of the bioreactor and caught within the effluent screening system with minimal further degradation. The majority of MBBR plastic media particles (> 80%) caught in the effluent screening system was larger than 9.5mm. Therefore the current 2 mm screening system is adequate to collect a majority of the broken MBBR plastic media prior to release. For microplastics smaller than 2 mm released within the effluent, most (average of 45.3 particles per survey) were between 63 and 11 μm, with <1 particle per survey larger than 500 μm. However it is noted that due to differences in particle size, large particles comprised a majority of the particle mass released within the effluent.
e. Determines the current volume of plastic media being released from the STP via release points W1 and W3, as referenced in the EA.	The average release of black polyethylene particles in the effluent is estimated to be 24 kg/day, and the average released in biosolids is estimated to be 3.73 kg/day. As no black polyethylene particles were recorded in the 6 influent samples, it is likely that most black polyethylene particles released from the STP are from the degradation of MBBR carriers in the plant.
4. The AQP must implement the SAQP and undertake analysis and interpretation of the data obtained to estimate the volume and size	There was no distinct relationship between STP inflow and the volume of plastic media (macro and microplastic) accumulated on

EE Requirement	Response
distribution of MBBR plastic media released over a range of hydraulic scenarios, and over the proposed lifespan of existing MBBR plastic media.	the screen or released, however there was a distinct relationship between the volume of macro plastic media accumulated on the screen and the daily flows that exceed the ADWF. This suggests that plastic material within the bioreactor may require a certain level of hydraulic force (i.e. flows greater than the ADWF) to flush larger broken MBBR plastic media through to the effluent screening system. Large increases in the volume of MBBR plastic media collected on the effluent screens can mostly be attributed to specific events, such as high flows and new mixers, however results from the last 6-months suggest the amount of breakage of MBBR plastic media may be increasing over time.
5. By 30 June 2022, the AQP must submit an environmental report to the department on the outcomes of the investigation	The due date for the environmental report was extended to 11 July 2022. A copy of this report will be provided to the Department of Environment and Science by this date.
6. The environmental report must be presented in a manner and contain sufficient information to allow for an independent review and substantiation of the material. The environmental report must at a minimum include:	
a. Details of the methodology applied in conducting the investigation, including any assumptions relied upon and the justification for those assumptions.	Detailed methodologies have been provided within each applicable appendix.
b. The results of the sampling, analysis and assessments carried out during the investigation.	The results, analysis and assessments have been provided within each applicable appendix.
c. The outcomes and findings of the investigation including discussion on the significance of the results and justification for any conclusions and/or recommendations.	Detailed discussions of the results have been provided within each applicable appendix.
d. A copy of the SAQP	Provided in Appendix B.

EE Requirement	Response
e. A copy of all of the raw data collected during the investigation in an excel spreadsheet.	All raw data has been provided as part of each applicable appendix. Raw data can be provided in excel form on request.
f. A copy of all laboratory certificates.	A copy of all laboratory certificates has been provided as part of each applicable appendix.
g. A copy of quality assurance and quality control procedures applied.	A copy of quality assurance and quality control procedures as been provided as part of each applicable appendix.

13 References

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Appendix A Notice to conduct or commission an environmental evaluation, 14 December 2021.

Notice

Environmental Protection Act 1994

Environmental Evaluation

Notice to conduct or commission an environmental evaluation

This notice to conduct or commission an environmental evaluation is issued by the administering authority pursuant to section 326B and section 521 (5) (c) (ii) of the Environmental Protection Act 1994.

Northern SEQ Distributor – Retailer Authority trading As Unitywater

33 King Street

CABOOLTURE QLD 4510

Attention: Mr George Theo, Chief Executive Officer

Your reference: EPPR00869113

Our reference: 101/0005498/ C-CPLRC-100084354/ E-100113006

Tuesday, 14 December 2021

Take notice: that under the *Environmental Protection Act 1994* (the Act) a notice to conduct or commission an environmental investigation is issued to Northern SEQ Distributor- Retailer Authority T/A Unitywater (Unitywater) (you) by the administering authority. The administering authority is the Chief Executive of the Department of Environment and Science (the department).

The notice to conduct or commission an environmental investigation is issued with respect to the activities of Kawana Sewage Treatment Plant (the STP), Main Drive, Bokarina, QLD 4575, on land described as Lot 101 on Plan SP295012 (the premises). Unitywater is authorised to undertake Environmentally Relevant Activity (ERA) 63-(1)(g) Sewage treatment >100,000 Equivalent Persons (EP) at the premises under the conditions of EPPR00869113 (the EA).

A. Grounds

The notice to conduct or commission an environmental investigation is issued on the following grounds:

1. Section 326B of the Act prescribes the following-
When environmental investigation required—environmental harm (1) This section applies if the administering authority is satisfied on reasonable grounds that— (a) an event has happened causing environmental harm while an activity was being carried out; or **(b) an activity or proposed activity is causing, or is likely to cause environmental harm.**

Section 14 of the Act defines **Environmental Harm** as-

Notice to conduct or commission an environmental evaluation

“any adverse effect, or potential adverse effect (whether temporary or permanent and of whatever magnitude, duration or frequency) on an environmental value, and includes environmental nuisance”.

Environmental harm may be caused by an activity— (a) whether the harm is a direct or indirect result of the activity; or (b) whether the harm results from the activity alone or from the combined effects of the activity and other activities or factors.

Section 9 of the Act defines **Environmental Value** as-

(a) “a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or

(b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation”.

The facts and circumstances forming the basis for these grounds are:

- 1) The STP has undergone a \$73 million upgrade to increase the capacity of the plant from 100,000 EP to 200,000 EP. The increase in intensity of use and risks of environmental harm presented by the augmentation, specifically the introduction of the new secondary treatment technology known as a Moving Bed Biofilm Reactor (MBBR) has not been assessed by the administering authority. Unitywater had obtained advice indicating that amendment of the EA was not expected to be required.
- 2) One of the risks associated with MBBR technology is loss of reactor containment of MBBR plastic media.
- 3) Unitywater contracted Monadelphous (MEPL) to construct the MBBR system whereby a biofilm of microorganisms grow on MBBR plastic media carriers to break down organic matter in wastewater. MEPL were acting under Unitywater’s EA while the upgrade of the STP was underway.
- 4) Unitywater has advised the department that its contract with MEPL stipulated that the augmented plant must comply with Unitywater’s environmental authority conditions.
- 5) On 22 June 2021 Unitywater advised departmental authorised officers that the MBBR contains in excess of 3 billion individual pieces of MBBR plastic media.
- 6) The EA authorises the release of contaminants to the environment from the STP in a way which mitigates environmental harm. The EA does not authorise the release of any plastic to the environment.
- 7) On 16 January 2020, while MEPL was operating the Kawana STP, departmental officers undertook a reactive compliance inspection to investigate notifications by Unitywater of non compliances with effluent quality releases due to the commissioning of the augmented STP.
- 8) During the inspection, departmental officers discussed the risks of the MBBR technology, including the loss of reactor containment and the potential that MBBR plastic media carriers could be released to the environment in breach of Unitywater’s EA. Officers from the department stated during the inspection that the department would consider such releases to be unlawful environmental harm as the releases were not authorised by the EA.
- 9) At the time the issue was raised by the department, Unitywater staff were unsure if the mitigation measures installed by MEPL were sufficient to maintain reactor containment of MBBR plastic media.
- 10) As a result of the discussion, Unitywater conducted inspections of the beaches adjacent to the release point W1, identified as the outfall pipe located in waters described as the Pacific Ocean off Warana Beach, Caloundra, approximately 1km offshore, (condition K LW1 of the current EA).
- 11) Release point W1 is located 1 km offshore of Warana at approximately 20m depth and is comprised of a number of diffusers that are specifically designed to diffuse and disperse contaminant releases authorised by the EA from the STP into tidal waters.

Notice to conduct or commission an environmental evaluation

- 12) On 22 January 2020 the department received email notification from Unitywater stating that Unitywater had inspected the beaches adjacent to the release point W1.
- 13) Unitywater confirmed MBBR plastic media (the approximate volume of a golf ball) was found on the beach, despite the fact that release point W1 is located 1 km offshore.
- 14) Furthermore, Unitywater advised the department that temporary screens had been installed on the outlet of the chlorine contact tanks (CCT) to limit the potential release of the MBBR plastic media to the environment.
- 15) Compliance and technical officers from the department attended the premises on 18 February 2020 to discuss the loss of reactor containment and release of MBBR plastic media, with Unitywater.
- 16) During the inspection, departmental officers observed glass jars containing complete and broken up pieces of MBBR plastic media released from the STP which had been collected from the beach by Unitywater adjacent to the location of the release point W1.
- 17) The MBBR plastic media had been collected by Unitywater from the beach between 21 January 2020 and 10 February 2020. Whilst the volumes collected appeared to be between 10 and 50mL in each jar, it is reasonable to consider that this represents a small fraction of the volume released due to the efficacy of the outfall diffuser, the distance of the outfall offshore of Warana Beach and the dispersive influence of tide, winds and currents.
- 18) On 10 March 2020, the department issued MEPL with a warning for contravention of section 430 (3) of the Act for breach of condition WT1 of the EA for release of MBBR plastic media from release point W1 in January 2020. Condition WT1 of the EA prescribes "*Other than as permitted within this environmental authority, contaminants must not be released from any site to any waters or the bed and banks of any waters*".
- 19) On 10 March 2020, the department issued Unitywater with a warning for contravention of section 431(1) of the Act for not ensuring MEPL complied with condition WT1 of the EA. Unitywater has advised the department that it is entitled to rely on the defence provided by s431(4) of the Act as it issued appropriate instructions and used all reasonable precautions to ensure MEPL complied with the EA; the alleged offence by MEPL was committed without the knowledge or approval of Unitywater; and Unitywater exercised all reasonable diligence to stop the commission of the offence.
- 20) On 24 September 2020 the department received notification from Unitywater which identified MBBR plastic media had again been released from the STP via WT1 ocean outfall, due to a mass sponge unknowingly growing in the clarifier pipes.
- 21) Unitywater advised that its investigation indicated that the sponge had disintegrated and flowed through chlorine contact tank 1 (CCT 1) and chlorine contact tank 2 (CCT 2) and blocked the temporary screening basket at the outlet of CCT 2.
- 22) The notification notice submitted by Unitywater stated that the temporary screening baskets had been retrofitted by Unitywater to allow effluent to flow through the CCTs and capture any broken MBBR plastic media that may have escaped from the MBBR.
- 23) Unitywater advised in the notification that it estimated the accumulation rate of MBBR plastic media in the basket is approximately 125 mL per day. Over the 5 days of the release Unitywater estimated that 625mL of media was discharged from the premises via WT1.
- 24) In the notification received on 24 September 2020, Unitywater acknowledged that the release of MBBR plastic from the premises was to the marine environment. Unitywater did not elaborate on how the release of MBBR plastic media had affected the marine environment.
- 25) As a result of the release of MBBR plastic media, Unitywater also conducted a clean-up sweep of the beach on 21 September 2020 adjacent to the release point W1. Unitywater found approximately 250mL of MBBR plastic media washed up on the adjacent beach. During subsequent inspections undertaken

Notice to conduct or commission an environmental evaluation

- by Unitywater on 22 and 23 September 2020 approximately 50mL of MBBR plastic media was collected from the beach. Unitywater did not undertake any inspections of the marine environment in the vicinity of the outfall location.
- 26) On 14 October 2020, MEPL submitted a notification to the department which stated approximately 500mL of MBBR plastic media was released via release point W1 as a result of the temporary screening baskets being blocked and overflowing. This notification related to the same release on 21 September 2020 that Unitywater had submitted to the department, however the volumes notified by MEPL were greater.
- 27) On Friday 6 November 2020, the department received an email notification from Unitywater stating that *“...during a shutdown activity overnight, a small warp in the CCT screen may have resulted in the potential release of MBBR plastic media from the plant”*.
- 28) As a result of the release of MBBR plastic media from the STP on 6 November 2020, a notification was received from Unitywater on 12 November 2020. In the notice, Unitywater acknowledged the release of plastic MBBR media from the STP was to the marine environment.
- 29) Additional email correspondence received by the department on 12 November 2020 confirmed that approximately 13 grams of MBBR plastic media had been collected from beaches adjacent to release point W1 as a result of the warp in the CCT from the 6 November 2020 release.
- 30) On 26 February 2021, Unitywater met with the department and reassured the department that it would work collaboratively with the department to make the STP compliant.
- 31) MEPL were operating the STP when the MBBR plastic media was released between 20 September 2020 and 6 November 2020.
- 32) The department issued MEPL with one Penalty Infringement Notice on 26 March 2021 for non-compliance with section 430 of the Act for breach of condition WT1 of the EA for releases of MBBR plastic media via release point W1 between 20 September 2020 and 21 September 2020.
- 33) The department also issued Unitywater with a warning notice on 26 March 2021 for non-compliance with section 431(1) of the Act for breach of condition WT1 of the EA whilst MEPL were operating the STP and the releases of MBBR plastic media occurred. Paragraph 19 of this notice describes Unitywater’s subsequent defence.
- 34) The department considered Unitywater’s response to the section 430 pre-enforcement letter which included commitments by Unitywater to implement a range of mitigation measures and retrofitted screens to prevent the release of MBBR plastic media from the augmented STP.
- 35) On 22 March 2021, the department received an email notification from Unitywater identifying a release of MBBR plastic media occurred from the premises as a result of hydraulic overload caused by heavy rainfall in the catchment.
- 36) A notification of the event was received on 26 March 2021 from Unitywater which stated that as a result of hydraulic overload at the discharge chamber of CCT 2, a permanently deployed floating boom twisted and failed resulting in the release of approximately 1 to 5 litres of MBBR plastic media from the STP at release point W3, the outfall pipe located in the Mooloolah River at a location described as opposite Portion 360, Parish of Mooloolah, County of Canning. According to the notification no media escaped into the ocean outfall via release point W1 and only released via W3 release point.
- 37) In the notification, Unitywater acknowledged that the release of MBBR plastic media from the premises to the Mooloolah River on 22 March 2021, was to the marine environment.
- 38) The department received a notification from Unitywater on 9 April 2021, which stated that on 5 April 2021, wet weather flows had caused the water level to rise and overtop the CCT 2 MBBR plastic media collection screen, resulting in broken MBBR plastic media that had been captured in the preceding 7 days to escape the retrofitted temporary screen and be discharged to chlorine contact tank three (CCT

Notice to conduct or commission an environmental evaluation

- 3). Inspection of release point W3 confirmed MBBR plastic media fragments had been discharged into the Mooloolah River.
- 39) In the notice, Unitywater acknowledge that release of MBBR plastic media from the site on 5 April 2021 was to the marine environment.
- 40) The department confirmed that Unitywater were operating the STP when the releases of MBBR plastic media occurred on 22 March 2021 and 5 April 2021.
- 41) Unitywater has provided advice that its interpretation of the technical schedule for the MBBR plastic media, is that the maximum anticipated loss of plastic media from the MBBR over a 12-month period due to plastic media degradation is 140m³.
- 42) Unitywater has provided advice that the observed loss of plastic media >2mm is around 1.5m³ over a 12-month period with this media captured and not released.
- 43) Unitywater has provided advice that known releases of plastic media >2mm to the marine environment from the STP are estimated between 5 and 10 litres.
- 44) The department raised concerns with Unitywater during the inspection of the STP on 22 June 2021 that MBBR media microplastics <2mm are generated from the circulation and mechanical movement of MBBR plastic media in the aerobic and anerobic chambers of the MBBR.
- 45) Unitywater also confirmed during the 22 June 2021 inspection that <2mm MBBR media microplastics are not captured in the retrofitted Chlorine Contact Tank screens because they are smaller than the 2 mm screen aperture. Unitywater and the department agreed at the time of the inspection that the MBBR media microplastics smaller than 2 mm would continue to be released to the environment via W1 (ocean outfall) during business as usual flow scenarios and to W3 (Mooloolah River outfall) during wet weather flows.
- 46) Unitywater has advised that they currently do not have an estimate of the volume of degraded plastic media of a size <2mm released through the screens to the receiving environment.
- 47) It is the departments assessment that degradation of the MBBR plastic media as reported and observed by department officers is likely to include the generation of plastic particles <2mm.
- 48) MBBR plastic media and its degraded microplastics are considered a pollutant to the aquatic ecosystems of the Pacific Ocean and the Mooloolah River.
- 49) The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPWWB) via the document titled Mooloolah River environmental values and water quality objectives, dated July 2010 (https://environment.des.qld.gov.au/data/assets/pdf_file/0027/87273/mooloolah-ev-2010.pdf) lists environmental values and water quality objectives (Basin No 141 (part), as:
- Lower Mooloolah River Estuary- Aquatic ecosystems, seagrass, human consumer, oystering, primary recreation, secondary recreation, visual recreation, industrial use and cultural and spiritual values.
- Open coastal waters - Aquatic ecosystems, seagrass, human consumer, primary recreation, secondary recreation, visual recreation, and cultural and spiritual values.
- 50) Plastic media and its degraded microplastics released from the STP are reasonably considered to contribute to or are likely to contribute to the effects that plastics in the marine environment have on the quality and/or physical characteristic of the environment that is conducive to ecological health.
- 51) This includes for example wildlife health. Microplastics have the potential to and do cause adverse effects to wildlife. Wildlife is reported throughout literature to consume and suffer adverse effects from microplastics, noting that the extent of harm is a continuing field of research. Healthy wildlife is a quality characteristic of the environment being part of an ecosystem that is conducive to ecological health.

Notice to conduct or commission an environmental evaluation

- 52) The department has a number of subject matter experts in the fields of endangered species protection for birds, turtles and benthic organisms who have confirmed that the release of microplastics to the environment can lead to ingestion by these organisms and can cause death of the individuals.
- 53) Furthermore, scientific studies on the impacts of macro and micro plastic on aquatic ecosystems have been undertaken over a long period of time, and have demonstrated that plastic ingestion causes a large range of impacts to marine organisms including death. (A copy of a summary of some of these studies is attached as **Appendix A.**)
- 54) The department considers it reasonable to conclude that the MBBR plastic media released to the Mooloolah River on 22 March 2021 and 5 April 2021 and ongoing to the Pacific Ocean via release point W1, is likely causing environmental harm.

B. Requirements

The report on the environmental investigation must address the following relevant matters:

1. By **5 January 2022** you must engage independent **Appropriately Qualified Persons** (AQP) to carry out the requirements of the notice and confirm the engagement to the department in writing to sunshinecoast.esr@des.qld.gov.au. The written confirmation of the engagement must include each persons' academic qualification and suitable experience relevant to the scope of work of the investigation each AQP will undertake.
2. At least once per calendar month you must submit a progress report describing progress towards the completion of the requirements of this notice.
3. By **28 February 2022** the AQP engaged in requirement 1 must design and commence implementing, a Sampling and Analysis Quality Plan (SAQP) that is representative for all reasonably foreseeable hydraulic operational scenarios expected to occur during the operation of the MBBR and that:
 - a. Proposes a size of MBBR plastic media which can be accurately collected, distinguished from other plastic sources in the influent and measured, and define why this size of MBBR plastic media to be sampled is proposed.
 - b. Assesses the breakdown rate of the MBBR plastic media in the MBBR due to existing mechanical forces as currently configured (such as collision with infrastructure, other media and abrasion with sediment in influent) and chemical breakdown processes (including that caused by ultraviolet UV degradation of the plastic and exposure to chemicals in the sewage influent); and
 - c. Determines the percentage of broken MBBR plastic media within the MBBR in a way which determines if the percent rate of breaking media is increasing or decreasing over time.
 - d. Determines the size distribution of the resultant breakdown plastic media with specific reference to current containment controls (i.e. 2 mm screen aperture); and
 - e. Determines the current volume of plastic media being released from the STP via release points W1 and W3, as referenced in the EA;

Notice to conduct or commission an environmental evaluation

4. The AQP must implement the SAQP and undertake analysis and interpretation of the data obtained to estimate the volume and size distribution of MBBR plastic media released over a range of hydraulic scenarios, and over the proposed lifespan of existing MBBR plastic media.
5. By **30 June 2022**, the AQP must submit an environmental report to the department on the outcomes of the investigation.
6. The environmental report must be presented in a manner and contain sufficient information to allow for an independent technical review and substantiation of the material. The environmental report must at a minimum include:
 - a. Details of the methodology applied in conducting the investigation, including any assumptions relied upon and the justification for those assumptions.
 - b. The results of the sampling, analysis and assessments carried out during the investigation.
 - c. The outcomes and findings of the investigation including discussion on the significance of the results and justification for any conclusions and/ or recommendations.
 - d. A copy of the SAQP
 - e. A copy of all of the raw data collected during the investigation in an excel spreadsheet.
 - f. A copy of all laboratory certificates
 - g. A copy of quality assurance and quality control procedures applied

Definitions:

Appropriately qualified person(s) means a person or persons who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis to performance relative to the subject matter using the relevant protocols, standards, methods or literature.

The environmental report must be submitted to the department on or before: **Thursday, 30 June 2022**

The suitably qualified person who prepares the environmental report must also provide a statutory declaration in the form attached to the environmental report submitted to the department.

Copies of the template statutory declarations can also be accessed from the Queensland Government website at www.qld.gov.au, using the publication number as a search term:

Statutory declaration for suitably qualified person ([ESR/2016/2266](#))

Take notice:

1. The requirements of the notice to conduct or commission an environmental investigation take effect immediately upon service of this notice;
2. This notice remains in force until further notice from the department; and
3. You are responsible for meeting the costs of conducting or commissioning the environmental evaluation, preparing the environmental report and providing any further information as requested by the department.

C. Reviews and appeals

The provisions regarding reviews of decisions and appeals are found in sections 519 to 539 of the Act.

A person who is dissatisfied with certain decisions of the department, may be able to apply to have the department review that original decision.

Generally, a request to have a decision reviewed must:

2. be made within 10 business days of the decision being notified to the person;
3. be supported by enough information to enable the department to decide the application for review; and
4. be made using the application form, Application for review of original decision ([ESR/2015/1573](#)) available on the Queensland Government website at www.qld.gov.au, using the publication number (ESR/2015/1573) as a search term.

Where an application has been made for a decision to be reviewed, the applicant may also apply to the relevant court for a stay of the decision to secure the effectiveness of the review.

Once the original decision has been reviewed, a person who is dissatisfied with the review decision may be able to appeal against that decision to the relevant court within 22 business days after receiving notice of the review decision.

A person whose interests are or would be adversely affected by a decision of the department may also be able to request a statement of reasons for a decision or a statutory order review under the *Judicial Review Act 1991*.

For further information about reviews and appeals see the information sheet, Internal review and appeals ([ESR/2015/1742](#)) available on the Queensland Government website at www.qld.gov.au, using the publication number (ESR/2015/1742) as a search term.

The information sheets are available on the Queensland Government website at www.qld.gov.au, using the publication number as a search term.

You may have other legal rights or obligations and should seek your own legal advice.

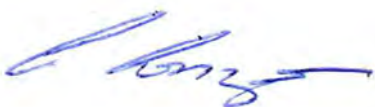
D. Penalty

Failure to comply with a notice to conduct or commission an environmental evaluation is an offence.

1. The maximum penalty for an individual is 300 penalty units, totalling \$ 41,355.
2. The maximum penalty for a corporation is 1500 penalty units, totalling \$ 206,775.
- 3.

Should you have any queries in relation to this notice, please contact Ben Grant of the department on telephone number 07 5459 6170.

Notice to conduct or commission an environmental evaluation



Signature

14 December 2021

Date

Gus Gonzo

Delegate of the Chief Executive

Department of Environment and Science

Environmental Protection Act 1994

Enquiries:

Sunshine Coast Compliance Centre

Ph: (07) 5459 6132

Email: sunshinecoast.esr@des.qld.gov.au

Appendix A- Literature review.

Plastic waste throughout the environment is known to be ubiquitous. Bergmann, Gutow & Klages (2009) suggest that the scale of plastic pollution by anthropogenic litter has been recognised as a serious global environmental concern. The authors note that marine litter is defined as any “*persistent manufactured or processed solid material discarded, disposed of or abandoned in the marine coastal environment*”. In June 2021, the Queensland Government released the Keeping Queensland Clean: the Litter and Illegal Dumping Plan (QLD 2021) which identifies that approximately 75% of waste found on the Australian beach is plastic, confirming that the ingestion of plastic waste is a significant issue leading to increased mortality of seabirds, turtles and other wildlife.

Plastic in the marine environment impacts marine species in a variety of ways. Ribero et. al (2018) suggest that the potential for microplastics to cause injury to marine organisms has been widely encountered and leads to the reduction of feeding rates and predatory performance, physical damage, oxidative stress, impacts of reproduction, decreased neurofunctional activity, development of pathologies and mortality. Fish are a known consumer of both macro and micro plastics. Menezes et al. (2019) identified that Dolphinfish ingested plastic by confusing it with a food source and/or being attracted to the floating debris and can bioaccumulate by eating smaller prey containing plastic. The authors also state that plastic causes physical harm (e.g decreased food intake, gut injuries and gastrointestinal obstruction) and chemical harm (e.g liver toxicity, pathology and bioaccumulation through the food web) which often is lethal.

Turtles are also well known to consume a range of plastic matter in the marine environment. Duncan et al. 2019 suggested that synthetic particles including microplastics were present in every turtle across all species and ocean samples even though not all individuals had ingested plastics. Limpus (2021) states that the Department of Environment and Science had observed an unusually large number of flatback turtles washed up dead in the Keppel Bay. Limpus states that fragments of floating hard plastics and soft plastics have been found in post hatchling turtles and is concerned that the turtles have been compromised because they have been swallowing plastic debris. Research undertaken by David Steward (Senior Conservation Officer- Threatened Species Coordination) confirmed that 50% of the worlds seabird species have been reported to be affected by marine debris ingestion. In some species more than 90% of the individuals examined have ingested plastic, which are those that have a zoo plankton diet or are surface feeders, including short tailed shearwaters and storm-petrels (at least eight species of storm petrels are known to occur off the Queensland Coast including one species that breeds near Lord Howe Island and listed as vulnerable under the *Environmental Protection and Biodiversity Act 1999* (EPBC Act)). Plastic ingestion has been linked to a variety of negative health effects in seabirds, including nutritional deprivation- starvation and reduced body mass and growth rates.

Crump et. al (2020) confirmed that hermit crabs exposed to plastic impairs information gathering, resource assessments and decision making whilst Alexiadou, Foskolos & Frantzis (2019) identified that stomach content analysis of cetacean species in the Greek Seas confirmed that at least half of those tested contained plastic. Duncan et al. (2019) states that microplastic ingestion in crabs can affect food consumption and energy balance and ingestion of microscopic uplasticised polyvinylchloride reduces growth and energy reserves in marine worms. Bangun, Wahyuningsih & Muhtadi (2018) undertook a study of the impacts of plastic on macrozoobenthos in the tidal zone which concluded that an increase in the number of microplastic densities has lead to a decrease in macrozoobenthos density. Cole & Galloway (2015) report that Pacific Oysters are susceptible to ingesting microplastics and report that the plastic affects the feeding quality and gamete quality. It was reported by Smith et al (2018) that shellfish and other marine organisms with intact gastrointestinal tract pose particular concern because they bioaccumulate and retain microplastics.

Human are also impacted by consuming marine organisms such as crabs as confirmed by Ribeiro et al. 2020 who states that as crabs are omnivores, feeding on algae, molluscs, worms, crustaceans and detritus, and as crabs foregut is used in many seafood dishes, one blue crab per person assuming that both the flesh of the claws/ legs and abdomen are eaten, a consumer can potentially be exposed to 3mg of plastic.

Plastic in the marine environment also has the ability to absorb other contaminants. Brennecke et al. (2016) research suggests that microplastics can absorb heavy metals often encountered in the marine environment and polyaromatic hydrocarbons and polychlorinated biphenyls are capable of sorbing to the plastic surface and becoming bioavailable to animals upon ingestion causing additional potential for toxicity.

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Appendix B SAQP.

Item No.	Sample and Analysis Rationale	Sample Location Type	Sample Location	Sample Type	Stream	Frequency Basis	Sample Frequency	Parameter	Sample Process	Analysis Process	EE Requirement Clause
P1	This test measures the total amount of material collected in the basket screens (nom. >2mm). The sample will be sieved to determine the amount and type of plastic caught in the effluent basket screens and sorted into MBBR media vs non-MBBR media. This information will be used for the dispersion modelling scenarios which may arise due to wet weather event overflows of the screens.	Kawana STP	Kawana STP effluent basket screens	All matter captured by Clarifier and CCT basket screens	Aggregate of captured particles in effluent downstream of bioreactor	Periodic frequency	Fortnightly	Material size fractions: >9.5mm 4.75mm - 9.5mm 2.36mm - 4.75mm <2.36mm	Analysis of total material collected from basket screens. Collected screenings is sub-sampled and screened into size fractions.	Visual sorting of plastic from MBBR media versus other plastic in each size fraction.	Addresses Part 3a - Sample MBBR plastic media collected in baskets and distinguish between MBBR and other plastics sources from the influent Addresses Part 3b/c - Plot of volume to assess breakdown rate and percentage
								% mass plastic in each size fraction (excluding organic material)			
								% MBBR plastic (excluding organic material) in each size fraction			
P2	This test samples the Kawana effluent and measures the plastics that pass through the existing 2mm screens and are discharged to the environment. The sample will be sorted into MBBR and non-MBBR. This information will be used for the dispersion modelling scenarios. i.e. plastic particle size, plastic type etc.	Kawana STP	Kawana STP effluent auto sampler	Liquid effluent: ADWF	Effluent	Periodic frequency	Monthly	Particle size fractions: >500 µm 20 µm - 500 µm <20 µm	Auto sampler from effluent stream collected in container.	Lab separation and analysis of particles for plastic type.	Addresses Part 4a - Estimate volume actually being released <2mm
								% Plastic in each size fraction			
								% MBBR plastic in each size fraction			
P3	Same test as P2, but to cover the scenario of different hydraulic operating conditions. The EE references the investigation to cover expected hydraulic scenarios.	Kawana STP	Kawana STP effluent auto sampler	Liquid effluent: wet weather	Effluent	Event Based	As events arise and allow	Particle size fractions: >500 µm 20 µm - 500 µm <20 µm	Auto sampler from effluent stream, collected in container. Samples collected at wet weather event triggers.	Lab separation and analysis of particles for plastic type.	Addresses Part 3 - SAQP is representative for reasonably foreseeable hydraulic conditions.
								% Plastic in each size fraction			
								% MBBR plastic in each size fraction			
P5	This test measures the loss in mass of the in service media and compares to new media. The purpose is to determine wear rate and understand if media is wearing more in one part of the MBBR than the other. It will determine how much of the media is lost by wear over the first 2 years of operation. Replication of the test on virgin media will permit correlation to the actual wear rate, and help predict future degradation rate.	Kawana STP	All MBBR zones	MBBR Media	Anoxic/Aerobic	One off	Once: Month 2	Media loss in mass compared to Virgin Hel-X media baseline.	Representative carrier samples from MBBR, followed by removal of biofilm.	Loss in mass of in-service media versus unused media.	Addresses Part 3a - Sample MBBR plastic media collected in baskets and distinguish between MBBR and other plastics sources from the influent

Item No.	Sample and Analysis Rationale	Sample Location Type	Sample Location	Sample Type	Stream	Frequency Basis	Sample Frequency	Parameter	Sample Process	Analysis Process	EE Requirement Clause	
P6	To provide a comparison with proposed wear rate testing of alternate media, and to correlate/calibrate a lab scale wear test with observational plant data.	Kawana STP	As received from supplier	Virgin Hel-X media and alternate media	Virgin Hel-X media and alternate media	One off	Once: Month 4	Media loss in mass	Random sample of unused media	Carried out on site. Media placed in drum roller with water and aggregate to determine wear rate. Sample size in drum roller subject to drum size.	Addresses Part 5 - estimate volume of MBBR plastic media released over the proposed lifespan.	
E1	The purpose of this test is to assess the visual recreation amenity requirements. It provides a baseline for plastics washed onto land and compares areas around the ocean and discharge point to an unimpacted ocean site. Mainly directed to visual recreation environmental value.	Environment	Kawana Beach	Plastics on land adjacent to waterway	Land adjacent to waterway	Periodic frequency	Monthly	g total plastics / m²	Manual collection of visible plastics only. Collected material is screened into size fractions.		Aquatic ecosystems and Visual Recreation WQO	
								g MBBR plastic / m²				
								All plastics (MBBR and non-MBBR) size fractions: >9.5mm 2.36mm - 9.5mm <2.36mm				
E2		Environment	Beach location away from Kawana Beach.			Periodic frequency		g total plastics / m²				Manual collection of visible plastics only. Collected material is screened into size fractions.
								g MBBR plastic / m²				
								All plastics (MBBR and non-MBBR) size fractions: >9.5mm 2.36mm - 9.5mm <2.36mm				
E3	Environment	Kawana Beach	Plastics on land adjacent to waterway resulting from weather event	Land adjacent to waterway	Event Based	Events to be defined based on dispersion modelling impact of specific weather conditions. Timing to follow spring tide subsequent to the defined event.	g total plastics / m²	Manual collection of visible plastics only. Collected material is screened into size fractions.	Visual sorting into MBBR plastic and non-MBBR plastics.	Aquatic ecosystems and Visual Recreation WQO		
							g MBBR plastic / m²					
							All plastics (MBBR and non-MBBR) size fractions: >9.5mm 2.36mm - 9.5mm <2.36mm					
E4	Environment	Beach location away from Kawana Beach.			Event Based		g total plastics / m²				Manual collection of visible plastics only. Collected material is screened into size fractions.	
							g MBBR plastic / m²					
							All plastics (MBBR and non-MBBR) size fractions: >9.5mm 2.36mm - 9.5mm <2.36mm					
E5	Environment	Mooloolah River, nearest accessible bank to river outfall	Event Based	g total plastics / m²	Manual collection of visible plastics only. Collected material is screened into size fractions.							
				g MBBR plastic / m²								
				All plastics (MBBR and non-MBBR) size fractions: >9.5mm 2.36mm - 9.5mm <2.36mm								

Item No.	Sample and Analysis Rationale	Sample Location Type	Sample Location	Sample Type	Stream	Frequency Basis	Sample Frequency	Parameter	Sample Process	Analysis Process	EE Requirement Clause
E6		Environment	Mooloolah River: downstream of discharge and background / control locations upstream of discharge.			Event Based		g total plastics / m²			
								g MBBR plastic / m²			
								All plastics (MBBR and non-MBBR) size fractions: >9.5mm 2.36mm - 9.5mm <2.36mm			
E7	To identify the scale of plastics occurring in the aquatic environment and quantify the contribution made by MBBR media plastic.	Environment	Ocean around outfall, with location to be confirmed based on dispersion modelling.	Background plastics in ocean and river waters	Ocean surface water	One off during "normal" climatic conditions	Month 3	g total plastics > 500 µm per litre sample	Collection method and volume to be confirmed, via preliminary trials to determine likely density of plastic particles. Samples obtained by trawling specified area identified by dispersion modelling.	Samples from control / background sites will only be analysed where MBBR plastic is detected in samples from potentially impacted sites.	Addresses - Human Consumer of Aquatic Foods and Aquatic ecosystems WQO's
E8		Environment			Ocean bottom water	One off during "normal" climatic conditions		g MBBR plastic > 500 µm per litre sample			
								g total plastics 20 µm to 500 µm per litre sample			
								g MBBR plastic 20 µm to 500 µm per litre sample			
								g total plastics > 500 µm per litre sample			
								g MBBR plastic > 500 µm per litre sample			
								g total plastics 20 µm to 500 µm per litre sample			
E9		Environment			Ocean floor sediment	One off during "normal" climatic conditions		g total plastics > 500 µm per litre sample			
								g MBBR plastic > 500 µm per litre sample			
E10		Environment			Ocean surface water	One off during "normal" climatic conditions		g total plastics > 500 µm per litre sample	Collection method and volume to be confirmed, via preliminary trials to determine likely density of plastic particles. Samples obtained by trawling specified area identified by dispersion modelling.		
								g MBBR plastic > 500 µm per litre sample			
E11		Environment			Ocean bottom water	One off during "normal" climatic conditions		g total plastics > 500 µm per litre sample			
								g MBBR plastic > 500 µm per litre sample			
E12		Environment			Ocean floor sediment	One off during "normal" climatic conditions		g total plastics > 500 µm per litre sample	Divers collecting specified mass of sediment over specified area.		
	g MBBR plastic > 500 µm per litre sample										
E17	To identify the scale of plastics occurring in the aquatic environment and quantify the contribution made by MBBR media plastic <u>following defined weather events.</u>	Environment	Ocean around outfall, with location to be confirmed based on dispersion modelling.	Background plastics in ocean and river waters resulting from weather events.	Ocean surface water	Event Based	Events based on dispersion modelling impact of specific weather conditions.	g total plastics > 500 µm per litre sample	Collection method and volume to be confirmed, via preliminary trials to determine likely density of plastic particles. Samples obtained by trawling specified area identified by dispersion modelling.	Samples from control / background sites will only be analysed where MBBR plastic is detected in samples from potentially impacted sites.	
E18		Environment	Ocean away from outfall as control / background site.			Event Based		g MBBR plastic > 500 µm per litre sample			
								g total plastics > 500 µm per litre sample			
								g MBBR plastic > 500 µm per litre sample			
E19		Environment	Mooloolah River near Outfall; location to be		River water	Event Based	Events based on dispersion	g total plastics > 500 µm per litre sample	Collection method and volume to be confirmed, via		

Item No.	Sample and Analysis Rationale	Sample Location Type	Sample Location	Sample Type	Stream	Frequency Basis	Sample Frequency	Parameter	Sample Process	Analysis Process	EE Requirement Clause
			confirmed based on dispersion modelling.				modelling impact of specific weather conditions. Timing to follow spring tide subsequent to the defined event.	g MBBR plastic > 500 µm per litre sample	preliminary trials to determine likely density of plastic particles. Samples obtained by trawling specified area identified by dispersion modelling.		
						g total plastics 20 µm to 500 µm per litre sample					
						g MBBR plastic 20 µm to 500 µm per litre sample					
E20		Environment			River depositional banks sediment	Event Based		g total plastics > 500 µm per litre sample	Collection of specified mass of sediment over specified area.		
						g MBBR plastic > 500 µm per litre sample					
E21		Environment	River estuary control / background site; location to be confirmed based on dispersion modelling.		River water	Event Based		g total plastics > 500 µm per litre sample	Collection method and volume to be confirmed, via preliminary trials to determine likely density of plastic particles. Samples obtained by trawling specified area identified by dispersion modelling.		
								g MBBR plastic > 500 µm per litre sample			
E22		Environment			River depositional banks sediment	Event Based		g total plastics > 500 µm per litre sample	Collection of specified mass of sediment over specified area.		
				g MBBR plastic > 500 µm per litre sample							
E23	To identify plastic potentially available for human consumption and plastic in biota	Environment	On Mooloolah River outfall	Plastics in filter feeders	River	Once off	Once: Month 4	mg total plastics > 20 µm per kg of filter feeders	Opportunistic sampling of available sessile invertebrates that may be consumed by humans, such as oysters and mussels.	Analysis of soft tissues.	Addresses - Human Consumer of Aquatic Foods and Aquatic ecosystems WQO's, and oystering
								mg total MBBR plastics > 20 µm per kg of filter feeders			
E24		Environment	Upstream Maroochy River as control / background site.		River	Once off		mg total plastics > 20 µm per kg of filter feeders			
								mg total MBBR plastics > 20 µm per kg of filter feeders			
E25		Environment	Rocky / canal site near mouth of Mooloolah River (potential recreational harvest site)		River	Once off		mg total plastics > 20 µm per kg of filter feeders			
								mg total MBBR plastics > 20 µm per kg of filter feeders			
E26		Environment	Rocky / canal site near mouth of Maroochy River as control / background site.		River	Once off		mg total plastics > 20 µm per kg of filter feeders			
								mg total MBBR plastics > 20 µm per kg of filter feeders			
E27		Environment	On ocean outfall	Plastics in fin fish, crabs and prawns	Ocean	Once off		mg total plastics > 20 µm per kg of aquatic species	Manual opportunistic collection of fin fish, crabs and prawns using a variety of equipment tailored to site conditions and targeting species e.g. Fyke nets, crab pots, traps, trawl nets, lines and cast nets. 2 samples of each available taxa from each site will be collected for analysis.	Analysis of gut and muscle tissue.	Addresses - Human Consumer of Aquatic Foods and Aquatic ecosystems WQO's
								mg total MBBR plastics > 20 µm per kg of aquatic species			
E28		Environment	Ocean away from outfall as control / background site.		Ocean	Once off		mg total plastics > 20 µm per kg of aquatic species			
								mg total MBBR plastics > 20 µm per kg of aquatic species			
E29		Environment	At or downstream of Mooloolah River outfall targeting likely recreational fishing site		River	Once off		mg total plastics > 20 µm per kg of aquatic species			
								mg total MBBR plastics > 20 µm per kg of aquatic species			
E30		Environment			River	Once off		mg total plastics > 20 µm per kg of aquatic species			

Item No.	Sample and Analysis Rationale	Sample Location Type	Sample Location	Sample Type	Stream	Frequency Basis	Sample Frequency	Parameter	Sample Process	Analysis Process	EE Requirement Clause
			Upstream Maroochy River (control / background site)					mg total MBBR plastics > 20 µm per kg of aquatic species			
E31		Environment	Mouth of Mooloolah River at recreational fishing area		River	Once off		mg total plastics > 20 µm per kg of aquatic species			
								mg total MBBR plastics > 20 µm per kg of aquatic species			
E32		Environment	Mouth of Maroochy River at recreational fishing area (control/background site)		River	Once off		mg total plastics > 20 µm per kg of aquatic species			
								mg total MBBR plastics > 20 µm per kg of aquatic species			
E33	To provide data as a leading indicator of potential for plastics to be available for aquatic species consumption. To provide information on potential for release of plastics from storage systems during abnormal weather events	Environment	On ocean outfall	Plastics accumulated in and on sessile benthic invertebrates and algae	Ocean	Once off	Once: Month 3	mg total plastics collected > 20 µm	Manual collection of biota that may trap plastic particles (e.g. encrusting algae, macroalgae)		Addresses - Human Consumer of Aquatic Foods and Aquatic ecosystems WQO's
								mg total MBBR plastics collected > 20 µm			
E34		Environment	Rocky reefs in ocean away from outfall (Dicky Beach or Pt Cartwright (control / background site)		Ocean	Once off		mg total plastics collected > 20 µm			
								mg total MBBR plastics collected > 20 µm			

Appendix C SAQP P1: Assessment of material collected on the 2mm effluent screens.

Appendix C: SAQP P1 Assessment of material collected on the 2 mm effluent screens

KAWSTP Project Management
Services



*Prepared for
Unitywater*

28 June 2022



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Summary

A 6-month investigation into the breakdown of MBBR plastic media at Kawana STP was carried out by collecting material at fortnightly intervals that was caught by the effluent screening systems having an aperture of 2 mm.

For each sample, the bulk volume of screenings collected was measured and the sample was subsampled, dried, separated into size fractions, and classified into material types of: MBBR plastic media, plastic other than from MBBR media, and non-plastics.

The volume of screenings has been monitored since January 2020 and was minimal until August 2020 when it increased suddenly after existing mixers in the bioreactors were modified and caused significant degradation. The modified mixers were quickly replaced and the amount of screenings returned to previous levels. In August 2021, the amount of screenings increased, although not to the extent observed in August 2020. This increase in August 2021 coincided with the commissioning of a new clarifier skimming system that progressively collected floating material that had accumulated in the clarifiers.

On average, the screenings comprised 98.6% by mass of MBBR plastic media and the remaining 1.4% consisted of plastics other than MBBR media as well as non-plastics such as organic material. Of the MBBR plastic media in the screenings, 87.4% by mass were particles larger than 9.5 mm which mostly comprised MBBR plastic media with one quarter of their cylindrical shape broken out. This indicates that once this piece is broken out and the resulting particles can fit through the submerged screens in the bioreactor, they are probably flushed out of the bioreactor without much further degradation and then caught in the effluent screening system.

The amount of screenings caught in the baskets appeared to increase during periods of high flow through Kawana STP and there was an increase in the proportion of large sized broken MBBR plastic particles after the extreme wet weather event in February 2022. This suggests that some of the large broken MBBR plastic particles might be retained in the bioreactor until the hydraulic forces associated with high flows pushes these larger broken particles through the submerged screens in the bioreactor to be caught in the effluent screening systems.

The amount of MBBR plastic media particles collected from the effluent screening systems both before and during this study has been variable. Although specific events can explain some of the abnormal volumes of broken MBBR plastic media collected from the effluent screening systems, the long-term trend suggests the amount of breakage of MBBR plastic media may be increasing over time.

Table of Contents

1	Introduction	1
2	Experimental Procedure	3
2.1	Sample Collection	3
2.2	Sample Preparation	3
2.3	Post-Sieving Procedure	3
3	Results	4
3.1	Volume of Screenings Collected	4
3.2	Screenings Particle Distribution	4
4	Analysis of Results	5
4.1	Volume of Screenings Collected	5
4.2	Screenings Material Type and Size Distribution	7
5	Conclusion	11

Attachments

Attachment 1: Wheelie Bin Volumetric Calibration MBBR Plastic Media

Attachment 2: Construction Sciences Sample Preparation and Sieving Methodology

Attachment 3: Construction Sciences Particle Distribution Results

Attachment 4: University of Newcastle Sample Analysis <1.18mm

Attachment 5: Results of Particle Size Distribution > 1.18mm Classified by Material Type

Tables

Table 1 - Proportion of Material by Size Fraction (Average of Samples)	9
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Figures

Figure 1 - Effluent Basket Screen with Captured MBBR Plastic Media Fragments (Aerial View)	2
Figure 2: Clarifier Surface Skimming System	2
Figure 3: Measurement of material volume in wheelie bin	3
Figure 4 - Average Daily Volume of Screenings	4
Figure 5 - Average Daily Volume of Screenings	6
Figure 6 - Size Distribution of MBBR Plastic Material	6
Figure 7 - Relationship of Screenings Volume and STP Inflow	7
Figure 8 - Relationship of Screenings Volume and STP Inflow for Daily Flows Exceeding ADWF	7
Figure 9 - Material Type Composition per Size Fraction (Average of Samples)	9
Figure 10 - Composition of Material Type by Size Fraction (Average of Samples)	10
Figure 11 - Typical Screenings Sample	10

1 Introduction

This report describes an analysis of the volume and material characteristics of the MBBR plastic media collected in the effluent screening system at Kawana STP over a 6-month period. The objective of the investigation was to understand the nature of the MBBR plastic media particles collected and sorted at different size fractions. This investigation was initiated to provide information in response to the Notice to conduct or commission an environmental evaluation EPPR00869113 issued by Department of Environment and Science on 14 December 2021. In particular, the following three points of this notice are addressed by this investigation:

1. breakdown rate of MBBR plastic media due to existing mechanical forces as currently configured;
2. percentage of broken MBBR plastic media within the MBBR to determine if the percent rate of breaking media is increasing or decreasing over time; and
3. size distribution of the resultant breakdown plastic media with specific reference to the current containment controls (existing 2 mm screen aperture).

This report has been prepared as an Appendix for a separate report addressing the environmental evaluation where other items beyond the scope of this report are considered. An explanation of the background leading to the environmental evaluation and overview of Kawana STP can be found in that report.

Prior to discharge from Kawana STP, treated wastewater is disinfected and pumped to the Pacific Ocean Outfall or, during periods of wet weather when flows exceed three times the daily average, excess effluent overflows to the licenced Mooloolah River discharge point. Since becoming aware of the risk of MBBR plastic media being released in the effluent, Unitywater has installed a set of basket screens having 2 mm aperture. There are four basket screens to ensure effluent from any configuration of the effluent system is screened before being released to the environment and these are located in and around the Chlorine Contact Tanks (CCTs). Figure 1 shows the aerial view of one of the basket screens that are typically wide and deep structures with significant steelwork. As such, a crane is required to lift the large screens from their locations. The black material at the bottom of the screen shown in Figure 1 is fragments of MBBR plastic media that has been caught by the basket screen. In addition to MBBR plastic media, these basket screens also capture any other material in the effluent, such as other plastics that may have entered the STP and passed through the plant, as well as leaves, sticks, etc.

During periods of high flows and/or fouling of the screens, effluent can overflow the CCT2 screen and buoyant material that has already been collected in the screen can float up and out of the screen. The two final basket screens in CCT3 prior to discharging to release points W1 and W3 were modified in 2022 to ensure the top of the screens are higher than the water retaining structures in the STP and therefore these baskets cannot overflow or lose their contents to the environment.

While the two final basket screens cannot overtop, fouling on these screens can cause effluent to flow over the Emergency Hydraulic Release (EHR) and if the screen on this release point fouls, plastic media will be lost to the environment. During the February wet weather event influent flows got up to 2300 L/sec which nearly overtopped the EHR. The design requires the plant is capable of inflows up to 2750 L/sec which are likely to overtop EHR and potentially discharge media to the environment.

The basket screens are usually cleaned fortnightly to minimise screenings build-up, although wet weather flows can impact this routine.

In addition to the basket screens, a system has been developed that removes and collects floating material from the surface of the clarifiers prior to reaching the basket screens (Figure 2). Following an initial trial in one clarifier in July 2021, this system was expanded to all four clarifiers. This system is less affected by high flows and has been successful in collecting broken MBBR plastic media before it reaches the CCT basket screens.



Figure 1 - Effluent Basket Screen with Captured MBBR Plastic Media Fragments (Aerial View)



Figure 2: Clarifier Surface Skimming System
(left photo shows surface skimming system and right photo shows 2mm screened collection container)

2 Experimental Procedure

2.1 Sample Collection

Material removed from the effluent basket screens and clarifier surface skimming systems was loaded into wheelie bins and the bulk volume estimated by measuring the distance from the top of each wheelie bin to the levelled material in the bin (Figure 3) and comparing to a volumetric calibration curve (**Error! Reference source not found.** Attachment 1). Bulk volume of material rather than mass was measured to eliminate variability from different material composition and changes in moisture level between samples.



Figure 3: Measurement of material volume in wheelie bin

Each sample was transported in wheelie bins to Construction Sciences (Kunda Park) for sample preparation (subsampling, drying, and sieving) described in the next section.

2.2 Sample Preparation

Sample preparation was carried out by Construction Sciences involving subsampling, washing the material to break up particle clusters, drying, and dry sieving into size fractions. The size fractions obtained from sieving were: < 0.075mm, 0.075 – 0.15mm, 0.15 – 0.3mm, 0.3 – 0.6mm, 0.6 – 1.18mm, 1.18 – 2.36mm, 2.36 – 4.75mm, 4.75 – 6.7mm, 6.7 – 9.5mm, and >9.5mm. Details of the method is described in Attachment 1.

2.3 Post-Sieving Procedure

After drying and sieving, material was visually sorted into either MBBR plastic media fragments, non-MBBR plastic media particles, and non-plastic material. This process was completed for size fractions greater than 1.18 mm where these materials could be visually distinguished. The samples were weighed using a Sartorius Lab Instruments Model BCE224I-1S for each material type and size fraction.

Material in size fractions less than 1.18 mm was difficult to accurately classify according to material types using visual observation and a sample of material less than 1.18 mm was provided to the University of Newcastle for review.

3 Results

3.1 Volume of Screenings Collected

The aggregated daily volume of all material collected per fortnight from the effluent basket screens and clarifier surface skimming systems is presented in Figure 4. The data pre-dates this investigation that commenced in December 2021 to provide further context to the results of this more recent 6-month study.

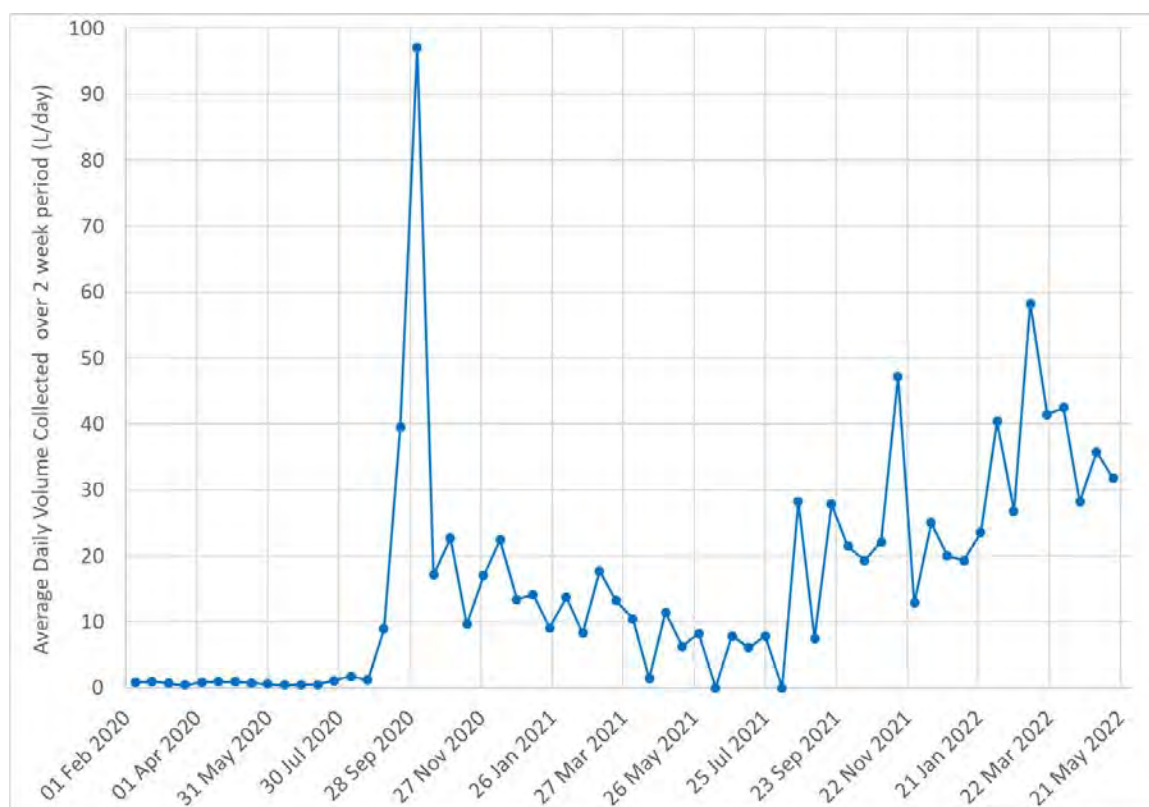


Figure 4 - Average Daily Volume of Screenings

3.2 Screenings Particle Distribution

Particle size distribution data obtained from the sample preparation stage can be found in [Attachment 2](#) and results of analysis of the sample fine particles less than 1.18 mm is provided in [Attachment 3](#). Note that [Attachment 3](#) includes data for all material types: MBBR plastic media, non-MBBR plastic media, and non-plastic. Most of the material in this small size fraction less than 1.18 mm was identified as black polyethylene, similar to the MBBR HDPE media, but other plastics were also found as noted.

The particle size distribution data on a mass basis for particles greater than 1.18 mm is provided in [Attachment 5](#).

4 Analysis of Results

4.1 Volume of Screenings Collected

Figure 4 showing the volume of screenings collected appears to have three distinctive phases and these are shown in **Error! Reference source not found.** as different colours with trend lines added to the second and third phases as well as an overall trend of all data. The first phase denoted by the blue line shows minimal screenings being collected but suddenly increases from early September 2020, peaking in October 2020 and quickly reducing to lower levels in November 2020. This sudden increase in broken MBBR plastic media caught in the basket screens in September 2020 most likely resulted from a new design anoxic mixer that was installed in the MBBR at Kawana STP where the mixer appeared to be slicing plastic media in the tank and causing degradation. Following this, another anoxic mixer design was installed that, from visual observations, greatly reduced damage to the plastic media. The second phase is denoted by a green line in **Error! Reference source not found.** where the volume of screenings continued to reduce as the damaged media found its way through the STP. The third phase shown in **Error! Reference source not found.** as the orange line commenced in August 2021 where the amount of screenings increased to around 20 to 40 litres per day based on the fortnightly average. This increase coincided with the commissioning of a new clarifier skimming system that progressively collected floating material that had accumulated in the clarifiers. However, the amount of screenings in the third phase shown in Figure 5 remained higher than Phase 2 over the following 9 months. This was most likely because the clarifier skimming system was progressively installed on all 4 clarifiers over the ensuing months but in addition, the STP experienced periods of higher flows from November 2021 and most notably after the extreme wet weather event in February 2022.

The amount of screenings appeared to increase after high flows probably from the hydraulic pressure created by high flows that might have forced more broken MBBR plastic media particles through the submerged screens in the bioreactor compartments that would have otherwise been retained by these screens. More large particles in the screenings would support this theory and Figure 6 shows a higher proportion of large MBBR plastic particles in the sample taken after the wet weather event in February 2022. The error bars in Figure 6 shows the range across the samples in the 6-month period. The vast majority of the screenings comprised whole MBBR plastic media particles but with one quarter of their cylindrical shape broken out. This indicates that once this quarter piece is broken out, the resulting particles can usually fit through the submerged screens in the bioreactor and are caught in the downstream effluent screening system. However, it is possible that a portion of the larger broken MBBR plastic media might be retained by the submerged screens in the bioreactor until high flows forces the large particle through the aperture of these screens, resulting in the increased volume and higher proportion of large MBBR plastic media in the screenings from the effluent basket screens.

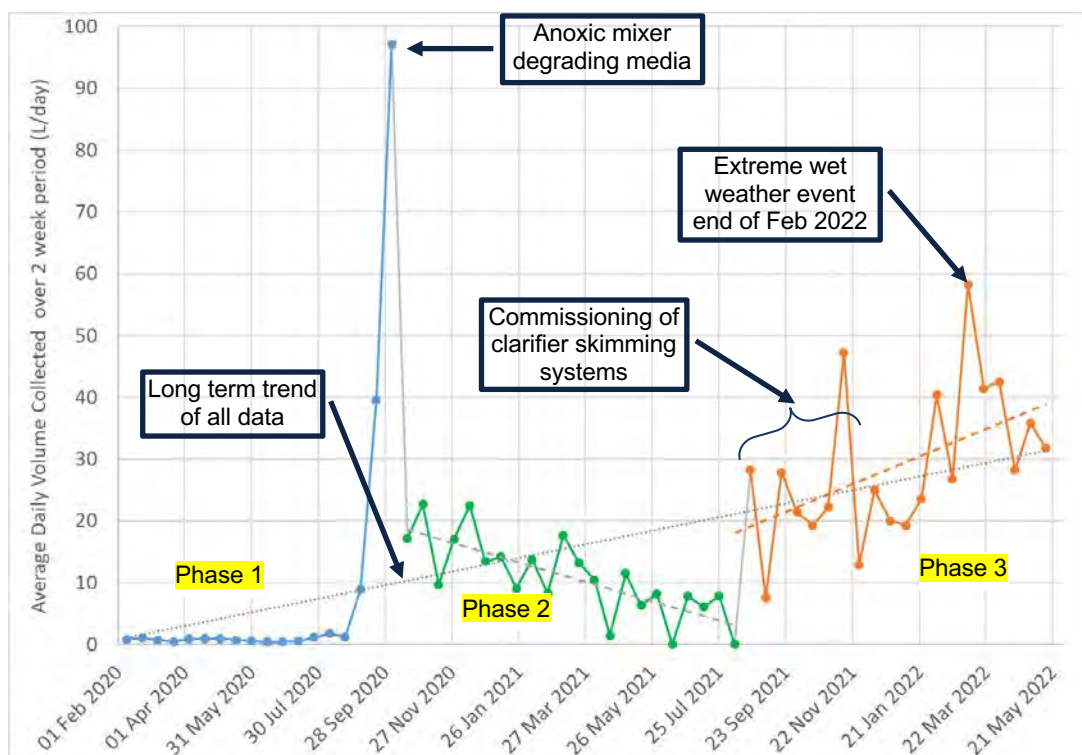


Figure 5 - Average Daily Volume of Screenings

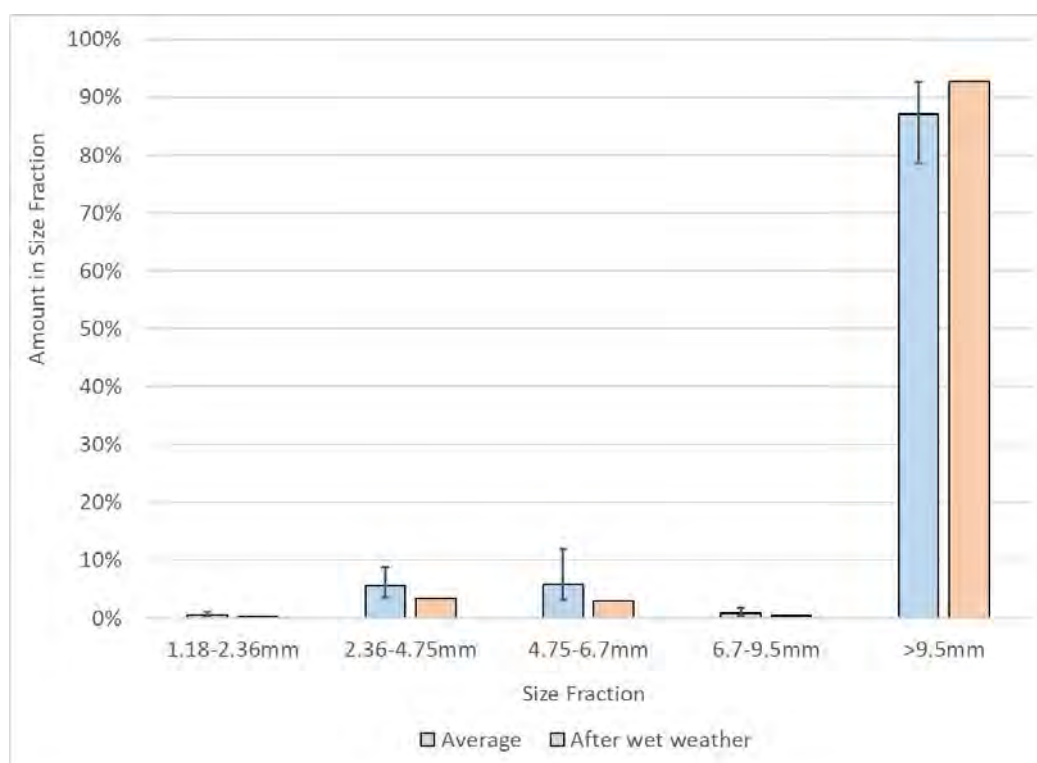


Figure 6 - Size Distribution of MBBR Plastic Material

The idea of higher flows flushing more MBBR plastic out of the MBBR was investigated, but as shown in **Error! Reference source not found.**, no meaningful relationship between the amount of screenings collected and the daily flow through the STP was identified. However, Figure 8 presents the same data on the vertical axis as Figure 7 but only for days where the inflow exceeds the average dry weather flow (ADWF). The horizontal axis of Figure 8 is the aggregated volume of STP inflow over the fortnight period, but only for days where the inflow exceeds ADWF. The relationship in Figure 8 is much stronger and therefore it

appears that volume of screenings collected is dependent on STP flows but only when the flow is greater than ADWF.

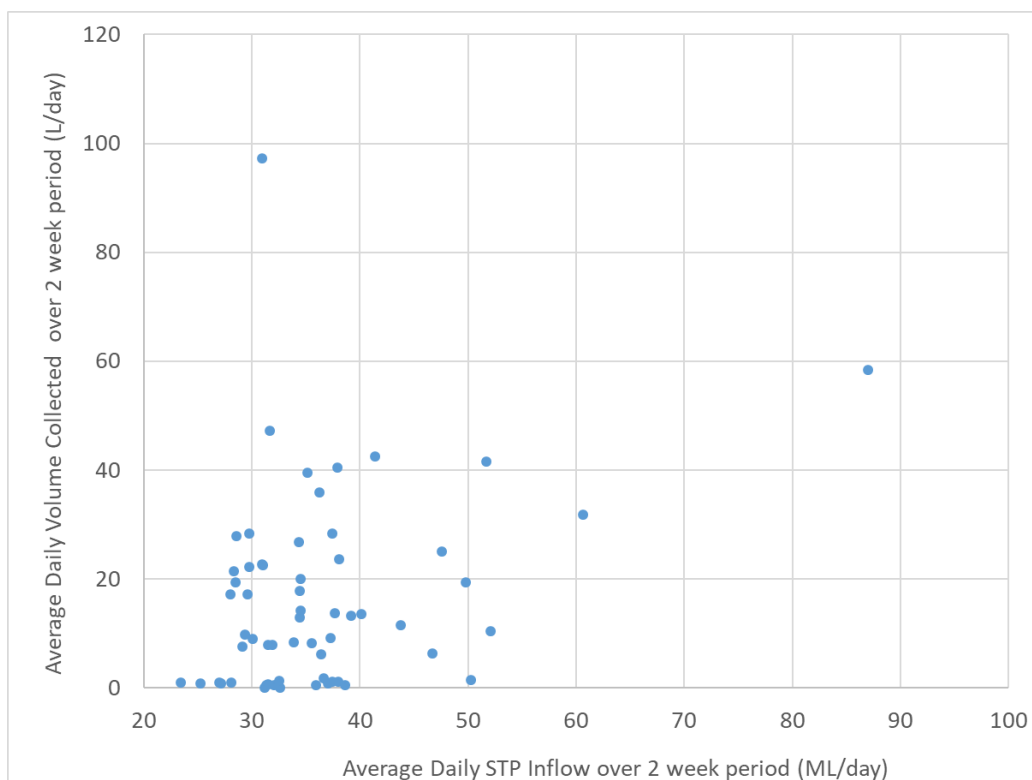


Figure 7 - Relationship of Screenings Volume and STP Inflow

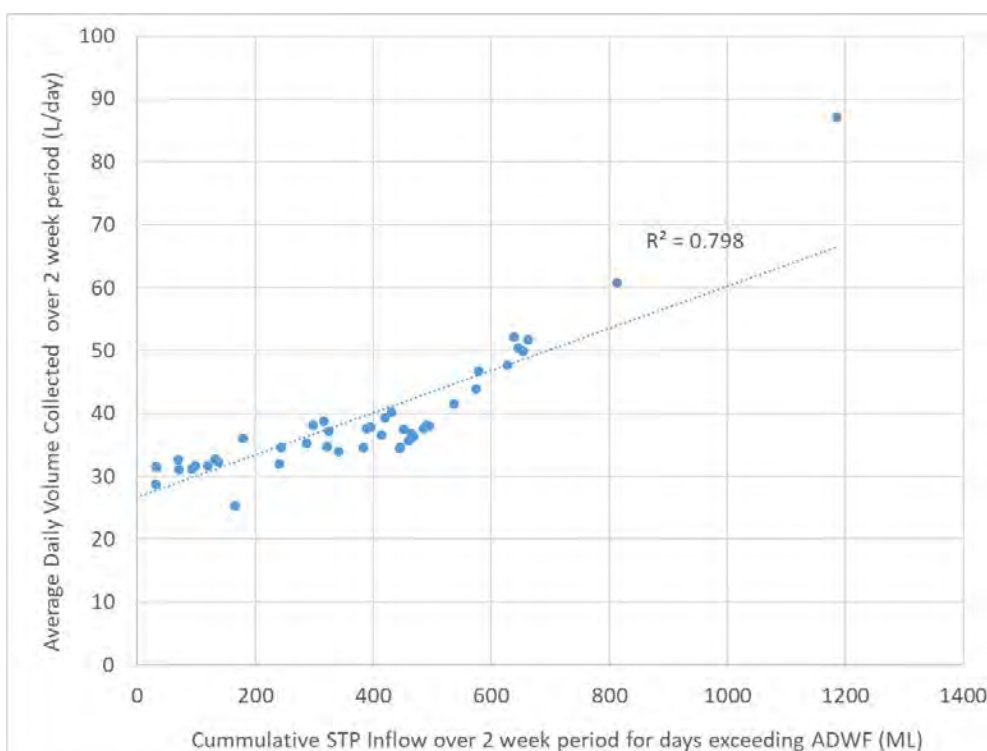


Figure 8 - Relationship of Screenings Volume and STP Inflow for Daily Flows Exceeding ADWF

4.2 Screenings Material Type and Size Distribution

For particles greater than 1.18 mm, MBBR plastic was the dominant material type found in the screenings (Table 1 and Figure 9) with particles larger than 9.5 mm significantly outweighing all other size fractions.

From the results in Attachment 5, 98.6% by mass of the screening material contained particles of MBBR plastic media and the remaining 1.4% comprised plastics that were not from MBBR media as well as non-plastics such as organic material. Based on an average of 30 litres of screenings collected per day, it is forecast that the effluent screening system might also collect around 150 litres per year of material that would have otherwise been discharged to effluent.

Figure 10 presents similar information to Figure 9 but normalises the quantity in each size fraction to 100% to highlight the increasing proportion of MBBR plastic as the size fraction increases. The higher proportion of large MBBR plastic media particles (87.4% > 9.5 mm) supports the observation that most of the MBBR plastic material found in the screenings was whole media with one quarter removed (Figure 11). This suggests that once a piece of MBBR plastic media has a piece removed that allows it to fit through the screens, it passes out of the bioreactor without undergoing much more degradation. A test screen with the same dimensions of the submerged bioreactor screens was used to confirm that when one quarter of the cylindrically shaped MBBR plastic media was removed, it could easily pass through the screen aperture. Although the proportion of MBBR plastic media particles in the size ranges 2.36 mm to 4.75 mm and 4.75 mm to 6.7 mm is much less than the >9.5 mm fraction by mass (Figure 9), they are higher than other size fractions and this may explain the quarter section removed from the whole MBBR plastic media. While removal of a quarter section of the MBBR plastic media is likely to be a dominant degradation mechanism, other degradation also occurs such as wear of the plastic which is observed in rounding of the edges of whole unbroken media retained in the bioreactor.

With the aperture of the basket screens being 2 mm, it was expected that smaller particles would be washed through the screen and not retained. Although small in proportion (< 1%), the results suggest that some of the particles smaller than 2 mm may become entrapped within the larger particles.

Table 1 - Proportion of Material by Size Fraction (Average of Samples)

Size Fraction	MBBR Plastic	Non-MBBR Plastic	Non-Plastic	Total
1.18 mm to 2.36 mm	62.74%	15.71%	21.54%	100%
2.36 mm to 4.75 mm	88.70%	5.76%	5.55%	100%
4.75 mm to 6.7 mm	98.73%	0.40%	0.87%	100%
6.7 mm to 9.5mm	89.77%	2.96%	7.27%	100%
> 9.5 mm	99.81%	0.01%	0.18%	100%

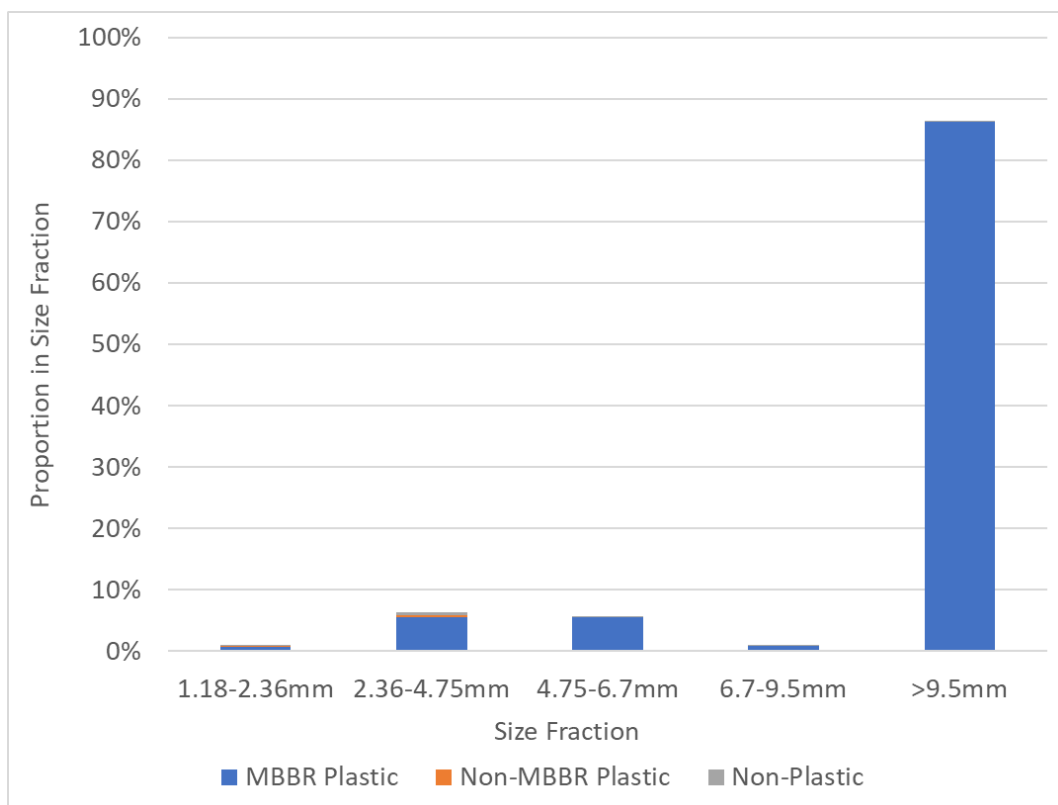


Figure 9 - Material Type Composition per Size Fraction (Average of Samples)

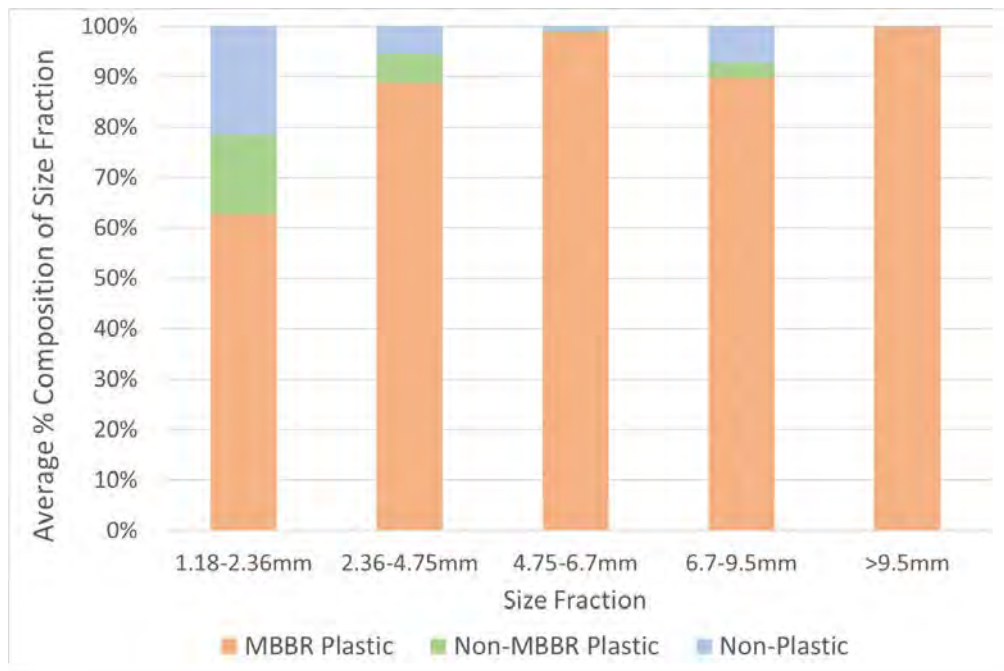


Figure 10 - Composition of Material Type by Size Fraction (Average of Samples)



Figure 11 - Typical Screenings Sample

5 Conclusion

The amount of MBBR plastic media particles caught in the effluent basket screens and in the clarifier surface skimming systems is variable. These systems screen particles greater than 2 mm in size, minimising the possibility of them being released to the outfalls. There was a short period in September 2020 when the volume of particles significantly increased due to a different type of anoxic mixer being used which quickly degraded the MBBR plastic media. A more effective mixer was then installed after observing this breakage and since then, the amount of broken particles reached more stable levels but is influenced by high flows through Kawana STP in times of wet weather flows.

Broken MBBR plastic media made up 98.6% by mass of the material collected from the effluent basket screens, and 87.4% by mass of the MBBR plastic media in the screenings was larger than 9.5 mm. This high proportion of large broken MBBR plastic media supports the idea that once a quarter section of the MBBR plastic media has been broken out, it is usually flushed out of the bioreactor without much further degradation. However, the amount of broken MBBR plastic media particles in the effluent basket screens increased after periods of high flow and the proportion of large particles also increased. This suggests the hydraulic forces caused by high flows through the STP forces more of the large size broken MBBR plastic media particles through the submerged screens in the bioreactor that may have otherwise been retained, and these are subsequently caught in the effluent screening systems.

Although some of the large amounts of screening material can be attributed to specific events, the long-term trend suggests the amount of breakage of MBBR plastic media may be increasing over time.

If the rate of breakage of MBBR plastic media did not increase over time and averaged 30 litres per day, then approximately 274 m³ of media could be lost from the bioreactor for the 25-year design life of the media. This is approximately 8% of the total volume of MBBR plastic media added to the bioreactor at the start of operation. This estimate neglects any changes in the rate of media breakage as well as the loss in media mass due to wear.

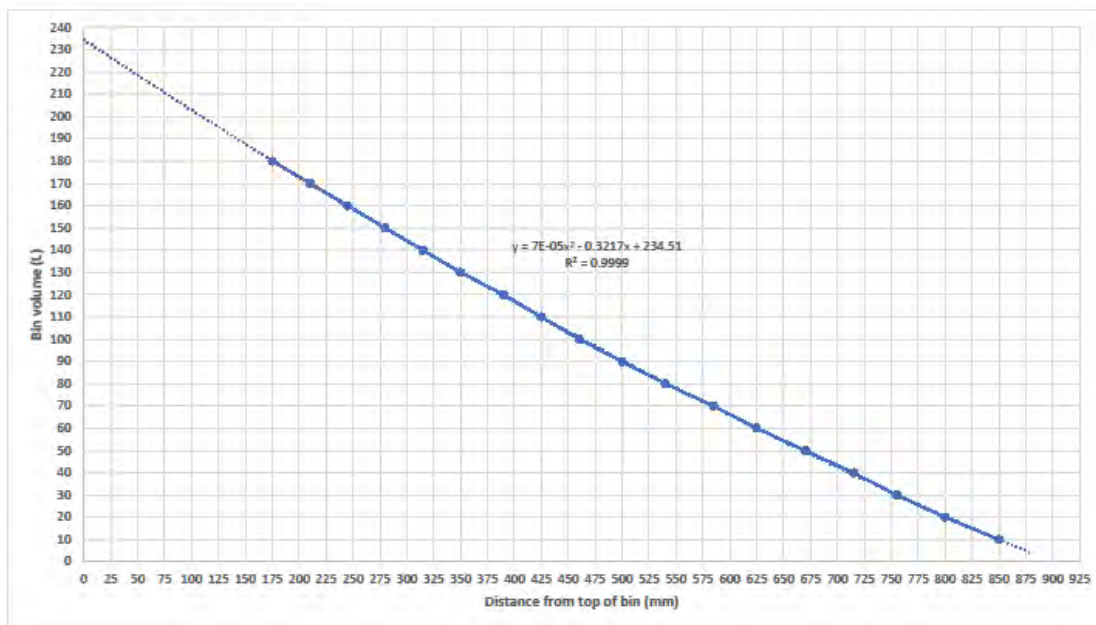
It is expected that MBBR plastic media breakage rate would increase due to the weakened structural integrity of the plastic media as the cross sections become thinner after being worn.

Attachments

Attachment 1: Wheelie Bin Volumetric Calibration

CALIBRATION

Volume (L)	Distance (mm)
10	850
20	800
30	755
40	715
50	670
60	625
70	585
80	540
90	500
100	460
110	425
120	390
130	350
140	315
150	280
160	245
170	210
180	175



Graph showing the Wheelie Bin Volumetric Calibration

Attachment 1: Construction Sciences Sample Preparation and Sieving Methodology



Technical Memorandum

Title	Kawana Sewerage Treatment Plant Effluent Plastics Sampling		
Client	Unity Water	Project No	3740ST/Q/24
Date	Friday, 13 May 2022	Office	Kunda Park
Author	Paul Mayes		

Sample Preparation Methodology

Bulk samples of material for particle size distribution analysis were received from Unity Water staff in 200 litre bins. The number of bins per sample and the quantity of material in each bin provided varied from sample to sample. It was assumed that the material collected into each bin was not thoroughly mixed prior to placement into the bins and as such stratification of material within and between bins was likely. The following procedure (based on AS1141.3.1) was used to mix and representatively split the bulk samples provided to produce five (5) replicate representative sub-samples from each bulk sample.

- The entire bulk sample was passed through a riffle/splitter box (see Figure 1 below) by progressively selecting material at random from the 200 litre bins provided until all bins were emptied of material. This procedure was undertaken to facilitate thorough mixing of the bulk sample.
- Further mixing of the bulk sample was then achieved by passing all subsamples back through the riffle/splitter box a second time without the removal of any of the subsamples from the process.
- During each splitting process material being placed in the sample riffle/splitter box was distributed evenly along the full length of the divider and material was fed into the riffle/splitter box from alternative sides on each successive split to reduce any systematic bias in the splitting process.
- Half the resultant subsamples were then removed from the sample splitting process, being set aside until the process was complete, in case they were required.
- The sample splitting process was then repeated, removing half the resultant subsamples with each successive split, until five (5) representative subsamples of the required test portion mass were obtained.
- These replicate subsamples were then vacuum sealed until required for testing.



Figure 1 – Riffle/Splitter box.



Sample Testing Methodology

Sample were then tested generally in accordance with the methodology described in AS1289.3.6.1, with slight variations necessary to deal with the intrinsic properties of the material under test. The testing process is described briefly below:

- a. Each vacuum sealed sample was placed in a container of sufficient volume and covered with water containing a dispersant solution and allowed to soak. The soaking process was aimed at breaking up and aggregations of fine particles and dislodging any fine particles adhering to the complex structure of the carrier plastics such that these finer particles could be quantified accurately during the subsequent sieving process.
- b. After a period of soaking the sample was incrementally washed over a 75 micron wash sieve to remove and material finer than 75 microns from the test portion.
- c. After initial washing, the sample was returned to the soaking container with fresh water and dispersant solution, allowed to soak again before a second washing over the 75 micron wash sieve.
- d. The process of soaking and washing was repeated until the washing water from the 75 micron sieve was visually clear of fine material.
- e. At the completion of the washing process the sample was allowed to air dry until a majority of visible surface water was removed.
- f. After air drying the sample was placed in a drying oven at 40°C until it achieved a constant mass.
- g. The dried sample was then progressively dry sieved on the following sieves: 13.2mm, 9.5mm, 6.7mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.425mm, 0.3mm, 0.15mm, 0.075mm, with the mass retained on each sieve recorded to provide a particle size distribution for the material.

Attachment 2: Construction Sciences Particle Distribution Results



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PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/52703-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40354
Supplied To:	Ben Goodall	Client Reference/s:	Sample 1
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1	Sample Location	
Sample Number	3740/S/216982	Location1	Sample 1
Sampling Method	Tested As Received	Location2	Replicate
Date Sampled	25/11/2021	Location3	1
Sampled By	Client	Location4	
Date Tested	21/12/2021	Material Type	Existing
Material Source	Client Sampled/Supplied		

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)	PARTICLE SIZE DISTRIBUTION GRAPH
13.2		100		
9.5		11		
6.7		11		
4.75		7		
2.36		1		
1.18		0		
0.600		0		
0.425		0		
0.300		0		
0.150		0		
0.075		0		

Remarks

Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.
Results apply to the sample/s as received.

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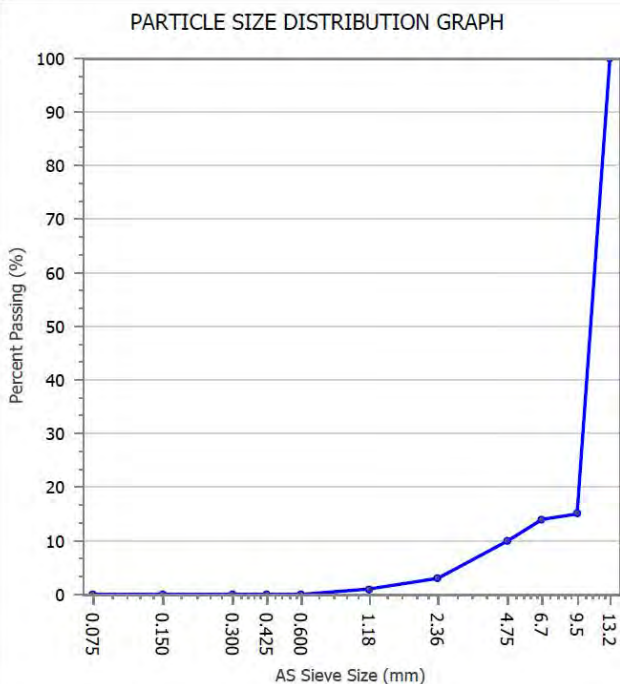
Email: SunshineCoast@constructionsciences.net

PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53400-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40356
Supplied To:	Ben Goodall	Client Reference/s:	Sample 2
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1	Sample Location	
Sample Number	3740/S/216987	Location1	Sample 2
Sampling Method	Tested As Received	Location2	Replicate
Date Sampled	9/12/2021	Location3	1
Sampled By	Client	Location4	
Date Tested	14/02/2022	Material Type	Existing
Material Source	Client Sampled/Supplied		

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)
13.2		100	
9.5		15	
6.7		14	
4.75		10	
2.36		3	
1.18		1	
0.600		0	
0.425		0	
0.300		0	
0.150		0	
0.075		0	



Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.
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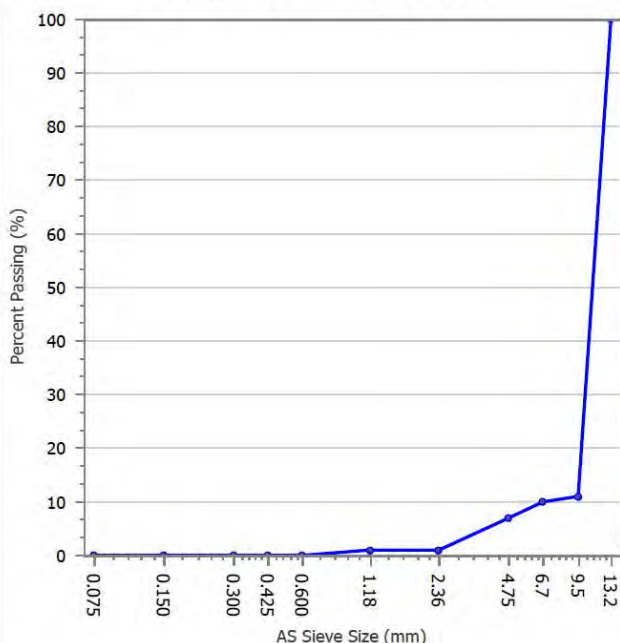
PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53399-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40881
Supplied To:	Ben Goodall	Client Reference/s:	Sample 3
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1	Sample Location	
Sample Number	3740/S/219704	Location1	Sample 3
Sampling Method	Tested As Received	Location2	Replicate
Date Sampled	22/12/2021	Location3	1
Sampled By	Client Sampled	Location4	
Date Tested	10/03/2022	Material Type	Existing
Material Source	Client Sampled/Supplied		

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)
13.2		100	
9.5		11	
6.7		10	
4.75		7	
2.36		1	
1.18		1	
0.600		0	
0.425		0	
0.300		0	
0.150		0	
0.075		0	

PARTICLE SIZE DISTRIBUTION GRAPH



Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.
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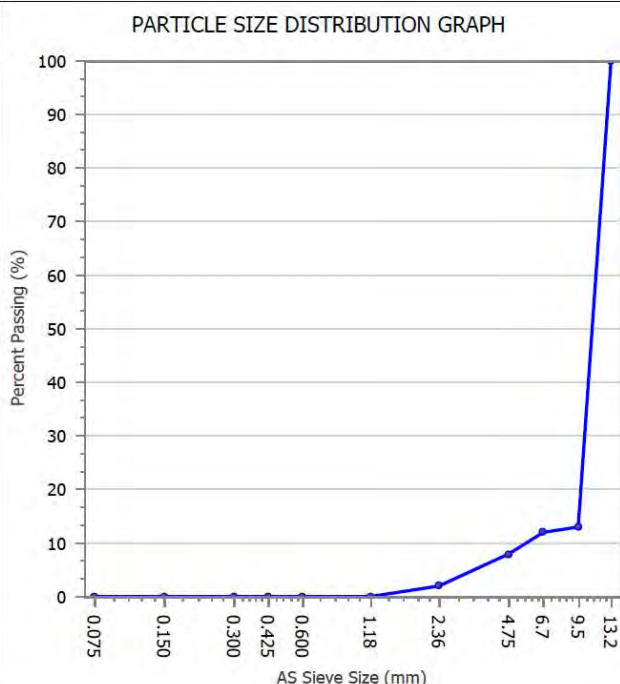
Email: SunshineCoast@constructionsciences.net

PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53432-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40882
Supplied To:	Ben Goodall	Client Reference/s:	Sample 4
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:		AS1289.3.6.1	
Sample Number	3740/S/219709	Sample Location	
Sampling Method	Tested As Received	Location1	Sample 4
Date Sampled	6/01/2022	Location2	Replicate
Sampled By	Client Sampled	Location3	1
Date Tested	13/03/2022	Location4	
Material Source	Client Sampled/Supplied	Material Type	Existing

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)
13.2		100	
9.5		13	
6.7		12	
4.75		8	
2.36		2	
1.18		0	
0.600		0	
0.425		0	
0.300		0	
0.150		0	
0.075		0	



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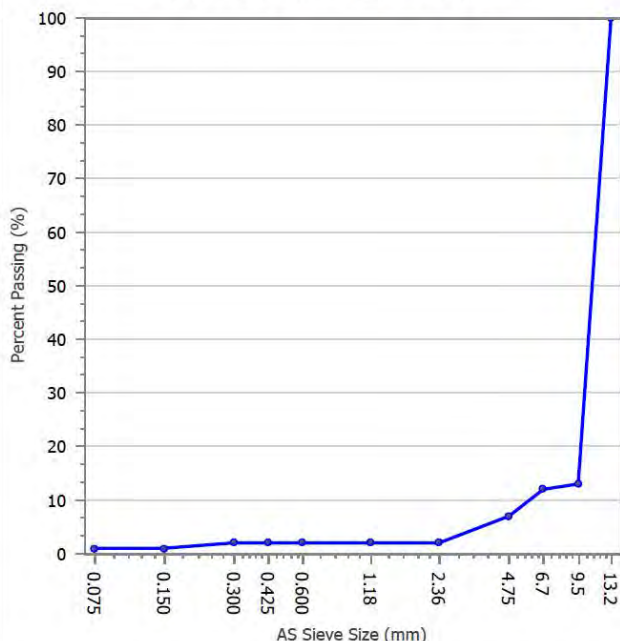
PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53543-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40883
Supplied To:	Ben Goodall	Client Reference/s:	Sample 5
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1		
Sample Number	3740/S/219714	Sample Location	
Sampling Method	Tested As Received	Location1	Sample 5
Date Sampled	20/01/2022	Location2	Replicate
Sampled By	Client	Location3	1
Date Tested	24/03/2022	Location4	
Material Source	Client Sampled/Supplied	Material Type	Existing

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)
13.2		100	
9.5		13	
6.7		12	
4.75		7	
2.36		2	
1.18		2	
0.600		2	
0.425		2	
0.300		2	
0.150		1	
0.075		1	

PARTICLE SIZE DISTRIBUTION GRAPH



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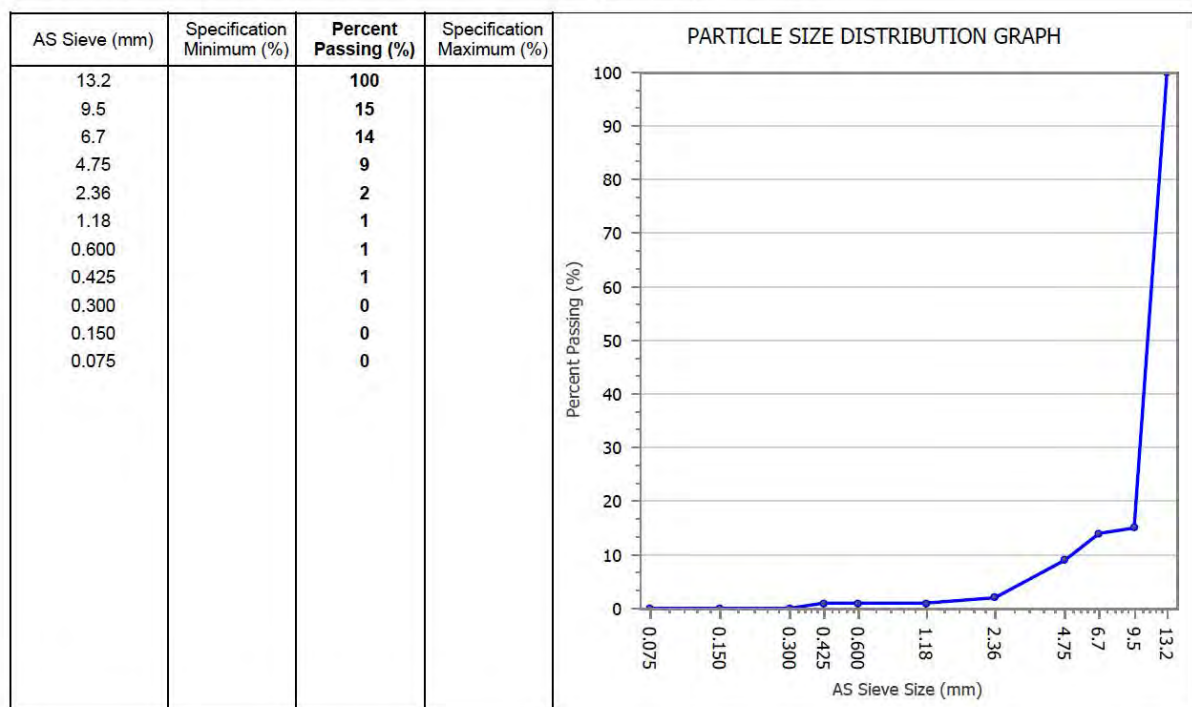
Fax: 07 5452 0133

Email: SunshineCoast@constructionsciences.net

PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53564-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40884
Supplied To:	Ben Goodall	Client Reference/s:	Sample 6
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1	Sample Location	
Sample Number	3740/S/219719	Location1	Sample 6
Sampling Method	Tested As Received	Location2	Replicate
Date Sampled	3/02/2022	Location3	1
Sampled By	Client	Location4	
Date Tested	25/03/2022	Material Type	Existing
Material Source	Client Sampled/Supplied		



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PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53593-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40885
Supplied To:	Ben Goodall	Client Reference/s:	Sample 7
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1		
Sample Number	3740/S/219725	Sample Location	
Sampling Method	Tested As Received	Location1	Sample 7
Date Sampled	17/02/2022	Location2	Replicate
Sampled By	Client	Location3	1
Date Tested	29/03/2022	Location4	
Material Source	Client Sampled/Supplied	Material Type	Existing

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)	
13.2		100		
9.5		10		
6.7		9		
4.75		6		
2.36		1		
1.18		0		
0.600		0		
0.425		0		
0.300		0		
0.150		0		
0.075		0		

PARTICLE SIZE DISTRIBUTION GRAPH

The graph plots Percent Passing (%) on the y-axis (0 to 100) against AS Sieve Size (mm) on the x-axis (0.075 to 13.2). The data points are: (0.075, 0), (0.150, 0), (0.300, 0), (0.425, 0), (0.600, 0), (1.18, 0), (2.36, 1), (4.75, 6), (6.7, 9), (9.5, 10), (13.2, 100). The curve shows a very low percentage of material passing through sieves smaller than 2.36 mm, followed by a gradual increase between 2.36 mm and 9.5 mm, and then a very steep increase at 13.2 mm.

Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.
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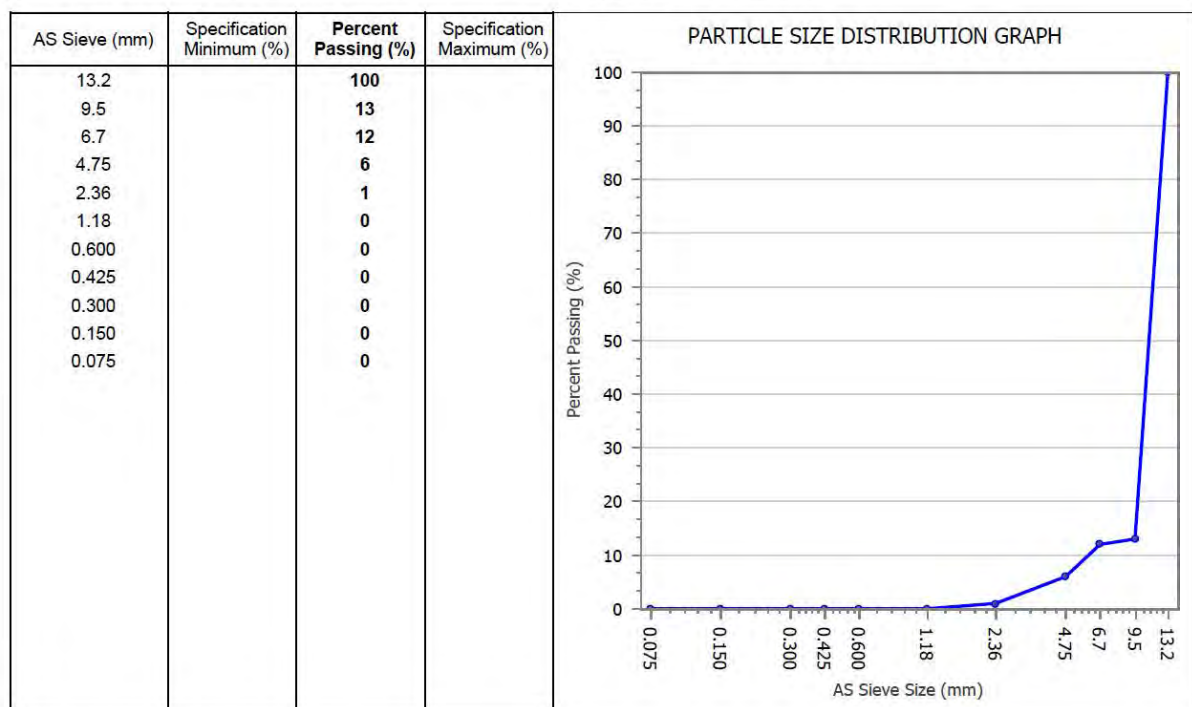
Fax: 07 5452 0133

Email: SunshineCoast@constructionsciences.net

PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53829-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40887
Supplied To:	Ben Goodall	Client Reference/s:	Sample 9
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:		AS1289.3.6.1	
Sample Number	3740/S/219735	Sample Location	
Sampling Method	Tested As Received	Location1	Sample 9
Date Sampled	17/02/2022	Location2	Replicate
Sampled By	Client Sampled	Location3	1
Date Tested	19/04/2022	Location4	
Material Source	Client Sampled/Supplied	Material Type	Existing



Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.
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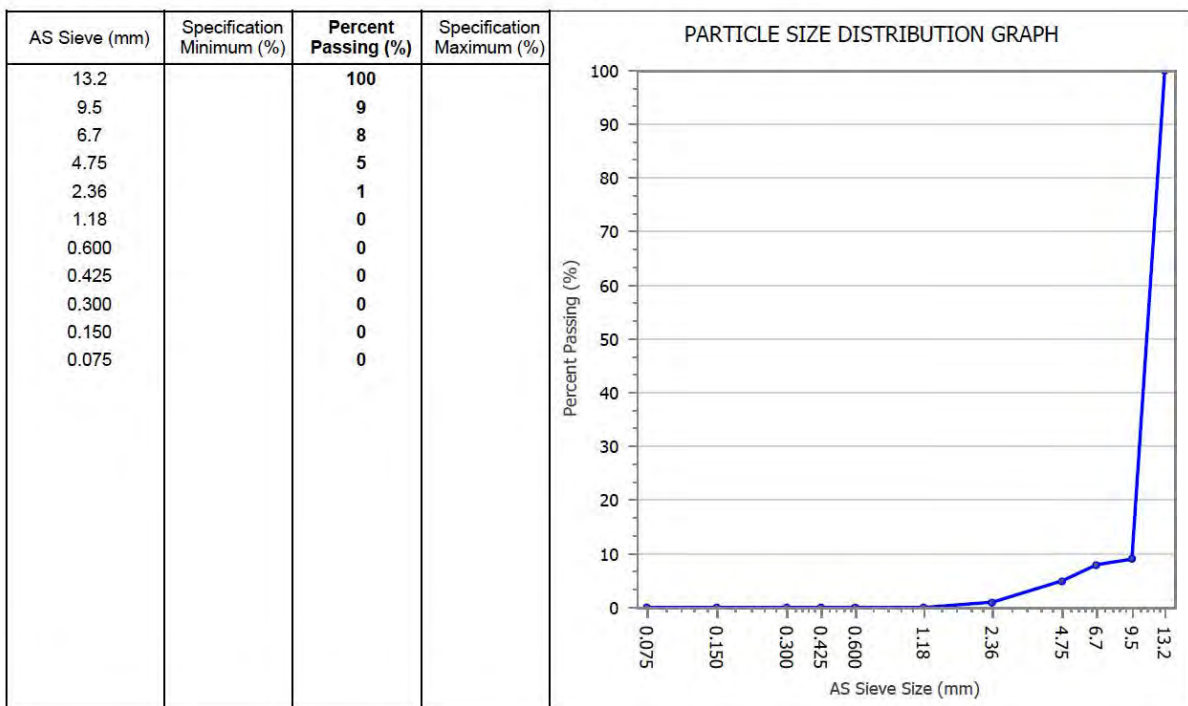
Fax: 07 5452 0133

Email: SunshineCoast@constructionsciences.net

PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53826-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40886
Supplied To:	Ben Goodall	Client Reference/s:	Sample 8
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1		
Sample Number	3740/S/219730	Sample Location	
Sampling Method	Tested As Received	Location1	Sample 8
Date Sampled	28/02/2022	Location2	Replicate
Sampled By	Client Sampled	Location3	1
Date Tested	19/04/2022	Location4	
Material Source	Client Sampled/Supplied	Material Type	Existing



Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received., Combined Sample collected 28/2/22 and 4/3/22.
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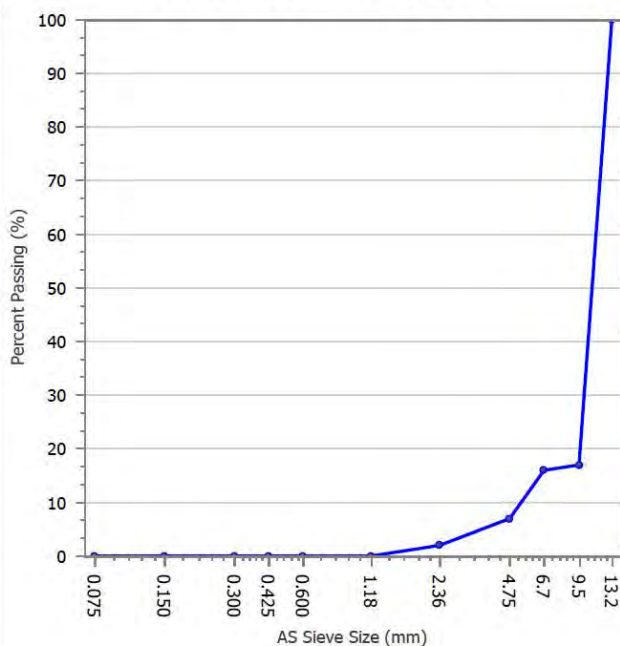
PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/53830-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40888
Supplied To:	Ben Goodall	Client Reference/s:	Sample 10
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures: AS1289.3.6.1			
Sample Number	3740/S/219740	Sample Location	
Sampling Method	Tested As Received	Location1	Sample 10
Date Sampled	1/04/2022	Location2	Replicate
Sampled By	Client Sampled	Location3	1
Date Tested	19/04/2022	Location4	
Material Source	Client Sampled/Supplied	Material Type	Existing

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)
13.2		100	
9.5		17	
6.7		16	
4.75		7	
2.36		2	
1.18		0	
0.600		0	
0.425		0	
0.300		0	
0.150		0	
0.075		0	

PARTICLE SIZE DISTRIBUTION GRAPH



Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.
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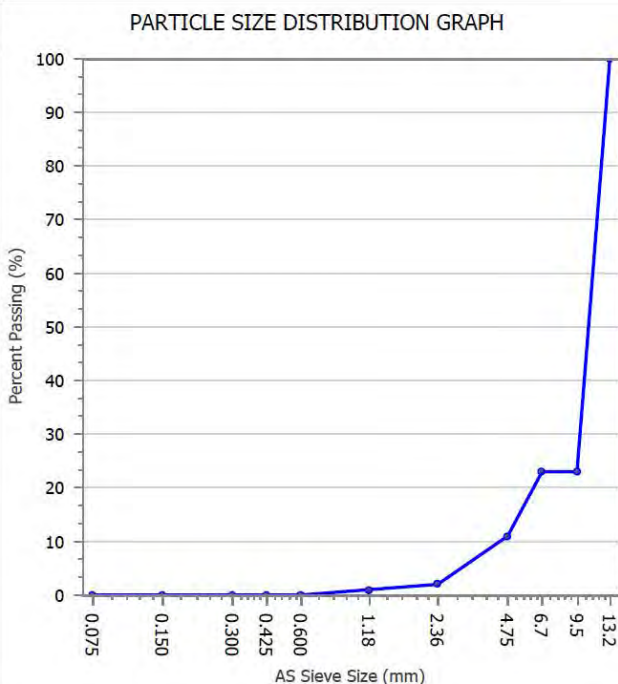
PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/54373-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40889
Supplied To:	Ben Goodall	Client Reference/s:	Sample 11
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures: AS1289.3.6.1	
Sample Number	3740/S/219745
Sampling Method	Tested As Received
Date Sampled	14/04/2022
Sampled By	Client Sampled
Date Tested	13/05/2022
Material Source	Client Sampled/Supplied

Sample Location	
Location1	Sample 11
Location2	Replicate
Location3	1
Location4	
Material Type	Existing

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)
13.2		100	
9.5		23	
6.7		23	
4.75		11	
2.36		2	
1.18		1	
0.600		0	
0.425		0	
0.300		0	
0.150		0	
0.075		0	



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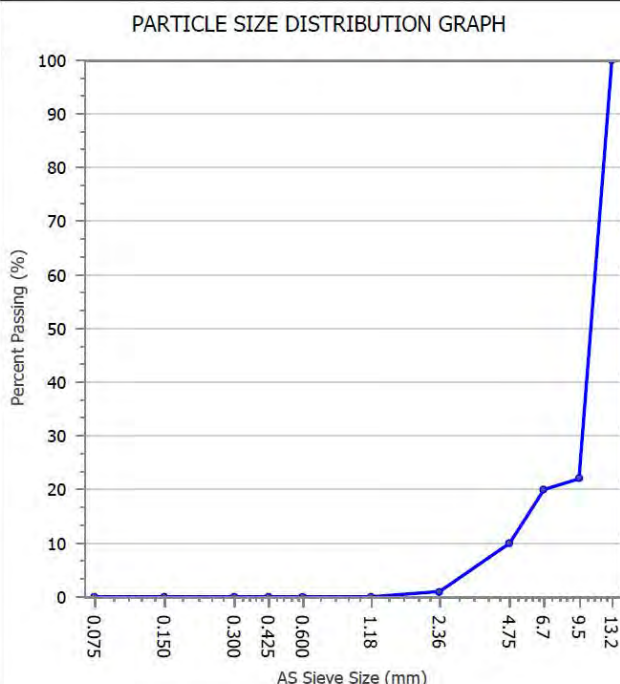
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PARTICLE SIZE DISTRIBUTION REPORT

Client:	Unitywater	Report Number:	3740/R/54374-1
Client Address:	Level 1, 33 King St, Caboolture	Project Number:	3740/P/2409
Project:	Kawana STP Plastics PSD Testing	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/40890
Supplied To:	Ben Goodall	Client Reference/s:	Sample 12
Area Description:		Report Date / Page:	3/06/2022 Page 1 of 1

Test Procedures:	AS1289.3.6.1		
Sample Number	3740/S/219750	Sample Location	
Sampling Method	Tested As Received	Location1	Sample 12
Date Sampled	28/04/2022	Location2	Replicate
Sampled By	Client Sampled	Location3	1
Date Tested	1/06/2022	Location4	
Material Source	Client Sampled/Supplied	Material Type	Existing

AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)
13.2		100	
9.5		22	
6.7		20	
4.75		10	
2.36		1	
1.18		0	
0.600		0	
0.425		0	
0.300		0	
0.150		0	
0.075		0	



Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.
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REPORT UNLOCKED

Verified By: Paul Mayes

Form ID: W9Rep Rev 2

Attachment 3: University of Newcastle Sample Analysis <1.18mm



Assessment of Microplastics in Kawana Sewage Treatment Plant Wastewater samples

Team Leader: Associate Professor Thava Palanisami

Technical Team:

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Ms Sania Afrose (Nanoplastics)

Update Report No:001

Environmental Plastics Innovation Cluster (EPIC)

Global Innovative Centre for Advanced Nanomaterials (GICAN)

Faculty of Engineering and Built Environment,

The University of Newcastle, Callaghan, NSW 2308

Scope of the work

The overall scope for this study was to estimate and characterise (size, shape and polymer type) plastics from Kawana Sewage Treatment Plant wastewater samples.

Samples received

S.No	Sample Codes
1	216982-600
2	216982-425
3	216982-300
4	216982 -PAN
5	216982-150
6	216982 -75
7	Effluent 1(23/12/2021)
8	Effluent 2(20/01/2022)
9	MBBR material

Extraction of microplastics

Sample processing was carried out under clean fume hoods in a Physical Containment (PC2) lab. All working areas were wiped down with 70% ethanol prior to starting experiments. Sample codes were given by laboratory personnel. The solid samples were size fractionated and processed for the $\geq 1\text{mm}$, $\geq 500\text{ }\mu\text{m}$, $\geq 250\text{ }\mu\text{m}$, $\geq 125\text{ }\mu\text{m}$, $\geq 63\text{ }\mu\text{m}$.

Characterisation of microplastics

Microplastics were categorised according to their shapes (fibres, fragments, films, glitter, foam) and sizes (classified into $\geq 1\text{mm}$, $\geq 500\text{ }\mu\text{m}$, $\geq 250\text{ }\mu\text{m}$, $\geq 125\text{ }\mu\text{m}$, $\geq 63\text{ }\mu\text{m}$, $\leq 63\text{ }\mu\text{m}$). After the visual examination, a representative portion of microplastics was analysed using various IR spectroscopy equipment. The spectrum was obtained at the 4cm^{-1} resolution and 16 scans. All of the spectrums were compared with omnic software library.

Results:

1. Classification by Size

S.No	Sample Codes	Weight	≥1mm	≥500 μm	≥250 μm	≥125 μm	≥63 μm	≤63 μm	Total	Per gram
1	216982-600	0.55g	0	423	34	NA	NA	NA	457	830.9
2	216982-425	0.15g	8	136	465	30	NA	NA	639	4260.0
3	216982-300	0.26g	0	8	200	35	NA	NA	243	934.6
4	216982-PAN	0.45g	0	0	12	15	500	750	1277	2837.8
5	216982-150	1.02g	0	0	52	146	96	60	354	347.1
6	216982 -75	0.612g	0	0	180	45	270	680	1175	1919.9

2. Classification by Shape

S.No	Sample codes	Shapes	Concentration (%)
1	216982-600	Fragment (rod shapes)	41.58
		Fragment	58.42
2	216982-425	Fragment	98.44
		Fragment (rod shapes)	1.25
		Fibers	0.31
3	216982-300	Fragment	96.71
		Fragment (rod shapes)	3.29
4	216982 -PAN	Fragment	99.14
		Fragment (rod shapes)	0.47
		Glitter	0.39
5	216982-150	Fragments	96.61
		Fibers	0.85
		Microbead	1.13
		Glitter	1.41
6	216982 -75	Fragment	98.55
		Fragment (rod shapes)	1.11
		Fibers	0.34

*fragments were higher in all samples.

C. Classification by Polymer type

S.No	Sample Codes	Polymer type	Concentration (%)
1	216982-600	Polyethylene (Mn 6500)	3.50
		Polyethylene chlorinated 25- 42 wt%	54.92
		Polypropylene	41.58
2	216982-425	Polyethylene	1.56
		Polyethylene chlorinated 25- 42 wt%	96.87
		Polypropylene, isotactic	1.25
		Polypropylene	0.31
3	216982-300	Polyethylene	4.94
		Polyethylene chlorinated 25- 42 wt%	91.77
		Polypropylene, isotactic	3.29
4	216982 -PAN	Polyethylene	1.10
		Polyethylene chlorinated 25- 42 wt%	98.04
		Polypropylene	0.47
		Polyethylene terephthalate	0.39
5	216982-150	Polyethylene	13.56
		Polyethylene chlorinated 25- 42 wt%	79.38
		Polypropylene, isotactic	3.67
		Polyethylene terephthalate	1.13
		Polyethylene	1.13
		Polyester	0.85
6	216982 -75	Polyethylene	2.30
		Polyethylene chlorinated 25- 42 wt%	96.26
		Polyester	0.34
		Polypropylene, isotactic	1.11

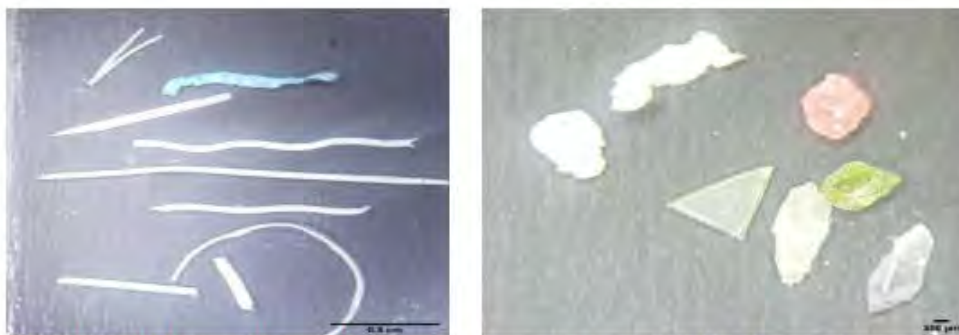


Fig 1 & 2. Rod shaped fragments and other fragments types found in the samples

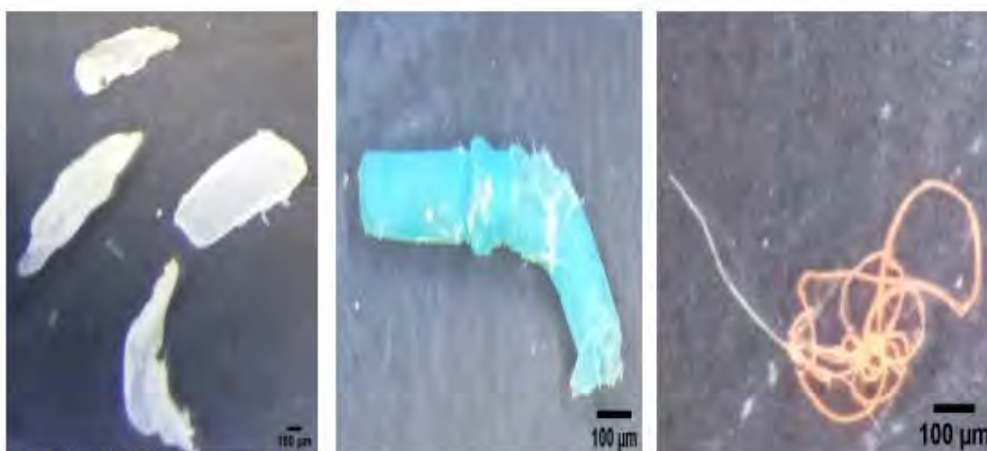


Fig 3&4. Fragments and fibres

Observation: The fragments were common among all the sample types. The white fragments were repetitive and can go down to $>63 \mu\text{m}$ which made up of Polyethylene chlorinated 25- 42 wt%.

WATER SAMPLES:

Two samples (Effluent 1 and Effluent 2) were filtered processed upto fine micron size, found no plastics and only non-plastic fragments made up bleaching agent.

Most of the published microplastics-WWTP studies showed fibres were common in treated wastewater whereas in the given samples there were no fibres detected and found only non-plastics (Bleaching agents).



Fig 5 & 6. Fragments in the effluent and MBBR unit

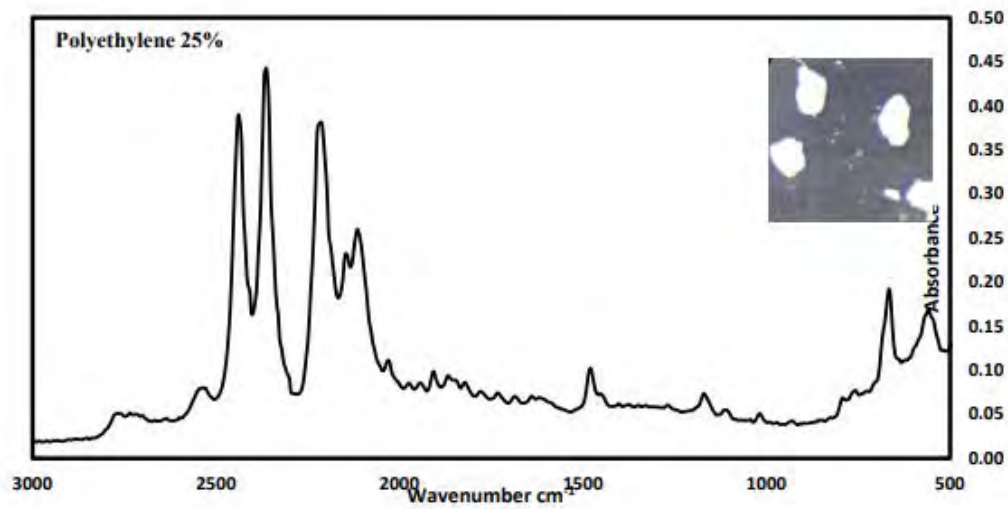


Fig 7. Spectra and the polymer type match with respective compound for the white fragments.
X axis – Wavenumber cm^{-1} . Y axis Absorbance.

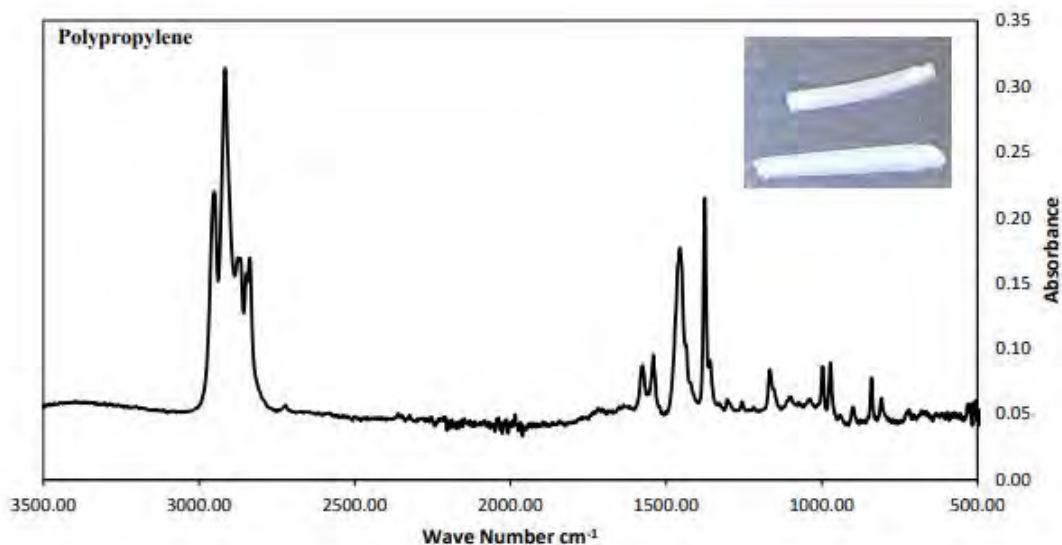


Fig 8. Spectra and the polymer type match with respective compound for the rod shaped fragments. X axis – Wavenumber cm^{-1} . Y axis Absorbance

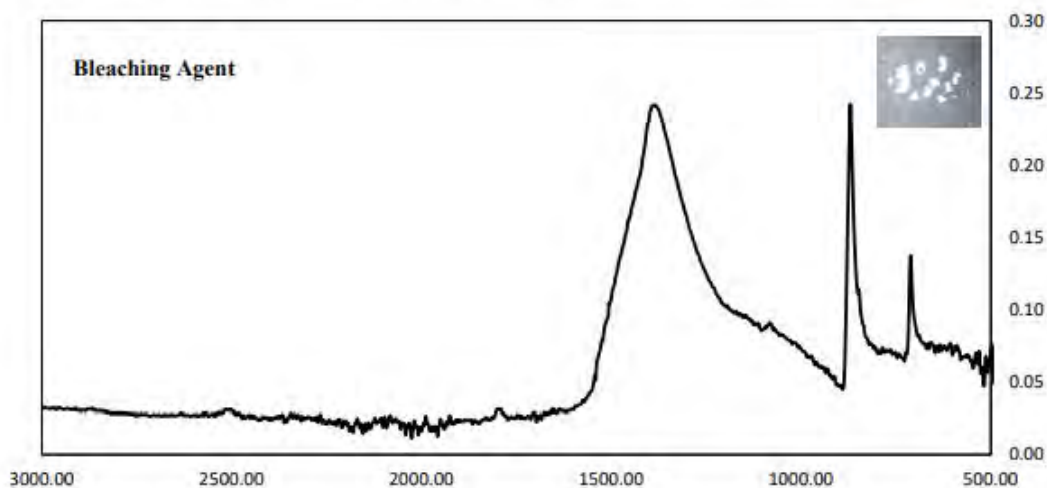


Fig 9. Polymer type match with respective compound for effluent non -plastic particles X axis – Wavenumber cm^{-1} . Y axis Absorbance.

References

Raju, S., Carbery, M., Kuttykattil, A., Senthirajah, K., Lundmark, A., Rogers, Z., Seb, S., Evans, G. and Palanisami, T. (2020) Improved methodology to determine the fate and transport of microplastics in a secondary wastewater treatment plant. Water Research.

Attachment 5: Results of Particle Size Distribution > 1.18mm Classified by Material Type

Sample Date		1.18 mm to 2.36 mm			2.36 mm to 4.75 mm			4.75 mm to 6.7 mm			6.7 mm to 9.5mm			> 9.5 mm		
		Material Type			Material Type			Material Type			Material Type			Material Type		
		MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic
25/11/2021	Mass (g)	1.5692	1.8879	0.256	54.5678	3.4734	5.2396	43.3977	0.02209	0.0426	5.0645	0	1.283	976.7715	0.046	0.1443
	% in Type	42.26%	50.84%	6.89%	86.23%	5.49%	8.28%	99.85%	0.05%	0.10%	79.79%	0.00%	20.21%	99.98%	0.00%	0.01%
	% MBBR	0.1%	0.2%	0.0%	5.0%	0.3%	0.5%	4.0%	0.0%	0.0%	0.5%	0.0%	0.1%	89.3%	0.0%	0.0%
9/12/2021	Mass (g)	12.480 ¹	2.6098	5.9272	75.1367	6.2844	7.6448	47.6843	0.2954	2.3491	5.213	0.7061	4.9404	1062.135 ²	0.1292	1.2202
	% in Type	59.38%	12.42%	28.20%	84.36%	7.06%	8.58%	94.75%	0.59%	4.67%	48.00%	6.50%	45.49%	99.87%	0.01%	0.11%
	% MBBR	1.0%	0.2%	0.5%	6.1%	0.5%	0.6%	3.9%	0.0%	0.2%	0.4%	0.1%	0.4%	86.0%	0.0%	0.1%
22/12/2021	Mass (g)	6.9335	1.0352	2.3323	53.951	5.525	4.0985	40.7554	0.2929	1.0905	9.0455	1.5286	0.2486	1125.090 ⁶	0.1898	0.624
	% in Type	67.31%	10.05%	22.64%	84.86%	8.69%	6.45%	96.72%	0.70%	2.59%	83.58%	14.12%	2.30%	99.93%	0.02%	0.06%
	% MBBR	0.6%	0.1%	0.2%	4.3%	0.4%	0.3%	3.3%	0.0%	0.1%	0.7%	0.1%	0.0%	89.8%	0.0%	0.0%
6/01/2022	Mass (g)	11.204	1.3128	1.6461	60.3866	3.4391	3.0614	51.6249	0.0504	0.2548	9.8561	0.0755	0.9835	967.291	0.0499	15.5731
	% in Type	79.11%	9.27%	11.62%	90.28%	5.14%	4.58%	99.41%	0.10%	0.49%	90.30%	0.69%	9.01%	98.41%	0.01%	1.58%
	% MBBR	1.0%	0.1%	0.1%	5.4%	0.3%	0.3%	4.6%	0.0%	0.0%	0.9%	0.0%	0.1%	85.8%	0.0%	1.4%
20/01/2022	Mass (g)	5.5796	0.7644	1.357	53.2769	2.6695	2.6656	51.3956	0.00343	0.00015	10.7481	0	0	980.1291	0.0036	0.016
	% in Type	72.45%	9.93%	17.62%	90.90%	4.55%	4.55%	99.99%	0.01%	0.00%	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
	% MBBR	0.5%	0.1%	0.1%	4.8%	0.2%	0.2%	4.6%	0.0%	0.0%	1.0%	0.0%	0.0%	88.4%	0.0%	0.0%
3/02/2022	Mass (g)	5.0416	0.9245	2.3701	65.4983	3.1744	3.1015	51.4702	0.0665	0.0447	9.8819	0.0515	0.1029	810.7679	0.0715	0.0787
	% in Type	60.48%	11.09%	28.43%	91.26%	4.42%	4.32%	99.78%	0.13%	0.09%	98.46%	0.51%	1.03%	99.98%	0.01%	0.01%
	% MBBR	0.5%	0.1%	0.2%	6.9%	0.3%	0.3%	5.4%	0.0%	0.0%	1.0%	0.0%	0.0%	85.1%	0.0%	0.0%
17/02/2022	Mass (g)	2.9654	0.7333	2.0121	37.7829	2.1767	1.6155	33.1698	0.0554	0.03342	5.8847	0.025	0.2055	806.5693	0.0353	0.1683
	% in Type	51.93%	12.84%	35.23%	90.88%	5.24%	3.89%	99.73%	0.17%	0.10%	96.23%	0.41%	3.36%	99.97%	0.00%	0.02%
	% MBBR	0.3%	0.1%	0.2%	4.2%	0.2%	0.2%	3.7%	0.0%	0.0%	0.7%	0.0%	0.0%	90.3%	0.0%	0.0%
28/02/2022 & 4/03/2022	Mass (g)	2.3799	1.1509	2.0763	32.0618	2.8932	2.9343	27.8893	0.4026	0.2609	4.4277	0.2144	0.1444	844.7282 ³	0	2.5361
	% in Type	42.44%	20.53%	37.03%	84.62%	7.64%	7.74%	97.68%	1.41%	0.91%	92.50%	4.48%	3.02%	99.70%	0.00%	0.30%
	% MBBR	0.3%	0.1%	0.2%	3.5%	0.3%	0.3%	3.0%	0.0%	0.0%	0.5%	0.0%	0.0%	91.4%	0.0%	0.3%

Sample Date		1.18 mm to 2.36 mm			2.36 mm to 4.75 mm			4.75 mm to 6.7 mm			6.7 mm to 9.5mm			> 9.5 mm		
		Material Type			Material Type			Material Type			Material Type			Material Type		
		MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic	MBBR Plastic	Non-MBBR Plastic	Non-Plastic
17/03/2022	Mass (g)	3.8113	0.9763	1.4992	40.8661	3.3499	2.5883	52.2851	0.3814	0.221	11.3374	0.1732	0.1699	764.8655	0	0.1594
	% in Type	60.62%	15.53%	23.85%	87.31%	7.16%	5.53%	98.86%	0.72%	0.42%	97.06%	1.48%	1.45%	99.98%	0.00%	0.02%
	% MBBR	0.4%	0.1%	0.2%	4.6%	0.4%	0.3%	5.9%	0.0%	0.0%	1.3%	0.0%	0.0%	86.7%	0.0%	0.0%
1/04/2022	Mass (g)	7.01	1.2638	1.7634	44.4029	2.444	2.4599	71.5668	0.2476	0.1617	7.6345	0.3761	0.0698	692.2594	0.1527	0.1843
	% in Type	69.84%	12.59%	17.57%	90.05%	4.96%	4.99%	99.43%	0.34%	0.22%	94.48%	4.65%	0.86%	99.95%	0.02%	0.03%
	% MBBR	0.8%	0.2%	0.2%	5.3%	0.3%	0.3%	8.6%	0.0%	0.0%	0.9%	0.0%	0.0%	83.2%	0.0%	0.0%
14/04/2022	Mass (g)	9.236	1.5979	2.8651	70.0455	4.4563	4.5175	102.1333	0.371	0.812	3.349	0.0779	0.005	676.54	0.1276	0.1889
	% in Type	67.42%	11.66%	20.91%	88.64%	5.64%	5.72%	98.85%	0.36%	0.79%	97.58%	2.27%	0.15%	99.95%	0.02%	0.03%
	% MBBR	1.1%	0.2%	0.3%	8.0%	0.5%	0.5%	11.7%	0.0%	0.1%	0.4%	0.0%	0.0%	77.2%	0.0%	0.0%
28/04/2022	Mass (g)	6.0105	0.8916	0.6439	80.542	2.616	1.6729	93.2197	0.2094	0.0423	16.4632	0.0665	0.0664	719.5215	0	0.0137
	% in Type	79.65%	11.82%	8.53%	94.94%	3.08%	1.97%	99.73%	0.22%	0.05%	99.20%	0.40%	0.40%	100.00%	0.00%	0.00%
	% MBBR	0.7%	0.1%	0.1%	8.7%	0.3%	0.2%	10.1%	0.0%	0.0%	1.8%	0.0%	0.0%	78.0%	0.0%	0.0%

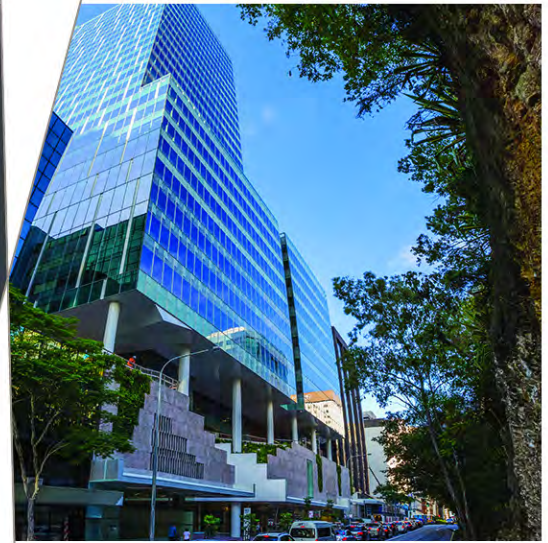
Appendix D SAQP P2, P3 & P7: Assessment of MBBR plastic media in effluent and comparison to microplastics entering the STP.

Appendix D: SAQP P2, P3 Assessment of microplastics in Kawana Sewage Treatment Plant

KAWSTP Project Management
Services

*Prepared for
Unitywater*

28 June 2022



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now

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Team Leader – Water Infrastructure

Date Approved 9/06/2022

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2	9 June 2022	Updates after comments	R.Donald	D.Gutteridge
3	28 June 2022	Updates after comments	R.Donald	R.Donald

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Summary

Microplastic particles in effluent from Kawana STP plant were investigated to determine the total amount of microplastic particles, and what proportion may have originated from MBBR carriers. The effluent stream was sampled downstream of the effluent basket screens and therefore not expected to contain particles larger than the screen aperture size of 2 mm.

The average concentration of microplastic particles was 20.8 microplastic particles per litre of effluent. Of these microplastic particles, between 23.9% and 93.3% were likely to have originated from the degradation of MBBR plastic media within the plant.

The term “Black PE” was used in this study to define a black polyethylene microplastic particle that may have originated from MBBR plastic media based on an assessment of colour, shape, and chemical composition. A complete match to MBBR plastic media was not possible due to variability of material and impact of environmental factors on the plastic.

Hydraulic flow rates in the STP do not appear to influence the concentration of microplastic particles less than 2 mm in size in the effluent or the proportion of Black PE materials. There was insufficient evidence to determine if the concentration of microplastics or the proportion of Black PE particles in the effluent was increasing or decreasing. The microplastic particle concentration in the effluent was higher than that reported from many other studies, however the scope of these other comparative studies limited the strength of this conclusion.

The mass of Black PE microplastic particles being discharged from Kawana STP was estimated and the results aligned with a previous study (refer Appendix E) that calculated between 20,000 and 38,000 kg of MBBR plastic media particles may have been lost from the in-service carriers in the bioreactor at Kawana STP over 2-years of operation.

A novel method for analysing the mass concentration of microplastic particles in a liquid stream onsite was tested by the University of Newcastle during this study, however this did not provide reliable results and the samples were subsequently tested in the laboratory.

The analysis of microplastic particles in STP streams is a new area of research that has yet to define a standardised approach in areas such as sampling methods, particle size analysis, and reporting. In particular, the sampling method has a high potential to influence the results.

Table of Contents

1	Introduction	1
2	Methods	2
2.1	Sampling	2
2.2	Sample Preparation	6
2.3	Microplastics Analysis	6
2.4	Novel Method for Total Plastic Mass Analysis	6
3	Results	7
3.1	Monthly Effluent	7
3.2	Wet Weather Effluent	8
3.3	Additional Stream Sampling	8
4	Analysis of Results	11
4.1	Influent	11
4.2	Effluent	11
4.3	Wet Weather Effluent	13
4.4	MBBR Feed	13
4.5	MBBR Discharge	14
4.6	Biosolids	14
4.7	Sampling Method	14
4.8	Comparison to Other STPs	15
5	Conclusion and Recommendations	16
6	Attachments	17

Attachments

Attachment 1: Microplastics Analysis Results

Attachment 2: University of Newcastle Report on Microplastics Analysis

Attachment 3: Published Results of Other Microplastics Studies at WWTPs

Attachment 4: University of Newcastle Report on Novel Method for Total Plastic Mass Analysis

Tables

Table 1 - Sampling Point Close Up Photos	3
Table 2 - Monthly Effluent Sample MP Results	7
Table 3 - Wet Weather Effluent Sample MP Result	8
Table 4 - Additional Influent Sample MP Results	9
Table 5 - Additional Effluent Sample MP Results	9
Table 6 - Additional MBBR Feed Sample MP Results	10
Table 7 - Additional MBBR Discharge Sample MP Results	10
Table 8 - Additional Biosolids MP Results	10
Table 9 - All Effluent Sample MP Results (Excluding Wet Weather and First 2 Samples)	11
Table 10 - Estimated MBBR Particle Size and Mass	12
Table 11 - Estimated Daily Mass Release of Black PE Particles in Effluent	12
Table 13 - Estimated Mass Release of Black PE Particles in Biosolids	14

Figures

Figure 1 - Sampling Points in Relation to Process Schematic	3
Figure 2 - Sampling Points in Relation to Plant Layout	4
Figure 3 - Glass Sample Container Inside Auto Sampling Machine	5
Figure 4 - Metal 10L Jerry Can for Transporting Water Samples	5
Figure 5 - Schematic of MP Results	7
Figure 6 - Effluent MP Concentration: Monthly Data	8
Figure 7 - Schematic of MP Results	10
Figure 8 - Correlation of MP Concentration and % Black PE in Effluent on STP Inflow	12
Figure 9 - MP Concentration All Effluent Samples	13

1 Introduction

This report describes an investigation into microplastic (MP) particles leaving Kawana Sewage Treatment Plant (STP) in the effluent during normal dry weather conditions and in wet weather conditions. The purpose of the investigation was to determine the quantity and type of MPs in the effluent and the contribution from the Moving Bed Biological Reactor (MBBR) plastic media. This investigation was initiated to support the Notice to conduct or commission an environmental evaluation EPPR00869113 issued by Department of Environment and Science on 14 December 2021. In particular, the study intended to address Items P2 and P3 of the Sampling and Quality Plan (SAQP). This investigation sought to answer the following key questions:

1. Can MP particles originating from MBBR plastic media be detected in the plant effluent and if so, in what quantity and is it increasing or decreasing?
2. Is the amount of MP particles in the effluent influenced by different hydraulic scenarios of the plant?

The study further investigated other selected liquid streams as well as biosolids within the Kawana STP plant to help identify the source of MPs in the effluent. A complete mass balance of MPs for the plant is a major undertaking due to the large numbers of unit processes configured in parallel and series that separate liquids and solids, and due to the number of internal recycle streams. Isolating the contribution of MBBR plastic particles using a mass balance analysis is therefore beyond the scope of this investigation. The streams analysed beyond the effluent were:

- influent entering the STP;
- MBBR feed (after primary settling);
- MBBR discharge (before secondary clarifiers), and;
- Biosolids after anaerobic digestion and dewatering.

MP studies at STPs is a relatively new area of research and although some studies show consistency in analysis equipment, few standards exist in areas such as sampling techniques, classification of results or size fractions of MP particles. Attachment 3 provides results of other studies on MPs at other STPs and a comparison of the results of this study has been made to some other investigations.

In further work, a novel method for total plastic mass analysis using a prototype analysis machine developed by University of Newcastle was tested on site for measuring total MP concentration. The objective of this work was to confirm an analysis technique that could analyse MP in liquid wastewater streams much faster and with less operator intervention than traditional laboratory techniques.

This report has been prepared as an Appendix for a separate report addressing environmental evaluation EPPR00869113 where items beyond the scope of this report are considered. An explanation of the background leading to the environmental evaluation and overview of Kawana STP can be found in that report.

2 Methods

2.1 Sampling

In accordance with the SAQP, a liquid effluent sample was collected monthly for 6 months, and a further sample was taken during the wet weather event at the end of February 2022 to provide data under different hydraulic conditions. The monthly effluent samples were taken using a Hach peristaltic auto-sampler taking hourly subsamples. The subsamples for the first two effluent samples were initially taken using a flow paced algorithm where quantity is proportional to influent flowrate, however this was later changed to fixed volume subsamples after MP results identified sampling problems using this method (refer description later in this section).

In addition to the monthly effluent samples, additional streams were sampled on 6 separate days to include influent, MBBR feed, MBBR discharge, final STP effluent, and biosolids. Although the plant experienced a degree of wet weather flows, sampling of these streams was delayed until the plant inflow was closer to ADWF.

Details of the additional individual sample streams are as follows:

1. **Influent:** the objective of this sample stream was to measure the MP entering the STP from external sources. This sample point collected raw sewage entering the STP, but excluded septage and thickened waste activated sludge (WAS) from Maleny STP (average 7.5 kL /day, compared to 140 kL/day primary thickened sludge and 41 kL/day secondary thickened sludge from Kawana STP, equivalent to approximately 4% of plant sludge volume). The sampling point also excluded septage and holding tank waste at an average 26 kL/day, equivalent to <0.1% of influent. Approximately 3 L sample was collected over each 24-hour period, comprising hourly sub-samples of equal volume.
2. **MBBR Feed:** the objective of this sample point was to measure MP particles entering the MBBR from external sources by taking samples of MBBR feed after screening, degritting, and primary settling but including liquid recycles from primary sludge dewatering (although expected to be minor compared to the MBBR feed). Approximately 5 L sample was collected over each 24-hour period, comprising hourly sub-samples of equal volume.
3. **MBBR discharge:** the objective of this sample point was to measure MP particles leaving the MBBR, hence include any contribution of MPs from the MBBR itself. Based on the MPs entering the MBBR from external sources, the contribution of MPs from breakdown of MBBR plastic media is expected to be the difference between MPs leaving and entering the MBBR. This sample point included the effects of any MPs recirculated from secondary sludge dewatering and digested sludge dewatering. Approximately 5 L sample was collected over each 24-hour period, comprising hourly sub-samples of equal volume.
4. **Effluent:** the objective of this sample point was to measure the MPs leaving the STP in the treated effluent. The autosampler drew treated effluent from the pipe connecting Chlorine Contact Tank 3 (CCT3) and the wet well for the effluent pump station. With the sample point being downstream of the effluent basket screens, this liquid stream was not expected to contain particles larger than the screen aperture size of 2 mm. Approximately 10 L sample was collected over each 24-hour period, comprising hourly sub-samples of equal volume.
5. **Biosolids:** the objective of this sample point was to measure the MP leaving the STP in sludge form. The biosolids sampling point was after anaerobic digestion and dewatering, with the sludge containing a combination of process streams from the Primary Lamella Settling Tanks (PLST) and the Secondary Lamella Clarifiers (SLC). Because this sample point contains biosolids originating from these combined streams, it is not possible to directly compare this stream with the MBBR feed and discharge streams, but data from this could provide a comparative indication of where MP leave the STP via the biosolids. Four grab samples of approximately 200 g were collected from the biosolids hopper discharge conveyor during a biosolids truck load-out event. Two of these samples were taken consecutively and analysed separately to provide insight into variability between adjacent samples.

In general, auto sampling machines were used to take a designated quantity of liquid from the process stream each hour over a 24-hour period. For biosolids, a grab sample from the discharge of the biosolids hopper was taken. Sample point locations are as shown in Figure 1, Figure 2, and Table 1.

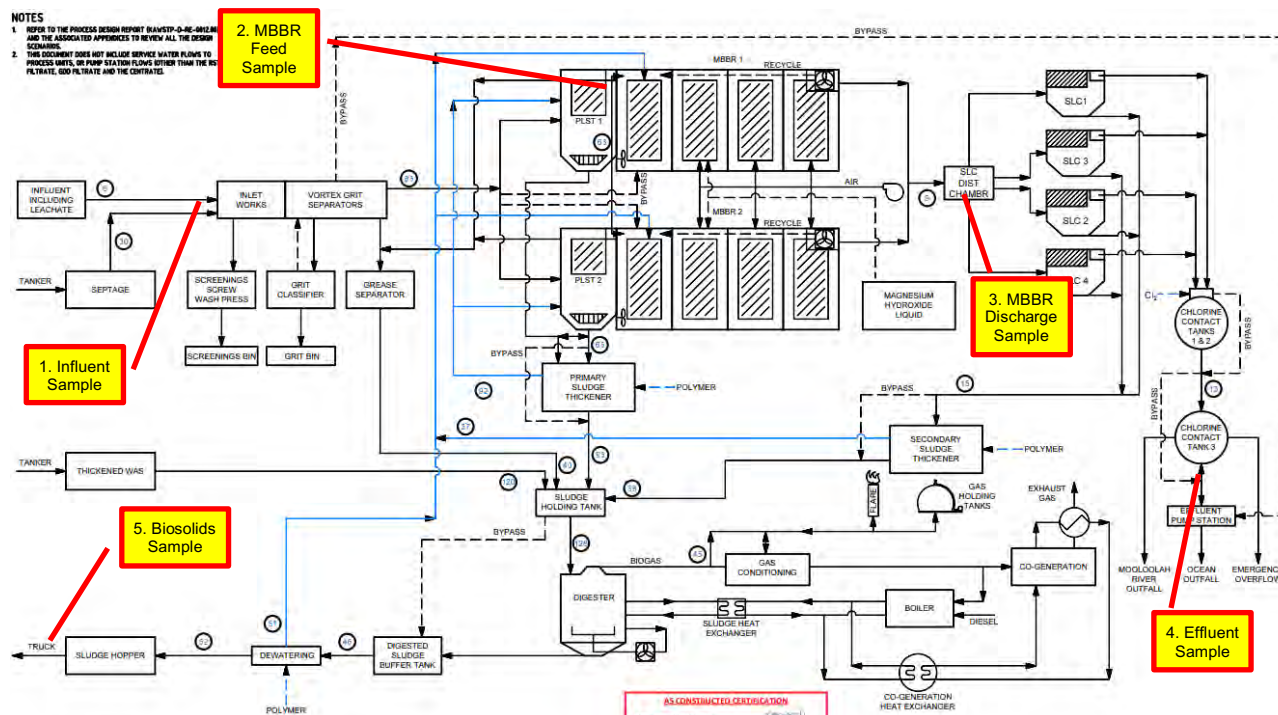


Figure 1 - Sampling Points in Relation to Process Schematic

Table 1 - Sampling Point Close Up Photos

Influent Sample	MBBR Feed Sample	MBBR Discharge Sample	Effluent Sample	Biosolids Sample
				

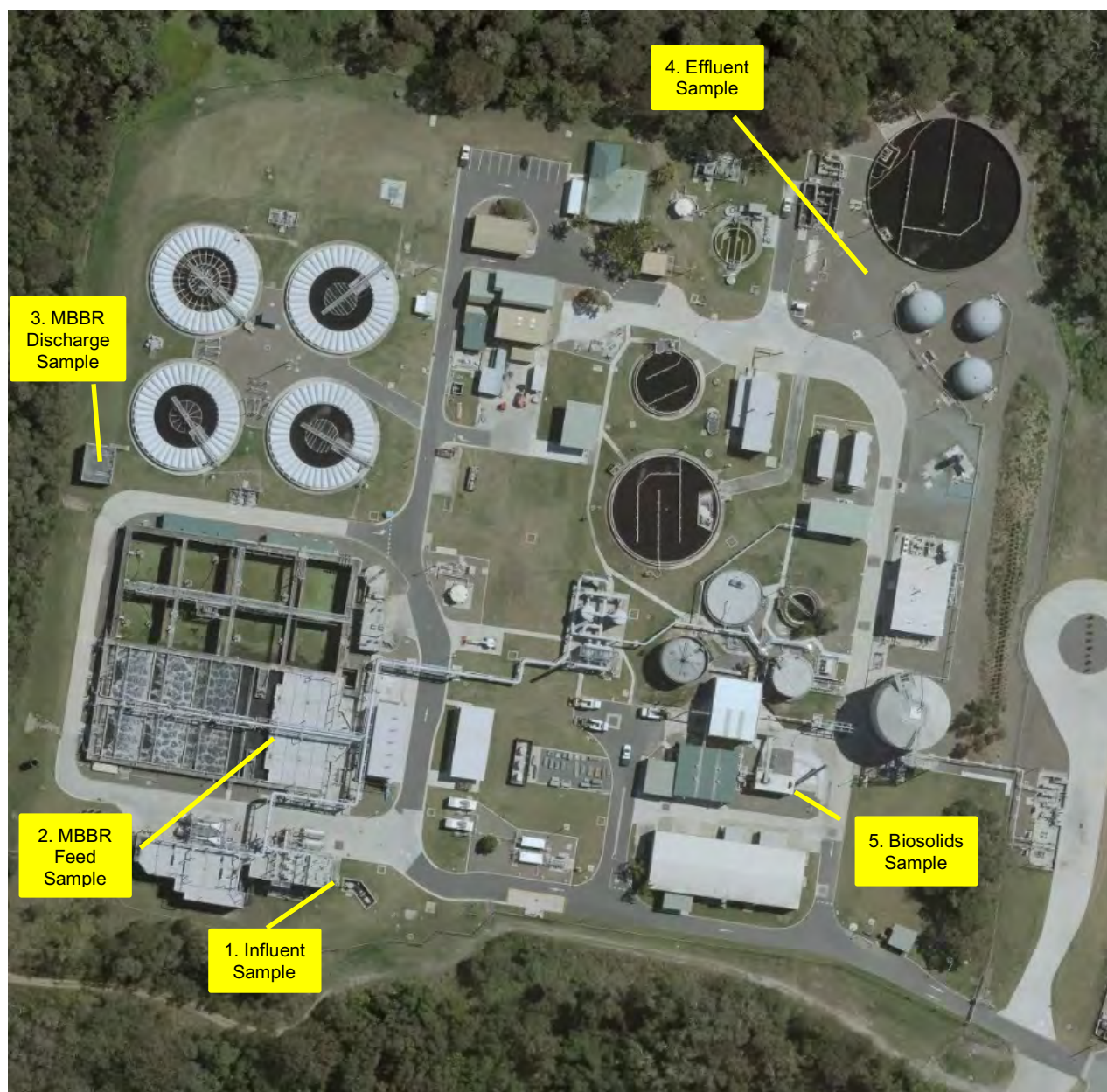


Figure 2 - Sampling Points in Relation to Plant Layout

Liquid samples were collected and stored in non-plastic containers (Figure 3 and Figure 4), however the samples were inevitably exposed to some plastic materials, most notably the collection hose for the auto-sampler. With the hydraulic residence time of the STP limited to much less than 1 day, the liquid samples were taken over the same 24-hour period. However, because the sludge residence time in the STP is much greater than 24 hours and is well mixed, aligning to the same 24-hour sampling period was not possible for the biosolids and therefore 4 biosolids samples were analysed on dates suitable for sampling. The samples were sent to the University of Newcastle for microplastics analysis, described further in this report.



Figure 3 - Glass Sample Container Inside Auto Sampling Machine

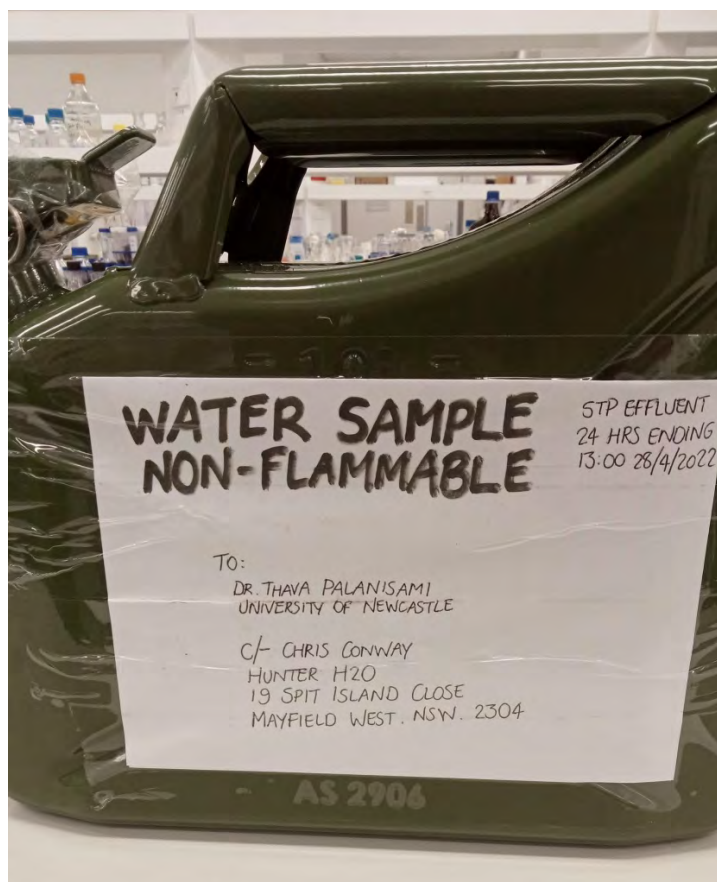


Figure 4 - Metal 10L Jerry Can for Transporting Water Samples

The sample details described above were followed for liquid samples, however after receiving the first two effluent results where, unexpectedly, no MPs were identified in the effluent samples (refer Attachment 1), the sampling methodology was reviewed and adjusted. In the case of these two early samples, the sampling error was identified as likely being as a result of liquid overflowed from the sample collection container, allowing MPs with lower SG than water (i.e. floating) to escape the vessel. This issue was corrected by adjusting the incremental sub-sample volumes to a value that avoided sample container overflowing and changing from flow paced subsample volumes to fixed volumes. However, in the interim period before this issue was conclusively identified, some manual grab samples were taken as noted in Attachment 1. Grab samples were recommended by the University of Newcastle as an industry standard for MP sampling which overcame the specific limitation with the autosampler, but could not represent the sample stream over a full 24-hour duration.

2.2 Sample Preparation

The method used for sample preparation by the University of Newcastle, including organics digestion and particle size sieving is described further in Attachment 1.

2.3 Microplastics Analysis

Microplastics analysis was carried out by the University of Newcastle with details of the methodology described in Attachment 1. It is important to note that conclusive confirmation that a MP particle has originated from MBBR plastic media is almost impossible. The techniques used in this study compared particles on the basis of colour, shape, and chemical composition based on Fourier Transformed Infrared (FTIR) Spectroscopic imaging techniques described on Attachment 2. With the Hel-X MBBR media being fabricated from recycled polyethylene, there is likely to be batch-to-batch variability in chemical composition, and the presence of biofilm of varying microscopic thickness attached to MP particles complicates the positive identification of the origins of the MP particles. Based on this, where a MP particle was identified as potentially being from MBBR plastic media based on colour, shape, and similar chemical composition, it was termed “Black PE” in this study. To accurately classify the origin of MP particles, a chemical or radioactive tracer might be a consideration, however this option is not possible for this study where the MBBR plastic media is already existing.

2.4 Novel Method for Total Plastic Mass Analysis

A novel method for analysing total plastic mass in a liquid effluent sample was tested at Kawana STP. Details of the methodology are described in Attachment 3.

3 Results

Attachment 1 shows the results of all microplastic analysis for samples collected at Kawana STP. The data is colour highlighted according to sample type, with results showing MP count by size fraction and MP shape type. Note that most influent stream samples contained significant quantities of fibre-shaped MPs where particle counting was not practicable. In this case, the results are shown as mass rather than particle count and these are highlighted in Attachment 1.

A summary of results for each sample stream is described in the following sub sections and the significance of the results is discussed in Section 4. Figure 5 provides a summary of all results.

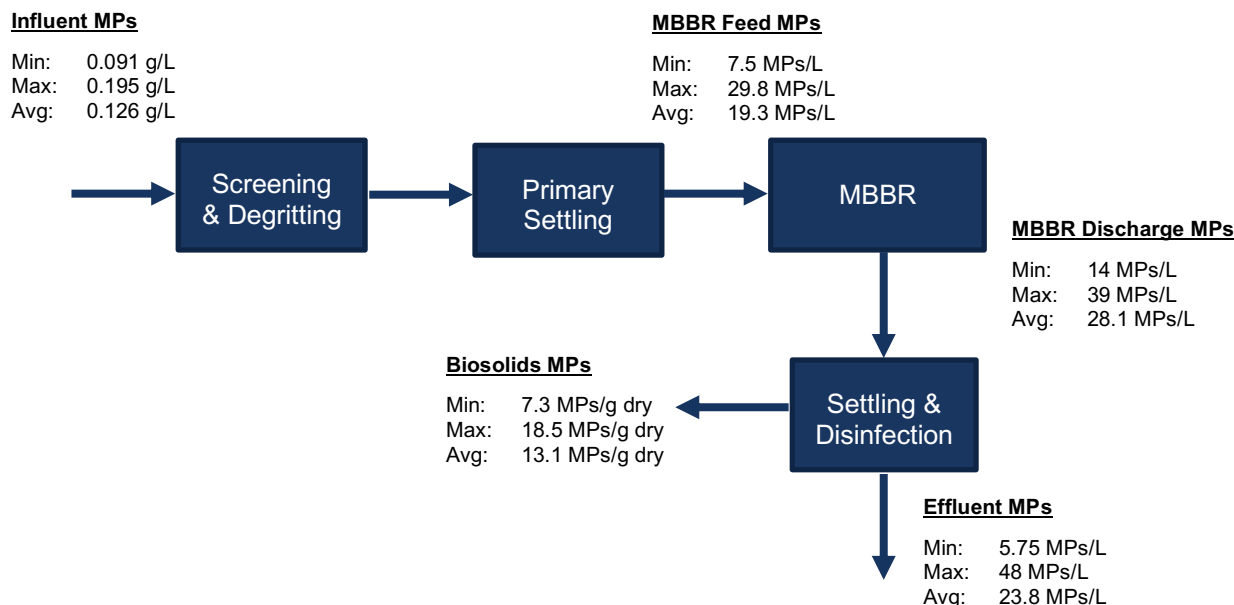


Figure 5 - Schematic of MP Results

3.1 Monthly Effluent

Results of monthly effluent samples are shown in the data in Attachment 1. Noting that Attachment 1 contains all effluent sample data, including monthly samples as well as effluent samples that form part of the individual sample streams described in Section 2.1, data is summarised for monthly effluent samples in Table 2. Particle size distribution for the effluent samples where MPs were found is shown in Figure 6.

Table 2 - Monthly Effluent Sample MP Results

Sample Date		23/12/2021	20/01/2022	17/02/2022	23/03/2022	28/04/2022	11/05/2022
Volume Analysed (L)		9	9	4	5	3	3
No. of MP particles	≥ 1mm	0	0	0	0	3	0
	≥ 500 µm	0	0	1	0	2	1
	≥ 250 µm	0	0	7	7	5	12
	≥ 125 µm	0	0	2	0	12	6
	≥ 63 µm	0	0	61	9	18	11
	≤ 63-11 µm	0	0	9	80	9	16
	Total	0	0	80	96	49	46
MPs per L		0	0	20	19.2	16.3	15.3
No. Black PE particles		0	0	54	86	12	11
% Black PE particles		N/A	N/A	67.5%	89.6%	24.5%	23.9%



Figure 6 - Effluent MP Concentration: Monthly Data

3.2 Wet Weather Effluent

Results for the wet weather event where Kawana STP experienced high flows in February 2022 (approx. 5xADWF) is shown in Table 3 highlighting the concentration of MPs in effluent during wet weather is more than twice that during dry weather flow.

Table 3 - Wet Weather Effluent Sample MP Result

Sample Date		25/2/2022
Volume Analysed (L)		2.5
No. of MP particles	≥ 1mm	3
	≥ 500 µm	0
	≥ 250 µm	14
	≥ 125 µm	24
	≥ 63 µm	19
	≤ 63-11 µm	60
	Total	120
MPs per L		48
No. Black PE particles		52
% Black PE particles		43.3%

3.3 Additional Stream Sampling

In addition to the monthly sampling sent to the University of Newcastle, a field crew was sent to site between 4th and 8th April, 2022 to provide more detailed analysis of the liquid and solid streams. The field crew took a number of samples and used a novel method for analysing MP's described in Attachment 3. While the analysis method provided encouraging results for measuring the quantity of some plastics, it was unsuitable for measuring the opaque black plastic media particles. Given the unsuitability of the field measuring equipment the samples collected were returned to the University and results obtained using the same techniques to assess the monthly samples.

Results of MP analysis for the 6 samples are summarised from Attachment 1 in Table 4, While other process streams comprise 6 additional samples, Table 5 only shows results for 4 samples because the sample taken on 17/2/2022 was also part of the monthly effluent samples (refer Table 2 for results) and the effluent sample taken on 2/3/2022 was inadvertently contaminated and had to be discarded.

Table 5, Table 6, Table 7, and Table 8. All liquid samples were taken by auto sampler except for the manual grab sample taken on 8/4/2022.

Table 4 - Additional Influent Sample MP Results

Sample Date		17/02/2022	2/03/2022	14/03/2022	20/03/2022	21/03/2022	8/4/2022
Volume Analysed (L)		3	2	2	2	2	2
Mass (g) of MP / No. of MP particles	≥ 1mm	0.24 g	2	0.087 g	0.061 g	0.024 g	8
	≥ 500 µm	0.3 g	1	0.015 g	0.012 g	0.09 g	19
	≥ 250 µm	0.021 g	5	0.074 g	0.058 g	0.108 g	1
	≥ 125 µm	0.013 g	7	0.017 g	0.045 g	0.011 g	16
	≥ 63 µm	0.007 g	6	0.008 g	0.006 g	0.003 g	6
	≤ 63-11 µm	0.004 g	7	2	8	5	11
	Total*	0.585 g	28	0.201 g	0.182 g	0.236 g	61
MPs per L ⁺		N/A	14	N/A	N/A	N/A	30.5
No. Black PE particles		0	0	0	0	0	0
% Black PE particles		0	0	0	0	0	0

* Total MP mass neglects particles in ≤ 63-11 µm size fraction

+ MPs per L not applicable for MP mass measurements

While other process streams comprise 6 additional samples, Table 5 only shows results for 4 samples because the sample taken on 17/2/2022 was also part of the monthly effluent samples (refer Table 2 for results) and the effluent sample taken on 2/3/2022 was inadvertently contaminated and had to be discarded.

Table 5 - Additional Effluent Sample MP Results

Sample Date		14/03/2022	20/03/2022	21/03/2022	8/4/2022
Volume Analysed (L)		4	5	4	2
No. of MP particles	≥ 1mm	0	2	0	2
	≥ 500 µm	0	0	0	0
	≥ 250 µm	1	4	5	6
	≥ 125 µm	2	13	2	2
	≥ 63 µm	8	26	3	7
	≤ 63-11 µm	12	90	84	62
	Total	23	135	94	79
MPs per L		5.75	27	23.5	39.5
No. Black PE particles		12	126	87	57
% Black PE particles		52.2%	93.3%	92.6%	72.2%

Table 6 - Additional MBBR Feed Sample MP Results

Sample Date		17/02/2022	2/03/2022	14/03/2022	20/03/2022	21/03/2022	8/4/2022
Volume Analysed (L)		5	2	2	2	2	2
No. of MP particles	≥ 1mm	2	1	0	0	0	1
	≥ 500 µm	8	2	0	0	0	0
	≥ 250 µm	15	2	1	2	14	4
	≥ 125 µm	75	7	27	3	16	2
	≥ 63 µm	13	4	2	8	18	2
	≤ 63-11 µm	36	2	17	24	7	6
	Total	149	18	47	37	55	15
MPs per L		29.8	9	23.5	18.5	27.5	7.5
No. Black PE particles		38	8	30	12	47	0
% Black PE particles		25.5%	44.4%	63.8%	32.4%	85.5%	0

Table 7 - Additional MBBR Discharge Sample MP Results

Sample Date		17/02/2022	2/03/2022	14/03/2022	20/03/2022	21/03/2022	8/4/2022
Volume Analysed (L)		5	2	2	2	2	2
No. of MP particles	≥ 1mm	0.1 g	0	2	0	0	0
	≥ 500 µm	0	5	14	4	4	3
	≥ 250 µm	6	1	12	12	12	2
	≥ 125 µm	0	8	14	18	18	6
	≥ 63 µm	5	4	6	28	28	6
	≤ 63-11 µm	64	10	19	16	16	39
	Total	75	28	67	78	78	56
MPs per L		15	14	33.5	39	39	28
No. MBBR-like particles		72	15	50	68	68	49
% Black PE particles		96%	53.6%	74.6%	87.2%	87.2%	87.5%

Table 8 – Additional Biosolids MP Results

Sample Date		15/02/2022	17/02/2022	10/03/2022	10/03/2022
Wet mass analysed (g)		50	50	50	50
No. of MP particles	≥ 1mm	3	9	10	3
	≥ 500 µm	16	14	28	7
	≥ 250 µm	14	70	78	32
	≥ 125 µm	33	74	66	30
	≥ 63 µm	41	46	70	24
	≤ 63-11 µm	9	28	7	12
	Total	116	241	259	108
MPs per g wet biosolids		2.32	4.82	5.18	2.16
No. Black PE particles		53	136	86	34
% Black PE particles		45.7	56.4	33.2	31.5

4 Analysis of Results

4.1 Influent

Analysis of MPs for the influent stream is shown in Table 4 and no Black PE particles were identified. The quantity of MP particles found in the influent samples varied substantially but dominated by large amounts of fibrous material likely to be of plastic origin in 4 out of 6 samples where determining the number of MP particles was not practical. This is not only because of the vast number of particles, but also because the fibrous material clumped together and identifying what could be classified as discrete particles was too subjective. For the influent samples on 2/3/2022 and 8/4/2022 (when the number of MP particles could be reliably counted) 28 and 30.5 MPs/L were found. Comparing these results for the same dates in the MBBR Feed (Table 6), the concentration of MPs reduced by about 36% and 75% respectively. A substantial reduction might be expected between the influent and MBBR Feed with opportunity for MPs to be separated in the screening, degritting, and primary settling processes. In a study by Rasmussen et al (2021) of MPs in a Swedish STP, around 73% of MPs in the influent was removed at the inlet works of the STP. This is consistent with the result found from Kawana STP on 8/4/2022 but not with the sample taken on 2/3/2022. Achieving consistency with this one result on 8/4/2022 is encouraging but limits the conclusions that can be reached.

4.2 Effluent

Neglecting the effluent results from the wet weather event and the initial results from 23/12/2021 and 20/1/2022 where results were skewed due to effluent sampling errors (no MPs found), the effluent MP concentration varied from 5.75 MP/L to 39.5 MP/L (Table 9), giving an average of 20.8 MP/L. The result of 5.75 MP/L from the effluent sample taken on 14/3/2022 is abnormally low compared to other data. Results of the manual grab sample taken on 8/4/2022 is also abnormally high. The reason for these variations is unclear and while neglecting these data points provides substantially more consistency in the results, there is no basis for doing so. Similarly, using the same sample days, the portion of Black PE particles varies between 23.9% and 93.3%, with an average of 64.5%. This is a significant range of results and the impact of flow was investigated because Table 3 suggested a significant increase in effluent MP concentration under high wet weather flow conditions. However, Figure 8 demonstrates the lack of correlation between the portion of Black PE particles and STP inflow, as well as between effluent MP concentration versus STP inflow where a range of hydraulic scenarios was assessed. However, with no clear trend visible in this data, the hypothesis that flow rates influence the concentration of MPs released and the portion of Black PE particles is not supported by the data.

Table 9 – All Effluent Sample MP Results (Excluding Wet Weather and First 2 Samples)

Sample Date		17/02/22	14/03/22	20/03/22	21/03/22	23/03/22	8/4/22	28/04/22	11/05/22	Average
No. of MP particles	≥ 1mm	0	0	2	0	0	2	3	0	0.9
	≥ 500 µm	1	0	0	0	0	0	2	1	0.5
	≥ 250 µm	7	1	4	5	7	6	5	12	5.9
	≥ 125 µm	2	2	13	2	0	2	12	6	4.9
	≥ 63 µm	61	8	26	3	9	7	18	11	17.9
	≤ 63-11 µm	9	12	90	84	80	62	9	16	45.3
	Total	80	23	135	94	96	79	49	46	75.3
MPs per L		20	5.75	27	23.5	19.2	39.5	16.3	15.3	20.8
No. Black PE particles		54	12	126	87	86	57	12	11	55.6
% Black PE particles		67.5	52.2	93.3	92.6	89.6	72.2	24.5	23.9	64.5
STP Influent Flow (ML/d)*		34.6	53.2	44.7	43.5	40.4	36.0	36.1	80.4	46.1

* STP influent flow calculated as average of total daily inflow ending midnight on preceding day of sample and total daily inflow ending midnight on sample day

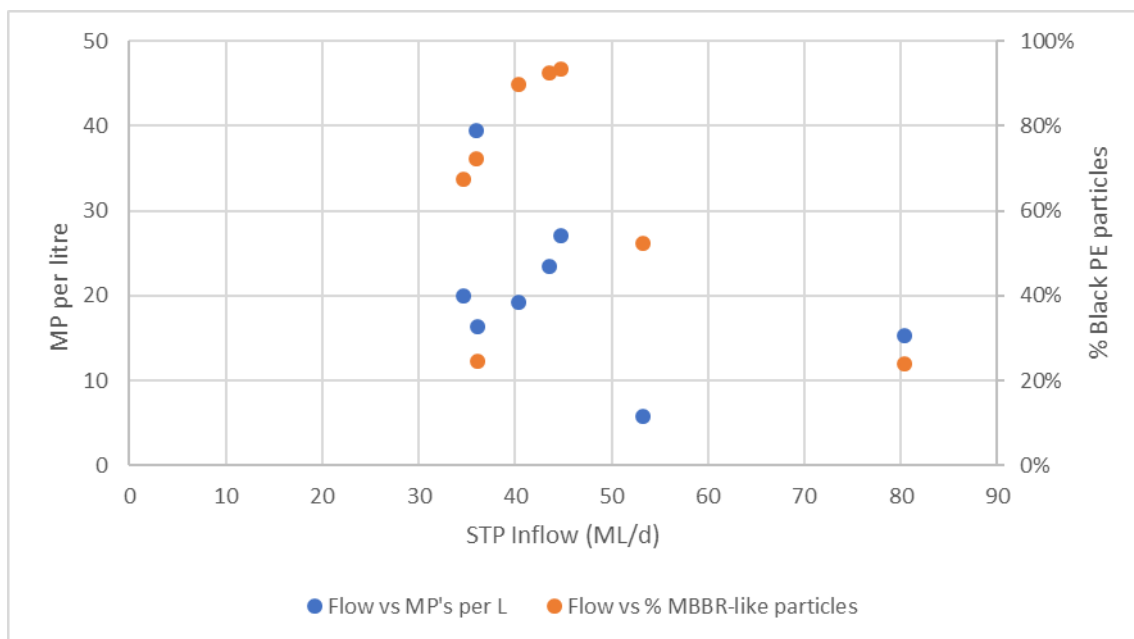


Figure 8 - Correlation of MP Concentration and % Black PE in Effluent on STP Inflow

The results of monthly MP concentration and percent of Black PE particles in the effluent stream (Table 2) indicates the potential for a downwards trend in both parameters, however the limited number of results does not support a conclusive finding. In addition, the result from the grab sample on 8/4/2022 does not support this trend, however other factors such as sampling method may have had a stronger influence on the results. Therefore, there is no strong evidence to conclude that the amount of Black PE plastic media particles in the effluent is increasing or decreasing.

The daily mass release of Black PE particles in the effluent is calculated in Table 11 using the sampled effluent results. In this calculation, particles are assumed to be cubic in shape (consistent with assumption in Attachment 4) having a characteristic dimension mid-way between the screen aperture sizes and a specific gravity of 0.95 per the Hel-X media manufacturer's data sheet. In the case of the largest 1mm screen size, the 2mm effluent basket screen aperture was used for the upper size limit. Size and mass data per particle size are shown in Table 10.

Table 10 - Estimated MBBR Particle Size and Mass

Size Fraction	Assumed Average Particle Size (µm)	Calculated Particle Mass (mg)
≥ 1mm	1500	3.2
≥ 500 µm	750	0.4
≥ 250 µm	375	0.05
≥ 125 µm	187.5	6.3x10 ⁻³
≥ 63 µm	94	79x10 ⁻³
≤ 63-11 µm	37	48x10 ⁻⁶

Table 11 - Estimated Daily Mass Release of Black PE Particles in Effluent

Date	17/02/22	14/03/22	20/03/22	21/03/22	23/03/22	8/04/22	28/04/22	11/05/22
Estimated Black PE Particle Release (kg/day)	4.7	0.5	56.0	2.7	2.6	87.5	31.7	6.7

The estimated mass release from the effluent samples in Table 11 has significant variability with higher values mostly influenced by the occurrence of larger particles >1mm. The average mass release of Black PE particles from Table 11 is 24 kg/day. If this was consistent over 2 years of operation, it is estimated that 17,520 kg could be released in that timeframe. Adding this to the amount estimated having been released via biosolids (3.73 kg/day; refer Section 4.6) totals 20,245 kg. This estimate compares favourably with a

previous study (refer Appendix E) of loss in mass of in-service MBBR plastic media over 2 years, that estimated between 20,000 and 38,000 kg of small MBBR plastic media particles may have been released from Kawana STP over the first 2-year operating period.

4.3 Wet Weather Effluent

Table 3 and Figure 9 shows the concentration of MP particles in effluent to be higher during the wet weather event (48 MP particles per litre) than other samples taken during periods of lower flows through the STP, except for the grab sample taken on 8/4/2022. This high concentration of MP particles during wet weather flows suggests the concentration of MP particles in effluent may increase as the flow through the STP increases, but the analysis shown in Figure 8 does not support this hypothesis. The portion of Black PE particles for the wet weather event was 43.3%, and this is within the range of results for other effluent samples (Table 9). Based on this analysis, the results from the wet weather flows did not provide conclusive evidence of any specific impact on Black PE particles being released during periods of high flow.

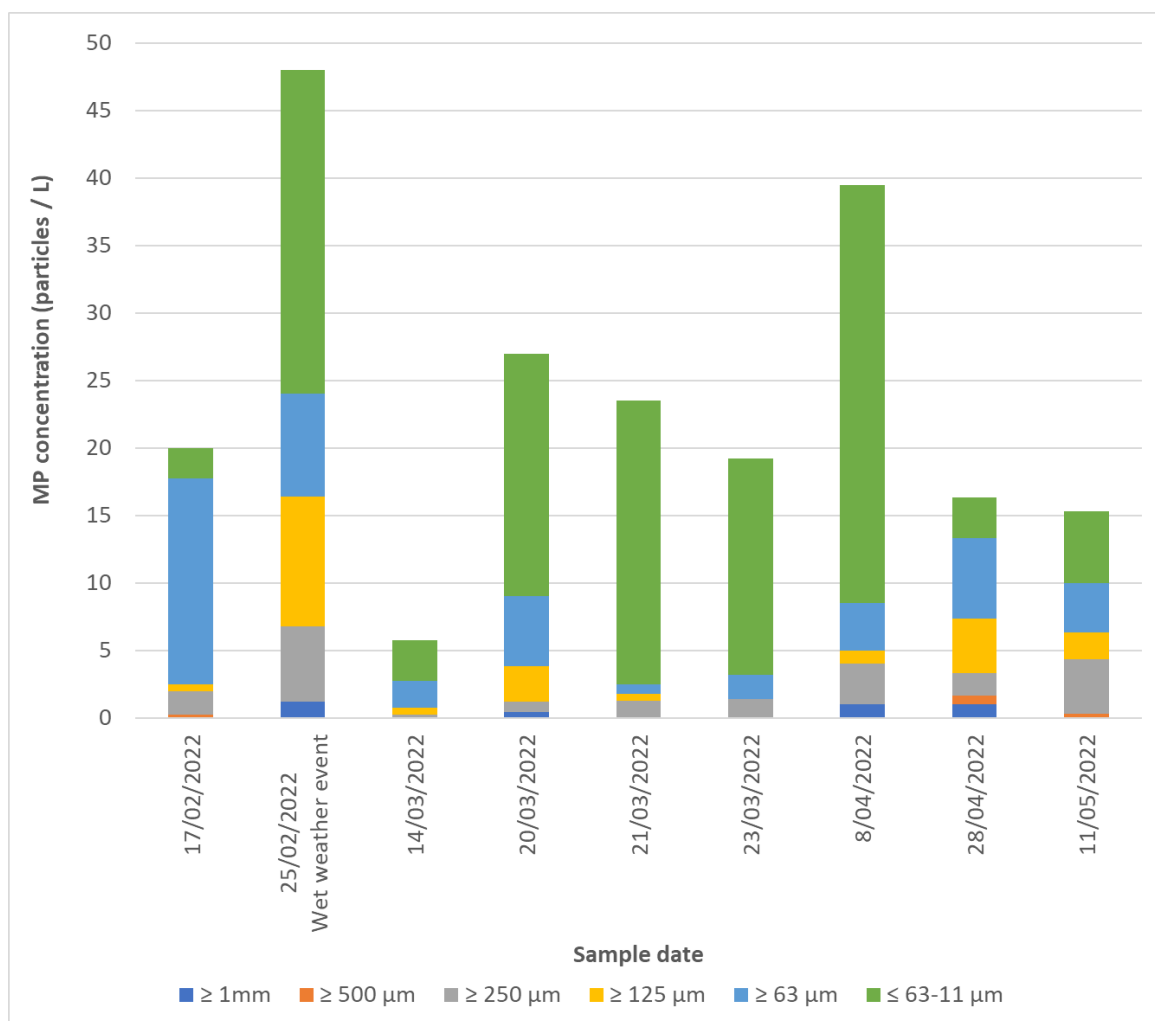


Figure 9 - MP Concentration All Effluent Samples

4.4 MBBR Feed

Detection of Black PE particles in the MBBR feed samples was not expected because this is upstream of the MBBR tank in the STP. However, results in Table 6 show between 25.5% and 85.5% of MP particles were Black PE, with the exception of the grab sample taken on 8/4/2022 where none were detected. Further investigation showed that the location of the first 5 samples taken by the auto-sampler did not isolate the MBBR tank from the feed sample. The location of a manual grab sample on 8/4/2022 was moved so that it

was not contaminated by MBBR liquid and, as expected, resulted in no Black PE particles found. Therefore, the results of the first 5 samples could not be compared for Black PE particle numbers.

4.5 MBBR Discharge

It was originally planned to compare the number of MPs and Black PE particles in the MBBR feed with that in the MBBR discharge streams. This was not possible due to the limitations described in Section 4.4.

4.6 Biosolids

The average daily production of biosolids from Kawana STP is about 15 wet tonnes per day. Applying this to the data in Table 8 and using the same methodology as that described in Section 4.1, the estimated mass release of Black PE particles in the biosolids is shown in Table 12. The average mass release of Black PE particles discharged via the biosolids stream is 3.73 kg/day. This mass is significantly less than the 24 kg/day estimated in the effluent stream (Section 4.2) but is also not consistent with the study by Rasmussen et al (2021) where much more mass of MPs was removed through the biosolids stream than the liquid effluent stream. This observation was supported by the work of Carr et al (2016) where MP particles were found to be removed mainly in the primary treatment zones via solids skimming and sludge settling processes that would be directed to biosolids at Kawana STP. The study undertaken by Rasmussen considered suspended growth systems in which there is a strong floc formation mechanism that enmeshes MPs within the floc structure that leads to increased removal of MPs into the sludge of the clarification stage. The biofilm sludge at Kawana forms a fairly weak and small floc that has a lower capacity to enmesh MPs. Subsequently, a higher proportion of MPs has been reported in the secondary effluent.

Table 12 - Estimated Mass Release of Black PE Particles in Biosolids

Date	15/02/22	17/02/22	10/03/22	10/03/22
Estimated Black PE Particle Release (kg/day)	2.33	6.51	4.75	1.34

4.7 Sampling Method

Auto-samplers are commonly used for sampling STP liquid streams. Sampling methodology for studies into MP in STPs is varied but grab samples using various apparatus are often used. Grab samples have the disadvantage of providing data only for that instance in time and therefore results from this method may not be representative if the nature of MP particles in these liquid streams varies significantly over time. Buoyancy of MP particles can have a significant impact on results for different sampling locations across the liquid stream depth. Auto-samplers usually take samples from submerged locations using a suction hose. In areas with low turbulence, this could bias the MP analysis results with MPs preferentially floating and therefore submerged suction lines on auto-samplers should only be used in areas of high mixing intensity. Similarly, grab samples taken using surface water only could bias the results of MP particle concentration per litre. The sampling locations for this study were generally in areas of high turbulence, however a thorough validation of adjusting sampling parameters such as depth of sample hose may provide insight into a more optimum configuration. However, this is further complicated by biofilm attached to MP particles that influence the specific gravity of the combined biofilm and plastic particle. This is because biofilm has a higher specific gravity than most plastic materials, and a biofilm coating a small MP particle is more likely to cause it to sink than a large particle having proportionally less surface area per total mass. This phenomenon is observed on the surface of the clarifiers at Kawana STP where larger MBBR plastic media particles tend to float.

Other observations of MPs during manual grab sampling includes MPs sticking to the side walls of sampling equipment, and therefore a consistent method of washing sampling equipment should be used. There is also the possibility of plastic equipment in auto-samplers (suction hose, sample pump components, etc) wearing and contributing to the MP results. Hence, sampling method is critical for the results but there is no universally accepted standard. There is substantial scope for investigating and optimising sample methods, however this is beyond the scope of this study.

4.8 Comparison to Other STPs

Studies into microplastics is a relatively new area of research and literature describing investigations of MPs at STPs is further limited. Attachment 3 presents results from other MP studies at STPs elsewhere. There was no published literature found on studies specific to MBBR plastic degradation and this finding was supported after consultation with suppliers of MBBR technology. Therefore, no comparison can be made on findings of MP particles likely to have originated from MBBR plastic media.

With no widely accepted standards on MP studies for aspects such as particle size, sampling method, and basis of reporting, comparison of the results from this study with other published literature is challenging. A thorough assessment and comparison of all other literature is a substantial undertaking and beyond the scope of this report. Nevertheless, a limited comparison is described in this section.

Effluent MP concentration from this study ranged from 5.75 MP particles per litre up to 48 MPs/L during the extreme wet weather event in February 2022 and 39.5 MPs/L from the grab sample on 8/4/2022. Removing these outliers from the data set results in an average of 19.9 MPs/L of effluent, but only marginally different to the average of 20.8 MPs/L when the outliers are retained. The average from this investigation contrasts to other Australian studies where Ziajahromi et al. (2017) found between 0.28 and 1.54 MPs/L and Raju et al. 2020 reported 2.76 MPs/L. In another investigation conducted by Ziajahromi et al. (2021) across a further three STPs, MPs were found in effluent ranging from concentrations of 0.18 to 0.96 MPs/L. A result of 20.2 MPs/L from this study at Kawana STP is higher than most other studies, and even discounting this value by the average of 65% of Black PE particles still leaves the quantity significantly higher.

Influent samples from this study were dominated by large quantities of fibrous material, where determining the particle count was not possible and therefore most results were expressed as g/L of influent. For samples containing large quantities of fibrous type MPs, an average concentration of 0.3 g/L was found. This value is difficult to compare against other studies where MP concentration is usually given in number of particles per litre. While it may be possible to infer the equivalent number of particles for the measured mass of MP particles in the influent from this study, it would be subject to significant error since the particle size distribution is not accurately known. Therefore, direct comparison of the influent results from this study has not been completed.

As described previously, MP data from other MBBR STPs was not available, hence it is not possible to accurately compare the MBBR discharge stream. Further, the MBBR feed stream was not sufficiently isolated from the MBBR anoxic tank in most of the samples taken in this study and these results could not be relied on for a comparison.

MP particle concentration in biosolids from this investigation ranged from 7.3 to 18.5 MP particles per gram of dry biosolids. In the study of MPs in three Australian STPs by Ziajahromi et al. (2021), the number of MP particles in biosolids was reported as being between 48.5 and 56.5 per gram of dry solids. In other investigations, Mintenig et al. (2017) identified between 1 and 24 MPs/g dry sludge, Crossman et al. (2020) found concentrations up to 14 MPs/g dry solids, and Harley-Nyang et al (2022) reported concentrations ranging from 37.7 to 286.5 MPs/g dry sludge. As described in Section 4.6, it was expected that a higher proportion of the MPs may have been found in biosolids compared to liquid effluent. With the wide range of variability in MPs concentration in biosolids reported from other studies, a higher result from Kawana STP could still fall within the range of results from studies at other STPs.

5 Conclusion and Recommendations

This study investigated MP particles in effluent from Kawana STP that were likely to have originated from degradation of MBBR plastic media. A sampling program of monthly effluent samples was expanded to other streams within the STP comprising influent, MBBR feed, MBBR discharge, and biosolids.

The treated effluent MP concentration varied from 5.75 MPs/L to 39.5 MPs/L, with an average of 20.8 MPs/L. The MP concentration during the extreme wet weather event in February 2022 was higher at 48 MPs/L. Of the MPs found in the effluent, the portion of Black PE particles was highly variable, between 23.9% and 93.3%. An investigation into whether hydraulic flows through the plant affected the concentration of MPs or the portion of Black PE MPs did not show any relationship.

The MP particle concentration in the effluent was higher than that reported from many other studies, however the impact of counting MP particles across different size fractions may have a significant influence on the comparison. For example, the results of a study measuring MP's down to 250 µm could not be compared with another study that measured down to 11 µm. Further detailed analysis is required to conclude the MP concentration from this investigation is substantially higher than at other STPs.

The mass of Black PE MP particles was approximated by calculating individual particle weights and release concentrations in the liquid effluent and biosolids streams. This calculation estimated that 20,245 kg of MBBR MP particles could have been released over a 2-year period of MBBR operation and this compared favourably with a previous study that estimated between 20,000 and 38,000 kg of MBBR plastic media particles may have been lost from the in-service MBBR carriers over the same timeframe.

Most of the influent samples taken were heavily contaminated with fibrous MP material that prevented individual counting of MP particles. For the two samples where individual MP particles could be counted, the concentration of MP particles reduced by about 36% and 75% from the influent to the MBBR feed stream. This compared to a study of MPs in a Swedish STP where around 73% of MPs in the influent was removed at the inlet works of the STP, however more data points should be considered to confirm this conclusion.

The sampling methods used in this study had a significant impact on the results where results from two early effluent samples were considered incorrect and the results of the MBBR feed stream samples were not representative. A detailed investigation of the impact of sampling parameters on MP results would have allowed the sampling methodology to be first validated and then standardised before collecting results for analysis, however this work would take considerably more time than that allocated for this study.

A novel method for analysing total plastic mass in a liquid effluent was tested on site at Kawana STP having the potential to reduce time and effort for analysing MPs in a liquid effluent stream. However, the analysis method was found to be unsuitable for measuring the opaque black MBBR plastic media particles.

MP analysis in STP streams is a new area of research that has yet to define a standardised approach on activities such as sampling methods, particle size analysis, and reporting. This study has provided some valuable insight into the release of MPs from MBBR plastic media from Kawana STP.

6 Attachments

Attachment 1: Microplastics Analysis Results

Sample	Date	Sample Description	Quantity Analysed (L or g)	Shapes	No. of MP particles (or mass for influent samples, denoted as 'g')						Polymer type (ATR-FTIR)	No. of Black PE particles
					≥ 1mm	≥ 500 µm	≥ 250 µm	≥ 125 µm	≥ 63 µm	≤ 63-11 µm		
Influent	17/2/22	24h ending 10am, hourly flow paced (variable volume) autosampler	3 L	Fibres	0.24 g	0.3 g	0.021 g	0.013 g	0.007 g	0.004 g	C, RA, PES, PA	0
				Fragments	0	0	0	0	0	0		
				Microbeads	0	0	0	0	0	0		
Influent	2/03/22	24h ending 10am, hourly flow paced (variable volume) autosampler	2 L	Fibres	1	0	2	0	0	0	RA, PES, PA	0
				Fragments	1	1	3	7	6	7	PE, PP, PVC	
				Microbeads	0	0	0	0	0	0		
Influent	14/3/22	24h ending 10am, hourly flow paced (variable volume) autosampler	2 L	Fibres	0.087 g	0.015 g	0.074 g	0.017 g	0.008g	0	C, CEL, RA, PES, PA	0
				Fragments	3	0	0	0	0	0	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Influent	20/3/22	24h ending 10am, hourly flow paced (variable volume) autosampler	2 L	Fibres	0.061 g	0.012 g	0.058 g	0.045 g	0.006 g	8	C, CEL, RA, PES, PA	0
				Fragments	0	0	0	0	0	0	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Influent	21/3/22	24h ending 10 am, hourly flow paced (variable volume) autosampler	2 L	Fibres	0.024 g	0.09 g	0.108 g	0.011 g	0.003 g	5	C, RA, PES, PA	0
				Fragments	0	0	0	0	0	0	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Influent	8/4/22	Grab sample 3pm	2 L	Fibres	0	0	0	1	2	3	RA, PES, PA	0
				Fragments	8	19	1	15	4	8	AC, PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Feed	17/2/22	24h ending 10am, hourly autosampler	5 L	Fibres	0	2	>100	50	10	28	RA, PVC, PA	38
				Fragments	2	6	15	25	3	8	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Feed	2/03/22	24h ending 10am, hourly autosampler	2 L	Fibres	1	2	0	0	1	1	RA, PES, PA	8
				Fragments	0	0	2	6	3	1	PE, PP, PMMA,	

Sample	Date	Sample Description	Quantity Analysed (L or g)	Shapes	No. of MP particles (or mass for influent samples, denoted as 'g')						Polymer type (ATR-FTIR)	No. of Black PE particles
					≥ 1mm	≥ 500 µm	≥ 250 µm	≥ 125 µm	≥ 63 µm	≤ 63-11 µm		
											PVC	
				Microbeads	0	0	0	1	0	0	PE	
MBBR Feed	14/3/22	24h ending 10am, hourly autosampler	2 L	Fibres	0	0	1	2	0	11	C, RA, PES, PA, PP	30
				Fragments	0	0	0	25	2	6	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Feed	20/3/22	24h ending 10am, hourly autosampler	2 L	Fibres	0	0	2	0	0	6	C, RA, PES, PA	12
				Fragments	0	0	0	3	8	18	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Feed	21/3/22	24h ending 10am, hourly autosampler	2 L	Fibres	0	0	1	2	3	3	C, RA, PES, PA	47
				Fragments	0	0	13	14	15	4	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Feed	8/4/22	Grab sample 3pm	2 L	Fibres	0	0	2	0	1	6	RA, PES, PA	0
				Fragments	1	0	2	2	1	0	PE, PP, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Discharge	17/2/22	24h ending 10am, hourly autosampler	5 L	Fibres	0.1g	0	1	0	1	0	AC, RA, PES, PA	72
				Fragments	0	0	4	0	4	64	PE, PP, PVC	
				Microbeads	0	0	1	0	0	0	PE	
MBBR Discharge	2/3/22	24h ending 10am, hourly autosampler	2 L	Fibres	0	0	1	0	2	1	C, RA, PES, PA	15
				Fragments	0	5	0	7	2	9	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	1	0	0	PE	
MBBR Discharge	14/3/22	24h ending 10am, hourly autosampler	2 L	Fibres	2	9	3	2	1	0	C, RA, PES, PA	50
				Fragments	0	5	9	12	5	19	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Discharge	20/3/22	24h ending 10am, hourly autosampler	2 L	Fibres	0	0	2	1	4	2	C, RA, PES, PA	68
				Fragments	0	4	10	17	24	14	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
MBBR Discharge	21/3/22	24h ending 10am, hourly autosampler	2 L	Fibres	0	0	4	7	1	1	C, RA, PES, PA	68
				Fragments	0	4	8	11	27	15	PE, PP, PMMA, PVC	

Sample	Date	Sample Description	Quantity Analysed (L or g)	Shapes	No. of MP particles (or mass for influent samples, denoted as 'g')						Polymer type (ATR-FTIR)	No. of Black PE particles
					≥ 1mm	≥ 500 µm	≥ 250 µm	≥ 125 µm	≥ 63 µm	≤ 63-11 µm		
				Microbeads	0	0	0	0	0	0		
MBBR Discharge	8/4/22	Grab sample 2pm	2 L	Fibres	0	0	0	1	0	3	C, RA, PES, PA	49
				Fragments	0	3	2	5	6	36	AC, PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Effluent	23/12/21	24h ending 10am, hourly flow paced (variable volume) autosampler	9 L	Fibres	0	0	0	0	0	0	N/A	0
				Fragments	0	0	0	0	0	0	N/A	
				Microbeads	0	0	0	0	0	0	N/A	
Effluent	20/1/22	24h ending 10am, hourly flow paced (variable volume) autosampler	9 L	Fibres	0	0	0	0	0	0	N/A	0
				Fragments	0	0	0	0	0	0	N/A	
				Microbeads	0	0	0	0	0	0	N/A	
Effluent	17/2/22	24h ending 10am, hourly auto sampler	4 L	Fibres	0	1	1	0	3	3	RA, PES, PA	54
				Fragments	0	0	5	2	58	6	PE, PP, PMMA, PVC	
				Microbeads	0	0	1	0	0	0	PE	
Effluent	25/2/22	Wet weather event, 24h ending 4pm, hourly auto sampler	2.5 L	Fibres	0	0	6	7	4	24	RA, PES, PA	52
				Fragments	3	0	8	17	15	36	PE, PP, PMMA, PVA	
				Microbeads	0	0	0	0	0	0		
Effluent	14/3/22	24h ending 10am, hourly auto sampler	4 L	Fibres	0	0	0	0	2	8	C, RA, PES, PA	12
				Fragments	0	0	1	2	6	4	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Effluent	20/3/22	24h ending 10am, hourly auto sampler	5 L	Fibres	0	0	0	1	2	10	C, RA, PES, PA	126
				Fragments	2	0	4	12	24	80	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Effluent	21/3/22	24h ending 10am, hourly auto sampler	4 L	Fibres	0	0	4	1	1	0	RA, PES, PA	87
				Fragments	0	0	1	1	2	84	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Effluent	23/3/22	Grab sample 12pm to 4pm	5 L	Fibres	0	0	3	0	0	4	RA, PES, PA	86
				Fragments	0	0	4	0	9	76	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		

Sample	Date	Sample Description	Quantity Analysed (L or g)	Shapes	No. of MP particles (or mass for influent samples, denoted as 'g')						Polymer type (ATR-FTIR)	No. of Black PE particles
					≥ 1mm	≥ 500 µm	≥ 250 µm	≥ 125 µm	≥ 63 µm	≤ 63-11 µm		
Effluent	8/4/2022	Grab sample 1pm	2 L	Fibres	0	0	0	0	1	12	PES, PA,RA	57
				Fragments	2	0	6	2	6	50	PE,PP,PVC	
				Microbeads	0	0	0	0	0	0		
Effluent	28/4/22	24h ending 1pm, hourly auto sampler	3 L	Fibres	0	2	3	6	16	6	RA, PES, PA	12
				Fragments	3	0	2	6	2	3	PE, PP, PS	
				Microbeads	0	0	0	0	0	0		
Effluent	11/5/22	24h ending 12:30pm, hourly auto sampler	3 L	Fibres	0	0	12	6	3	10	RA, PES, PA	11
				Fragments	0	1	0	0	8	6	PE, PP, PMMA, PVC	
				Microbeads	0	0	0	0	0	0		
Biosolids	15/2/22	Grab Sample 10am	50 g (wet) 14.0 g (dry)	Fibres	3	4	3	2	7	3	CEL, RA, PES, PP PA	52
				Fragments	0	12	11	24	34	6	PE, PP, PS	
				Microbeads	0	0	0	7	0	0	PE	
Biosolids	17/2/22	Grab Sample 3pm	50 g (wet) 13.02 g (dry)	Fibres	3	5	16	9	2	6	PP, PA	136
				Fragments	6	9	54	64	44	22	PE, PP,	
				Microbeads	0	0	0	1	0	0	PE	
Biosolids	10/3/22	Grab sample 7am	50 g (wet) 14.31 g (dry)	Fibres	8	21	36	14	16	4	RA, PES, PA	86
				Fragments	2	7	41	44	54	3	PE, PP, PS, PVC	
				Microbeads	0	0	1	8	0	0	PE	
Biosolids	10/3/22	Grab sample 7am	50 g (wet) 14.8 g (dry)	Fibres	0	1	4	2	6	4	AC, RA, PES, PA	34
				Fragments	3	6	28	28	18	8	PE, PP, PS	
				Microbeads	0	0	0	0	0	0		

Attachment 2: University of Newcastle Report on Microplastics Analysis



REPORT NO.2

ASSESSMENT OF MICROPLASTICS IN KAWANA STP

Mr Subash Raju - Lab analysis and reporting
A/Prof Thava Palanisami - Project Leadership



June 2022

The project was conducted according to our university confidentiality policy for all industry projects. Sample type, analysis, results, and client details are protected.

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Table of Contents

1.Extraction of Microplastics.....	2
1a.Extraction of MPs from liquid samples	2
1b.Extraction of MPs from solid samples.....	2
2.Characterization of Microplastics	2
2a.MPs Morphology analysis	2
2b.Polymer identification and characterisation using vibrational spectroscopy	3
3.Results	3

Objective: Extraction, quantification, and identification of Microplastics from the samples received from Unitywater

Types of samples processed for this report:

1. INFLUENT (IN)
2. PRE-MBBR TREATMENT (PM)
3. MBBR DISCHARGE (MD)
4. EFFLUENT (EF)
5. BIOSOLIDS

Methodology

1.Extraction of Microplastics

1a.Extraction of MPs from liquid samples

- A volume of 2- 5L of water samples was taken for digestion using Fenton Agent
- After digestion, the water samples were passed through stainless sieves of different size ranges from $\geq 1\text{mm}$, $\geq 500\ \mu\text{m}$, $\geq 250\ \mu\text{m}$, $\geq 125\ \mu\text{m}$, $\geq 63\ \mu\text{m}$, and $\leq 63-11\ \mu\text{m}$.
- The filtered sieves were examined under the microscope, and the microplastics were collected using a surgical needle and immersed in deionized water to remove residuals.
- Microplastics were categorized according to their shapes (fibres, fragments, microbeads) and sizes (classified into $\geq 1\text{mm}$, $\geq 500\ \mu\text{m}$, $\geq 250\ \mu\text{m}$, $\geq 125\ \mu\text{m}$, $\geq 63\ \mu\text{m}$, and $\leq 63-11\ \mu\text{m}$), the particles were captured using Capture V2.3 and processed using (Image J 1.53e).
- Based on the size classification, we can understand the sources, for eg. Microbeads are considered primary microplastics(intentionally manufactured in small sizes), fragments and fibres are the result of break-down of large plastic items, called secondary Microplastics).

1b.Extraction of MPs from solid samples

- The wet biosolids were dried at 70°C for 24 to 48 hours in an oven, and then samples were ground gently to loosen the microplastics bound to the dry aggregates.
- The samples were digested with Fenton reagent for 30 minutes and were cooled down before mixing with non toxic density solution (specific gravity of $1.85\ \text{g/ml}$). The samples were sonicated at low energy for 10 minutes.
- The supernatant was then passed through different size sieves ranging from $\geq 1\text{mm}$, $\geq 500\ \mu\text{m}$, $\geq 250\ \mu\text{m}$, $\geq 125\ \mu\text{m}$, $\geq 63\ \mu\text{m}$, and $\leq 63-11\ \mu\text{m}$.

2.Characterization of Microplastics

2a.MPs Morphology analysis

The sieves were examined under a microscope coupled with image analysis (Figure1 to 5). Microplastics were collected and categorized according to their shapes (fibres, fragments,

microbeads) and sizes (classified into $\geq 1\text{mm}$, $\geq 500\text{ }\mu\text{m}$, $\geq 250\text{ }\mu\text{m}$, $\geq 125\text{ }\mu\text{m}$, $\geq 63\text{ }\mu\text{m}$, $\leq 63\text{-}11\text{ }\mu\text{m}$). The collected particles were immersed in Milli-Q water to remove attached residuals and further characterisation.

2b. Polymer identification and characterisation using vibrational spectroscopy

The particles were washed with Milli-Q water and dried before identification. The polymer identification was carried using MicroFTIR couple with ATR (Nicolet iz10). The spectrum was obtained at the 4 cm^{-1} resolution and 16 scans. The polymer chemistry was matched and extracted using Global Polymer and chemicals libraries (Omnice software V9.12.1002). Any weathered particles required the use of our in house library and other open source libraries developed for environmental plastics. The polymer chemistry was assigned, as per standard procedure, based on the highest per cent matching (Figure 6).

3. Results

- **INFLUENT Samples:** We found large fibre mass in all influent samples, except the 02/03/2022 samples, for all the size classes. These fibers are of mixed chemistry, consists of cellulose, polyamide, rayon, cellophane, and polyester. These fibers mass could arise from wet wipes and other hygiene products. The fibers were higher than fragments in all the influent samples, and no fragments or microbeads were detected. Due to significant mass, we used a gravimetric approach and weighed the total fiber mass.
- **MBBR Feed Samples:** Unlike in influent samples, there were no fibres found in the MBBR feed samples. The particle size is dominated by $\geq 250\text{ }\mu\text{m}$, which is higher than 1 mm and $500\text{ }\mu\text{m}$ size category. Around 25-85% of fragments are black polyethylene fragments (Black PE) particles among the total fragments found. Most of fragments uniform in texture, color and cuboid, squares, rectangle or combination of all.
- **MBBR Discharge Samples:** The MBBR discharge samples are dominated by fine size microplastics ($\leq 63\text{-}11\text{ }\mu\text{m}$), indicating that the physical and mechanical weathering may be occurring that generates fine fragments. Of the microplastic particles found in the samples, between 57% and 96% were identified as black PE fragments based on Microscopic examination and polymer spectrum.
- **Biosolid samples:** The biosolids are generally the reservoir of all types of MPs (fibers, fragments, microbeads). The number of black PE particles were higher than fibers and microbeads. The fragments and microbeads were mainly made up of polypropylene and polyethylene. Heavy loads of sediments and silt are some of the challenges encountered while detecting fine particles $< 63\text{ }\mu\text{m}$ size category. It has slowed down the analysis significantly as we spent more time going through particle by particle assessment, discounting non-plastic types. Of the microplastic particles found in the biosolids samples, between 33.2% and 56.4% were identified as black PE based on Microscopic examination and polymer spectrum.

- **Effluent samples:** Effluent samples looked very clear and did not require digestion. The results clearly showed the black PE fragments dominated in all size classes, ranging from 23-93.3% of the total microplastic particles identified in the samples. In wet weather samples, the fine size class particles (<250 µm) were higher than the different sizes in the wet weather sample. Around 43.3% of microplastic particles found in the wet weather samples are black PE fragments.

4. Conclusions and Recommendations

The analysis methodology implemented in this project, has helped us to identify the microplastic particles up to 11 µm size and also classify MPs in to shape and color. Except influent samples, black PE fragments found in all other samples, dominated the microplastic composition. The FTIR analysis showed that these black fragments polyethylene nature, broken pieces from large plastics (secondary microplastics). It was surprising to find fewer microplastics in the influent samples from our experience working with samples from other wastewater plants around Australia and published literatures, except for the huge fibre mass.

There is an opportunity to optimise site-specific sampling methods (type, time, replicates, etc). Also, in line with published work, grab sampling for consecutive days at different times is the best approach. A direct adaptation of automated sampling used for nutrients and chemical monitoring is unsuitable for Microplastics analysis. The variability between influent, MBBR samples and effluent samples can be minimized using a specialized automated sampler, designed using non-plastic components' ability to pump large volumes.

The source apportionment for the black PE particles could be done accurately using combination of advanced chemical analysis and tracer studies. Similarly potential for trophic transfer and bioaccumulation could also be examined using model organisms. We applied similar approaches to help Food NSW, NSW DPI and Hunter Water, therefore we have expertise and technical capabilities to conduct further advanced studies, but this requires substantially more time and resources. Our results could serve as a baseline to conduct such advanced studies if needed.

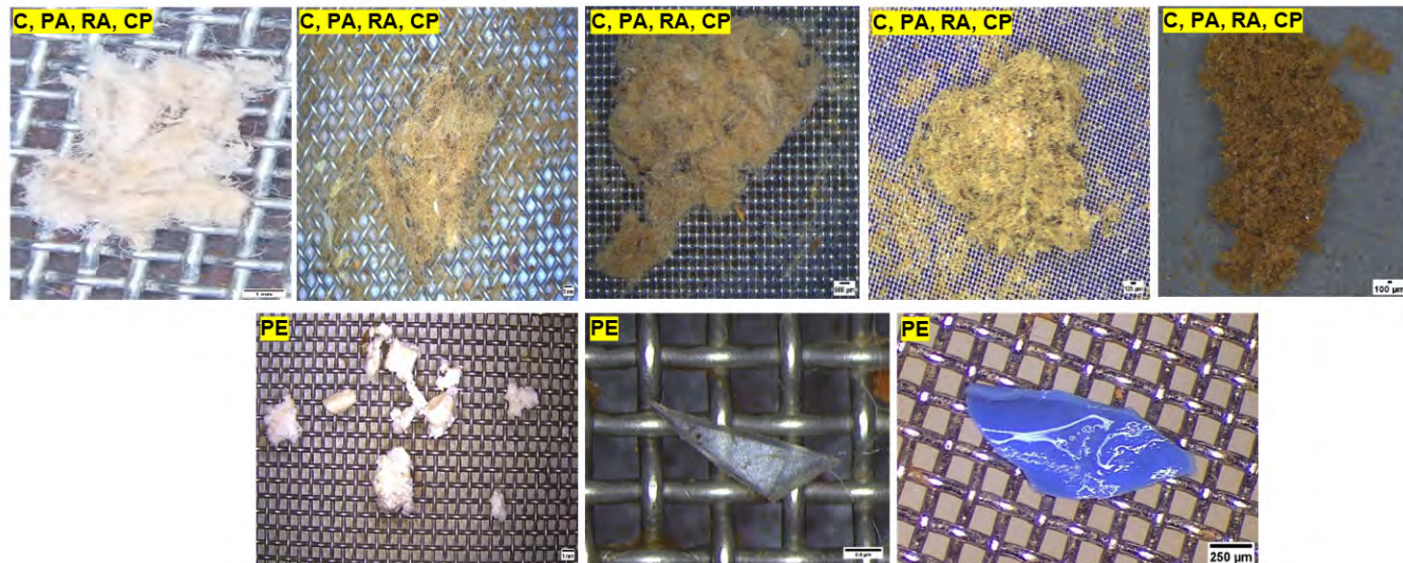


Figure 1. Different shapes of MPs from influent samples. The fiber masses found in all size ranges. (C - Cellulose; PA - Polyamide; RA - Rayon; CP - Cellophane; PE - Polyethylene)

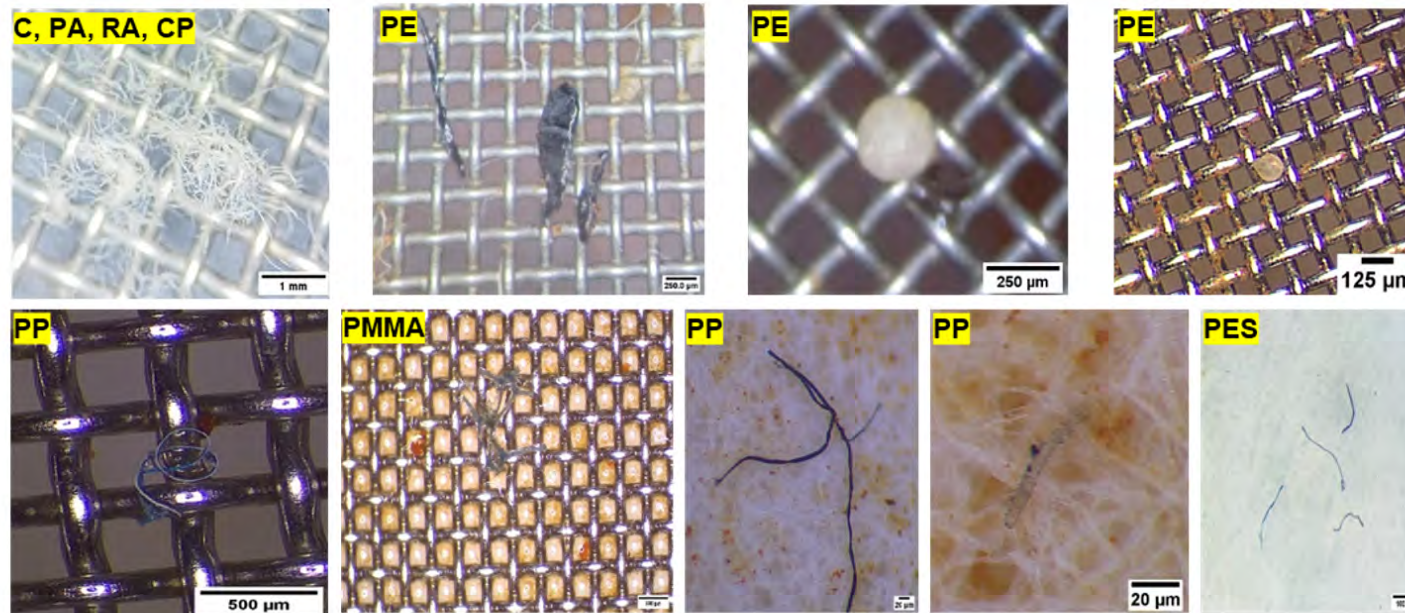


Figure 2. The MPs from MBBR feed samples. The fibers and fragments were common comparison with microbeads. (C - Cellulose; PA - Polyamide; RA – Rayon; CP – Cellophane; PE – Polyethylene; PES – Polyester; PMMA - polymethyl methacrylate)

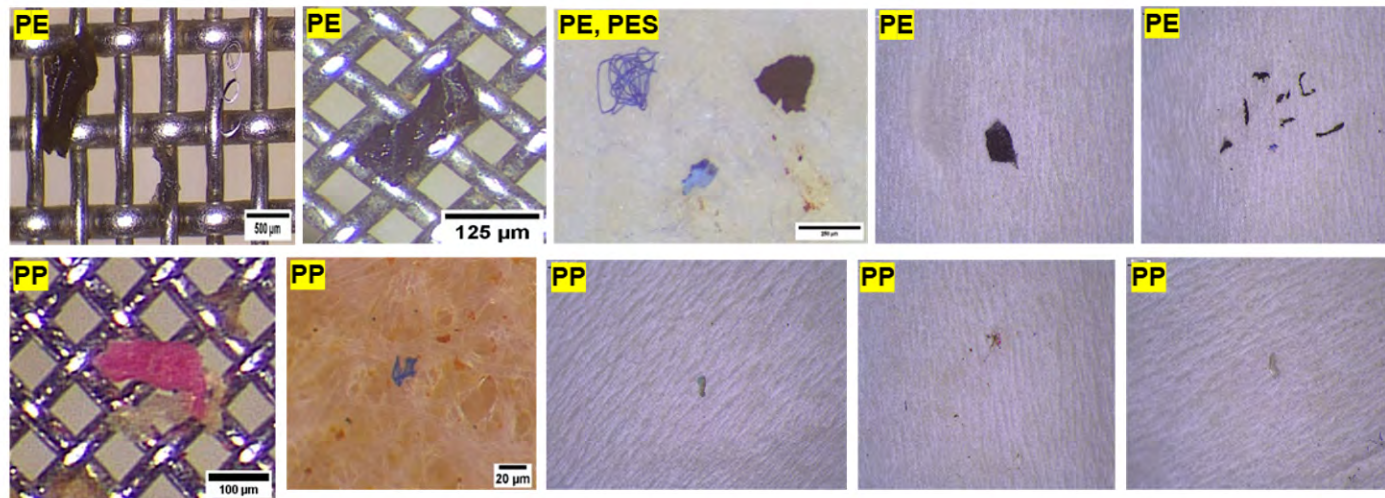


Figure 3. The MPs from MBBR discharge samples. (PE – Polyethylene(Black PE); PES – Polyester; PP - Polypropylene)

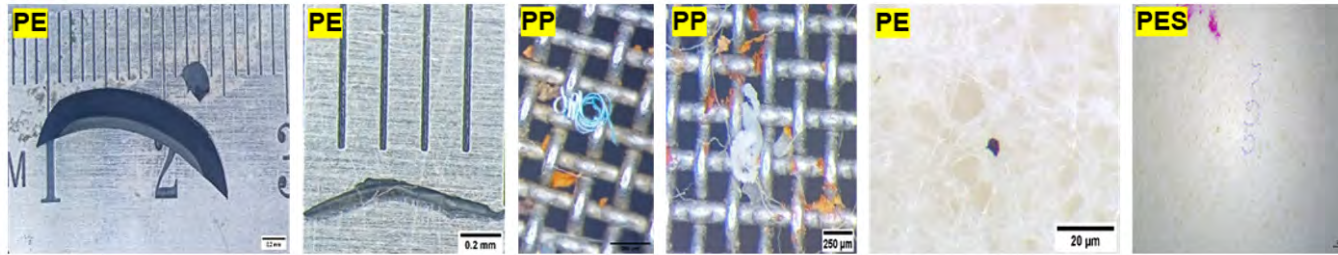


Figure 4. The MPs from Effluent samples(PE – Polyethylene(Black PE); PES – Polyester; PP - Polypropylene).

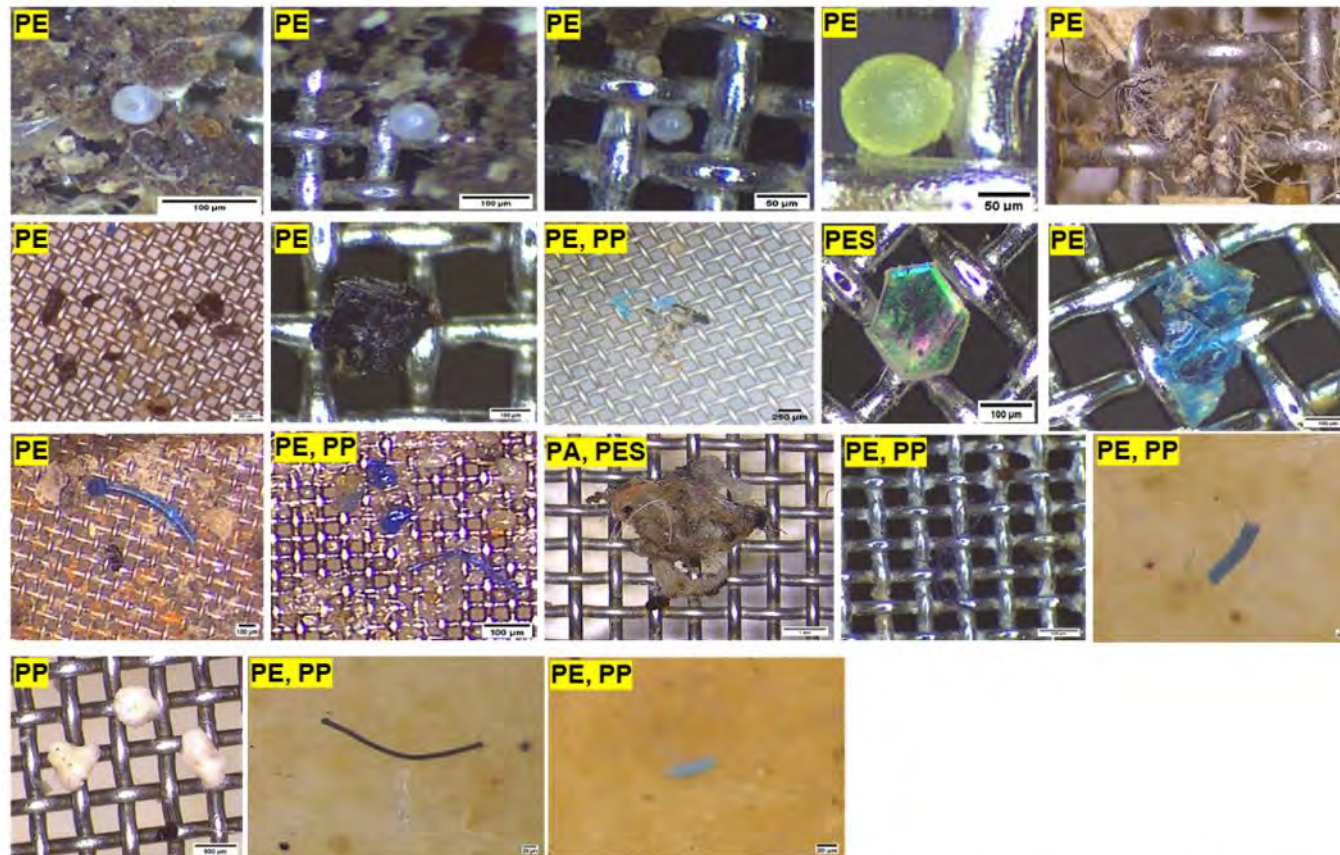
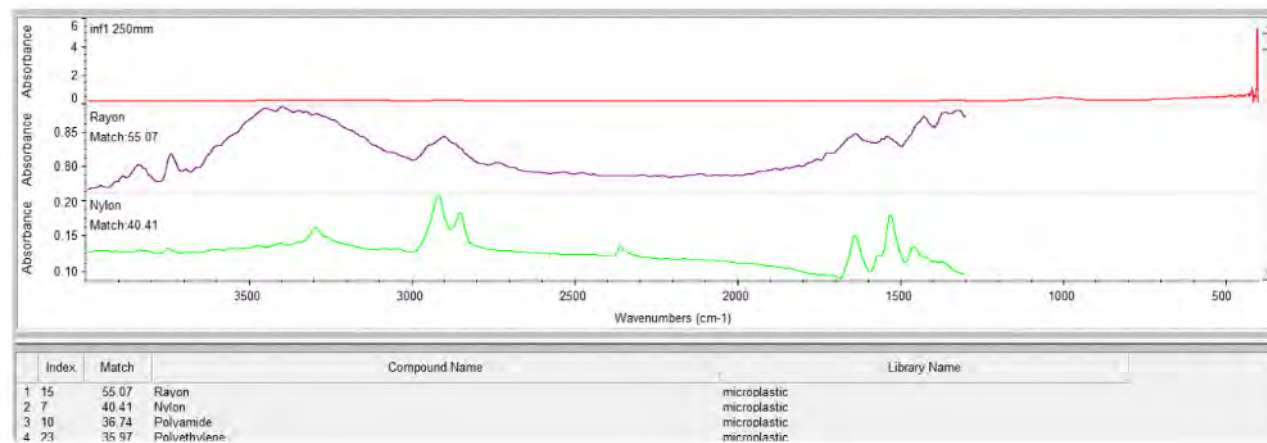
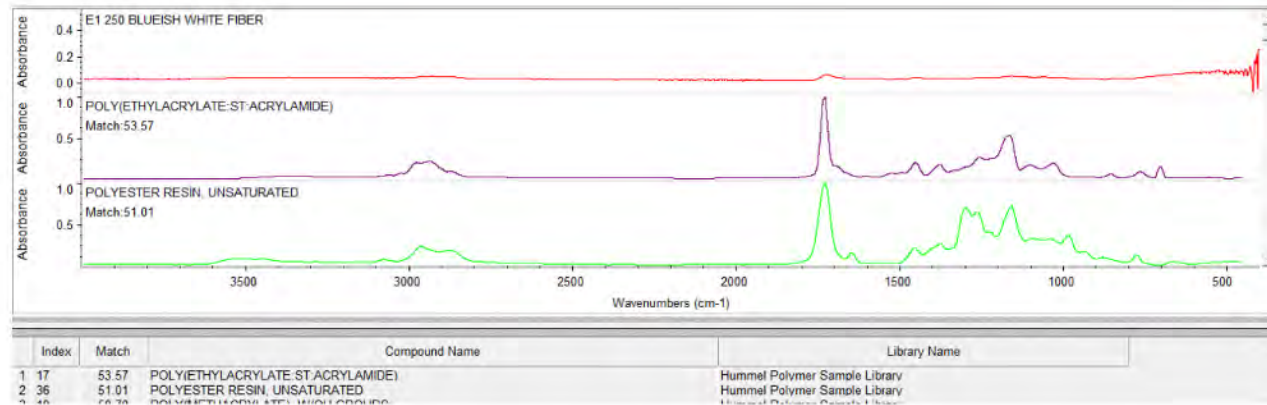
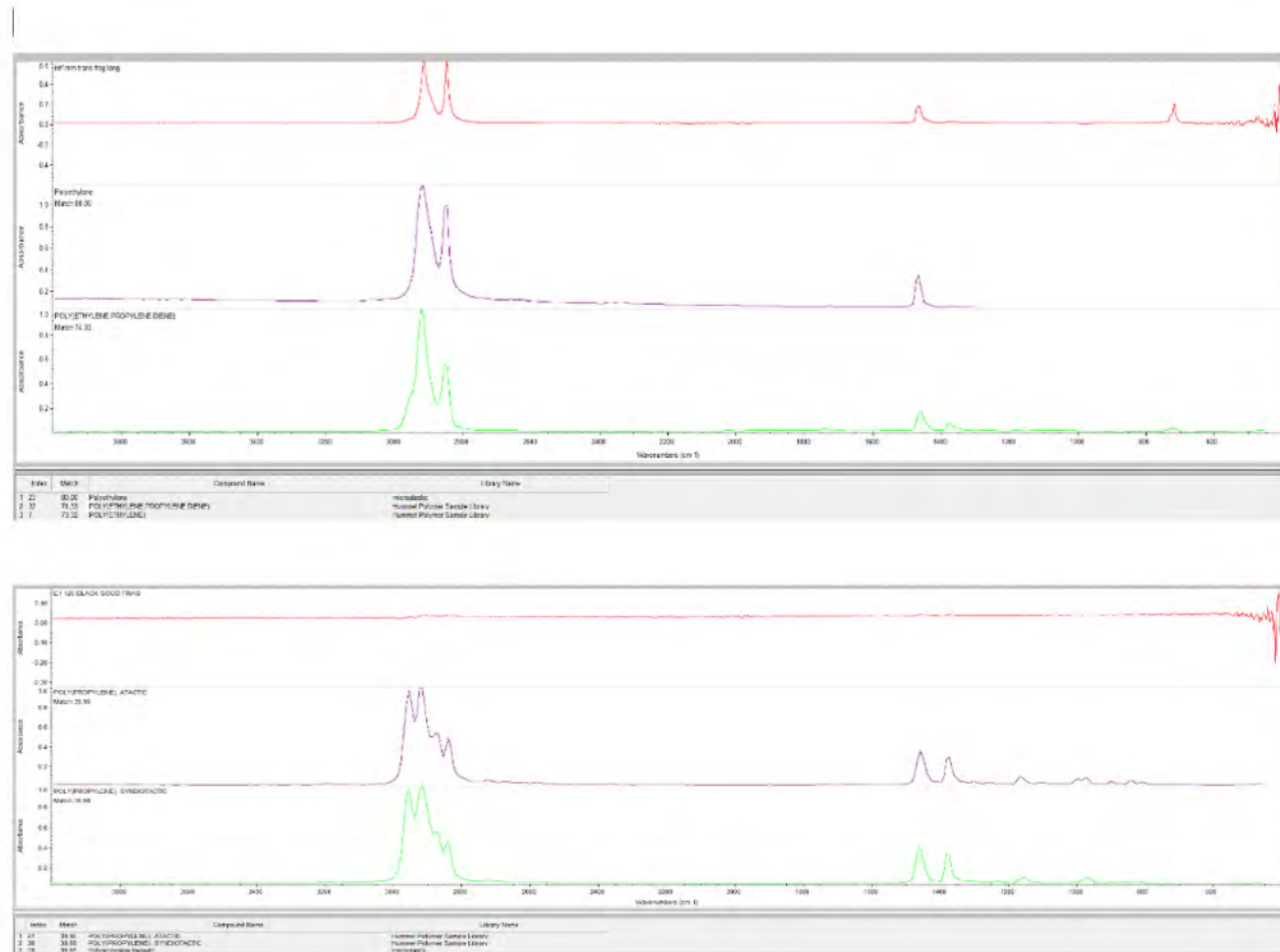


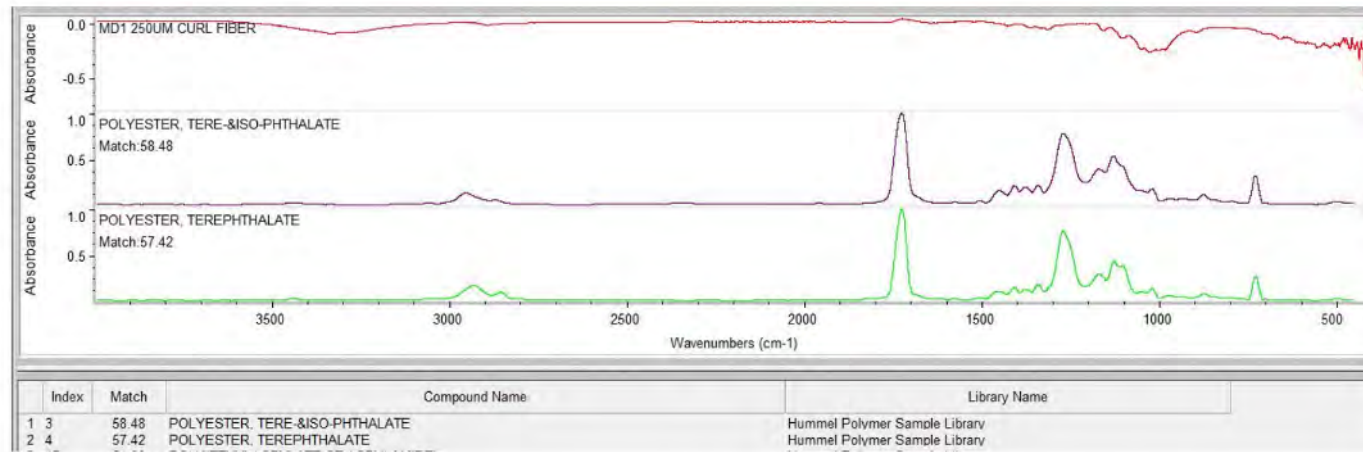
Figure 5. The MPs from biosolid samples and the microbeads, fragments including glitters and fibres were common in all samples (PE – Polyethylene; PES – Polyester; PP – Polypropylene).

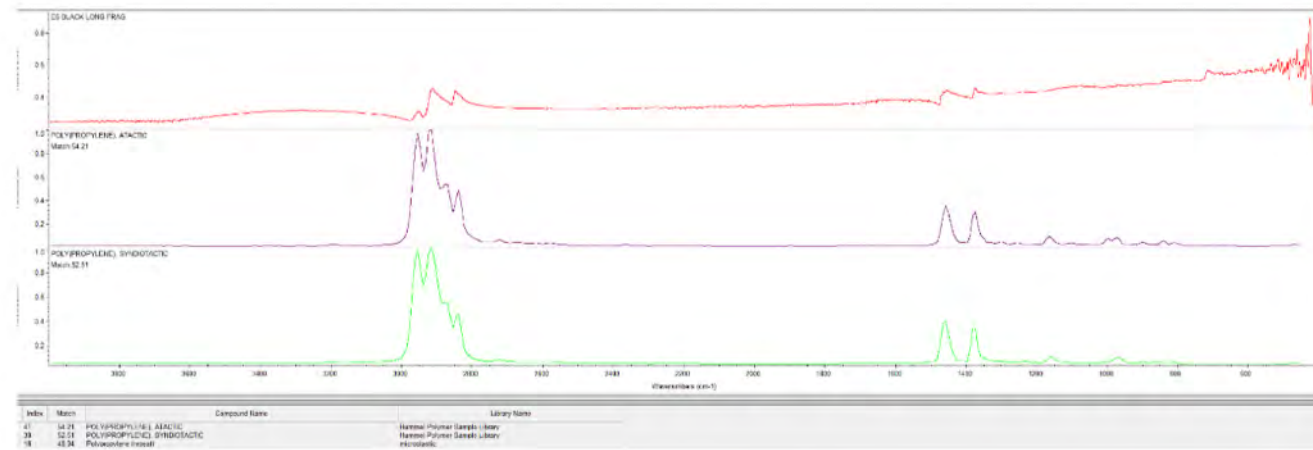
Figure 6. Representative spectral search and compound identification for the polymer particles from samples











END OF THE REPORT

Attachment 3: Published Results of Other Microplastics Studies at WWTPs

Study No.	Samples and Location	MPs in Influent/ or in Effluent	Polymer Types	Sampling method, purification or extraction and Characterisation	Conclusions	References
1	a) 18 locations across six continents b) reference, marine sewage-sludge disposal site. c) Effluent. d) Three different frontloading washing machines.	a) 2 to 31 fibres/250mL of sediment. b) Disposal-sites >250% more. c) 1 particle/L. d) Garments released >100 fibres/L	a) PES<PC< PP< PE<PA fibres b) PES <PC c) PES< PC<PA. d) all polyester	a) 1 cm deep sediments b) Van Veen grabs deployed 5-10 cm c) Glass bottles metal cap d) with and without cloth. Sodium chloride (NaCl) solution and ATR FTIR.	Sewage-disposal main source for marine. Washing machines are important source of fibres.	(Browne et al. 2011)
2	a) Incoming water b) Effluent water c) ~25 g wet weight Sweden.	a) 3200 000 particles/hr b) 1770 MPs particles/hr i) 720 MPs/kg wet weight ii) 16.7*10 ³ MPs at dw kg	Plastic fibres > fragments > flakes in the sewage sludge.	Ruttner sampler. 300µm mesh, stereomicroscope and ATR-FTIR	1.1 - 1.8 MPs/m ³ in the effluent plume > 0.45 m ⁻³ in the reference area	(Magnusson 2014)
3	7 Sea water samples and 16 sediment samples were collected.	a) Influent =180 fibres, 430 synthetic particles/L. b) Sea water = 0.01 and 0.65 fibres/L and 0.5 to 9.4 particles/L	Efficiency >96%. Polymer types not characterised.	Pumping and filtration techniques, using stereomicroscope and sodium chloride.	An average of 4.9 fibres and 8.6/L Fibre 25 times > the particles.	(Talvitie et al. 2015)
4	12 WWTP in 10 tertiary treatment and two secondary effluent sites.	1 particle/1.14 m ³ of final effluent. 31 MPs / 28.4 million litres of surface-filtered effluent An average of 5 particles/5g.	PE similar in toothpaste formulations.	Grab samples and a stack of 8" dm sieves, a surface filtering assembly and FTIR. Diluted bleach 8.25% sodium hypochlorite.	~99.9% removal.	(Carr et al. 2016)
5	Influent coarse screening, grit and grease effluent, primary effluent, the final effluent.	Influent average of 15.70 MP/L	a) red < blue < green<other colours. b) PS, PC, PU, PET, PA, PP, alkyd PE. c) flakes, fibres, film, beads, foam.	Steel buckets (10L) and FTIR. Washed with water.	Grit and grease removal 44.59%; 0.25 MP/L in final effluent (98.41%). Aeration and clarification removed 20.07%.	(Murphy et al. 2016)
6	17 different wastewater treatment across the United States.	On average, less than 1 particle/L effluent.	Fibres <fragments<films< foams< pellets. Average of 13 billion of MP particles /day.	A set of Tyler sieves. FTIR or Raman spectroscopy	Bias in sampling collection method. Study needed for advanced (tertiary) treatment and combined sewer systems.	(Mason et al. 2016)

Study No.	Samples and Location	MPs in Influent/ or in Effluent	Polymer Types	Sampling method, purification or extraction and Characterisation	Conclusions	References
7	Seven WWTPs, Ireland.	45 µm >63 µm lower sludge mass at the larger size fraction >212 µm.	75.8% fibres, fragments, films, and spheres HDPE, polyethylene (PE) PES, PC, PET, PP, and PA.	Elutriation column. Stereomicroscopy, polariser, Zinc Chloride, ATR-FTIR, SEM	Vigilant management practices biosolids. Possibility of microbial remediation method.	(Mahon et al. 2017)
8	12 WWTPs, Germany.	0 to 50 MP/m ³ > 500 µm. 10 to 9000 MP/m ³ < 500 µm. Total discharges: 9 x 10 ⁷ to 4 x10 ⁹ MP particles.	Mostly by -PE. Synthetic fibres by PEST.	Mobile pumping device with PVC hose, Sodium hydroxide, FPA-based micro-FTIR	Enzymatic-oxidation with FPA-based micro-FTIR. Post-filtration reduced discharge by 97%.	(Mintenig et al. 2017)
9	10 municipal WWTPs discharges Raritan River, central New Jersey (NJ), US.	24 m ⁻³ Freshwater upstream of WWTP 71.7 m ⁻³ at Freshwater downstream of WWTP.	Only the size and not the type of polymer.	Plankton nets 153 mm mesh size at river surface. Sodium Chloride, Reflected microscope (Stereomicroscope)	First study on 63 µm, 125 µm sizes, > 355 µm in the fresh water.	(Estahbanati and Fahrenfeld 2016)
10	Primary, Secondary, Tertiary treatment plant, Australia	1.54, 0.48, 0.28 MPs/L at final effluent	92% and 99% of polystyrene microplastic Fibres - the dominant. 500, 190, 100 mm, 25 mm sizes.	Custom-made pumping device. Sodium Iodide, ATR-FTIR	Rose Bengal staining method for suspected plastics. MPs not completely removed even after advanced treatment processes	(Ziajahromi et al. 2017)
11	Secondary Treatment plant, Australia	Influent: 11.80 MPs/L, Waste activated sludge: 7.91 ± 0.44/L and UV-treated effluent: 2.76 ± 0.11/L	Glitters were dominant and made up of PET, PBT. Fibres were dominant in effluent (PES, PA, Acrylic fibres)	Sodium Iodide, ATR-FTIR	Rose Bengal and Nile red staining adopted for finding fine size particles. Glitters, fruit stickers were detected in WAS. MPs were highly settled in sludge than effluent.	(Raju et al. 2020)

Study No.	Samples and Location	MPs in Influent/ or in Effluent	Polymer Types	Sampling method, purification or extraction and Characterisation	Conclusions	References
12	Secondary Treatment plant, Australia	Influent: 1.52 MPs/L, Effluent: 0.77 MPs/L, Wet Sludge: 0.45/g, Dry Sludge: 1.23/g	PES, PA, PP, PE	Sodium Iodide, ATR-FTIR	Fibres were dominant all samples than fragments	Unpublished GICAN MPs analysis Services
13	3 Australian WWTPs	Influent: 55 to 98 MPs/L, Effluent 0.18 to 0.96 MPs/L; Biosolids: 48.5 to 56.5 MPs/g	PET, PE, PP, Nylon	Sodium Iodide, ATR-FTIR	7.5–16% of MPs in influent present in biosolids. Majority of MPs (69–79%) removed by screening and grit removal	Ziajahromi et al. 2021
14	WWTP products, Australia	Biochar contain 3.3 particles/gram Biosolids: 8.8 particles/gram _u	PS, PES, PE, PA, PP	Sodium Iodide, ATR-FTIR	Fibres were dominant than fragments. In all samples from 250µm to 63µm particles were found higher.	GICAN MPs analysis Services
15	Nash WWTP, UK	Influent: 150,000 ± 47,000g MP/day or $6.34 \times 10^8 \pm 2.99 \times 10^8$ MP/day. No MPs 1000–5000 µm in effluent /seven-day sampling Sludge: 128,000 ± 124,000 g/day and $3.52 \times 10^8 \pm 1.56 \times 10^8$ MP/day Scum: (26,000 ± 18,000 g/day and $1.6 \times 10^7 \pm 6.1 \times 10^6$ MPp/day) Sewage sludge: 0.01 g or 24.7 MP per g of dried sludge		Zinc Chloride	Feed and effluent samples by an automatic sampling system Seven-day sampling. 100% removal efficiency of MPs in the range of 1000 – 5000 µm in effluent.	(Lofty et al. 2022)

Attachment 4: University of Newcastle Report on Novel Method for Total Plastic Mass Analysis



Project title:

Mass and characteristics of Microplastics at a WWTP

Sub Report-1

METHOD DEVELOPMENT AND ANALYSIS OF TOTAL MICROPLASTICS CONCENTRATIONS

Team

Dr Geetika Bhagwat-Method development, fieldwork and report preparation
Mr Nethaji Subash - Sample analysis at the UoN lab
Project Leadership: A/Prof Thava Palanisami

Environmental Plastics Innovation Cluster(EPIC)
Global Innovative Centre for Advanced Nanomaterials (GICAN)
The University of Newcastle, NSW, Australia

The project was conducted according to our University's confidentiality policy for all industrial projects. Sample type, analysis, results, and client details are protected.

Contents

Table of Contents

1. On-site work details:	3
2. Digestion:	4
3. Sieving:	4
4. Microscopic examinations	4
5. Polymer identification	5
6. Microplastic particle count	5
7. Quantification of microplastics	6
8. Overall challenges in quantification of MBBR particles in wastewater samples	8
9. Conclusions	9
10. Guidance for field monitoring	9

This document reports the material characterisation results and follow up analysis.

2 GICAN-GB02
11/05/2022

Project code: EPIC-GICAN-GB02

Type of Service: METHOD DEVELOPMENT AND ANALYSIS OF TOTAL MICROPLASTICS CONCENTRATIONS

Method development: xx
Sampling date: 5-6th April 2022
Sample processing: 7-8 April 2022
Report generated: 11th May 2022

Type and number of samples processed for the report:

1. INFLUENT (IN)
2. PRE-MBBR TREATMENT (PM)
3. MBBR DISCHARGE (MD)
4. EFFLUENT (EF)

This report is for the samples that were collected during the site visit 5-8th April 2022

Objective:

To test the applicability of novel IR method for measuring total microplastics concentration from the effluent for routine monitoring purposes.

Methodology

1. On-site work details:

1. Influent, Pre-MBBR (MBBR feed), MBBR discharge and effluent each were manually collected (grab sampling) by Geetika with the help of the WWTP staff between 5-8th April 2022. All the samples except effluent were digested overnight on-site with Fenton reagent (without heat or stir).
2. In our routine analysis at our research facility at the University of Newcastle, digested samples are always passed through stainless steel sieves of various size ranges. This allows for a gradual separation of particles in the digestate which is followed by microscopic examination. After particle counting, the particles of interest are identified using a vibration spectroscopy technique.
3. It is important to achieve maximum sample clarity in order to be able to detect microplastics using any spectroscopy, which is a crucial step but unfortunately highly time consuming.
4. Heat digestion, sieving, microscopic analysis and FTIR identification of samples were not carried out on-site due to a lack of necessary equipment and time constraints. However, to be able to quickly isolate MBBR material, samples were digested with peroxide and a portion of the digested sample was taken for filtration through 4-7 µm cellulose acetate filters. This was done to see if most of the processing can be done on-site.
5. For demonstration purposes, the digestate was passed through the 4-7 µm cellulose acetate filter. Due to the residual clumps in the influent and pre MBBR samples (which still remain after digestion) of organic matter in the digestate, as expected, only <250 mL of digestate could be passed through the filter before it clogged the filter completely. It was exhibited that sequential sieving, although time-consuming, is a necessary step to separate particles from a large quantity of water. Sieving ensures a gradual removal of bigger chunks of material and allows for accurate particle analysis and counting.
6. Filtration of 8-15 L of effluent was successfully carried out in the lab through a 4-7 µm cellulose acetate filter over a duration of a few hours. The filters were brought back to the University for further processing.

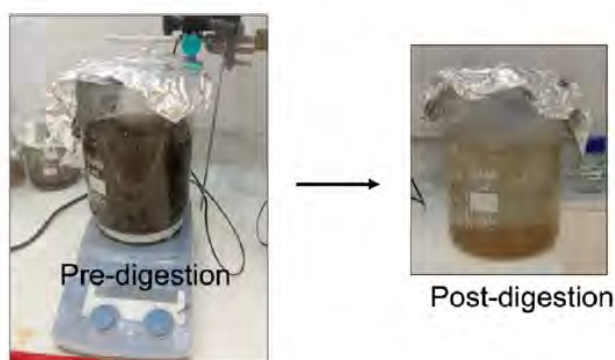
3 GICAN-GB02
11/05/2022

7. A novel method for microplastic quantification was tested on-site for its application in the quantification of microplastics. The technique was found helpful in the determination of total plastic (non-dark) quantification.
8. For an accurate particle analysis in the IN, PM and MD, another set of samples were brought to Newcastle and the samples were processed using the following standardized method:

2. Digestion:

Due to the high amount of organic matter, all the samples except effluent were heat digested (Image 1 below) using Fenton reagent of varying concentrations. The Fenton concentration used for the digestion depends on the complexity and organic matter content of the samples.

Image 1



3. Sieving:

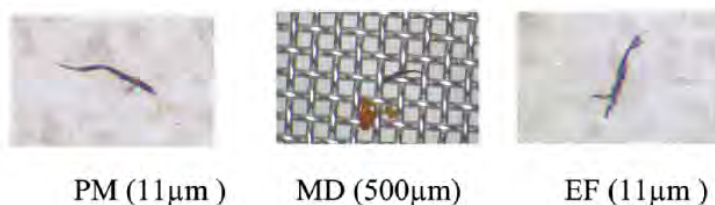
The digested samples were then passed through a series of stainless-steel sieves to separate microplastic particles of different sizes. The sieving procedure is time-consuming as demonstrated during Geetika's on-site visit.

NOTE: The concentration of Fenton reagent used for digestion does not impact microplastics (based on previous laboratory testing) and has been optimised through preliminary testing.

4. Microscopic examinations

Sieved particles from each size range were examined and counted using a microscope. Black MBBR material was found in Pre-MBBR, MBBR discharge and Effluent as shown below.

Image 2

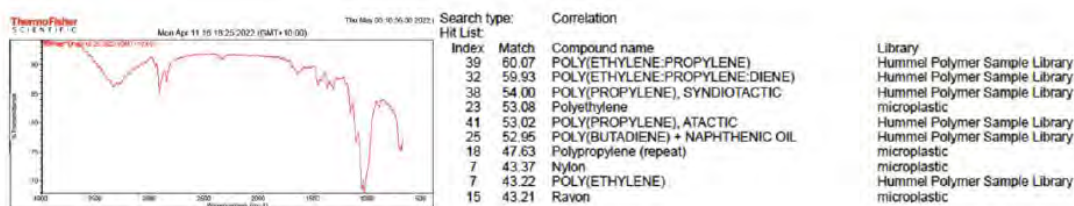


5. Polymer identification

5.1. Black particles in PM, MD and EFF:

Identified black particles were characterised using our advanced FTIR. The spectra were compared with a Global polymer library and our laboratory database which showed a maximum match (60%) with Polyethylene:Polypropylene as shown below. This indicates that the bond spectra identified by library search matches both Polyethylene and Polypropylene which is expected in a typical recycled plastic. The blending of PE and PP eliminates the sorting process used in the regular recycling process. Please note that both polymers have a very similar polymer structure (only an extra CH₂ molecule in Polypropylene).

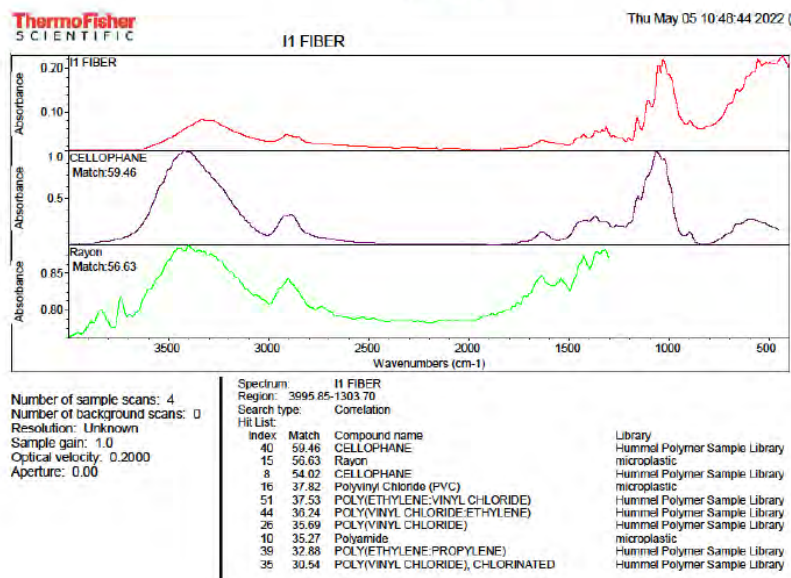
Image 3



5.2 Fibrous mass in influent samples:

As communicated with previous samples, the processing of the influent sample produced a fibrous mass that was isolated and characterised using micro-FTIR. When compared with the available database the maximum spectral match was found with Cellophane and Rayon as shown below:

Image 4



6. Microplastic particle count

During the site visit, grab sampling was used for acquiring water samples. In those samples, especially in the influent water, the amount of organic chunk was almost non-existent after heat digestion for an appropriate amount of time. This made the counting of MBBR particles feasible in the influent samples. It is possible that the water sampled using the autosampler

5 GICAN-GB02

11/05/2022

contains the toilet paper portion that has a high cellulose content and usually sinks at the bottom. This is, however, just a hypothesis and requires further exploration.

6.1 Microplastic count in the water collected via grab samplings:

GRAB SAMPLING (particle numbers) 08 Apr 2022									
Sample type	Volume processed	≥ 1mm	≥ 500 µm	≥ 250 µm	≥ 125 µm	≥ 63 µm	≥ 63-11 µm	Total plastics	MBBR particles
IN	2L	8	19	1	16	6	11	61	0
PM	2L	1	0	4	2	2	6	15	0
MD	2L	0	3	2	6	6	39	56	49
EF	2L	2	0	6	2	7	62	79	57

6.2 Microplastic count in the water collected via autosamplers (for comparison):

AUTOSAMPLER (weight and particle number) 21 Mar 2022									
Sample type	Volume processed	≥ 1mm	≥ 500 µm	≥ 250 µm	≥ 125 µm	≥ 63 µm	≥ 63-11 µm	Total plastics	MBBR particles
IN	2L	0.024g	0.09g	0.108g	0.011g	0.003g	5	0.236g	0
PM	2L	0	0	14	16	18	7	55	47
MD	2L	0	4	12	18	28	16	78	68
EF	4L	0	0	5	2	3	84	94	87

7. Quantification of microplastics

7.1 Mass, density and shape-based calculation:

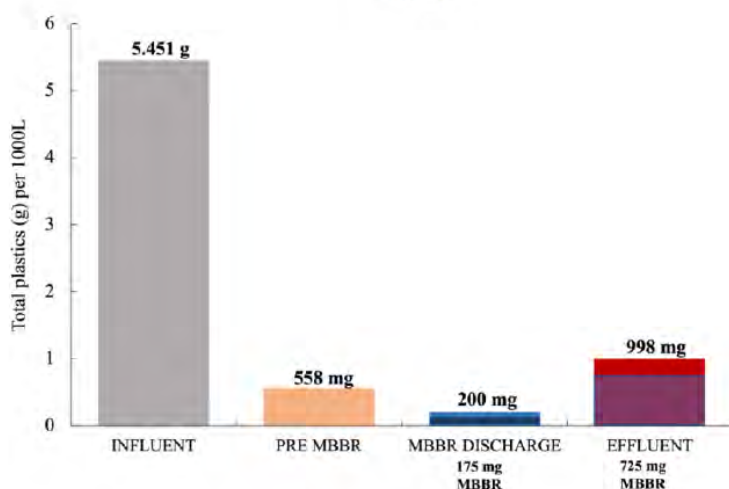
The mass of the estimated MBBR contribution in the effluent is the function of the extent of disintegration, environmental weathering, the number of particles, the size of the particles, the shape of the particle and Particle size distribution (PSD). The microplastic particles found in the samples are cubical in shape. The mass calculation of microplastics is done based on the current literature with the following assumptions:

- All particles were equally weathered, therefore, have the same density
- All particles were cubical in shape
- All particles had a homogenous particle size distribution in a particular size class
- The particles found in a size class are <5 micron bigger than the pore size
- The density of the MBBR particles was 0.95 g.cm⁻³
- The density of other mixed plastic was 1.04 g.cm⁻³ (average of PE, PP, PES and NY)
- The size of the particles caught in the filter 63-11 µm was 37 µm (average)
- When more than 70% of the particles are MBBR, 0.95 g.cm⁻³ was used for calculations

7.2 Calculated mass (mg):

GRAB SAMPLING (particle mass in mg/L-1) 08 Apr 2022, Image 5									
Sample type	≥ 1mm	≥ 500 µm	≥ 250 µm	≥ 125 µm	≥ 63 µm	≥ 63-11 µm	Total plastics	Non-MBBR	MBBR
IN	4.18400	1.24213	0.00817	0.01634	0.00078	0.00029	5.45172	5.45172	0
PM	0.52300	0.00000	0.03269	0.00204	0.00026	0.00016	0.55815	0.55815	0
MD	0.00000	0.17813	0.01484	0.00557	0.00071	0.00094	0.20019	0.02502	0.17516
EF	0.95000	0.00000	0.04453	0.00186	0.00083	0.00149	0.99871	0.27365	0.72506

Image 5



7.3 IR spectroscopy based microplastic mass estimation

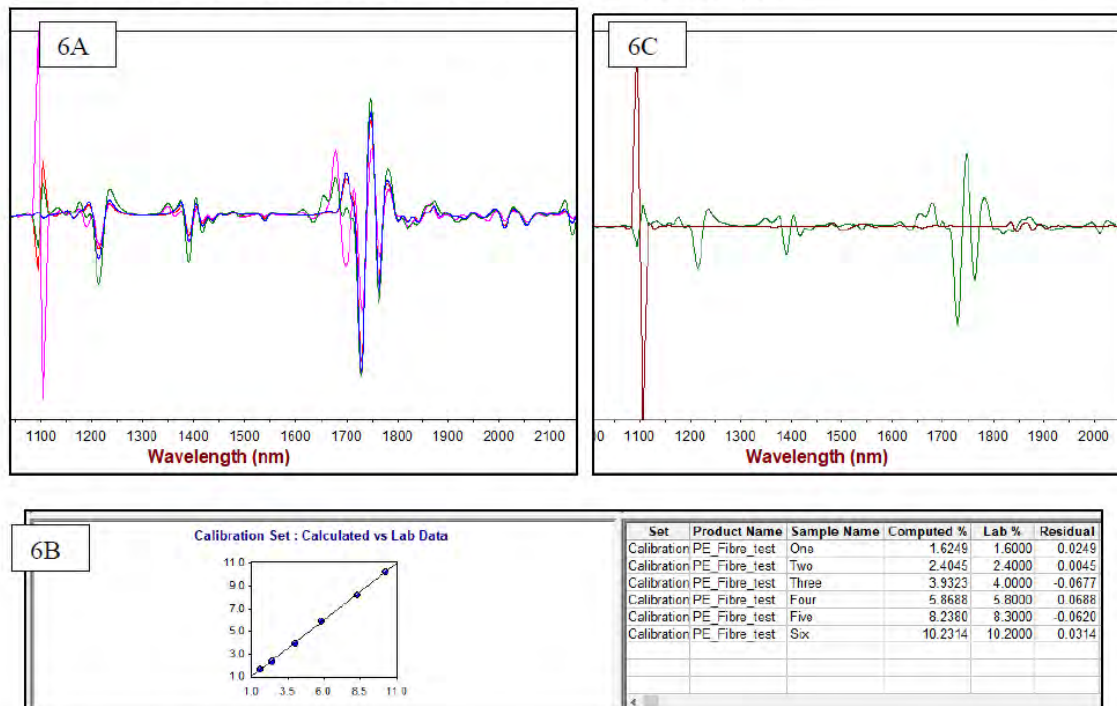
1. We tested a new method (image provided) to quantify microplastics in the samples. This method was based on molecular overtone and combination vibration. The 5 most common polymers of plastics (Polyethylene, Polypropylene, Polyester, Polyethylene terephthalate and Nylon) were tested and the peak between 1703-1747 nm was found to be the distinctive absorption peak for all plastics as shown in image 6A. This pre-testing was conducted at UoN prior to the site visit. To make sure that the instrument is calibrated after it was brought on-site, manual calibration of the instrument was conducted, and all the polymers were reanalysed, and peak positions were noted. The mixed plastic samples received from the WWTP staff were analysed with the instrument and plastic specific peaks were found in the same region, thus providing verification of the spectral region.
2. Polyethylene is the most abundant plastic polymer in the environment and since all plastic types showed peaks at nm, we used aged (8-month incubation in the natural marine environment) polyethylene to create a calibration curve as shown in image 6B. The mass of microplastics in the clumps of fibres (21 Mar 2022 from autosampler) produced after processing the influent samples was 3.7 mg based on regression analysis.
3. The sensitivity of the new method was determined by reanalysing the samples used for calibration and including blind samples in the analysis. Results indicated that the instrument is useful in the accurate quantification of >1.3 mg of plastic sample.
4. We used aged MBBR material to prepare a standard curve but due to the opaque nature and black colour of the sample, the spectral peaks were very weak (image 6C, red = MBBR signal, green = white polyethylene signal) as the light could not penetrate into the sample properly. All the current techniques for microplastic quantification need a calibration based on the polymer weight. It is essential to note that the polymer weight matches the peak intensities in all the non-black polymers. Unfortunately, in this case, the smaller MBBR particles showed better peaks compared to bigger MBBR pieces; possibly due to environmental weathering which is known to increase the crystallinity of polymers making them less opaque. This challenged the suitability of the estimation for the HeliX media using the novel method that was tested. Therefore, it was concluded that the direct quantification method can only be used with polymers that allow light penetration. The powdered MBBR samples received after artificial disintegration also showed weak and inconsistent



7 GICAN-GB02
11/05/2022

spectral peaks and therefore considered inept to be included in the analysis. The new MBBR media (white, non-recycled Polyethylene) that was received from the WWTP would be ideal for direct quantification since it can be easily calibrated.

5. It was also determined that cellulose acetate filters can be used for this analysis as there was no overlapping in the region when plastic-specific peaks were identified.



8. Overall challenges in quantification of MBBR particles in wastewater samples

8.1 Sample processing

Digestion and purification of influent samples is a time-consuming procedure due to the complexity of the medium. The digestion of the influent samples on-site (without heat followed by the non-sequential sieving of the sample directly through the 4-7 μm cellulose acetate filter) did not produce consistent data. Filtration of the effluent samples on-site was conducted but since the MBBR particles had a weak signal and contributed almost 73% of the total microplastics, the total quantifiable mass of microplastics might not have reached the threshold of 1.3 mg which is the lowest detectable limit of the instrument. Therefore, it was concluded that the direct quantification of non-MBBR (non-black particles) and indirect quantification of MBBR (mass balance) can only be achieved if a much higher volume of water (details in section 10) is filtered. For lower volume, microscopic evaluation was deemed most suitable for particle count and density-based theoretical mass estimation.

8.2 Sampling method

The characteristics and quantities of microplastics in the samples received using the autosampler (all previous samples) were different to those sampled using the grab sampling method. Especially, in the case of influent samples, the digestate had little to no chunks of fibres which made the counting of microplastics far more efficient. The grab sampling is the most accepted sampling method in the wastewater microplastic research and is suggested for sampling in future for any microplastic related research. If auto-sampling is the preferred method by the end-user, our team can help with designing a special auto-sampler that would be suitable for Microplastics sampling in Wastewater.

8.3 Direct quantification of MBBR particles

8 GICAN-GB02

11/05/2022

As discussed in section 6.2, the MBBR material does not allow the light to penetrate which is why the IR based method cannot be used for the direct quantification of MBBR particles. The other issue that was found in the quantification of MBBR was the weathering-induced changes in the spectral properties of MBBR material. Environmental weathering of MBBR media, which is a function of the surface area and particle size, showed an enhanced IR signal strength but the signal wasn't consistent in the replicates.

9. Conclusions

1. There is currently no method available in research that can quantify microplastics other than the novel method that we tested for this project. This method, however, cannot be used with the opaque black MBBR media.
2. Our tests with other polymer types indicated that the novel method that was tested can be highly useful if the MBBR polymers allow light penetration.
3. Our analysis and literature on WWTP suggest that grab sampling is the most preferred method of sampling. While an autosampler can sample large quantities of water over long periods of time, the microscopic plastic particles tend to float which could bring bias to the sample. Further, the standard auto-sampler designed for chemical and nutrient monitoring has a built-in back-flush that isn't appropriate for sampling microplastics. On the other hand, grab sampling can also bring more bias and may overrepresent the microplastic concentration. As expected, this topic is currently discussed in the microplastic research community. Still, the current literature on WWTP suggests grab sampling (ideally using 10-20 L buckets) for consecutive days as a suggested method. If auto-sampling is the preferred method by the end-user, our team can help design the special auto-sampler suitable for Microplastics sampling in Wastewater.

10. Guidance for field monitoring

10.1 On-site measurement of total MPs in the Effluent stream:

The sample volume that can be completely processed in 4-5 days is only 2L which does not represent the water coming in and going out of the WWTP every day. To successfully determine the a) microplastic load in the influent, b) additional load caused due to the fragmentation of MBBR media and c) the total microplastic load in the effluent; at least triplicate 30 L samples need to be processed. This number is based on our experience with processing wastewater in the past few years. In addition, sampling method, sampling time and seasonal variations cannot be discounted as they will contribute to a variable microplastic load. In addition, the number of microplastics in pre-MBBR samples could vary based on the sampling location, therefore, it is advised that the samples sent in the future are from the same point.

Bottom line: The best approach is continuous filtering of 30-50L (based on the expected number of particles) followed by Portable IR measurement and when/if any spike in the value is encountered, to be cross-checked using UoN lab facilities (with duplicate samples)

10.2 On-site measurement of total MPs in the influent:

MBBR samples require extensive sample pre-treatment, processing and digestion therefore, enough volume of sample has to be as clean as the effluent followed by the use of the portable IR measurement.

10.3 Determine MBBR% on site:

Our optimised method in the lab is efficient when non-black polymers are used. However, the HeliX MBBR media generates a low inconsistent signal. Therefore, the direct quantification of the MBBR cannot be done on site and can only be achieved using the traditional methods standardised at our UoN laboratory.

END OF REPORT

9 GICAN-GB02
11/05/2022

Appendix E SAQP P5: Assessment of loss in mass of in-service MBBR plastic media.

Appendix E: SAQP P5 MBBR In-Service Carriers Loss in Mass

KAWSTP Project Management
Services

Prepared for
Unitywater

8 July 2022



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1	17/12/2021	Initial issue	L.Walsh	R.Donald
2	13/1/2022	Analysis of second unused carrier sample	R.Donald	R.Donald
3	31/5/2022	Table 3 description	R.Donald	R.Donald
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Executive Summary

The wear of plastic MBBR carriers used at Kawana STP was investigated to determine if there is likely to have been any loss in mass after being in-service for approximately 2 years. Samples of MBBR carriers were collected from the anoxic and first aeration zones of both MBBR bioreactors, and the biofilm removed. The mass of these MBBR carriers was compared to the mass of two sets of unused carriers (First Samples and Second Samples). The Second Samples were taken after noticing a variation in cut length of the First Samples. The average mass of the First Samples was 3.8% higher than the Second Samples.

The carriers from the anoxic tanks were on average 9.72% lighter than the First Samples of unused carriers and 6.27% lighter than the Second Samples of unused carriers. Similarly, the carriers from the first aeration tanks were on average 6.32% lighter than the First Samples of unused carriers and 2.74% lighter than the Second Samples of unused carriers.

Even though there is a difference in the mass of unused carriers, the results identified that the in-service carriers were consistently lighter than the unused carriers.

Assuming the unused carriers are representative of the carriers that were first put into service at Kawana STP, visual examination of the in-service carriers suggests this decrease in mass is likely due to wear of the carriers in the bioreactor.

Considering the MBBR carriers have been in-service at Kawana STP for approximately 2 years, achieving a 25-year design life normally expected of MBBR carriers would be challenging if this current rate of degradation continues.

There is some uncertainty regarding the mass of the MBBR carriers initially loaded at Kawana STP and still in service. Further, it has been assumed that the unused carriers in storage at Kawana STP that were analysed are representative of the carriers that were initially loaded.

Table of Contents

1	Introduction	1
1.1	Purpose	1
1.2	Background	1
2	Experimental Procedure	2
2.1	Carrier Sampling from Bioreactor	2
2.2	Removal of Biofilm from In-Service MBBR Carriers	2
2.3	Chemical Treatment of Unused MBBR Carriers	2
2.4	Drying the MBBR Carriers	3
2.5	Weighing the Samples	3
2.6	Measurement of Unused Carriers	4
3	Results	5
3.1	Visual Assessment,	5
3.2	Analytical Results	6
4	Analysis of Results	10
5	Conclusion	11

Tables

Table 1: Unused Carriers – First Samples	6
Table 2: Unused Carriers – Second Samples	7
Table 3: Chemically Treated Unused Carriers – First Samples	7
Table 4: Carriers from MBBR1 Anoxic Tank	8
Table 5: Carriers from MBBR2 Anoxic Tank	8
Table 6: Carriers from MBBR1 Aeration Tank 1	9
Table 7: Carriers from MBBR2 Aeration Tank 1	9

Figures

Figure 1: Oven Drying the Carrier Samples	3
Figure 2: Weighing the Carrier Samples	3
Figure 3: MBBR Carriers from Anoxic Tank	5
Figure 4: MBBR Carriers from Aeration Tank 1	5
Figure 5: Unused MBBR Carriers – First Samples	6

1 Introduction

1.1 Purpose

This report provides the results of an experimental investigation of the loss in mass of in-service plastic carriers in the moving bed biofilm reactor (MBBR) at Kawana STP (KAWSTP).

1.2 Background

Unitywater has identified risks associated with loss in plastic from the MBBR carriers, with a project underway to respond to an Environmental Evaluation (EE) issued by the Department of Environment and Science (DES) relating to the risk of plastic from MBBR carriers in the marine environment. A situation of ongoing MBBR carrier degradation that risks discharge to the environment may have significant consequences from an environmental regulatory and public perception perspective.

Basket style screens with 2mm aperture are already in place at KAWSTP to reduce the risk of plastic release to the environment.

The KAWSTP bioreactor has a total of eight separate tanks, or zones, comprising two parallel process trains (MBBR1 and MBBR2) with each train having one anoxic and three aerobic zones. Incoming sewage flow is evenly split and flows through each bioreactor train, starting from the anoxic zone and passing through each of the three aerobic zones, one after the other.

In an MBBR, each bioreactor zone is filled with large quantities of carriers. The carriers are small plastic mouldings specially designed to maximise treatment performance. The in-service MBBR carriers at KAWSTP are cylindrically shaped, 13 mm in diameter and 13 mm in length, with internal elements that encourage biofilm growth, attachment, and detachment. The carriers are manufactured from recycled high-density polyethylene (HDPE), and have a specific gravity low enough for the carriers to remain in suspension in the bioreactor and high enough to avoid rafting on the surface.

The volume of each bioreactor zone varies between 775 m³ and 892 m³. Each zone is filled with around 50% to 65% of carriers by volume, with the carriers suspended in the liquid. Contaminants are biologically removed from the sewage by the bacteria colonising the MBBR carriers as a biofilm. MBBR carriers are retained within each bioreactor zone by large submerged cylindrical screens mounted in the separating head walls between each bioreactor tank. The screens are designed to only allow liquid and particles less than 10 mm to pass through. MBBR carriers that have broken into smaller particles can pass through these screens and out of the bioreactor.

Large volumes of air are pumped into the aerobic zones of the bioreactor through submerged coarse bubble diffusers. While the anoxic zones do not use air mixing, a large vertical shaft mixer is used to keep the contents mixed. This action in the bioreactor tanks can cause degradation of the MBBR carriers. It is generally considered that MBBR carriers do not need to be replaced before about 25 years of service, and must therefore withstand the physical forces due to mixing and air agitation and the ongoing collisions with other carriers and bioreactor walls.

2 Experimental Procedure

2.1 Carrier Sampling from Bioreactor

A random sample of MBBR carriers were taken from the anoxic zone and first aeration zone of both MBBR1 and MBBR2 using a pool scoop. A mechanical mixer is used in the anoxic zone whereas submerged air diffusers are used in the aeration zones. It was assumed that carrier wear was likely to be consistent in all aeration zones and the first aeration zones was selected for the analysis. Within each MBBR zone sampled, four samples of approximately 165 carriers were taken from different locations and placed in 500 mL sample containers. The sample containers each filled to a level of approximately 5 mm from the top of the carriers to the lid of the sample container. The number of carriers in each sample container were counted after sample processing and analysis. A total of 16 sample containers filled with carriers were processed:

- > MBBR 1 anoxic sample 1 of 4 to sample 4 of 4
- > MBBR 2 anoxic sample 1 of 4 to sample 4 of 4
- > MBBR 1 aeration sample 1 of 4 to sample 4 of 4
- > MBBR 2 aeration sample 1 of 4 to sample 4 of 4

2.2 Removal of Biofilm from In-Service MBBR Carriers

Biofilm was removed from the carriers using a combination of 10% sodium hydroxide (NaOH) and 10% citric acid ($C_6H_8O_7$), sourced from Maleny STP storage tanks. The 30% sodium hydroxide was diluted to 10% concentration with tap water, and the 50% citric acid was diluted to 10% concentration with tap water. The biofilm was removed from the carriers using these steps:

- > 10% NaOH was added to each sample container and allowed to soak for approximately 1 hour with the sample lids on.
- > Sample containers were gently shaken to loosen biofilm, liquid was drained, and the contents rinsed using tap water and drained again. The rinse and drain process was repeated until the liquid ran clear of biofilm particles.
- > 10% NaOH solution was added to each sample container, the lid replaced, and allowed to stand for 5 days.
- > Sample containers were gently shaken to loosen biofilm, liquid was drained, and the contents rinsed using tap water and drained again. The rinse and drain process was repeated until the liquid ran clear of biofilm particles.
- > 10% NaOH solution was added to each sample container, the lid replaced, and allowed to stand for a further 2 days.
- > Sample containers were gently shaken to loosen biofilm, liquid was drained, and the contents rinsed using tap water and drained again. The rinse and drain process was repeated until the liquid ran clear of biofilm particles.
- > 10% citric acid solution was added to each sample container, the lid replaced, and allowed to stand for 1 hour.
- > Sample containers were gently shaken to loosen biofilm, liquid was drained, and the contents rinsed using tap water and drained again. The rinse and drain process was repeated until the liquid ran clear of biofilm particles.

2.3 Chemical Treatment of Unused MBBR Carriers

To reduce the risk of bias in the analysis through loss in mass of carriers caused by chemical degradation, a sample of 500 unused carriers was also exposed to 10% sodium hydroxide (NaOH) and 10% citric acid ($C_6H_8O_7$), following approximately the same procedure for removing biofilm from the in-service carriers. Unused carriers were added to 3 x 500 mL sample containers and the following steps taken:

- > 10% NaOH was added to each sample container and allowed to stand for 5 days with the sample lids on.
- > Sample containers were shaken, liquid was drained, and the contents rinsed using tap water and drained again. The rinse and drain process was repeated 6 times.

- > 10% citric acid solution was added to each sample container, the lid replaced, and allowed to stand for 1 hour.
- > Sample containers were shaken, liquid was drained, and the contents rinsed using tap water and drained again. The rinse and drain process was repeated 6 times.

2.4 Drying the MBBR Carriers

Each sample of carriers was distributed evenly across a set of 5 aluminium trays, with the orientation of carriers consistent across samples. The samples were oven dried (Figure 1) at 60° for approximately 3 hours, or until they were dry to touch.



Figure 1: Oven Drying the Carrier Samples

2.5 Weighing the Samples

Once dried, carriers in each sample were counted and they were left to cool for approximately 5 minutes. Each sample was then weighed and the average mass per carrier calculated. These values were compared to the control sample of unused carriers to analyse changes in carrier mass.



Figure 2: Weighing the Carrier Samples

2.6 Measurement of Unused Carriers

Visual examination of unused carriers shows a degree of variability from one carrier to another, likely arising from the manufacturing process (mainly cut length). Although the sample size of unused carriers (approximately 500) is likely to minimise the effects of individual carrier-to-carrier mass variability, it is unclear whether there may be batch to batch variability. To investigate this possibility of as-supplied MBBR carriers having variable mass, further samples were taken from multiple bags of unused carriers stored at Kawana STP. In this investigation, a larger sample of 15 sets of 100 carriers were weighed and the results used as a comparison to the in-service carriers. This second set of sampled unused carriers is denoted Second Samples, with the first set denoted First Samples.

3 Results

3.1 Visual Assessment,

Following biofilm removal from the in-service carriers, the MBBR carriers were visually compared, noting the degree of “whitening” of the carriers (Figure 3 and Figure 4). The “whitening” appeared to be more prominent on carriers from the anoxic zone which were also more visibly rounded and with less rigidity compared to the carriers from aerobic zone. Figure 5 shows the First Sample of unused carriers following chemical treatment where whitening was not observed. The in-service carriers were all whole carriers showing signs of wear, such as rounding of edges.



Figure 3: MBBR Carriers from Anoxic Tank



Figure 4: MBBR Carriers from Aeration Tank 1



Figure 5: Unused MBBR Carriers – First Samples

3.2 Analytical Results

A summary of the mass reduction for all samples of MBBR carriers is provided in this section.

Table 1 and Table 2 provide the results of the mass of unused carriers from the first and second batches of samples. This data presented was used as the basis for calculating the average mass of unused carriers.

Table 3 shows the mass of unused carriers (First Samples) following chemical treatment. The test was carried out to determine if chemical treatment of the carriers would cause a loss in mass by comparing the average mass after chemical treatment with unused carriers without chemical treatment. As shown in Table 3, the test was repeated for three batches of carriers numbering 166 to 168 per batch. The mass after chemical treatment showed minimal variation from the average unused carrier mass shown in Table 1. The average loss in mass of 0.18% is likely to be within experimental error associated with equipment and methodology and therefore it was taken that chemical treatment did not cause any loss in mass.

Assuming the material composition between First Samples and Second Samples remained consistent to the extent of maintaining the same chemical resistance, further testing of the Second Samples was not required.

Table 1: Unused Carriers – First Samples

No. of carriers in sample	Total mass of sample (g)	Average mass/ carrier (g)
166	78.5212	0.47302
166	78.4674	0.47270
168	80.0938	0.47675
Average		0.47416

Table 2: Unused Carriers – Second Samples

No. of carriers in sample	Total mass of sample (g)	Average mass/ carrier (g)
100	45.9881	0.4599
100	46.3285	0.4633
100	45.5297	0.4553
100	45.5175	0.4552
100	45.8651	0.4587
100	45.6259	0.4563
100	44.8503	0.4485
100	45.1093	0.4511
100	45.0922	0.4509
100	44.8520	0.4485
100	46.0650	0.4607
100	45.2509	0.4525
100	46.3822	0.4638
100	46.5697	0.4657
100	46.008	0.46008
Average		0.4567

Table 3: Chemically Treated Unused Carriers – First Samples

No. of carriers in sample	Total mass of sample (g)	Average mass/ carrier (g)	Mass loss compared to Unused Carrier
166	79.033	0.47610	-0.41%
166	78.2248	0.47123	0.62%
168	79.3994	0.47262	0.32%
Average loss in mass			0.18%

Tables 4 to 7 presents the results of in-service carriers sampled from the Kawana STP bioreactor across both MBBR1 and MBBR 2 trains from the anoxic tanks and from the first aeration tank of the process. Note that the average loss in mass shown in this analysis is based on the average mass per carrier across all samples in each group. For example, from Table 1, the average mass per unused carrier = $(78.5212 + 78.4674 + 80.0938) / (166 + 166 + 168) = 0.47416$.

Table 4: Carriers from MBBR1 Anoxic Tank

Sample No.	No. of carriers in sample	Total mass of sample (g)	Average mass/ carrier (g)	Mass loss compared to Unused Carrier
1/4	167	72.3365	0.43315	8.65%
2/4	174	74.6238	0.42887	9.55%
3/4	172	73.2951	0.42613	10.13%
4/4	179	76.268	0.42608	10.14%
Average loss in mass c.f unused carriers, First Samples				9.63%
Average loss in mass c.f unused carriers, Second Samples				6.17%

Table 5: Carriers from MBBR2 Anoxic Tank

Sample No.	No. of carriers in sample	Total mass of sample (g)	Average mass/ carrier (g)	Mass loss compared to Unused Carrier
1/4	172	73.7871	0.42899	9.53%
2/4	181	77.5612	0.42851	9.63%
3/4	172	73.3472	0.42644	10.07%
4/4	178	75.94	0.42663	10.03%
Average loss in mass c.f unused carriers, First Samples				9.81%
Average loss in mass c.f unused carriers, Second Samples				6.36%

Table 6: Carriers from MBBR1 Aeration Tank 1

Sample No.	No. of carriers in sample	Total mass of sample (g)	Average mass/ carrier (g)	Mass loss compared to Unused Carrier
1/4	163	72.866	0.44703	5.72%
2/4	162	72.8755	0.44985	5.13%
3/4	163	72.8332	0.44683	5.76%
4/4	172	78.808	0.45819	3.37%
Average loss in mass c.f unused carriers, First Samples				4.97%
Average loss in mass c.f unused carriers, Second Samples				1.34%

Table 7: Carriers from MBBR2 Aeration Tank 1

Sample No.	No. of carriers in sample	Total mass of sample (g)	Average mass/ carrier (g)	Mass loss compared to Unused Carrier
1/4	172	75.1955	0.43718	7.80%
2/4	174	76.5517	0.43995	7.22%
3/4	166	72.308	0.43559	8.14%
4/4	173	75.8493	0.43844	7.54%
Average loss in mass c.f unused carriers, First Samples				7.67%
Average loss in mass c.f unused carriers, Second Samples				4.13%

4 Analysis of Results

There was very little, if any “whitening” of the unused carriers, with little difference between the unused carriers with and without chemical treatment. Carriers from the anoxic zone had more exterior “whitening” than carriers from the aeration zone. Carriers with a lot of “whitening” also had a rougher surface, with scuffed areas more prominent on the edges of the cylindrical carriers, and with more pronounced rounding of the edges of the carriers. Comparison between the unused carriers with and without chemical treatment showed minimal visual differences.

The average mass of in-service carriers in the anoxic and first aeration tanks of MBBR1 and MBBR2 is less than the mass of unused carriers. In particular, the in-service carriers from the anoxic tanks are on average 9.72% lighter than the First Samples of unused carriers and 6.27% lighter than the Second Samples of unused carriers. Similarly, the in-service carriers from the first aeration tanks are on average 6.32% lighter than the First Samples of unused carriers and 2.74% lighter than the Second Samples of unused carriers.

There was minimal loss in mass of unused carriers due to chemical treatment, indicating the loss in mass of in-service carriers was unlikely to be the result of chemical treatment for biofilm removal. Little breakage of the carriers was observed, and all of the in-service carriers used in the investigation were whole, not broken. That is, the loss in mass of in-service carriers was due to wear and not breakage.

Unitywater has advised that the Kawana STP bioreactor contains 154,240 kg of plastic MBBR carriers in the anoxic tanks and 367,040 kg across all aeration tanks. Taking the results of the in-service carriers compared to the unused carriers of the First Samples with 9.72% in the anoxic tank and assuming 6.32% loss in carrier mass across all aeration tanks, the total loss in mass of plastic carriers over the 2 years is estimated as 38,189 kg. Taking the results of the in-service carriers compared to the unused carriers of the Second Samples with 6.27% in the anoxic tank and assuming 2.74% loss in carrier mass across all aeration tanks, the total loss in mass of plastic carriers over the 2 years is estimated as 19,704 kg.

The average mass of unused carriers in the Second Samples was 3.7% less than the First Samples. Since the mass of the unused carriers is used as a basis for comparison to the unused carriers, it is important to have confidence in this value. However, even if the mass of every unused carrier available in storage at Kawana STP is measured, the actual mass of the carriers first loaded into the bioreactor at Kawana STP is not conclusively known.

5 Conclusion

The MBBR plastic carriers sampled from Kawana STP appear to have lost in the order of 6 to 10% mass in the anoxic tanks and 3 to 6% in the first aeration tank, assuming the samples of unused carriers used as a comparison are representative of the carriers in the bioreactor. It is understood that the carriers have been in service for around 2 years and they visually appear to be worn, such as rounding of the corners. It is estimated that in the order of 20,000 to 38,000 kg of plastic particles from worn MBBR carriers may have been lost from the bioreactor since start-up.

The process design report for Kawana STP advises a 25-year design life for MBBR carriers. If the rate of MBBR carrier degradation identified from this analysis is not significantly reduced, the MBBR carriers are unlikely to provide the design life and ultimately the amount of plastic lost from the bioreactor will be substantial. Further to this, consideration should also be given to carrier degradation through breakage where worn carrier surfaces will provide less structural integrity that is likely to result in carriers breaking into smaller fragments before completely wearing out.

It is important to acknowledge that this analysis has calculated the possible loss in mass of in-service carriers on the assumption that the sampled unused carriers in storage at Kawana STP is representative of those first loaded. While this might be likely, it cannot be fully confirmed.

Limitations in the methodology used in this analysis have been considered, including:

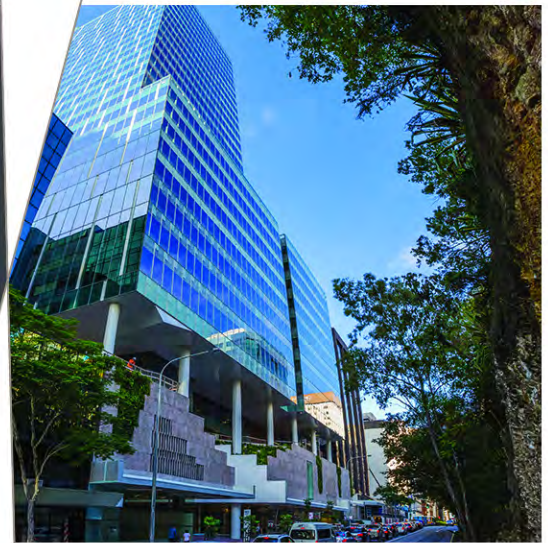
- > Unused carrier sample size: further samples of unused carriers could be taken to understand the variability in mass to be used as a basis for comparison of loss in mass of in-service carriers.
- > In-service carrier sample size: this study assessed over 600 carriers per bioreactor tank. While the sample size used in this analysis may already provide results that are sufficiently statistically robust, a statistical assessment may provide further insight to the degree of confidence in the results.
- > Bioreactor zones: this investigation assessed carriers from the anoxic and first aeration tanks where it was assumed the first aeration tank was representative of all aeration tanks. Further analysis might consider samples from all eight bioreactor tanks (2 x MBBR trains x 4 tanks per train) to provide a more accurate assessment of total plastic loss across the entire bioreactor.
- > Chemicals to remove biofilm: sodium hydroxide and citric acid provided good visual efficacy of biofilm removal, but other types may be considered, such as Fenton's Reagent and/or ultrasonics. More detailed microscopic examination to confirm biofilm removal may also be considered. If all biofilm was not removed, then the loss in mass of in-service carriers may have been underestimated in this analysis.
- > Impact of chemicals on plastic: further consideration could be given to the potential effect of chemicals on the plastic. Since both in-service and unused carriers were both subject to the same chemical treatment, there is unlikely to be any comparative difference in loss in mass due to chemical action on the plastic, but the interaction of the biofilm with the chemicals and any subsequent effect on the plastic was not investigated in this study.
- > Drying time and temperature: visual assessment was used to confirm the degree of dryness of the in-service carriers and that the oven temperature had no impact on the plastic. A less subjective standard may be considered for degree of dryness, such as oven humidity, and microscopic examination of the plastic. If all moisture was not removed from the in-service carriers, then the loss in mass may have been underestimated in this analysis.

Appendix F SAQP P6: Assessment of mechanical degradation testing of MBBR plastic media.

An Accelerated MBBR Carrier Degradation Test Procedure

KAWSTP Project Management
Services

304600296



*Prepared for
Unitywater*

28 June 2022



now



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Summary

An experimental investigation was completed to investigate the rate of mechanical degradation of MBBR carriers. A test procedure was developed using rotary tumblers containing grinding media, plastic MBBR carriers, and water. Different types of grinding media and other parameters were investigated, and “medium” and “large” sized rocks grinding media were identified as demonstrating wear and breakage mechanism of the test carriers that resembled that observed of the in-service Hel-X carriers at Kawana STP.

The test using “medium” sized rocks grinding media indicated that between 1 and 2 weeks of testing Hel-X carriers in the rotary tumbler under the test conditions was equivalent to about 2 years of those carriers being in service at Kawana STP by comparing the loss in mass. Analysis of the test results suggest that the in-service Hel-X carriers may begin to experience higher rates of breakage after about 6 years in operation where the number of broken carriers escaping the MBBR would increase. It is stressed that further investigation is required to confidently conclude this.

The tests showed that the Warden Biomedia carrier types exhibited significantly enhanced mechanical properties that resisted mechanical degradation in the rotary tumbler test. In particular, the smallest Bioflo+ carrier showed more resistance to degradation.

There does not appear to be a standard or widely accepted test methodology for comparing the mechanical strength of MBBR plastic carriers and forecasting their longevity. With limited external guidance, this investigation relied on trial and error methods to establish a test procedure. As a result, several limitations were identified and it is recommended that consideration be given to these and further investigative work carried out to refine the test procedure. As such, the conclusions drawn from this assessment should be considered preliminary.

Table of Contents

1	Introduction	1
1.1	Purpose	1
1.2	Background	1
2	Experimental Procedure	2
2.1	Rotary Tumblers	2
2.2	Grinding Media Selection and Test Configuration	2
2.3	Drying Carrier Samples	5
2.4	Weighing the Samples	5
2.5	Recording Experimental Results	5
3	Results: “Medium” Sized Rock Grinding Media	7
3.1	Analytical Results	7
3.2	Evaluation of Results	7
4	Results: “Large” Sized Rock Grinding Media	9
4.1	Analytical Results	9
4.2	Evaluation of Results	9
5	Limitations	11
6	Conclusion and Recommendations	12

Appendices

N/A

Tables

Table 1 - Grinding Media Types	2
Table 2 - Rock Grinding Media Characteristics and Test Configuration	4
Table 3 - Results of Carrier Testing with “Medium” Sized Rock Grinding Media	7
Table 4 - Results of Carrier Testing with “Large” Sized Rock Grinding Media	9

Figures

Figure 1 – Rotary Tumblers: Twin Barrel QT66 (L) and Large QT12 (R)	2
Figure 2 - Examples of Porcelain Ceramic and Blue Metal Grinding Media Types	3
Figure 3 - Comparison of Edge Rounding of In-Service and Test Carrier	3
Figure 4 - Whitening Characteristic of In-Service Carriers	3
Figure 5 - Coarse Sand Grinding Media Trapped in Carrier	4
Figure 6 - Oven Drying Carrier Samples	5
Figure 7 - Weighing the Carrier Samples	5
Figure 8 - Characterisation of Carrier Degradation Mechanisms: Wear (L) and Breakage (R)	6
Figure 9 – Degradation of Hel-X Carriers Throughout Rotary Tumbler Test (L to R: progressive through test)	6
Figure 10 – Rotary Tumbler Testing Carriers Using “Medium” Sized Rocks Grinding Media	8
Figure 12 - Rotary Tumbler Testing Carriers Using “Large” Sized Rocks Grinding Media	10
Figure 13 - Breakage of Bioflo+ (L), Biopipe (C), and Biotag (R) Carriers	10

1 Introduction

1.1 Purpose

This report explains the investigation into a method for testing the mechanical strength properties of moving bed biofilm reactor (MBBR) plastic carriers. The objective of the investigation was to explore a test procedure that provides mechanical degradation results of Hel-X HXF13KLL+ MBBR carriers (<https://www.hel-x.eu/en/technical-details/>) similar to that observed in the in-service Hel-X carriers at Kawana STP (KAWSTP), but in a shorter time frame. The investigation also compares mechanical degradation of Hel-X carriers with alternate HDPE carriers provided by Warden Biomedia (<https://www.wardenbiomedia.com/products/index.htm>). This investigation was initiated in response to two main requirements:

1. To meet part of the requirements of the Notice to conduct or commission an environmental evaluation dated 14 December 2021, to assess the breakdown rate of MBBR plastic media in the MBBR due to existing mechanical forces as currently configured
2. To assist in the planning and analysis of further mechanical degradation testing of Hel-X and other plastic MBBR carriers where it is understood that Unitywater plans to commission further assessment in an independent laboratory.

1.2 Background

The activated sludge treatment process at KAWSTP was changed to an MBBR process in the last major upgrade project for the plant. The majority of the Hel-X MBBR plastic carriers have been in service at KAWSTP since July 2019, with further addition of around 5% of the carriers in December 2019. Unitywater has identified risks associated with loss in plastic from the MBBR carriers, with a project underway to respond to an Environmental Evaluation (EE) issued by the Department of Environment and Science (DES) relating to the risk of plastic particles from MBBR carriers to the marine environment. Basket style screens, having 2mm aperture, are in place at KAWSTP to reduce the risk of plastic release to the environment by screening all effluent before release. These screens are currently cleaned every 2 weeks, and this process is labour intensive involving a crane for heavy lifts. There is a risk of these screens overflowing in wet weather and losing their contents to the STP discharge points. A project is underway to provide an automatic cleaning solution to continually remove captured plastic particles, reducing the risk of overflows and reducing manual labour effort. In addition to the screens, a surface skimming and screening system has been developed for each of the clarifiers that collects a portion of the floating broken carriers before they reach the basket screens.

The in-service Hel-X MBBR carriers at KAWSTP are cylindrically shaped, 13mm in diameter and length, with internal elements that encourage biofilm growth, attachment, and detachment. The volume of each bioreactor zone varies between 775m³ and 892m³ with each zone being filled with around 50% to 65% of carriers by volume that are suspended by the liquid. MBBR carriers are retained within each bioreactor zone by large submerged cylindrical screens mounted in the separating head walls between each bioreactor tank. The screens are designed to only allow liquid and particles less than 10mm to pass through. MBBR carriers that have broken into smaller particles can pass through these screens and out of the bioreactor. Large volumes of air are pumped into the aerobic zones of the bioreactor through submerged coarse bubble diffusers. The anoxic zone does not use air and mixing is provided by a large vertical shaft mixer. This action in the bioreactor tanks can cause degradation of the MBBR carriers through both a wear and breakage mechanism. Wear of the in-service carriers has been observed through sampling, and between approximately 300 and 700 litres of broken carriers are collected from the screening systems fortnightly. Industry practice suggests that MBBR carriers do not need to be replaced before about 25 years of service and must therefore withstand the physical forces due to mixing and air agitation and the ongoing collisions with other carriers and bioreactor walls. Besides the environmental impact of potential release of plastics to the environment from degraded MBBR plastic carriers, there is concern that degradation of MBBR carriers may impact the treatment performance of the plant over its design life.

2 Experimental Procedure

2.1 Rotary Tumblers

The experimental work used barrel-shaped rotary tumblers supplied by Aussie Sapphire (Models QT66 #006-092 and QT12 #006-091) shown in Figure 1. The twin barrel QT66 model comprised two separate drums, each being half the volume of the large barrel QT12 model.

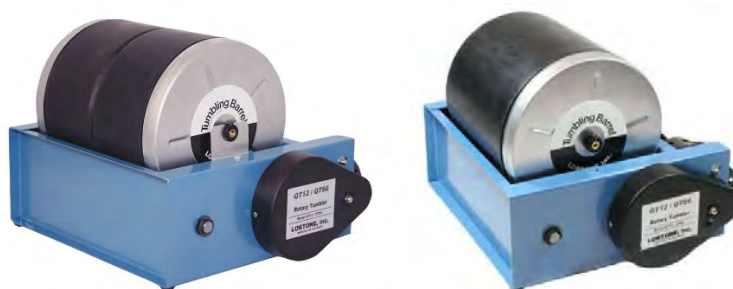


Figure 1 – Rotary Tumblers: Twin Barrel QT66 (L) and Large QT12 (R)

The rotary tumblers were originally designed for polishing gemstones where water and an abrasive (e.g. ceramic grit) is added to the stones inside the barrel and allowed to rotate for about 1 week. The abrasive action smooths the stones, providing an attractive finish. The rotary tumblers were originally suggested by The University of Queensland for wear testing of MBBR carriers.

2.2 Grinding Media Selection and Test Configuration

Prior to carrying out quantitative assessment of carrier degradation from the action of the rotary tumblers, a qualitative assessment of grinding media type was completed. In this investigation, different grinding media was used with Hel-X carriers to identify which grinding media type degraded the carriers to provide similar visual results to the observed in-service carriers and broken fragments. In addition to different types of grinding media, different ratios of grinding media to MBBR carriers and water were tested.

Observations from carriers tested in the rotary tumblers were used to progressively make decisions on the selection of grinding media type, quantity of water, and number of carriers used, where some instances resulted in rapid carrier degradation and other combinations had little impact on the carriers even after several weeks. The different grinding media tested is described in Table 1, with examples shown in Figure 2.

Table 1 - Grinding Media Types

Description	Source	Details
Porcelain ceramic 6mm spheres	Aussie Sapphire, SKU 583	
Porcelain ceramic 6x6mm triangles	Aussie Sapphire, SKU 584	Refer Figure 2
Porcelain ceramic 3x8mm cylinders	Aussie Sapphire, SKU 585	
Porcelain ceramic 12x25mm ACC	Aussie Sapphire, SKU 586	Refer Figure 2
Coarse sand	Ben Goodall	Refer Figure 5
20mm blue metal gravel	Kawana STP	Refer Figure 2
“Medium” sized rocks	Kawana STP landscaped areas	Refer Table 2
“Large” size rocks	Kawana STP landscaped areas	Refer Table 2



Figure 2 - Examples of Porcelain Ceramic and Blue Metal Grinding Media Types

The selection of grinding media was a 'trial and error' process with the aim to replicate visual characteristics of the in-service carriers, such as specific locations of wear and whitening of the carriers. Figure 3 shows a comparison between an in-service carrier, shown below on the left, and a test carrier, shown on the right, highlighting rounding of the edges of the in-service carrier. Figure 4 highlights the whitening characteristic of in-service carriers.



Figure 3 - Comparison of Edge Rounding of In-Service and Test Carrier



Figure 4 - Whitening Characteristic of In-Service Carriers

Porcelain ceramic grinding media types described in Table 1 were initially tested with the Hel-X carriers in the rotary tumblers. The small spherical and cylindrical grinding media variants were first tested and resulted in no physical change in the appearance of the Hel-X carriers. Larger and more dense porcelain ceramic grinding media was then tested but showed minimal wear, even after several weeks in the rotary tumblers, and this media type was deemed to be unsuccessful and not further tested.

Blue metal gravel was tested as a grinding media type, which provided a closer replica to the in-service worn carriers than porcelain ceramic types, but the Hel-X carriers were still insufficiently degraded after several weeks. The rate of wear by the blue metal rock media seemed to reduce over time, and coarse sand was added in an attempt to accelerate the wear. This combination of grinding media types did not sufficiently increase the rate of Hel-X carrier degradation and resulted in the sand particles filling and clogging the

carriers (Figure 5), creating difficulties in measuring (weighing) the carriers. Test with blue metal gravel and coarse sand was discontinued.



Figure 5 - Coarse Sand Grinding Media Trapped in Carrier

Larger and heavier grinding media was then selected, using “medium” sized rocks and “large” sized rocks sourced from landscaping areas at Kawana STP, with physical characteristics shown in Table 2. Water was filled to just below the surface of the carriers and grinding media in both sets of tumbling barrels. The “medium” sized rocks were used in the large rotary tumbler with a combination of Hel-X carriers and 3 variants supplied by Warden Biomedia:

- Biopipe+ (https://www.wardenbiomedia.com/products/Biopipe_plus.htm) cut at 12mm length
- Biotag (<https://www.wardenbiomedia.com/products/Biotag.htm>) cut at 12mm length
- Bioflo+ (https://www.wardenbiomedia.com/products/Bioflo_plus.htm) cut at 12mm length

Details of test configuration are provided in Table 2.

Table 2 - Rock Grinding Media Characteristics and Test Configuration

	“Medium” Size Rock Grinding Media	“Large” Size Rock Grinding Media
Photo		
Median Dimensions	50 mm diameter	95 x 40 x 35 mm
Average Mass	49.22 g	154.71 g
Rotary tumbler used	Large (QT12)	Half (QT66)
No. of grinding particles (rocks)	14	2
Carriers tested in rotary tumbler	100 Hel-X 50 Biopipe 50 Biotag 75 Bioflo	15 Hel-X 15 Bioflo 15 Biotag 15 Biotag

2.3 Drying Carrier Samples

When collecting the wear testing results, the carriers were removed from the rotary tumblers, placed in a colander having 4mm square holes, rinsed with water to remove worn material, and left to air dry for approximately 15 minutes. They were then laid out in sets of aluminium trays and placed in an oven (Figure 6) to dry at 60°C for approximately 2 hours, or until carriers were dry to touch.



Figure 6 - Oven Drying Carrier Samples

2.4 Weighing the Samples

Once dried, the number of carriers in each sample were counted and left to cool for approximately 5 minutes. Each sample was weighed using a Sartorius Lab Instruments Model BCE224I-1S (Figure 7) and these values were compared to the original mass to calculate a percentage of mass loss. This process was repeated weekly.



Figure 7 - Weighing the Carrier Samples

2.5 Recording Experimental Results

When recording the experimental results, it was important to understand the two forms of degradation that were being observed: wear and breakage. A definition was adopted to distinguish between the two mechanisms. Wear was defined as the mass loss where it was difficult to discern individual broken fragments by the naked eye, and this estimated to be around less than 500 µm particle size, typically resulting in rounding of the carrier edges. Breakage on the other hand was defined as separated particulates greater than approximately 2mm. The result of wear and breakage on the remaining Hel-X carrier is shown in Figure 8.



Figure 8 - Characterisation of Carrier Degradation Mechanisms: Wear (L) and Breakage (R)

With both wear and breakage mechanisms were observed of the in-service Hel-X carriers. Wear of the Hel-X carriers was observed in sampled carriers from the MBBR tanks, with all sampled carriers showing some degree of wear. Breakage (as well as wear) was identified in the carrier fragments collected fortnightly from the basket style screens and surface skimming system. In order for the carriers to escape the MBBR tanks, a section of the carrier had to be broken away to allow it to pass through the bioreactor submerged screens. Generally, this required at least one quadrant of the cylindrical carrier to be removed. With both wear and breakage mechanisms acting on the in-service carriers, the rotary tumbler test treated all particles separated from the main cross-sectional base of the Hel-X carrier as a form of mass loss and analysis was carried out on this basis. To ensure that there would always be a consistent number of carriers present from the beginning to the end of testing, these bases were included in the mass. **Error! Reference source not found.** illustrates typical carrier degradation, with carriers on the left-hand side of the picture showing limited degradation at the early stage of the test and carriers on the right-hand side towards the end of the test, showing carrier bases remaining but sections of the carrier peripheral broken off.



Figure 9 – Degradation of Hel-X Carriers Throughout Rotary Tumbler Test (L to R: progressive through test)

3 Results: “Medium” Sized Rock Grinding Media

3.1 Analytical Results

Table 3 presents the masses and cumulative percentage mass loss of a sample of 100 Hel-X carriers, and 50 Biopipe+, 50 Biotag, and 75 Bioflo+ carriers, throughout the test duration in the rotary tumblers. The results show the decrease in mass and increase of percentage mass loss over time.

Table 3 - Results of Carrier Testing with “Medium” Sized Rock Grinding Media

Days from Start of Test	Mass of Remaining Carriers (g)				Loss of Carriers (%)			
	Hel-X	Biopipe+	Biotag	Bioflo+	Hel-X	Biopipe+	Biotag	Bioflo+
0	45.9218	56.9153	45.6288	58.3214	N/A	N/A	N/A	N/A
8	43.9015	54.472	43.7863	56.43	4.40	4.29	4.04	3.24
14	42.8582	53.2552	42.7921	55.3567	6.67	6.43	6.22	5.08
21	41.6338	52.072	41.8832	54.3115	9.34	8.51	8.21	6.88
29	40.1713	50.6625	40.7286	53.1100	12.52	10.99	10.74	8.94
33	36.7609	50.1584	40.3123	52.6294	19.95	11.87	11.65	9.76
35	36.6560	50.0037	40.1857	52.4884	20.18	12.14	11.93	10
40	36.5002	49.6493	39.9451	52.2197	20.52	12.77	12.46	10.46
42	35.8517	49.5878	39.8548	52.1167	21.93	12.87	12.65	10.64
47	33.3085	49.1333	39.4848	51.7362	27.47	13.67	13.47	11.29
49	32.0365	48.9047	39.2900	51.5278	30.24	14.07	13.89	11.65
54	29.9654	48.6468	39.0530	51.2762	34.75	14.53	14.41	12.08
56	28.9406	48.4985	38.9300	51.1289	36.98	14.79	14.68	12.33
62	26.5567	48.1556	38.6497	50.8397	42.17	15.39	15.30	12.83
70	24.7186	47.7661	38.3153	49.8241	46.17	16.08	16.03	14.57

3.2 Evaluation of Results

Figure 10 shows the pattern of degradation of Hel-X and Warden Biomedia carriers using “medium” sized rock grinding media in the rotary tumbler test. The point where the degradation mechanism for Hel-X carriers shifted from wear only to wear plus breakage occurred at around 30 days and 12.5% loss in carrier mass when carriers began to break into pieces. At this point, the rate of loss in mass of the Hel-X carriers appeared to increase, as indicated by the linear trends in Figure 10. By 54 days of the test duration, there were no whole Hel-X carriers remaining, corresponding to all carriers able to pass through the submerged cylindrical screens in the bioreactor. These points are highlighted by the red band in Figure 10. A previous investigation of loss in mass of in-service Hel-X carriers identified that between 4.5% and 8% loss in carrier mass had occurred when considering wear mechanism only after approximately 2 years of those carriers being in-service in the MBBR (blue band in Figure 10). The equivalent loss in mass of the Hel-X test carriers occurred between 8 and 14 days after commencing the rotary tumbler test, suggesting that between 1 and 2 weeks of testing Hel-X carriers in the rotary tumbler under the test conditions was equivalent to 2 years of those carriers being in service at Kawana STP. Interpolating using the linear trend of loss in mass of Hel-X carriers experiencing degradation by wear only shown in Figure 10, it is estimated that the test carriers experienced similar loss in mass as the in-service carriers (4.5% to 8%) after about 11 days of the rotary tumbler test. With the point at which the Hel-X test carriers starting to break at 30 days of the test, this could suggest that this second point is reached about 3 times longer than the first. With the in-service carriers being in place for about 2 years, it might be suggested that the in-service carriers could see significant

breakage after about 6 years. There is room for error in this assessment and it is recommended that further investigation be carried out to validate this hypothesis.

Figure 10 also shows the difference in mechanical degradation rate of the Warden Biomedia carriers (Biopipe+, Biotag, and Bioflo+) compared to Hel-X carriers. By the end of the test period (70 days), the Warden Biomedia carriers had not shown any breakage, compared to the Hel-X carriers where mass loss was approaching 50%, and by 54 days of the test, there were no Hel-X carriers unbroken. Visual observation and the rate of loss in mass of Warden Biomedia carriers indicates that these carriers experienced the wear-only mechanism for at least 2.3 times longer than the Hel-X carriers (Figure 10), although the exact value of how high this enhancement multiplier could go could not be identified by this test. This could be further explored by extending the duration of the test. Of the Warden Biomedia carrier types, Bioflo+ showed the lowest rate of mass loss in the rotary tumbler test.

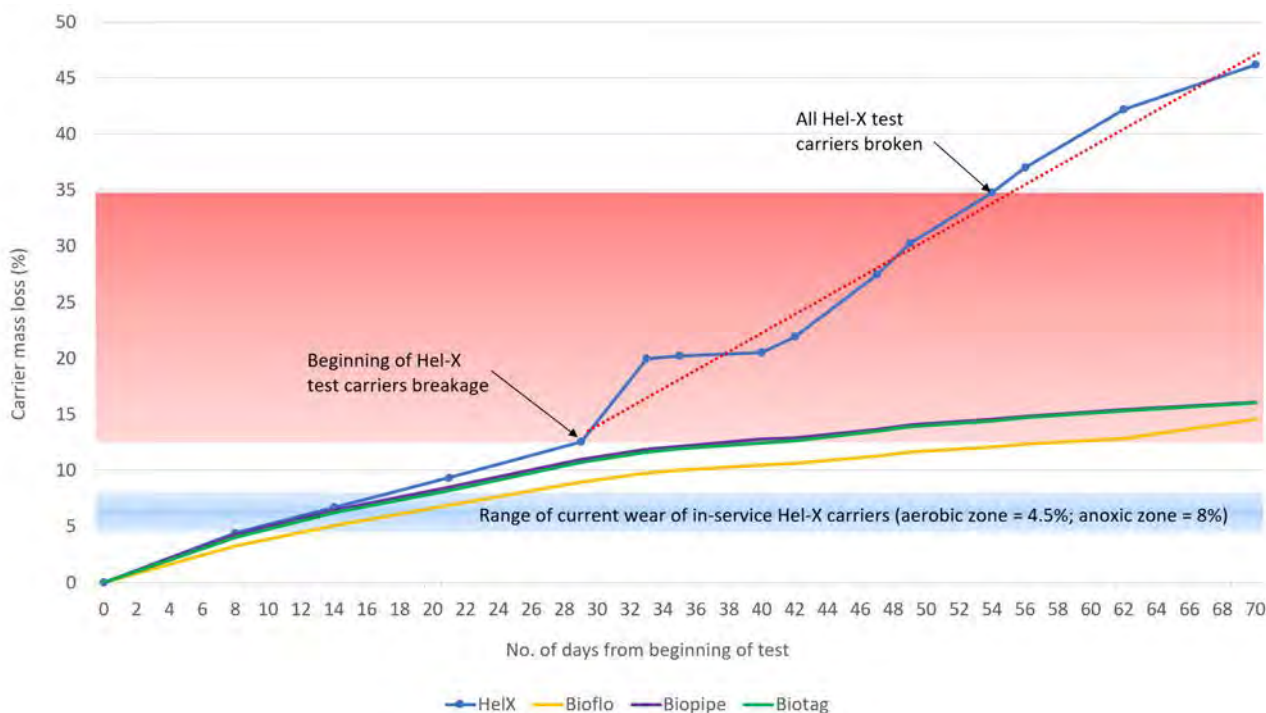


Figure 10 – Rotary Tumbler Testing Carriers Using “Medium” Sized Rocks Grinding Media

4 Results: “Large” Sized Rock Grinding Media

4.1 Analytical Results

Table 4 shows the masses and percentage mass loss of a sample of 15 each of Hel-X, Biopipe+, Biotag, and Bioflo+ carriers due to mechanical degradation by “large” sized rock grinding media. The results follow a similar pattern to that of the “medium” sized rock test, but at an accelerated rate.

Table 4 - Results of Carrier Testing with “Large” Sized Rock Grinding Media

Days from Start of Test	Mass of Remaining Carriers (g)				Loss of Carriers (%)			
	Hel-X	Biopipe+	Biotag	Bioflo+	Hel-X	Biopipe+	Biotag	Bioflo+
0	6.9063	17.0746	13.6886	11.6643	0	0	0	0
8	6.15 / 4.54	-	-	-	11 / 34.31	-	-	-
15	-	15.2665	12.3996	10.7659	-	10.59	9.42	7.70
19	-	14.8803	12.1281	10.5093	-	12.85	11.40	9.90
21	-	14.7235	12.0164	10.43	-	13.77	12.22	10.58
26	-	14.4191	11.7958	10.2648	-	15.55	13.83	12.00
28	-	14.2329	11.6526	10.1995	-	16.64	14.87	12.56
33	-	13.7949	11.2265	9.9995	-	19.21	17.99	14.27
35	-	13.5166	11.0229	9.9189	-	20.84	19.47	14.96
40	-	13.0474	10.6056	9.7582	-	23.59	22.52	16.34
42	-	12.826	10.3501	9.6326	-	24.88	24.39	17.42
48	-	12.1309	9.1821	9.373	-	28.95	32.92	19.64
56	-	11.6138	8.0892	9.1125	-	31.98	40.91	21.88

4.2 Evaluation of Results

Figure 11 shows the pattern of degradation of Hel-X and Warden Biomedia carriers using “large” sized rock grinding media in the rotary tumbler test where, after 8 days, all Hel-X carriers had broken. Where the test using “medium” size rocks grinding media (Figure 10) was terminated at 70 days resulting in about 15% loss in mass of the Warden Biomedia carriers, the rotary tumbler test using “large” sized rocks significantly increased the loss in mass of the carriers to between 22% and 42% during a shorter test duration. The end point of the “medium” size rock test is denoted by the red circle in Figure 11 for comparison purposes. Figure 12 shows the state of the Warden Biomedia carriers at the conclusion of the rotary tumbler test using “large” sized rocks grinding media. It was observed that breakage of the Warden Biomedia occurred only in the outer layer and although they were designated as being broken, they could not be easily passed through the submerged cylindrical screens in the bioreactor (although their broken particulates could). This is in contrast to the Hel-X carriers where even at the early stages of breakage, their structural stability was significantly diminished, making it easy for them to be pushed through the submerged cylindrical screens in the bioreactor. Comparing Figure 11 to Figure 10 further highlighted the superior mechanical degradation properties of the Bioflo+ compared to Biopipe+ and Biotag, which may be a function of its smaller diameter, although this relationship is not upheld when comparing the larger Biopipe+ with Biotag. While the rotary tumbler test using “large” sized rocks grinding media extended the amount of breakage compared to the test with “medium” sized rocks, Figure 11 did not clearly show a point where the rate of mass loss increased due to a shift from wear only to a wear plus breakage mechanism.

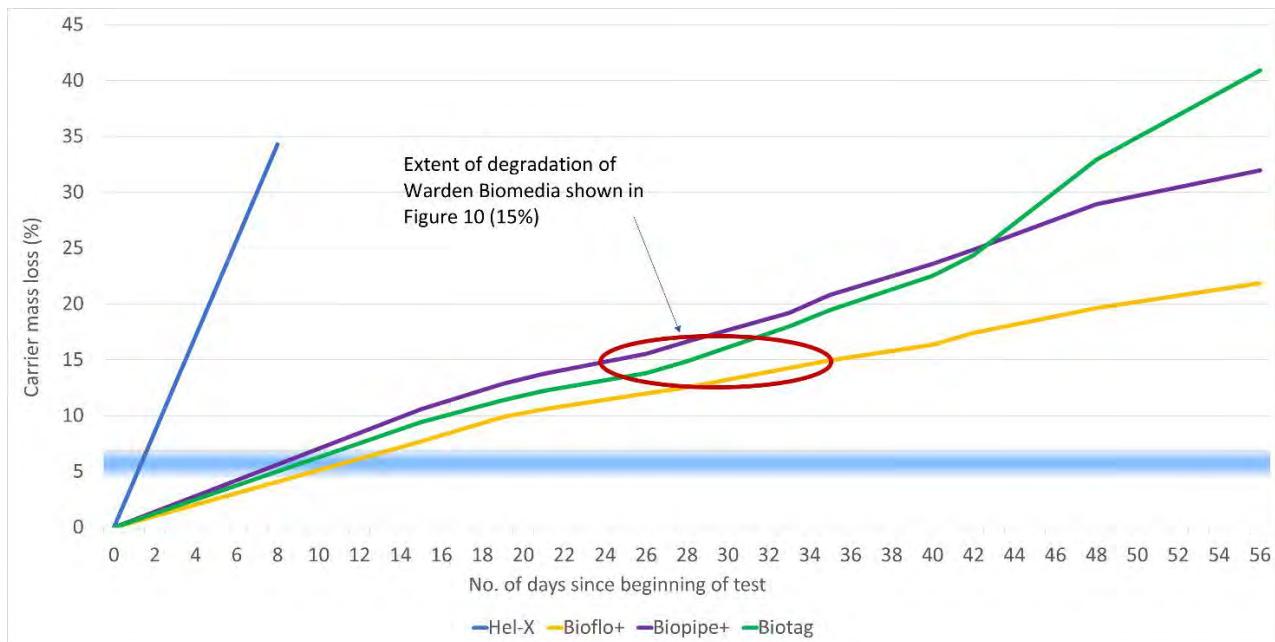


Figure 11 - Rotary Tumbler Testing Carriers Using “Large” Sized Rocks Grinding Media



Figure 12 - Breakage of Bioflo+ (L), Biopipe (C), and Biotag (R) Carriers

5 Limitations

The experimental investigation was considered to be limited by the following:

- Distinguishing wear and breakage mechanisms: although a definition of wear versus breakage was adopted, this was not based on any widely recognised classification and was not considered beyond visual assessment. When comparing test carriers from the rotary tumblers to the in-service carriers, a more robust assessment may include a measure of the degree of wear versus breakage to compare the two mechanisms more independently.
- Transition from wear to wear plus breakage mechanism of Warden Biomedia: tests using the “medium” sized rock continued for 70 days and this was insufficient to observe a transition from wear to wear plus breakage of the Warden Biomedia carriers. A longer test duration should provide further insight to where this transition occurs.
- Scope of carriers testing: tests were only carried out on Hel-X and Warden Biomedia types. Testing a wider range of carriers would provide further data to assess carrier performance. Unitywater is considering AnoxKaldnes K5X MBBR carriers as a potential replacement for the Hel-X carriers, however none were available at the time of testing.
- Impact of degraded carriers on biological performance of carriers: observations of in-service Hel-X carriers have confirmed a degree of degradation. The effect of having worn Hel-X carriers in service in the Kawana STP MBBR is unclear and Unitywater may wish to quantify this impact.
- Assessing carriers that would pass through the submerged cylindrical bioreactor screens: Hel-X carriers were assessed and then weighed during the test based on how material remained attached to the central cross piece of the Hel-X carrier. Towards the end of the test when minimal material remained attached to the central cross piece, those carriers would have almost certainly fit through the submerged cylindrical bioreactor screens. Another perspective of assessing carriers for weighing may have been on their ability to fit through the screen and escape the bioreactor.
- Broken carrier particle size distribution: at each time interval of weighing the remaining mass of the Hel-X carriers, only whole carriers were weighed. Carrier fragments that were not attached to the central cross piece of the Hel-X carriers were discarded where small particles were lost through the colander holes when rinsed with water, and larger fragments from the carrier periphery were not considered. These discarded particles would be too small to be retained by the submerged cylindrical screens in the bioreactor, and there was no opportunity to assess the resulting particle size distribution and compare to the broken carriers obtained from the basket style screens and surface skimming systems.
- Effect of wear of the rock grinding media: while the carriers were observed to wear over the test duration, there was evidence of the rocks grinding media also wearing. This resulted in small changes in rock mass but also a smoother surface texture which may have an impact on the carrier wear rate, where, perhaps a smoother rock would cause less wear.
- Water fill level: water was filled to just below the surface of the carriers and grinding media mixture in each rotary tumbler at the start of the test. The ratio of water to carriers and grinding media may impact the degradation rate, where it is considered that too much water would allow the plastic carriers to float inside the rotary tumbler and avoid some impact from the heavier grinding media. This could be further investigated and a water ratio defined, and volume of water added could be accurately measured.
- Drying temperature of carriers: the oven used to dry the carriers had a minimum temperature of 60°C. While thermal degradation of the plastic carriers is not expected to be a significant risk at 60°C, a lower drying temperature of 40°C might reduce this risk.
- This investigation has not assessed the effect of chemical breakdown processes, including that caused by ultraviolet UV degradation of the plastic and exposure to chemicals in the influent.

6 Conclusion

This experimental investigation assesses the mechanical degradation of Hel-X carriers and other carriers supplied by Warden Biomedia using a rotary tumbling test apparatus with selected grinding media and water. The results of the study highlighted that both wear and breakage mechanisms observed in the in-service Hel-X carriers from the Kawana STP MBBR could be qualitatively reproduced using the experimental arrangement. Different types of grinding media were used to degrade the MBBR carriers, and “medium” and “large” sized rocks were found to result in degradation consistent with observations of the in-service Hel-X carriers.

Between 1 and 2 weeks of testing in the rotary tumblers using “medium” sized rocks grinding media appeared to provide results consistent with in-service Hel-X carriers after about 2 years of operation at Kawana STP. The test results showed a noticeable transition from a wear mechanism to a wear plus breakage mechanism of the Hel-X carriers. The rate of degradation of carriers experiencing this latter mechanism was faster than that for wear only. Correlating observations made of the in-service carriers with the test results suggests that the in-service Hel-X carriers may begin to experience higher rates of breakage after about 6 years in operation where the number of broken carriers escaping the MBBR would increase.

The tests showed that the Warden Biomedia carrier types exhibited significantly enhanced mechanical properties that resisted mechanical degradation in the rotary tumbler test. In particular, the smallest Bioflo+ carrier showed the highest resistance to degradation.

Mechanical degradation involves complex mechanisms and there is scope for further analytical and experimental studies to better quantify this. Owing to a lack of widely accepted test methodologies for comparing the mechanical strength of MBBR plastic carriers and forecasting their longevity, this investigation relied on trial and error methods to establish a test procedure. The analysis of this experimental investigation should be considered preliminary findings and further experimental work that addresses limitations described in this report could be considered. In addition, further analysis should be carried out to decide when the media should be replaced from the STP.

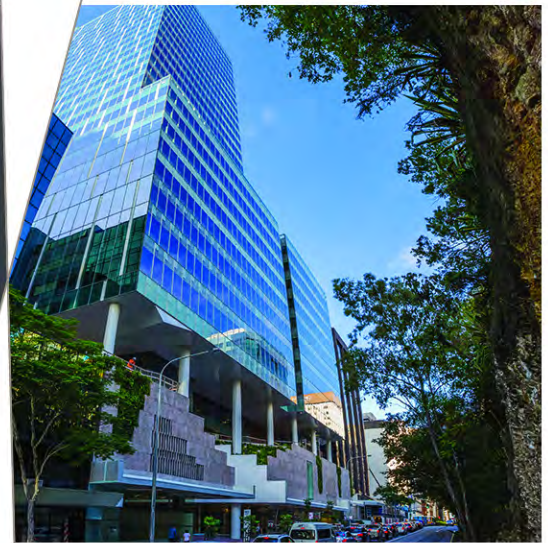
Appendix G SAQP P7: Assessment of MBBR plastic media chemical breakdown.

Appendix G: Assessment of MBBR Plastic UV and Chemical Breakdown

KAWSTP Project Management
Services

*Prepared for
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13 June 2022



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Summary

Degradation of MBBR plastic media at Kawana STP is unlikely to be caused by chemical attack in concentrations expected to be in sewage. Under microscopic examination, samples of the plastic media did not show signs of being affected by UV or chemical exposure.

Table of Contents

1	Introduction	5
2	Analysis	6
2.1	Estimate of Chemicals Concentrations	6
2.2	Chemical Resistance of HDPE	6
2.3	UV Resistance of HDPE	6
2.4	Microscopic Examination	6
3	Conclusion	7
4	Attachments	8

Attachments

Attachment 1: Report on Laboratory Examination of MBBR Plastic Media

1 Introduction

This report describes an investigation into the UV and chemical resistance of the MBBR plastic media in service at Kawana STP. The objective is to understand whether degradation of the MBBR plastic media can be attributed to UV damage or to chemicals likely to be present in sewage influent.

This report has been prepared as an Appendix for a separate report addressing environmental evaluation EPPR00869113 where other items beyond the scope of this report are considered. An explanation of the background leading to the environmental evaluation and overview of Kawana STP can be found in that report.

2 Analysis

2.1 Estimate of Chemicals Concentrations

The current configuration of Kawana STP has a design capacity for 200,000 equivalent persons (EP) with sewage inflows mostly from residential households, but also from commercial businesses and a small proportion from light industry. There are no known large trade waste customers in the catchment. Detergents and cleaning products are likely to dominate but the range of chemicals in sewage inflows would be substantial. Considering detergents from sources such as laundry, dishwashing, and personal hygiene, they contain surfactants, enzymes, and a range of other additives in smaller quantities. An assessment of all possible chemicals in sewage is beyond the scope of this work, however Tomczak-Wandzel et al. (2009) reported the average surfactant concentration in domestic wastewater to be 10 to 20 mg/dm³ or approximately 0.001 to 0.002% w/w. This is very low and other chemicals are expected to be present in similar concentrations or less.

2.2 Chemical Resistance of HDPE

The MBBR plastic media at Kawana STP is manufactured from recycled HDPE. Information on chemical resistance of HDPE is widely available and data provided by Ineos Olefins and Polymers was consulted:

(<https://www.ineos.com/globalassets/ineos-group/businesses/ineos-olefins-and-polymers-usa/products/technical-information--patents/ineos-hdpe-chemical-resistance-guide.pdf>).

There were no reagents listed in this chemical resistance table that indicated the low concentrations of chemicals in sewage discussed in Section 2.1 would result in anything other than satisfactory compatibility with HDPE.

Further evidence of HDPE compatibility with chemicals present in sewage is based on the extensive use of HDPE by manufacturers of MBBR plastic media. In addition, the widespread use of HDPE for sewage pipework systems without reports of chemical attack under normal conditions also verifies the low likelihood of MBBR plastic media degradation at Kawana STP due to chemicals.

2.3 UV Resistance of HDPE

UV resistance of HDPE is enhanced by the addition of a range of UV additives, with carbon black being one that results in the characteristic black colour. In a study by Sahu et al. (2020) on the effect of UV light on the mechanical behaviour of HDPE/Carbon black composites, it was found that properties such as tensile strength were not significantly affected by UV exposure. Demonstrating the suitability of HDPE to UV resistance, HDPE is also a popular choice for above ground pipework, in addition to numerous other engineering uses.

2.4 Microscopic Examination

Laboratory examination of samples of the Kawana STP MBBR plastic media was carried out by Zedcon Scientific Services in February 2020. In this study, the samples were microscopically examined for signs of chemical attack and UV degradation and the composition of the plastic was determined by Fourier Transform Infrared Spectrometry (FTIR). Examination of the material found no evidence of chemical attack or UV degradation. The report is provided in Attachment 1.

3 Conclusion

This study investigated whether UV exposure or chemical attack has significantly contributed to the degradation of the MBBR plastic media at Kawana STP. A review of chemical compatibility and UV resistance of HDPE was carried out. Based on this review and the microscopic examination of MBBR plastic media samples from Kawana STP, it is unlikely that the degradation observed in the plastic media has been caused by chemical attack or UV exposure.

4 Attachments

Attachment 1: Report on Laboratory Examination of MBBR Plastic Media



ZEDCON SCIENTIFIC SERVICES

ABN 21 298 113 858

ACN 050 725 178

CONSULTING FORENSIC AND MATERIALS SCIENTISTS

DATE: 21 February 2020

REFERENCE: 200218

REPORT ON: LABORATORY EXAMINATIONS AND ANALYSES OF
HEL-X MEDIA FROM KAWANA STP, QUEENSLAND

FOR: MONADELPHOUS ENGINEERING PTY LTD



PREPARED BY:

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Disclaimer

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INTRODUCTION

In accordance with instructions received from Mr B. Loughton on behalf of Monadelphous Engineering, we have completed laboratory examinations and analyses on the samples of new and used recycled HDPE Hel-X media from the Kawana STP site.

The objective of this investigation was to examine the media samples in order to gain an understanding of the nature and mechanism of the breakages that was occurring to the small helix biocarriers.

The following samples were received;

Sample 1:	Broken media from walkway (collected from beginning)
Sample 2:	Broken media (collected recently)
Sample 3:	Media that has been exposed to the sun.
Sample 4:	New unused media.

HEL-X PRODUCT

The Hel-X product (Code HXF13KLL+) is a small cylindrical unit with a flat outer spiral, crossed inner walls and 20 lamellas all constructed from black coloured recycled high-density polyethylene (HDPE).

It is important to note that the product is manufactured from recycled HDPE not new virgin HDPE which introduces several variables including fillers and the re-grind feedstock quality from batch to batch. The more times HDPE is recycled the more temperature and crystallinity effects that can occur which affect the physical properties of the final product.

EXAMINATION OF BROKEN MEDIA FOR EVIDENCE OF UV DEGRADATION

A comparative microscopic examination of media that was broken and/or exposed to the sun found no evidence to indicate any UV degradation had occurred. The breaks in the helixes were characteristic of physical damage from abrasion or mechanical fracture and not from any polymer degradation process, including not from UV exposure.

Based on the examinations conducted, we see no value in proceeding with any proposed laboratory accelerated UV chamber testing.

EXAMINATION OF BROKEN MEDIA FOR EVIDENCE OF CHEMICAL ATTACK

The microscopic examination of media that was broken found no evidence to indicate any chemical attack or chemical degradation has occurred. The breaks in the helixes were characteristic of physical damage from abrasion or mechanical fracture and not from any chemical exposure process.

Based on the examinations conducted, we see no reason to consider that the wastewater chemistry is having a bearing on the state of the media.

COMPOSITION OF MEDIA

The media is described in the specification data as consisting of black coloured recycled HDPE. The use of recycled polymers can introduce physical property performance variations depending upon the source of the polymer feedstock and number of times a batch of HDPE has been recycled. Every melt flow event in polymers such as polyethylene changes the microcrystalline structure and hence alters brittleness and strength. Additionally, the quantity and type of fillers used will also affect the elasticity and durability of the final product.

The four (4) samples identified above were analysed by using Fourier Transform Infrared Spectrometry techniques to fingerprint the polymer content and to semi-quantitatively assess the inert filler content. A comparison of the infrared spectra allows an assessment of the consistency in composition of the media from one batch to another.

Copies of the resultant infrared spectra are appended for your reference. The results show that all four samples consist of filled polyethylene with no foreign polymers present. There is evidence of significantly varying amount of filler in the different samples. Increased filler content can explain altered physical properties and hence altered performance. That said, Sample 1 consisting of broken media from the walkway contained very little filler, consistent with Samples 3 and 4 whilst Sample 2 consisting of broken media collected recently contained significantly more filler. Both Samples 1 and 2 are broken media, possibly indicating that the physical forces causing the breakages are in any event greater than the influences of filler content variations.

SUMMARY

This investigation on the media samples submitted has determined the following;

- The media is not breaking from either UV degradation or chemical attack.

- There is no evidence to indicate the wastewater chemistry is affecting the integrity of the media.
 - The media does consist of black-coloured HDPE as per the product specifications.
 - Spectrometric analysis shows an inert mineral filler may also be present at varying amounts from batch to batch.
 - The current samples indicate that the physical forces to which the media is being exposed, causing breakage, is likely to be in excess of the effect of compositional variations but further testing and analyses would be required to confirm this is the case.
-

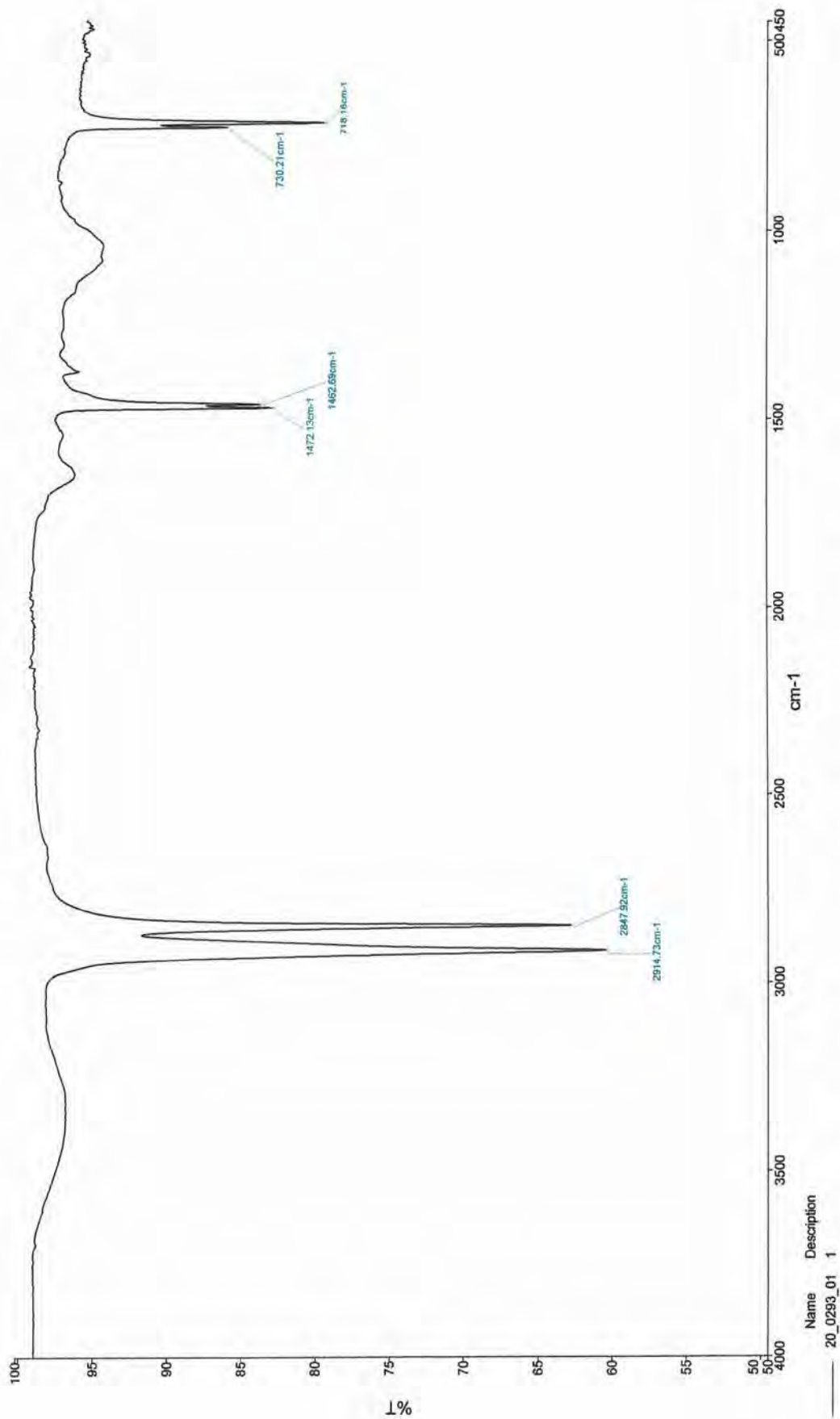
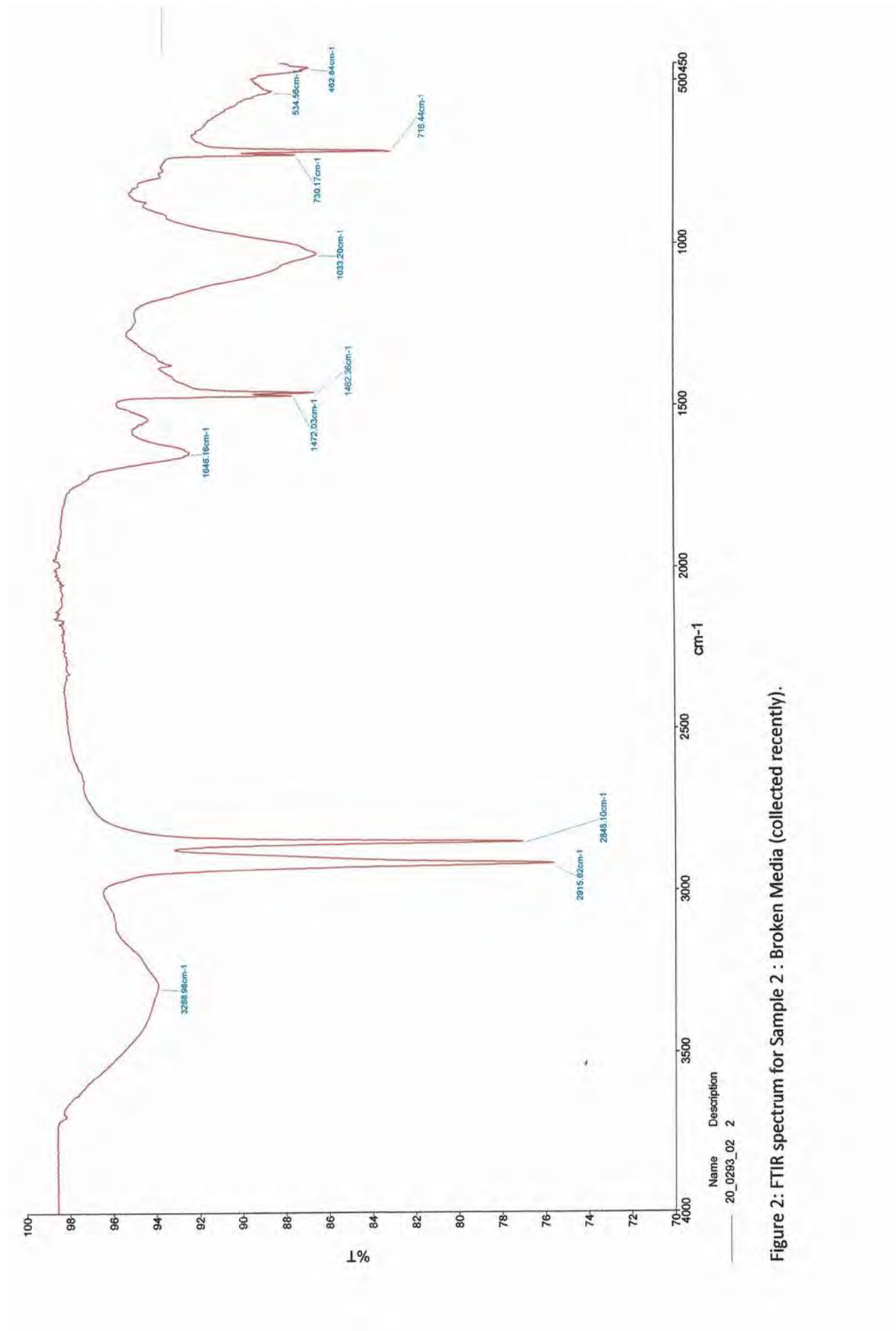


Figure 1: FTIR spectrum for Sample 1 : Broken Media from Walkway (collected from beginning).



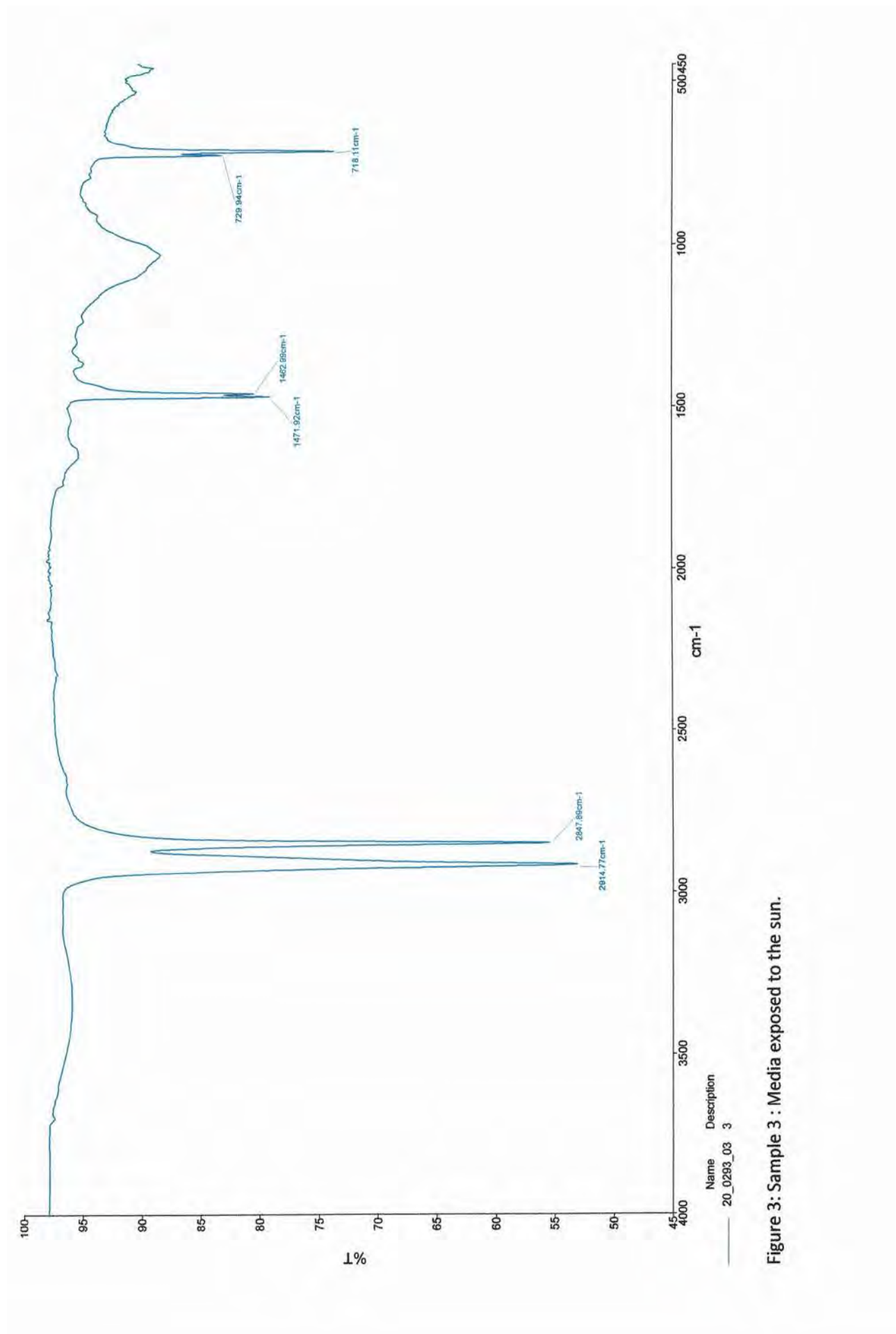
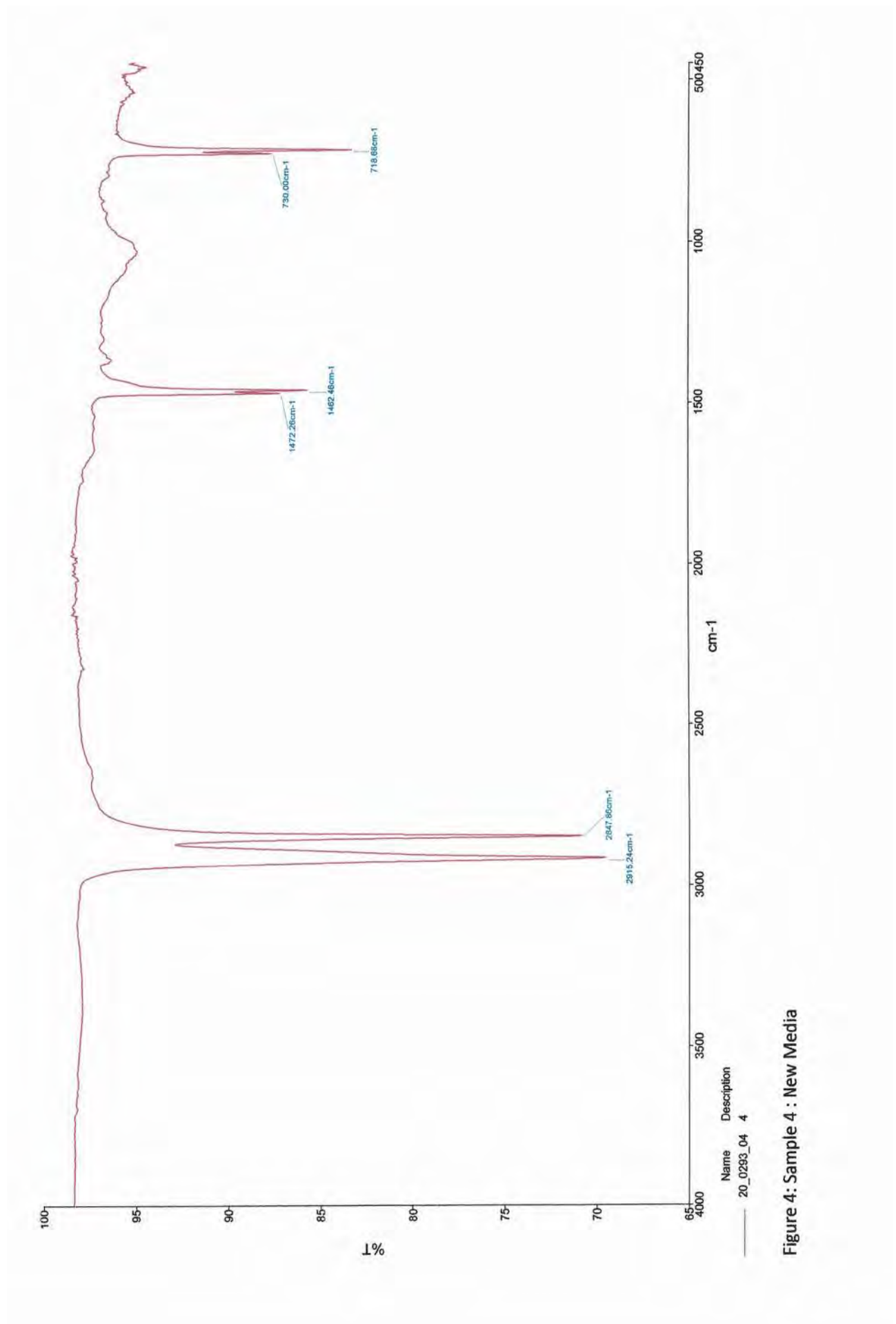
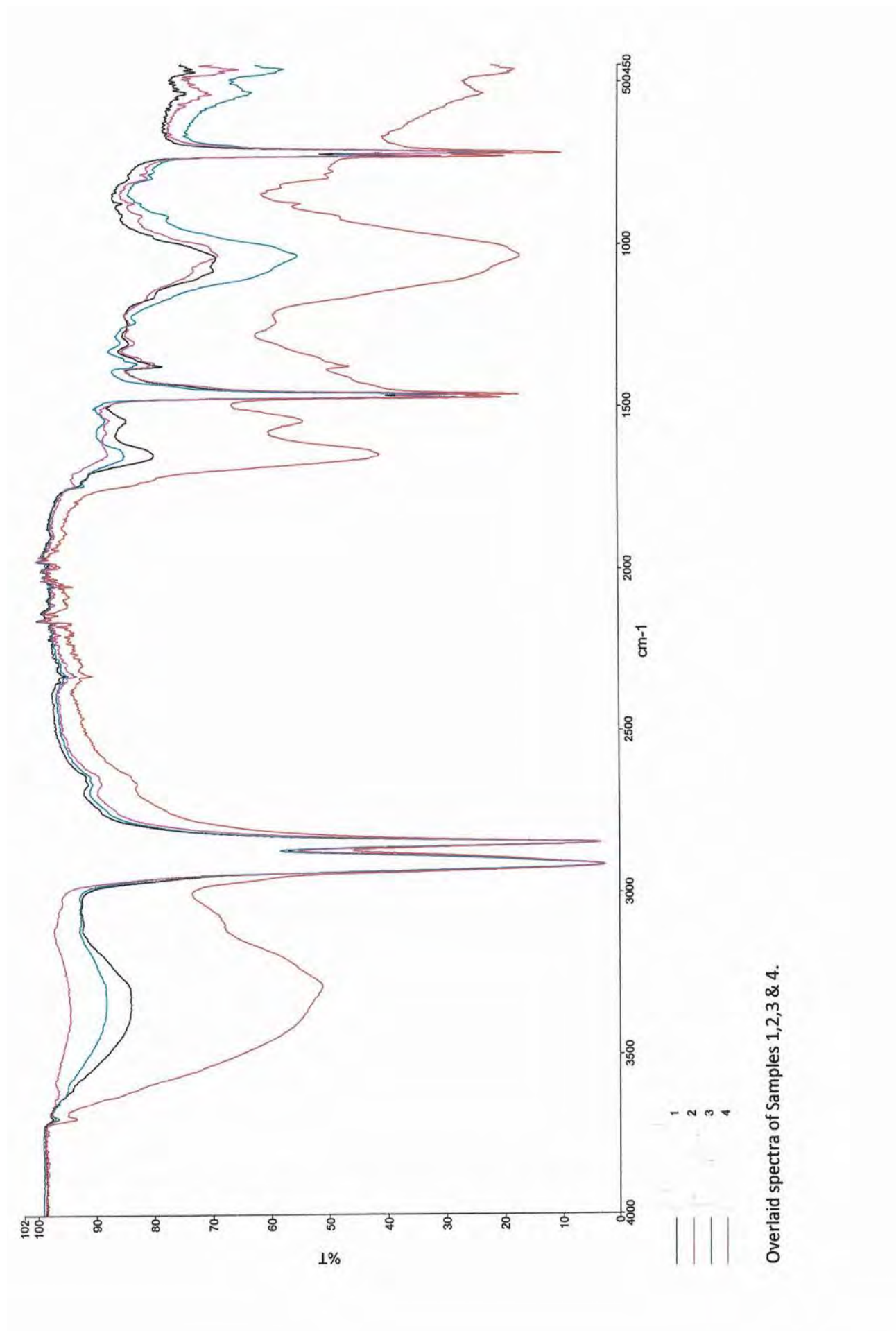


Figure 3: Sample 3 : Media exposed to the sun.





Appendix H Dispersion Modelling.

Unitywater

**Kawana STP Environmental
Evaluation:
Hydrodynamic and Particle
Tracking Modelling Assessment**

Final Report

8 June 2022



Intrawater Pty Ltd
ABN 32 613 167 927

intrawater.com

Contents

	Page
Executive Summary	1
1 Introduction	3
1.1 Project background	3
1.2 Environmental Evaluation requirements	3
1.3 Study objectives	3
2 Model development	5
2.1 Mooloolah River	5
2.2 Pacific Ocean	12
3 Particle tracking assessments	26
3.1 Assessment approach and assumptions	26
3.2 Mooloolah River assessment	30
3.3 Pacific Ocean assessment	36
4 Conclusions	45
References	47

Figures

Figure 1 Mooloolah River model domain and mesh

Figure 2 Mooloolah River bathymetry

Figure 3 Location of calibration and validation sites

Figure 4 Hydrodynamic calibration – MIKE 21 model results and ADCP flow data

Figure 5 Hydrodynamic validation results - MIKE 21 model results and EHMP salinity data

Figure 6 Pacific Ocean model domain and mesh

Figure 7 Pacific Ocean bathymetry

Figure 8b Roses of wind direction versus wind speed (Sunshine Coast Airport) - 3pm

Figure 9 Hydrodynamic calibration - MIKE 3 model results and MSQ water elevation data

Figure 10 Model calibration – Spectral Wave model results and wave buoy monitoring data (Caloundra) – Significant wave height (top) and Maximum wave height (bottom)

Figure 11 Model calibration – Spectral Wave model results and wave buoy monitoring data (Caloundra) – Peak wave period (top) and Peak wave direction (bottom)

Figure 12 Model calibration – Spectral Wave model results and wave buoy monitoring data (Mooloolaba) – Significant wave height (top) and Maximum wave height (bottom)

Figure 13 Model calibration – Spectral Wave model results and wave buoy monitoring data (Mooloolaba) – Peak wave period (top) and Peak wave direction (bottom)

Figure 14 Model validation – MIKE 3 model results and ADCP monitoring data (Release Point W1 – lower water column) – Velocity magnitude (top) and Velocity direction (bottom)

Figure 15 Model validation – MIKE 3 model results and ADCP monitoring data (Release Point W1 – mid water column) – Velocity magnitude (top) and Velocity direction (bottom)

Figure 16 Model validation – MIKE 3 model results and ADCP monitoring data (Release Point W1 – top water column) – Velocity magnitude (top) and Velocity direction (bottom)

Figure 17 Daily rainfall data for the Kawana and Caloundra region

Figure 18 Predicted flow released to the Pacific Ocean (release point W1) and the Mooloolah River (release point W3)

Figure 19 Location of Release Point W3

Figure 20 Predicted release rates for release point W3

Figure 21 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm)

Figure 22 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_6mm)

Figure 23 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_6mm)

Figure 24 Location of Release Point W1

Figure 25 Predicted release rates for release point W1

Figure 26 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm) (full model domain)

Figure 27 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm) (Caloundra to Mooloolaba)

Figure 28 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm) (Warana Beach)

Figure 29 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_6mm) (Caloundra to Mooloolaba)

Figure 30 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_6mm) (Caloundra to Mooloolaba)

Executive Summary

The objective of this Hydrodynamic and Particle Tracking Assessment has been to support an Environmental Evaluation relating to the Kawana STP. The assessment has included extensive numerical modelling and analysis of how particles from the STP's Moving Bed Biofilm Reactor (MBBR) may potentially be released and transported in the receiving waters of the Mooloolah River, as well as the coastal waters of the Pacific Ocean.

The results from the modelling have informed the design and implementation of the Environmental Evaluation's Sampling and Analysis Quality Plan by identifying potential zones of accumulation in the environment, thereby predicting the environmental fate of the media if released to either waterway.

Two hydrodynamic and advection/dispersion models were developed specifically for application in these assessments: a 2D model of the Mooloolah River estuary, and a 3D model of the Pacific Ocean, extending from Moreton Island to Noosa. Each were developed using the MIKE suite of modelling software.

Following calibration and validation of both models, three scenarios were considered with simulations undertaken over a 12-month period to allow for a representative range of both release and ambient conditions.

The three scenarios represented the following potential release conditions:

- Scenario 1 - Discharge of MBBR particles < 2 mm where these smaller particles pass through the effluent basket screens
- Scenario 2 - Undetected release of a portion of all sizes of MBBR particles due to undetected damage to the basket screens
- Scenario 3 - Overtopping of the basket screens during an extreme wet weather event and associated release to both the Pacific Ocean and Mooloolah River outfalls. Although no longer possible with the current configuration of effluent basket screens, this scenario investigated the potential dispersion of particles from the previous plant configuration.

The following key findings were drawn from the modelling assessments:

Mooloolah River

The results for Scenarios 1 and 2 present similar patterns of accumulation within the estuary with the following locations being identified as potential high concentration areas:

- A. The reach downstream of Release Point W3 and upstream of Parrearra Weir
- B. Mid-estuarine reaches near the Brightwater Eastern Conservation Area
- C. Foreshore areas between Mooloolah Island and Minyama Island

The modelling also indicates the potential for greater accumulation in reach "A", immediately following a release event. Depending on the magnitude of the release and the relative strength of tidal currents against the freshwater flows driven by runoff in the upstream catchments, particles are predicted to be potentially retained in this area and deposited within the intertidal zones and into the embayment near the Parrearra Weir. These particles have the potential to be retained in this vicinity until the following wet weather event which effectively flushes the particles downstream.

Further downriver the predicted areas of accumulation "B" and "C" appear to predominantly correlate with intertidal zones along the mid-estuarine river banks and the more artificially developed foreshores in the lower estuary.

The results for Scenario 3 represent similar distributions but with a greater accumulation predicted near the Parrearra Weir, relative to the sites downstream. This indicates the prediction of higher concentrations near the weir, prior to subsequent weather events that flush the particles downstream with sufficient magnitude to avoid deposition on the intertidal areas of the middle and lower estuary.

Pacific Ocean

Regardless of the scenario, the predicted distribution of higher particle concentrations consistently lies between Currimundi Lake in the south, and the Point Cartwright headland in the north. This distribution is generated as a result of the simulation of the complex prevalent hydrodynamic conditions (wind, waves and tides) as well as wind drift applied directly to buoyant particles on the sea surface.

Higher concentrations are predicted between Wurtulla Beach and the southern end of Pacific Boulevard, with the highest concentration predicted between Wyanda Drive and Currawan Street.

The modelling results for Scenario 3 (one hour release) present a more southerly accumulation on the foreshore. This demonstrates the effect on the transport of buoyant media from a single release event and how the prevailing conditions can influence their fate. During, and subsequent to, this release, the influence of northerly winds, a southward tidal stream and also an easterly wave climate has provided for greater distributions on the shoreline south of the W3 release point.

1 Introduction

1.1 Project background

The Kawana STP is located on Main Drive, Bokarina and the Landsborough STP on Forestry Road, Landsborough. The Kawana STP is one of the largest STPs on the Sunshine Coast and has been identified as a future centralised treatment facility, with possible future loads of up to 600,000 equivalent persons (EP). The Kawana STP is currently designed for a treatment capacity of 200,000 EP, with average dry weather flows of up to 46 ML/day and peak wet weather flows up to 2,850 L/s.

Under the provisions of the Environmental Authority EPPR00869113, combined releases from Landsborough STP and Kawana STP are discharged preferentially to the Pacific Ocean, approximately 1 km offshore of Wyanda Park, Kawana (release point W1). An alternate licenced discharge point in the Mooloolah River (release point W3) can be used when the ocean outfall is unavailable, or under prescribed wet weather conditions.

In January 2020, it was identified that small quantities of broken plastic carriers/media from the plant's Moving Bed Biofilm Reactor (MBBR) had the potential to be discharged in the effluent. As an immediate action to address this concern, Unitywater installed basket screens with a 2 mm mesh at the effluent release points to prevent further media release to the environment.

In parallel with further detailed investigations into the cause of the media releases and how these can be addressed, Unitywater has also been in consultation with the Department of Environment and Science (DES) on this matter, providing notification of events that are inconsistent with the STP's Environmental Authority conditions, and collaborating to identify ways to reduce the risk of recurrence.

1.2 Environmental Evaluation requirements

On 14 December 2021, Unitywater was issued a Notice (Appendix A of the main report) to conduct or commission an Environmental Evaluation (EE) by the Chief Executive Officer of the DES, with respect to the activities of the Kawana STP. The EE issued on 14 December 2021 superseded an earlier EE issued on 27 October 2021.

The EE requires Unitywater to appoint Appropriately Qualified Persons (AQP's) to conduct specified activities, including assessment of the breakdown rate of MBBR plastic media at the STP and potential for release to the environment over the lifespan of the STP. A Sampling and Analysis Quality Plan (SAQP) is also required that addresses all reasonably foreseeable hydraulic operational scenarios expected to occur during the operation of the MBBR.

To inform the design and implementation of the SAQP, hydrodynamic and dispersion modelling was included in the scope to determine the likely fate of the MBBR media particles released to the receiving waters of the Mooloolah River and the Pacific Ocean.

Intrawater was commissioned by Unitywater to undertake the dispersion modelling of the media in the receiving waterways, with Ed Beling, as a Principal and Director of Intrawater, approved as an AQP by DES.

1.3 Study objectives

The objectives of this study are to:

- Develop fit for purpose hydrodynamic, advection and dispersion models of the receiving waterways to allow for simulation of transport and fate of MBBR media particles potentially released in the effluent.
- Undertake model scenarios to predict the fate of MBBR media particles potentially released from both release points W1 and W3. Scenarios to include a suitable range of particles sizes and characteristics.

- Prepare a report describing the results of the modelling and the likely dispersion of media in terms of environmental fate. This report and the results of the modelling to inform the basis for the design of field-based surveys to be included in the SAQP.

2 Model development

2.1 Mooloolah River

2.1.1 Background

The hydrodynamic and advection dispersion model of the Mooloolah River developed for this study was based on an existing 2D RMA model of the estuary. The RMA model has been used over a series of previous projects relating to water quality in the river as well as the potential impacts from releases to the river from the Kawana STP (Intrawater, 2018 and 2020).

2.1.2 Software selection

The MIKE 21 software was selected for use in this study with application of the following modules:

- MIKE 21 Flow Model Flexible Mesh (FM)
- MIKE 21 Particle Tracking (PT)

The rationale for moving from the RMA software with conversion to the MIKE 21 software was as follows:

- The MIKE 21 suite of models included the additional functionality to model the transport of individual particles based on simulation of hydrodynamic currents and surface wind acceleration. This functionality was deemed to be of significant importance in light of the requirements of the EE to determine the fate of MBBR media particles released to the receiving waters of the Mooloolah River.
- The MIKE suite of models allowed for increased simulation speed due to several innovations and efficiencies that are not available in the RMA modelling system. These include the ability to utilise multiple cores and Graphics Processing Units (GPUs). These aspects allow for shorter run times as well as data processing efficiencies.

2.1.3 Software overview

2.1.3.1 MIKE 21 FM

The MIKE 21 FM software was selected as the core hydrodynamic module for the Mooloolah River model. This software represents a 2D modelling system based on a flexible mesh approach, developed for applications within oceanographic, coastal and estuarine environments.

The hydrodynamic module is based on the numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain both Cartesian and spherical coordinates can be used.

The spatial discretisation of the primitive equations is performed using a cell-centred finite volume method. The spatial domain is discretised by subdivision of the continuum into non-overlapping element/cells. In the horizontal plane an unstructured grid is used comprising of triangles or quadrilateral elements. An approximate Riemann solver is used for computation of the convective fluxes, which makes it possible to handle discontinuous solutions.

2.1.3.2 MIKE 21 PT

The MIKE 21 PT module is used for modelling the transport and to determine the fate of dissolved, suspended and sedimented substances discharged or accidentally spilled in lakes, estuaries and coastal waters. The particles/substances may be a pollutant of any kind, conservative or non-conservative, for example: suspended particles, bacteria or chemicals.

The pollutant is considered as particles being advected with the surrounding water body and dispersed as a result of random processes in two dimensions. The particles may settle with a constant settling velocity and settled particles may be resuspended. A corresponding mass is attached to each particle which may be reduced during the simulation due to decay. The model

calculates the path of each particle and outputs the instantaneous concentrations of individual classes.

2.1.4 Model structure

2.1.4.1 Model domain and mesh

Figure 1 presents the extents of the model domain and the 2D model mesh. The domain and mesh extend from the river mouth at Mooloolaba, upstream to the tidal limit within the Kawana Forest Bushland Reserve. Mountain Creek and the complex configuration of canals are also incorporated into the mesh design, alongside the weir structures upstream and downstream of the Parrearra Lake. Roughness characteristics of the river bed were applied through distribution of Manning's n values ranging from 0.02 to 0.04 s/m^(1/3).

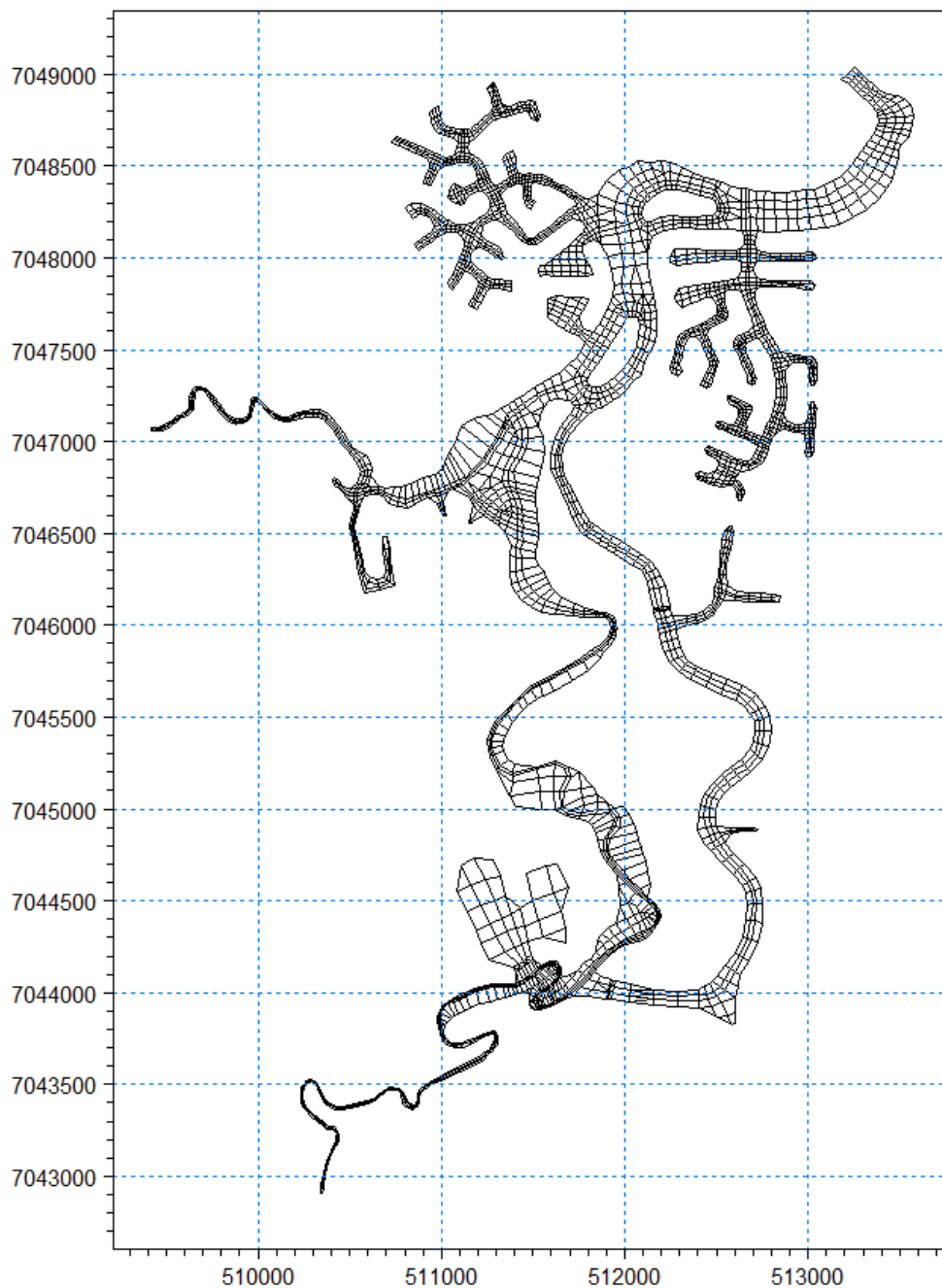


Figure 1 Mooloolah River model domain and mesh

2.1.4.2 Bathymetry

The bathymetric data applied to the Mooloolah River model mesh is presented in Figure 2. The data was derived from a digital elevation model developed for the RMA model (updated in 2018). The model was generated from multiple sources including survey data and nautical/boating charts. It is noted that some inter-tidal areas are attributed nominal elevations in the absence of accurate survey data.

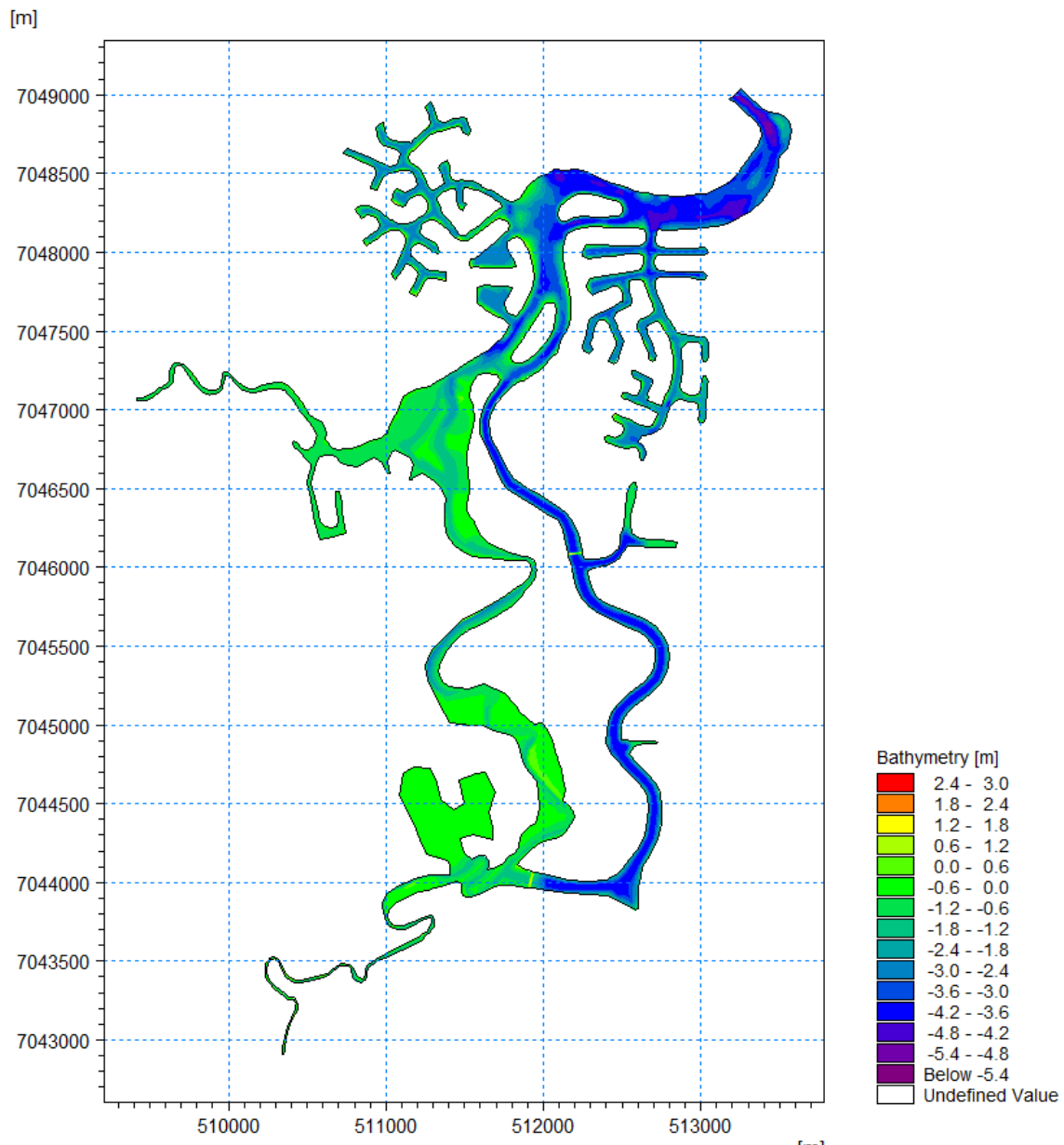


Figure 2 Mooloolah River bathymetry

2.1.4.3 Boundary conditions

Boundary conditions for the model were represented by the following datasets:

- Catchment inflows: Output from an eWater Source model of the Mooloolah catchment (updated in 2018)
- STP inflows: Predicted or monitored releases from the Kawana STP via release point W3
- Downstream tidal boundary: Tidal output from storm surge gauge 011008A, operated by Maritime Safety Queensland (MSQ)

- Wind forcing: Data from the Bureau of Meteorology (BoM) station 040861, located at the Sunshine Coast airport. The data was applied in the form of wind speed and wind direction and included readings at three-hourly intervals.

2.1.5 Calibration and validation

2.1.5.1 Datasets

Calibration of the model was undertaken against Acoustic Doppler Current Profile (ADCP) data to assess the hydrodynamic performance of the model. The ADCP data was collected on behalf of Healthy Land and Water (formerly Healthy Waterways). The flow data was collected across a transect at the mouth of the river, as presented in Figure 3.

Validation of the model was undertaken against salinity data to assess the hydrodynamic and advection dispersion performance of the model. The salinity data was collected at seven sites in the river, as part of the Environmental Health Monitoring Program (EHMP) operated by Healthy Land and Water. The locations of the EHMP sites are also presented in Figure 3.

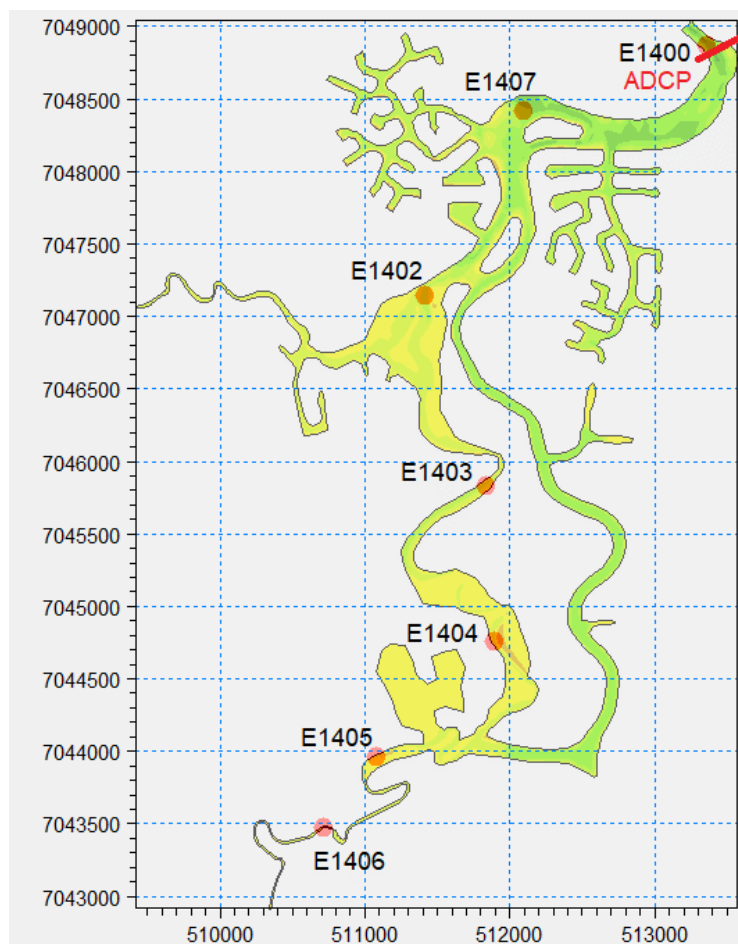


Figure 3 Location of calibration and validation sites

2.1.5.2 Results and interpretation

The results of the model calibration against the ADCP flow data are presented in Figure 4. From this comparison, the model is observed to reproduce the amplitude and timing of the tidal flows well at the mouth of the estuary. This provides confidence that the volumetric interchange near the downstream boundary is being adequately captured by the model.

The results of the model against the EHMP salinity data are presented in Figure 5. The results present a robust correlation between the model results and the monitoring data at all the sampling

sites. The model successfully reproduces the responses to large and small rainfall events where salinity values are prone to decrease significantly throughout the river as a result of the freshwater inflows from the catchments. Similarly, the model successfully simulates the salt intrusion following these wet weather events.

From the results of both the calibration and validation runs, it is concluded that there is a high degree of confidence that the model is resolving the hydrodynamics as well as the advection and dispersion processes within the estuary. In light of these findings, the MIKE 21 model was considered fit for purpose with respect to application of the particle tracking assessment.

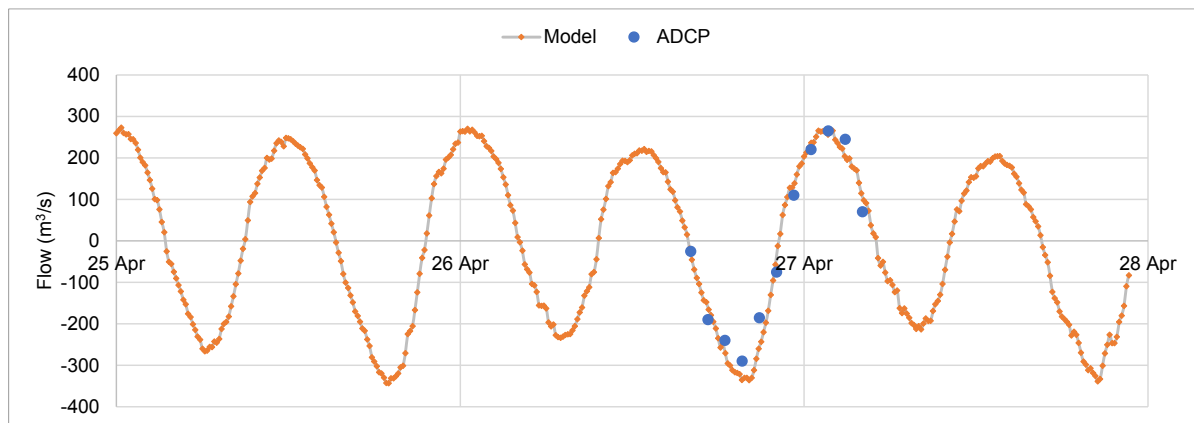


Figure 4 Hydrodynamic calibration – MIKE 21 model results and ADCP flow data

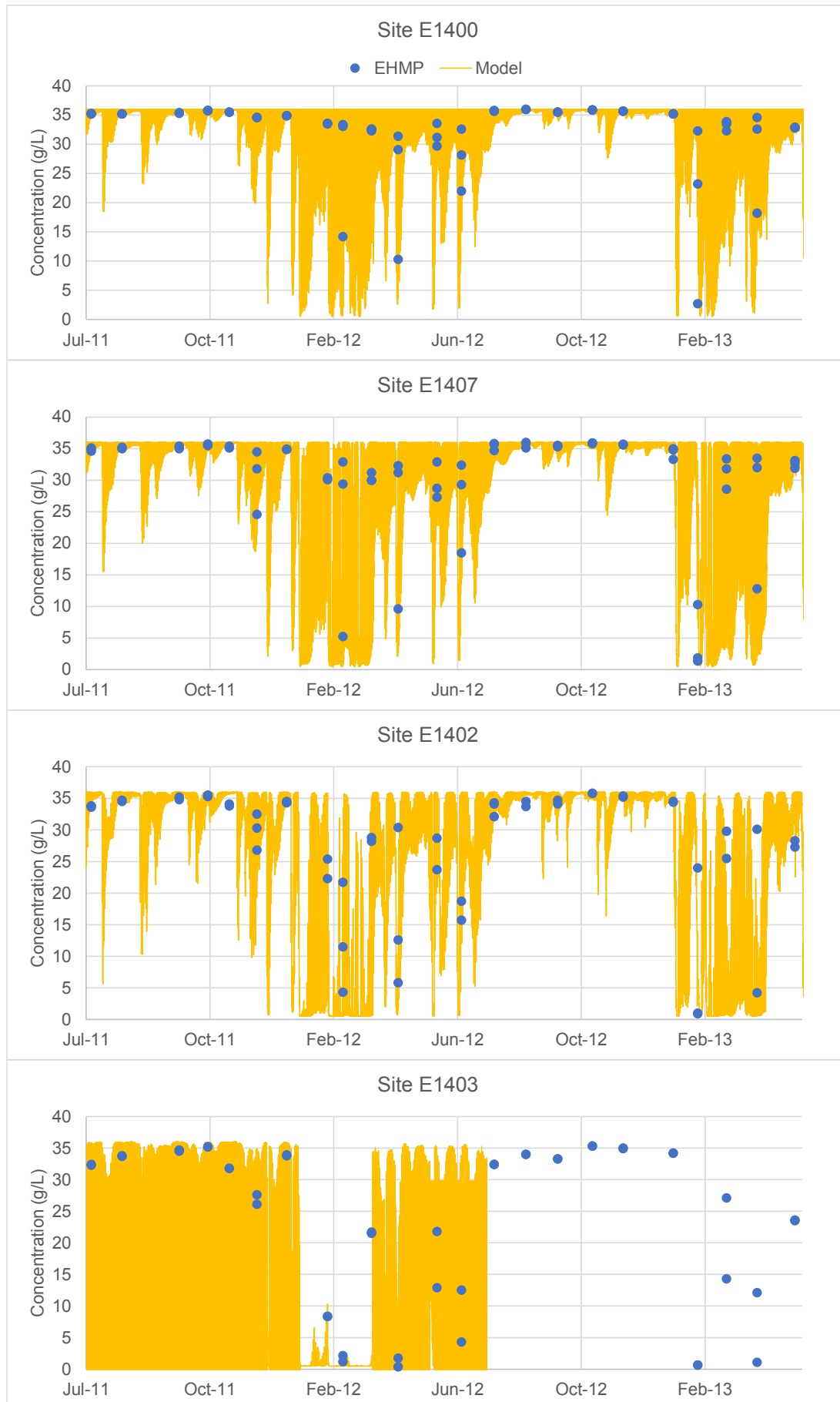




Figure 5 Hydrodynamic validation results - MIKE 21 model results and EHMP salinity data

2.2 Pacific Ocean

2.2.1 Background

In the absence of an existing model refined sufficiently to simulate the releases from the Kawana STP to the ocean, a new hydrodynamic and dispersion model was developed for this study.

As discussed below, many of the datasets used to develop the model have however been derived or extracted from other models.

2.2.2 Software selection

The MIKE 3 software was selected for use in this study with application of the following modules:

- MIKE 3 Flow Model Flexible Mesh (FM)
- MIKE 3 Particle Tracking (PT)

The rationale for selecting the MIKE 3 software was:

- The MIKE 3 and MIKE 21 suite of models are easily interfaced and allow for consistency in the modelling approaches for both the Mooloolah River and the Pacific Ocean. Essentially, MIKE 3 is the 3D version of the MIKE 21 software discussed previously in Section 2.1.3, allowing for modelling of multiple layers through the water column.
- The MIKE 3 software offers the same PT functionality to model individual particles with simulation of media movement based on hydrodynamic currents and surface wind acceleration. Similar to the modelling of the Mooloolah River, this functionality was deemed to be of significant importance in light of the requirements of the EE to determine the fate of MBBR media particles released to the receiving waters of the Pacific Ocean.
- The MIKE 3 suite of models allows for advanced simulation speeds due to several innovations and efficiencies through the ability to utilise multiple cores and GPUs.

2.2.3 Software overview

2.2.3.1 MIKE 3 FM

The MIKE 3 Flow Model FM is a modelling system based on a flexible mesh approach, developed for applications within oceanographic, coastal and estuarine environments.

The hydrodynamic module is based on the numerical solution of the three-dimensional incompressible Reynolds averaged Navier-Stokes equations invoking the assumptions of Boussinesq. Both the full 3D Navier-Stokes equations and the 3D shallow water equations can be applied, with the latter invoking the hydrostatic pressure assumption. Thus, the model consists of continuity, momentum, temperature, salinity and density equations and is closed by a turbulent closure scheme. In the horizontal domain both Cartesian and spherical coordinates can be used. The free surface is taken into account using a sigma-coordinate transformation approach.

The spatial discretisation of the governing equations in conserved form is performed using a cell-centred finite volume method. The spatial domain is discretised by subdivision of the continuum into non-overlapping element/cells. In the horizontal plane an unstructured grid is used while in the vertical domain a structured discretization is used. The elements can be prisms or bricks whose horizontal faces are triangles and quadrilateral elements, respectively.

For the time integration, a semi-implicit approach is used where the horizontal terms are treated explicitly, and the vertical terms are treated implicitly. The interface convective fluxes are calculated using an approximate Riemann solver. This shock-capturing scheme enables robust and stable simulation of flows involving shocks or discontinuities such as hydraulic jumps.

2.2.3.2 MIKE 3 PT

The MIKE 3 PT module closely resembles the structure of the MIKE 21 PT module discussed previously in Section 2.1.3.2 and allows for the same determination of fate of particles, but with adaptation to a 3D model domain.

2.2.4 Model structure

2.2.4.1 Model domain and mesh

Figure 6 presents the extents of the model domain and the model mesh in the horizontal plane. The domain and mesh extend from the northern extents of Moreton Bay in the south, northward to Noosa Heads, and offshore approximately 46 km from the Bokarina/Warana foreshore. At this distance offshore, water depths generally drop to between 90 and 150 m AHD.

Significant refinement in the mesh is included between Point Cartwright and Caloundra allowing for a lateral dimension of the mesh elements between approximately 100 to 150 m. Pumicestone Passage is also incorporated into the mesh with sufficient resolution to define the channel and sand banks.

Roughness characteristics of the ocean bed are applied through application of a bed roughness height of 0.08 m.

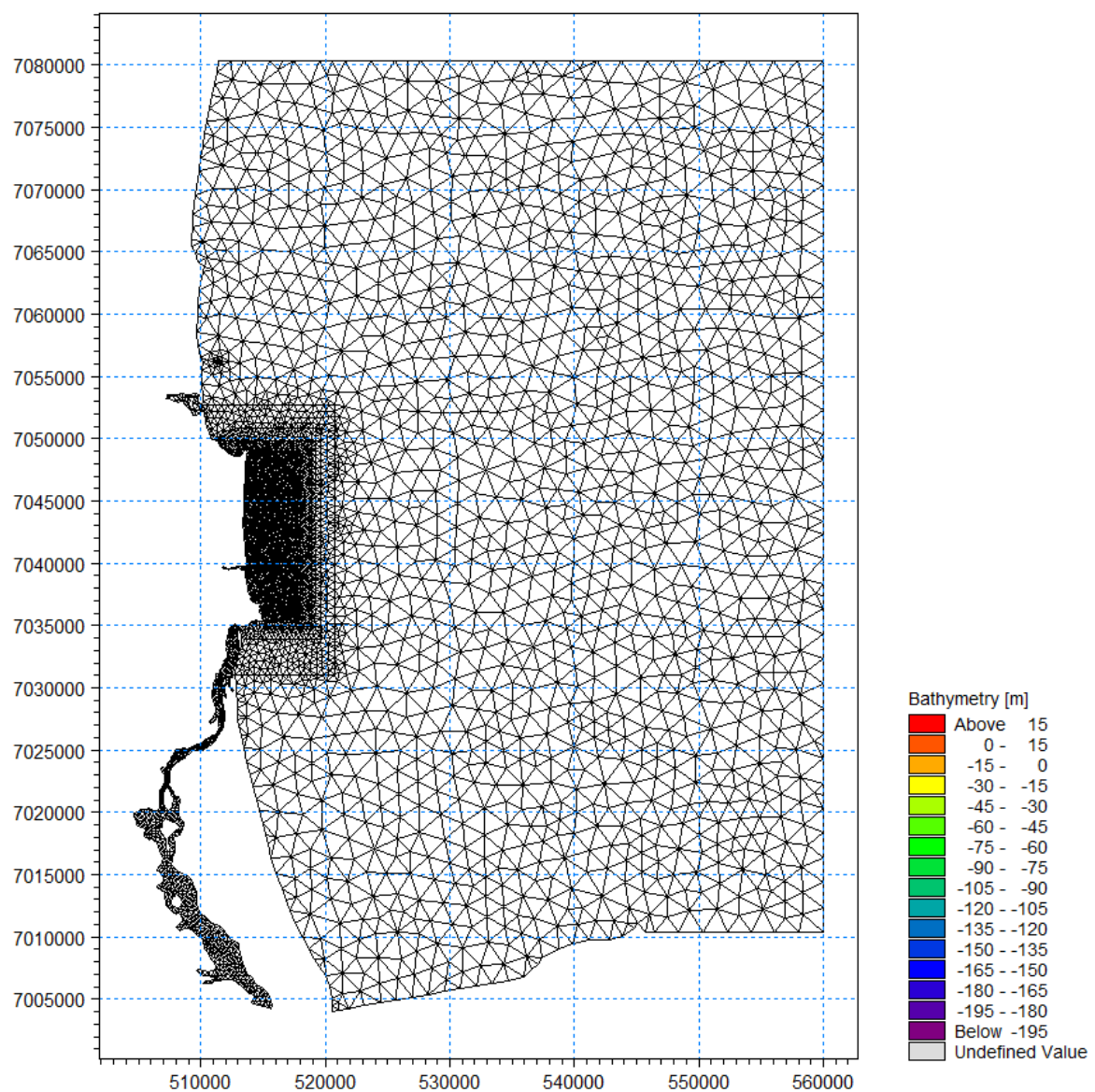


Figure 6 Pacific Ocean model domain and mesh

2.2.4.2 Bathymetry

The bathymetry applied to the model mesh is presented in Figure 7. The data was extracted from a 100 m resolution DEM of the Great Barrier Reef and Coral Sea owned by GeoScience Australia. The DEM represents a compilation of available bathymetry data developed over the past ten years from various sources including deep-water multibeam surveys, airborne LiDAR bathymetry acquired by the Australian Hydrographic Office and satellite derived bathymetry. The finalised bathymetry dataset was developed through edits as point clouds to remove noise, given a consistent WGS84 horizontal datum, and an approximate Mean Sea Level (MSL) vertical datum.

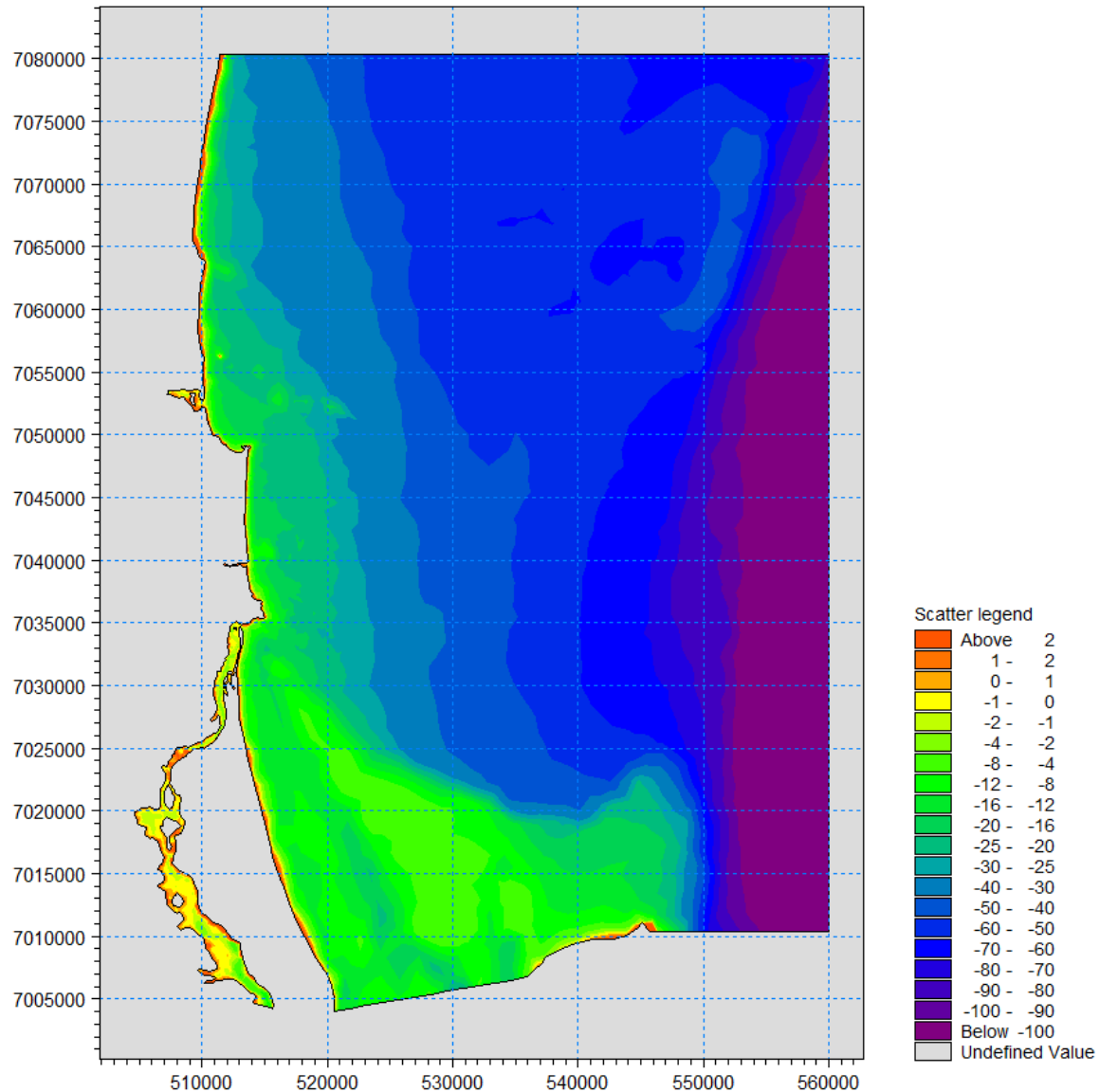


Figure 7 Pacific Ocean bathymetry

2.2.4.3 Boundary conditions

Tidal and oceanic currents

The boundary conditions for the open water boundaries of the MIKE 3 model were extracted from a regional hydrodynamic model which covers South-East Queensland. The regional model was developed by DHI for the Australian Maritime Safety Authority using input data from the Bluelink ocean forecasting model developed by CSIRO. The boundary conditions extracted for the ocean model used in this assessment therefore include influences from both tidal and offshore oceanic currents such as the East Australian Current (EAC).

The data was applied as a Flather condition incorporating timestep data for surface elevation and 2D depth-averaged velocity components (u-component, v-component). The boundary conditions were applied to the following model node-strings:

- Northern boundary (to the east of Noosa Heads)
- Eastern boundary (offshore deep water)
- Southern boundary (to the east of Moreton Island)
- Moreton Bay boundary (between Bribie Island and Moreton Island)
- Pumicestone Passage boundary (between Bribie Island and Sandstone Point)

Wind conditions

Wind data from BoM station 040861, located at the Sunshine Coast airport, was used as input to the MIKE 3 model. The data was applied in the form of wind speed and wind direction and included readings at three-hourly intervals.

Summaries of the long-term wind conditions at the airport are provided in Figure 8a and Figure 8b, in the form of wind rose diagrams, for data collected at 9 am and 3 pm respectively. As a general seasonal summary, winds from October to March are shown to be predominantly from the south-east to south-east/north-east and from April to September from the west south-west.

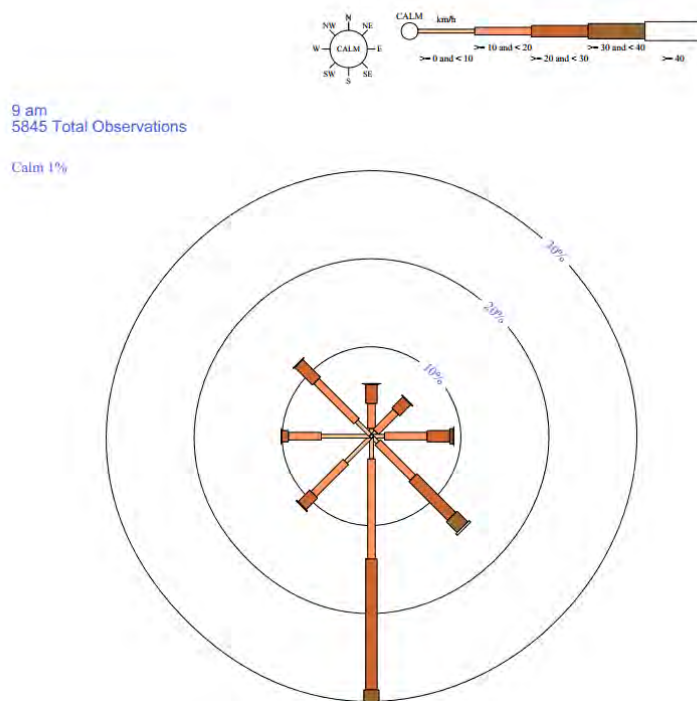


Figure 8a Roses of wind direction versus wind speed (Sunshine Coast Airport) - 9am

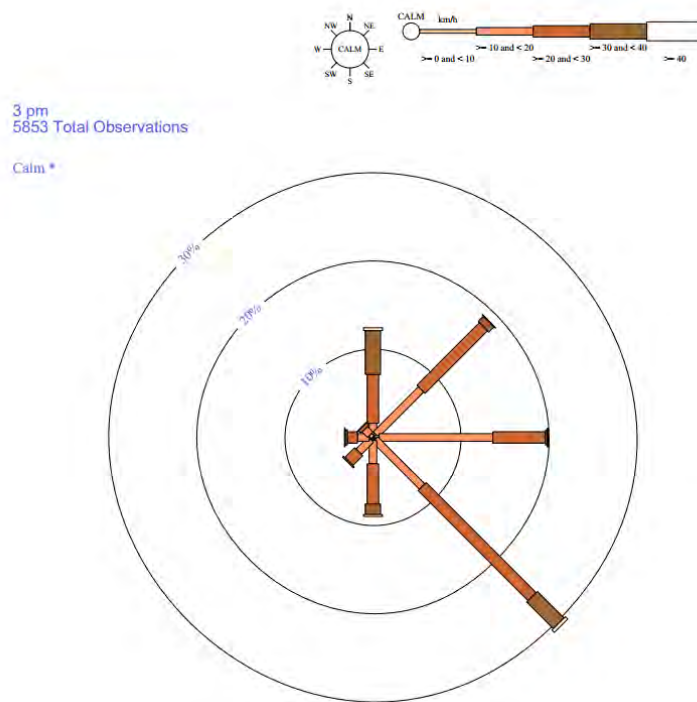


Figure 8b Roses of wind direction versus wind speed (Sunshine Coast Airport) - 3pm

Wave forcing

Wave radiation was also introduced to the model as driving forces for the MIKE 3 model so as to calculate wave induced flow. The wave radiation stresses were derived from a MIKE 21 Spectral Wave model developed for the same model domain presented previously in Figure 6. The Spectral Wave model incorporated boundaries derived from the Queensland Government wave monitoring sites and also included local wind forcing through application of data from the BoM Sunshine Coast station 040861.

2.2.5 Calibration and validation

2.2.5.1 Datasets

The MIKE 3 model was calibrated against water elevation data collected from the MSQ storm surge gauge 011008A, located at Mooloolaba.

Calibration of the Spectral Wave model was provided against historical data from the Queensland Government wave monitoring program, at the following sites: Caloundra and Mooloolaba

The MIKE 3 model was validated against ADCP data collected in the vicinity of the Kawana STP release point W3, approximately 1 km offshore of Bokarina/Warana Beach. This data was collected over a three-month long deployment in 2013, on behalf of Unitywater, for the Infrastructure Planning and Approvals Studies (IPAS) project (CH2M, 2014/15).

2.2.5.2 Results and interpretation

The results of the model calibration against the storm surge tidal elevation data are presented in Figure 9. From this comparison of model results against monitoring data, the model is observed to reproduce the amplitude and phases of the tidal regime well in the vicinity of Mooloolaba. Of note is the simulation of transition between spring and neap tidal amplitudes. While there is some observed level of either over or under prediction in the high or low tide peaks, these are considered minor, and the tidal elevations are considered to be well reproduced by the model.

The comparison of the Spectral Wave model results against the wave buoy data shows how accurately the model is representing the wave climate in terms of wave height, wave period and

direction. Significant and maximum wave heights are presented in Figure 10 for Caloundra, followed by the associated wave period and wave direction data in Figure 11. The same sets of data are presented in Figure 12 and Figure 13 for Mooloolaba.

Model validation is presented with comparison of MIKE 3 model results for velocity magnitude and direction against ADCP monitoring data collected near the release point W3. The results are presented in Figure 14, Figure 15 and Figure 16 for the lower, mid and higher water column respectively.

Given the significant complexity of the waters in this location and the prevalent influences of tides, waves and wind, as well as potentially other coastal currents, the results indicate that the model is simulating the hydrodynamic conditions near the ocean outfall well, in terms of both velocity magnitude and direction.

Interestingly, the results correlate relatively well with previous modelling undertaken by GHD (2011) but with a potential for higher current velocities predicted by both the MIKE 3 model and measured during the ADCP deployment. The GHD modelling concluded *“that tidal streams were relatively low and orientated along a north to south axis, parallel to the coast. A tidal stream of 0.08 m/s has only a 5% probability of exceedance and the 10th percentile of tidal currents could be as low as 0.01 m/s. However, when tidal forces are combined with wind and waves, it is suggested that a substantial modification of the currents may occur leading to the creation of a rather dynamic and complex receiving water environment”*.

From the results of both the calibration and validation exercises, it is concluded that the model is resolving the hydrodynamics in the coastal region of interest, with a high degree of confidence. The MIKE 3 model was therefore considered fit for purpose with respect to application of the particle tracking assessment.

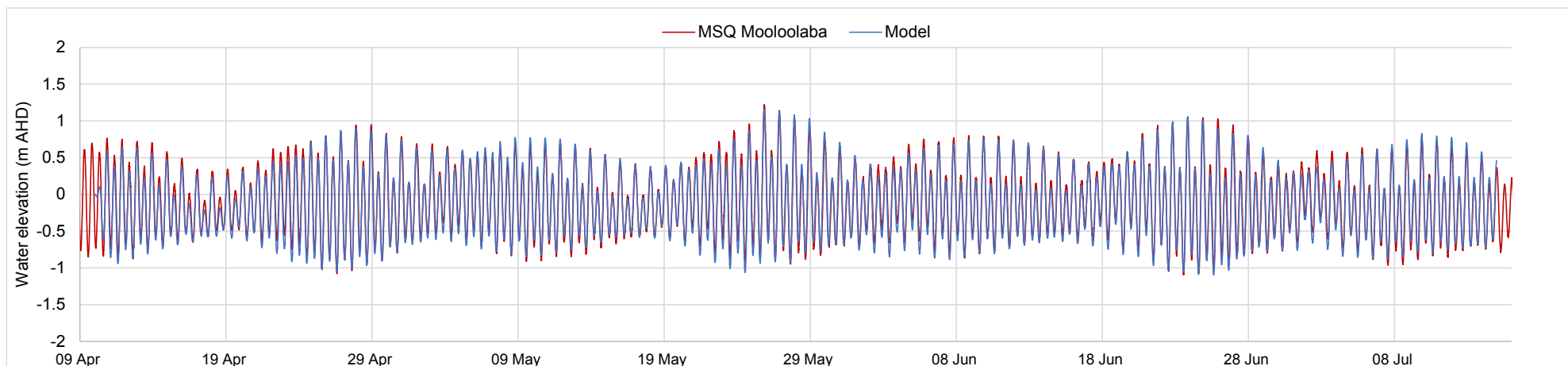


Figure 9 Hydrodynamic calibration - MIKE 3 model results and MSQ water elevation data

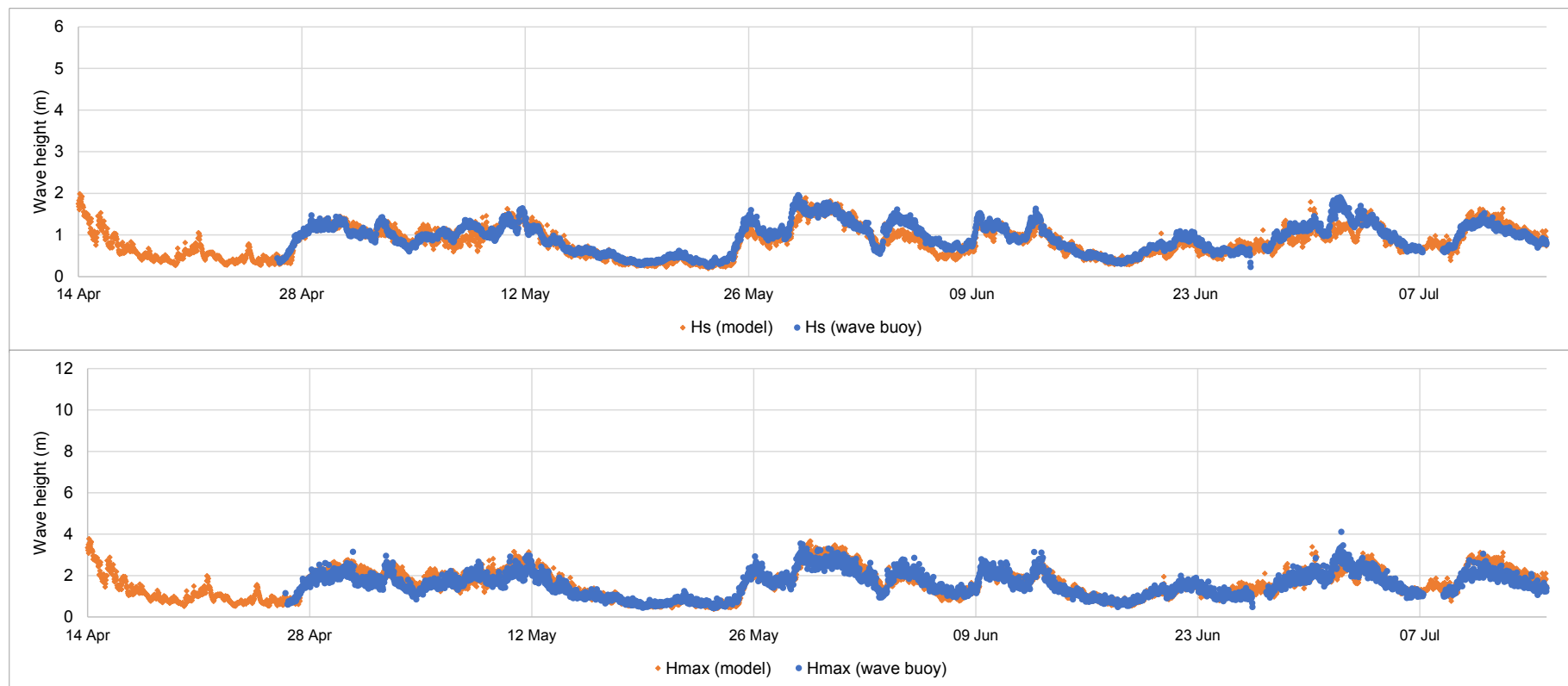


Figure 10 Model calibration – Spectral Wave model results and wave buoy monitoring data (Caloundra) – Significant wave height (top) and Maximum wave height (bottom)

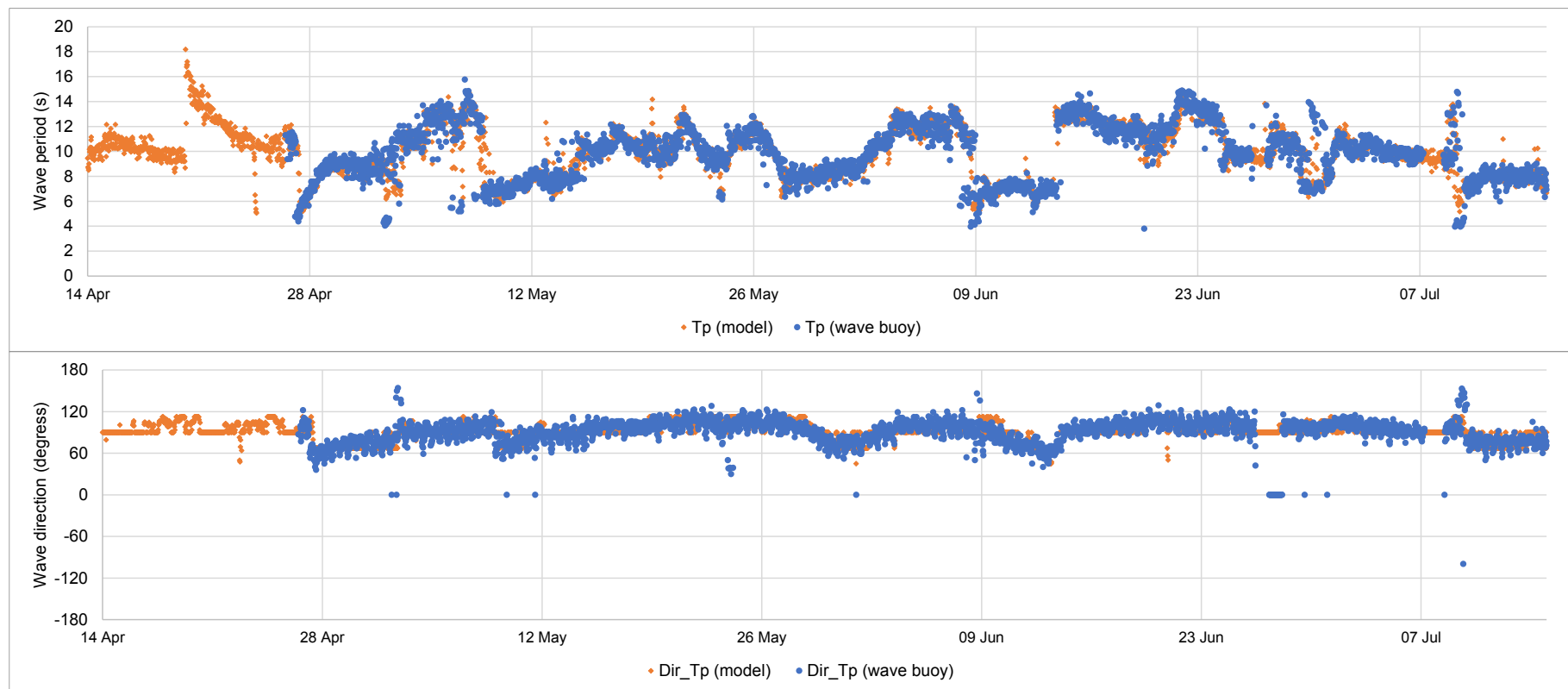


Figure 11 Model calibration – Spectral Wave model results and wave buoy monitoring data (Caloundra) – Peak wave period (top) and Peak wave direction (bottom)

Cal

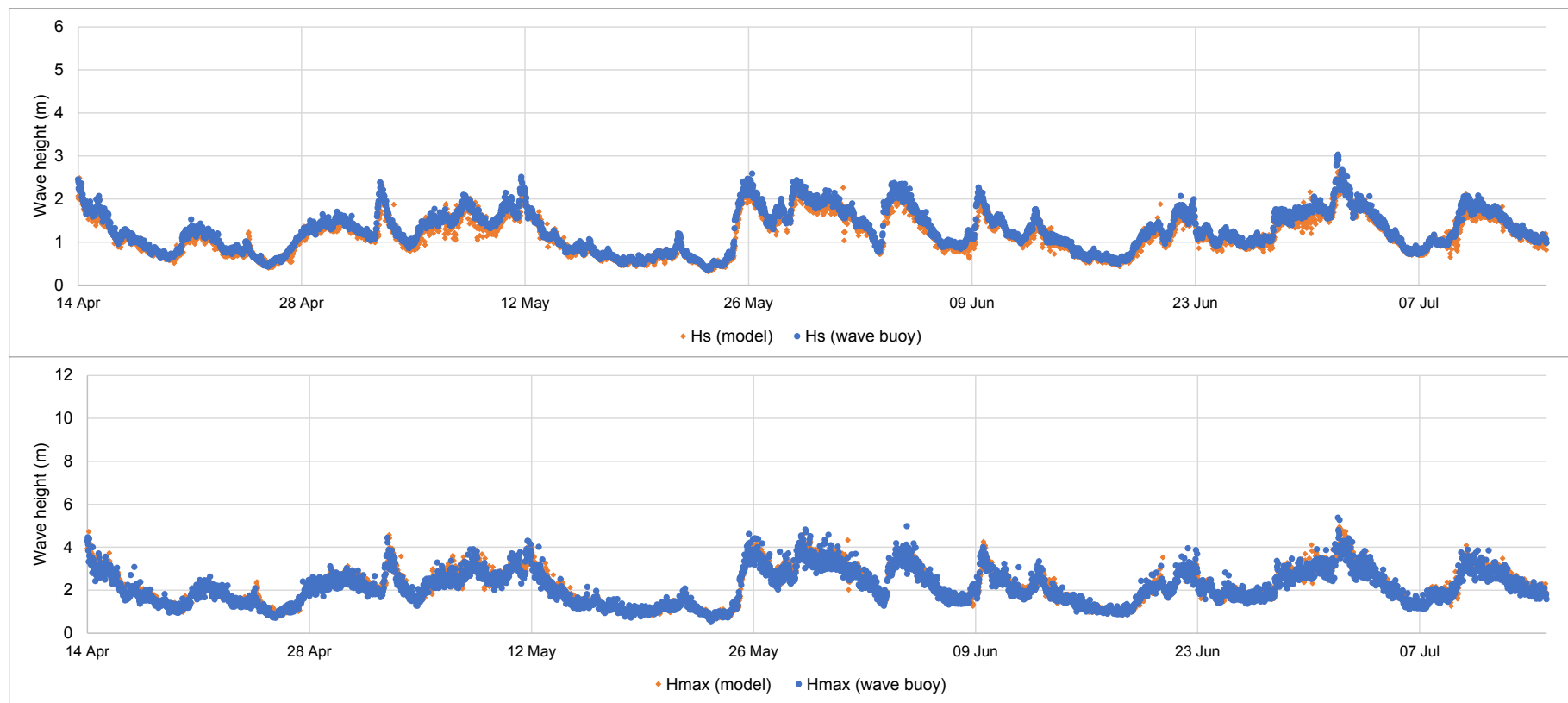


Figure 12 Model calibration – Spectral Wave model results and wave buoy monitoring data (Mooloolaba) – Significant wave height (top) and Maximum wave height (bottom)

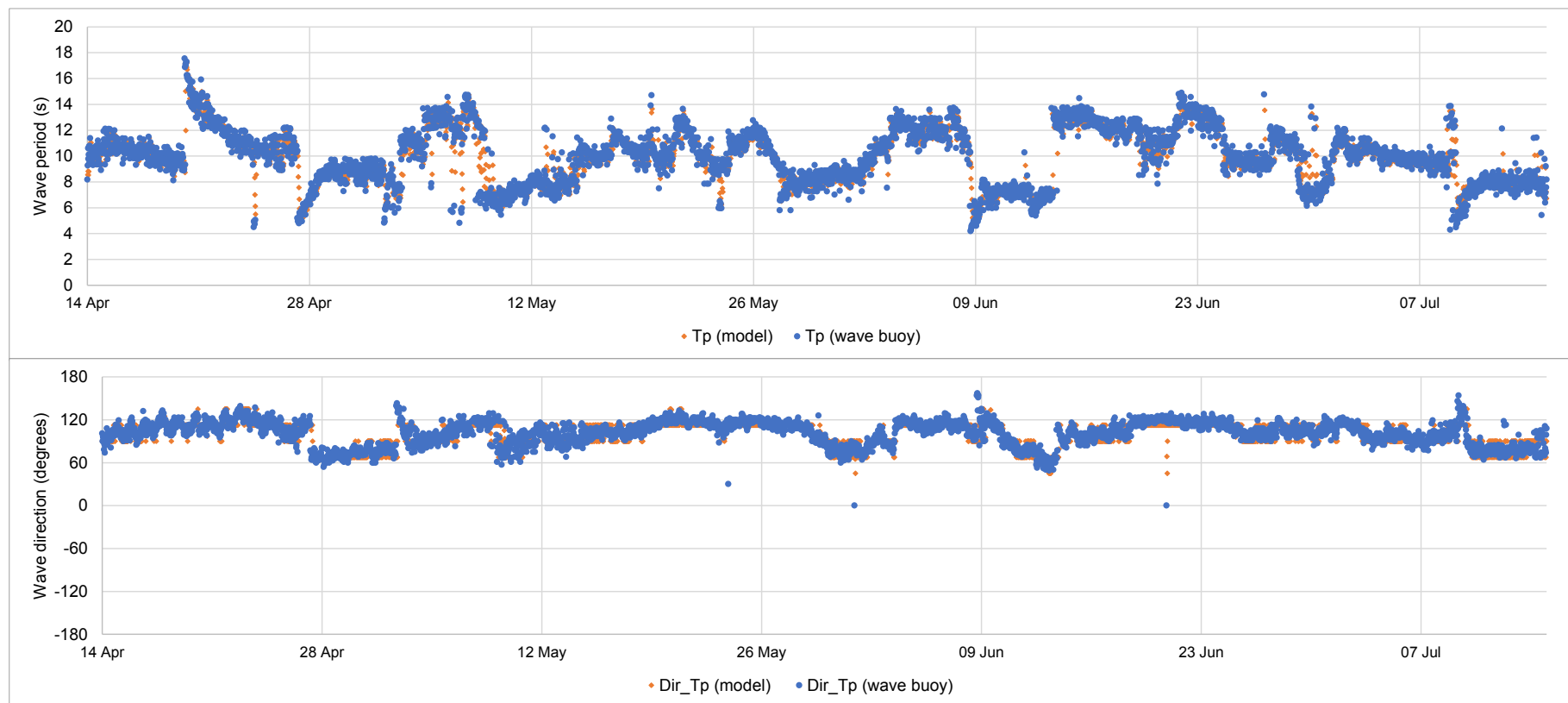


Figure 13 Model calibration – Spectral Wave model results and wave buoy monitoring data (Mooloolaba) – Peak wave period (top) and Peak wave direction (bottom)

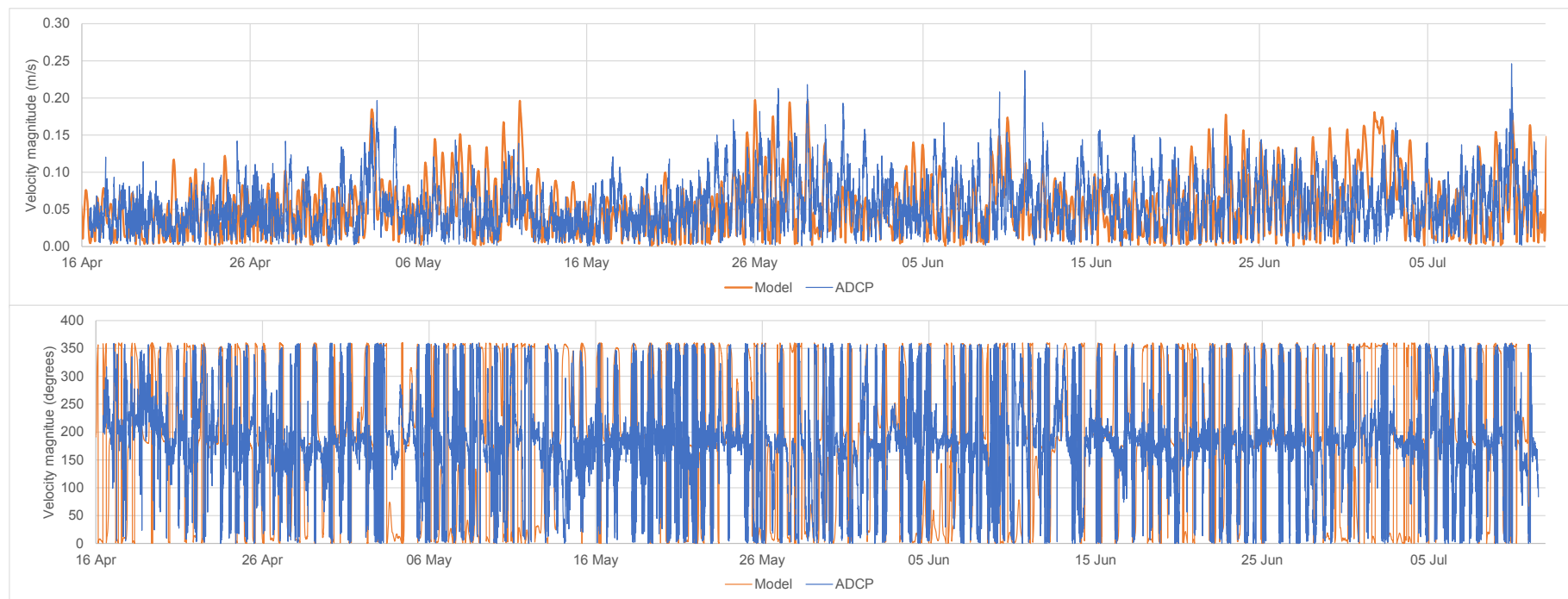


Figure 14 Model validation – MIKE 3 model results and ADCP monitoring data (Release Point W1 – lower water column) – Velocity magnitude (top) and Velocity direction (bottom)

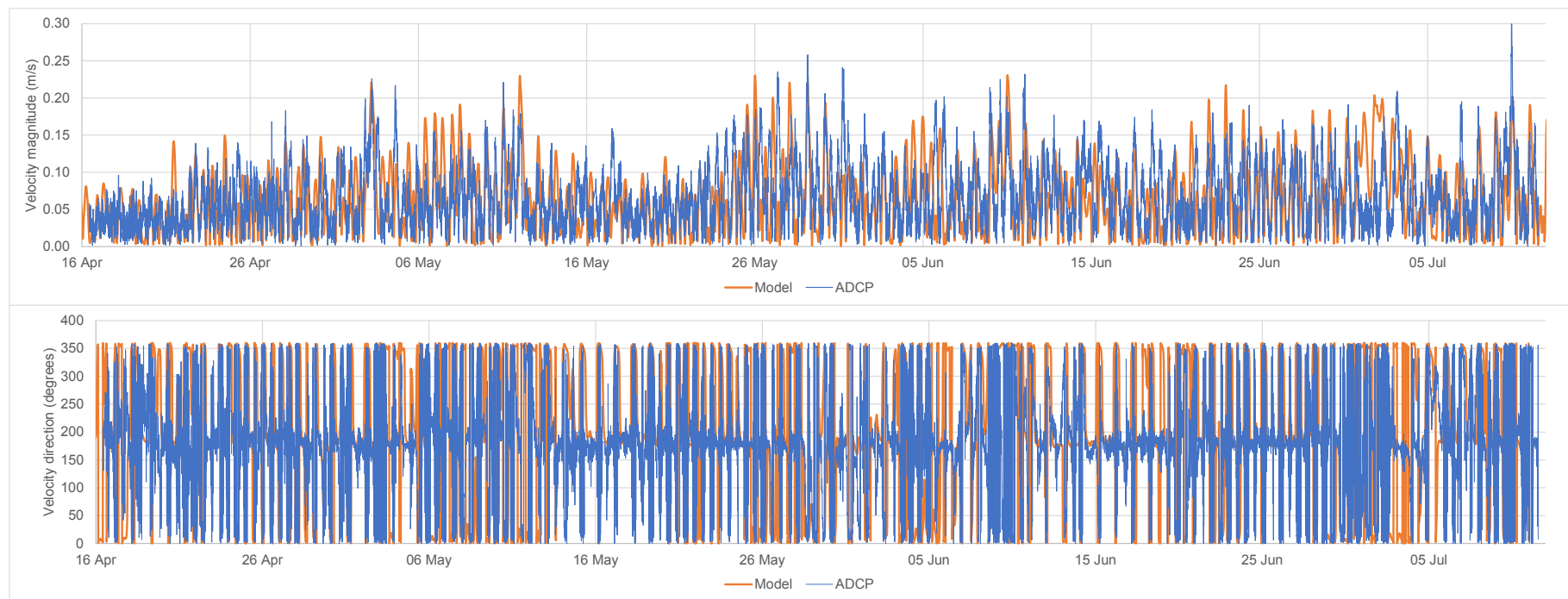


Figure 15 Model validation – MIKE 3 model results and ADCP monitoring data (Release Point W1 – mid water column) – Velocity magnitude (top) and Velocity direction (bottom)

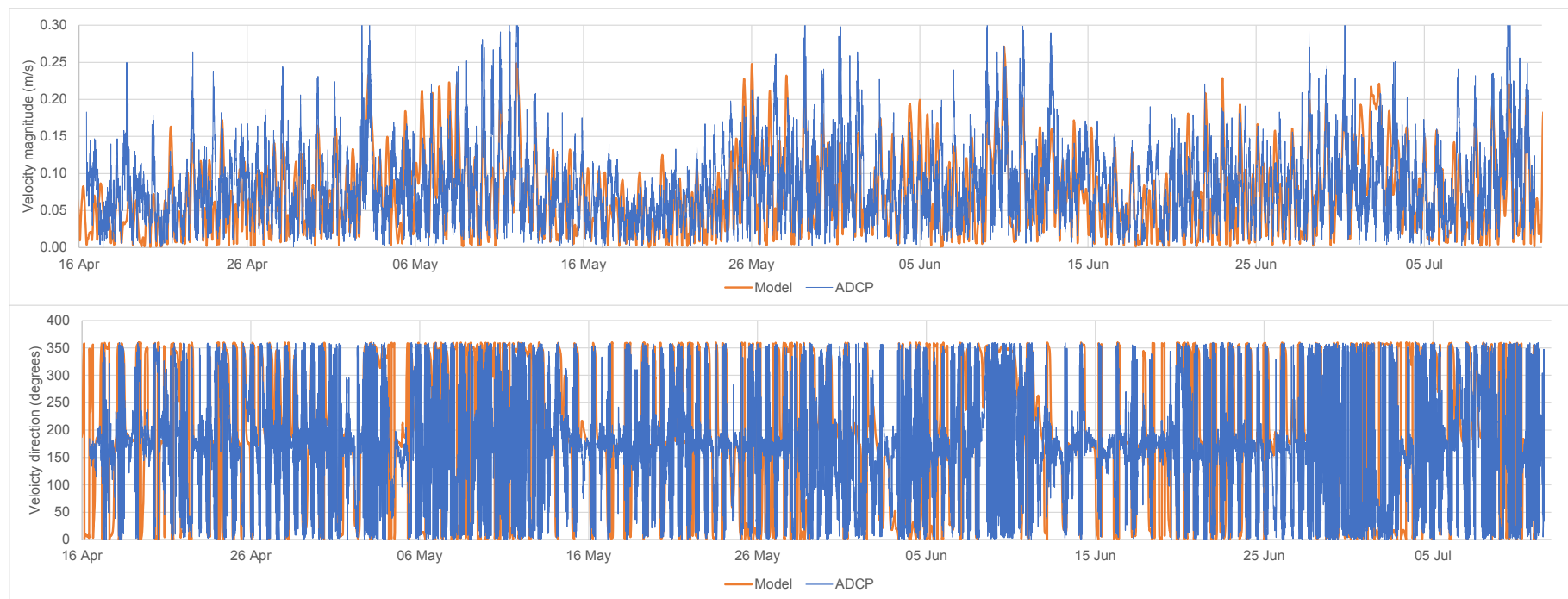


Figure 16 Model validation – MIKE 3 model results and ADCP monitoring data (Release Point W1 – top water column) – Velocity magnitude (top) and Velocity direction (bottom)

3 Particle tracking assessments

3.1 Assessment approach and assumptions

3.1.1 Assessment approach

The primary objective of the scenario testing was to predict the environmental fate of the MBBR media particles that could potentially be released within the effluent and into the receiving waters.

Data on the sizing, weights and expected discharge rates for a suite of different particle types were provided by Unitywater and its consultants. This data allowed for development of the scenario release conditions discussed in Sections 3.2.1 and 3.3.1. As discussed in Sections 3.2.1.2 and 3.3.1.2, limitations presented by the MIKE PT software were also considered in the development of these scenario conditions.

The results from the scenario runs were statistically analysed over a long-term simulation period to generate an understanding of the most likely accumulation areas for each particle type.

3.1.2 Scenario simulation period

Using historical climatic, tidal and wave data to drive the model, each scenario was run over a period of 12 months. The simulation period was selected based on both climatic conditions as well as availability of data to force/drive the model. A higher rainfall period was deemed most suitable so as to allow for a range of release conditions for the river and the ocean.

The period commencing at the start of October 2011 and ending at the end of September 2012 was ultimately selected so as to represent a higher rainfall year which included a varied range of wet weather events and associated release conditions for the river and the ocean. Importantly, in addition to more minor and moderate conditions, the range of release events within this 12-month period, included events that were considered more extreme and with the potential to overtop specific configurations of the mesh basket screens.

The start and end dates of this simulation period were selected based on the distribution of rainfall and predicted releases, allowing for a reasonable period to track particles following the last release to the river in June 2012. Importantly, this period also fell within the temporal extents of the tidal/current boundary conditions discussed in Section 2.2.4.3 (2011 to 2015).

Figure 17 presents the daily rainfall data collected by BoM for the Kawana and Caloundra region from 2008 to 2017. Adopting the water balance model discussed in 3.2.1.2, Figure 18 presents the predicted discharge flows to the Mooloolah River and the Pacific Ocean for the same period.

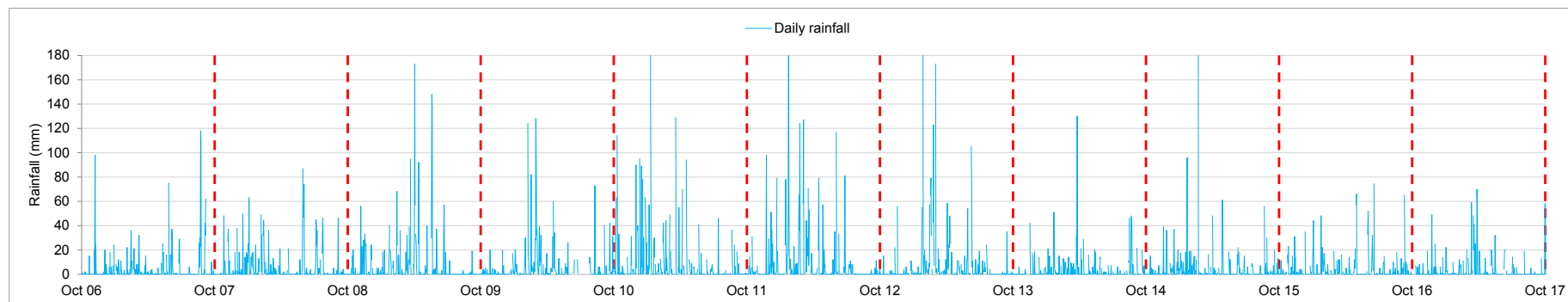


Figure 17 Daily rainfall data for the Kawana and Caloundra region

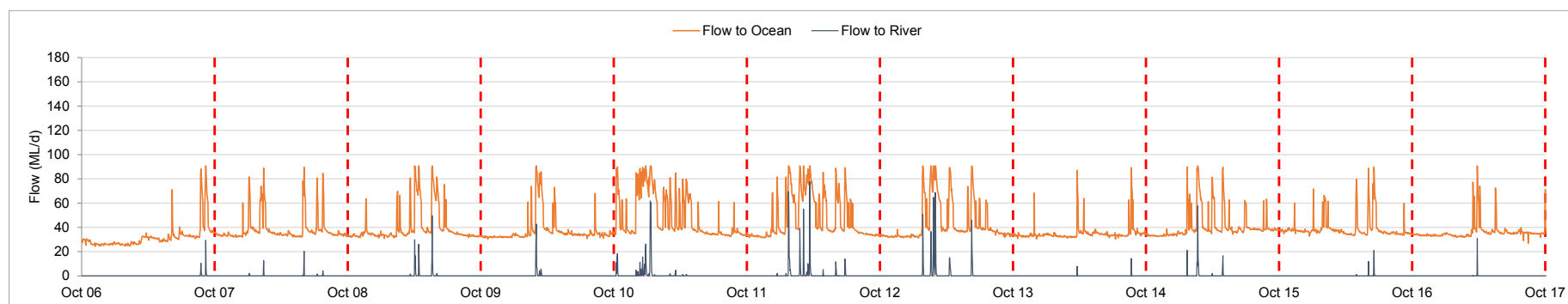


Figure 18 Predicted flow released to the Pacific Ocean (release point W1) and the Mooloolah River (release point W3)

3.1.3 Assumptions

3.1.3.1 Particle characteristics

The characteristics of different particle sizes were informed by investigations undertaken by Unitywater and their consultants, and the requirements of the EE. These investigations focussed on both particles that were smaller than the 2 mm screen size aperture (and therefore may pass through the screens), as well as those larger than 2 mm (and therefore may be caught on the screens).

The data provided takes into account particle shape, intraparticle and interparticle pack voidage as well as the specific gravity of the media. Further details regarding these calculations are presented in Attachment A.

3.1.3.2 PT Software

The following parameterisation, assumptions and limitations related to the application of the PT software in both the Mooloolah River and Pacific Ocean.

Model limitations

The release conditions were adapted to address the following two software limitations:

- **Minimum release rate:** The software has a requirement that an integer value is assigned for the number of particles released per time step. As both models used a time step of 30 seconds, a particle release rate of at least one particle every 30 seconds was required if a discharge was to be assumed in any one given time step. The implication of this limitation for this assessment, was that low particle release rates e.g. 0.3 particles/minute, would not be read or acknowledged by the software and no particle release would occur. In these circumstances, the release rates were increased to one particle per 30 second time step so as to ensure simulation of the release of relevant particle types.
- **Maximum release rate:** The software simultaneously calculates the path of each particle released into the model domain. The more particles released therefore increases the computational requirements and consequently the simulation times. If excessive particles are released, the software will be unable to undertake all the relevant calculations and the simulations will fail. While there is no specified value for how many particles that can be simulated, initial runs in both models eventuated in unsuccessful simulations. The implication of this limitation for this assessment, was that the number of particles released needed to be reduced for some scenarios. A particle age also needed to be applied in some simulations. The particle age allowed for removal of particles after a specified time after their release.

To compensate for these modifications, scaling factors were applied to the results from relevant scenarios. These scaling factors with notes regarding their derivation are presented in Attachment C.

Model parameterisation

The following parametrisation was adopted for the PT model:

- **Decay (resulting in reduction of particle mass):** No decay was assumed as there was considered to be limited opportunity for dispersed buoyant particles to be mechanically degraded in the aquatic environment.
- **Particle age:** Scenario specific with details presented in Sections 3.2 and 3.3.
- **Settling:** No settling was assumed. While attached marine growth could have the potential to impact particle buoyancy over longer periods of time, it was assumed that the MBBR particles are likely to remain buoyant in sea water since their specific gravity is less than 1.0.
- **Dispersion:** a scaled eddy viscosity formulation was assumed in the horizontal, with zero dispersion assumed in the vertical.
- **Drift profile:** the drift profile included both hydrodynamic forcing as well as surface wind acceleration.

Model uncertainty

As discussed previously in Sections 1.2 and 1.3, a primary objective of the modelling undertaken in this assessment has been to simulate the likely environmental fate of media particles potentially released to the receiving waters of the Mooloolah River and the Pacific Ocean. The modelling results, in turn, have provided valuable information for the design and implementation of the SAQP.

The numerical modelling for this assessment has been undertaken following accepted industry standard practices. It is noted however, that in line with similar assessment studies, the modelling undertaken should be considered as a representative approximation to the real world and not without accepted levels of uncertainty. It should therefore be understood that each model is based on a series of assumptions, and also dependent on the accuracy of its input data. The model results should therefore be interpreted as indicative of the conditions expected in the receiving waters, and not absolutes.

3.2 Mooloolah River assessment

3.2.1 Scenario descriptions

3.2.1.1 Scenario types

The following three scenario types were modelled for the Mooloolah River assessment:

Scenario 1: Wet weather releases of MBBR particles < 2 mm.

This is a scenario potentially expected under the current operating regime where smaller particles below 2 mm in size pass through the effluent basket screens. Under wet weather conditions, when the hydraulic capacity of the ocean outfall is exceeded, a proportion of these particles are assumed to be released to the river. A single particle type was simulated in this size range:

- PT1_1mm: Nominal size of 1 mm, with an assumed mass of 0.45 mg/particle

Scenario 2: Hypothetical wet weather releases of undetected release of a portion of all sizes of MBBR particles.

In this hypothetical scenario, it is assumed the basket screens have been breached by a hole, or other damage, to the screens that goes undetected, despite regular screen inspections. It is assumed that 10% of particles pass through this breach in the screens and under wet weather conditions, when the hydraulic capacity of the ocean outfall is exceeded, a proportion of these particles are assumed to be released to the river. The following particle types were simulated:

- PT2_2mm: Nominal size range of 1.18 to 2.36 mm, with an assumed mass of 20.4 mg/particle
- PT2_4mm: Nominal size range of 2.36 to 4.75 mm, with an assumed mass of 25.9 mg/particle
- PT2_6mm: Nominal size range of 4.75 to 6.7 mm, with an assumed mass of 52.5 mg/particle
- PT2_8mm: Nominal size range of 6.7 to 9.5 mm, with an assumed mass of 74.5 mg/particle
- PT2_11mm: Nominal size range of 9.5 to 13 mm, with an assumed mass of 453.1 mg/particle

It is noted that these releases are not expected to occur under normal operating practice but have been included in the assessment as a hypothetical scenario to assist understanding of the fate of released particles.

Scenario 3: Overtopping of the basket screens during an extreme wet weather event and associated release to the Pacific Ocean and Mooloolah River outfalls assuming the previous basket screen configuration at the STP.

This scenario has been included to provide insight into potential releases from overtopping of basket screens in the plant configuration prior to May 2021. This scenario represents a rain event that occurs just prior to the basket screens being emptied in line with maintenance schedules, and the contents captured on the screens released within one hour as they overtop. The following particle types were simulated in this scenario:

- PT3_2mm: Nominal size range of 1.18 to 2.36 mm, with an assumed mass of 20.4 mg/particle
- PT3_4mm: Nominal size range of 2.36 to 4.75 mm, with an assumed mass of 25.9 mg/particle
- PT3_6mm: Nominal size range of 4.75 to 6.7 mm, with an assumed mass of 52.5 mg/particle
- PT3_8mm: Nominal size range of 6.7 to 9.5 mm, with an assumed mass of 74.5 mg/particle
- PT3_11mm: Nominal size range of 9.5 to 13 mm, with an assumed mass of 453.1 mg/particle

It is noted that these releases are no longer possible under the current screen configuration but have been included in the assessment as an extreme wet weather scenario to assist understanding of the fate of particles that could have been released under the previous plant configuration.

All particle types applied within the Mooloolah River assessment were assumed to have unlimited particle age i.e. there was no removal of particles after a specified time after their release.

3.2.1.2 Release conditions

Release of treated effluent to the Mooloolah River (Release Point W3) occurs generally when the hydraulic capacity of the ocean outfall is exceeded due to wet weather. The location of Release Point W3 is presented in Figure 19.

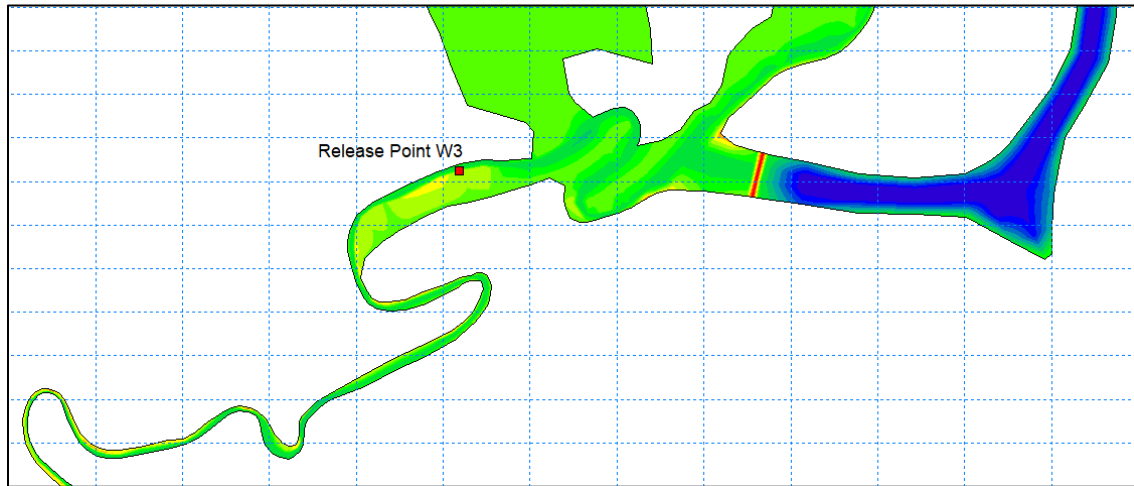


Figure 19 Location of Release Point W3

To develop an understanding and predictive ability to determine release conditions to the river, a water balance model was developed for previous Unitywater projects (Intrawater, 2020). The primary objective of this model was to allow estimation of expected short-period, sub-daily, effluent flow patterns over a range of different climatic conditions as well as for various population scenarios.

From this modelling, the volumes that would exceed the assumed hydraulic capacity of the ocean outfall could then be predicted. The proportion of flows expected to be directed to the Mooloolah River and those discharging to the ocean could therefore also be estimated. Further details of this modelling are presented in Attachment B. For the purposes of this assessment, the hydraulic capacity of the ocean outfall was assumed to be 1,050 L/s. An influent Average Dry Weather Flow (ADWF) of 33 ML/d was also assumed.

The release rates predicted for these conditions are presented in Figure 20.

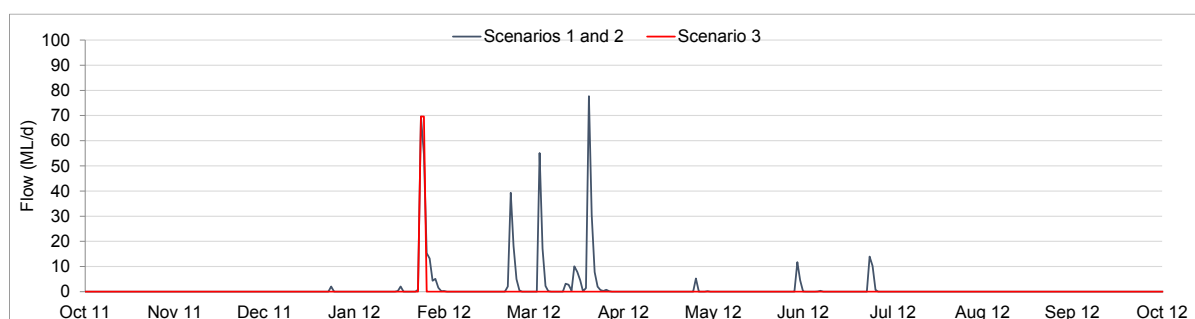


Figure 20 Predicted release rates for release point W3

For Scenarios 1 and 2, the release rates were adapted to address the software limitations discussed in Section 3.1.3.2. Therefore, a release rate of one particle per 30 seconds (or 120 per hour) was applied for periods of discharge presented in Figure 20.

For Scenario 3, the following quantities of particles per time step were released over the one-hour release period presented in Figure 20. These values account for the volume of particles assumed to be collected on the screens over a 14-day period as well as the predicted level of flow splitting between the river and ocean outfalls.

- PT3_2mm: 55 per 30 seconds (or 6,600 per hour)
- PT3_4mm: 412 per 30 seconds (or 49,440 per hour)
- PT3_6mm: 144 per 30 seconds (or 17,280 per hour)
- PT3_8mm: 11 per 30 seconds (or 1,320 per hour)
- PT3_11mm: 373 per 30 seconds (or 44,760 per hour)

3.2.2 Scenario results and interpretation

The results of the scenarios are presented spatially as distributions of maximum sedimented/deposited mass concentrations calculated over the simulation period.

For brevity, only one particle type per scenario has been presented below. For Scenarios 2 and 3, this includes mid-sized (~6 mm) particle types.

Figure 21, Figure 22 and Figure 23 present the results for Scenario 1 (PT1_1), Scenario 2 (PT2_6mm) and Scenario 3 (PT3_6mm) respectively.

A full set of the scenario results are provided in Attachment C1.

In summary, the modelling predicts that:

- There are similar patterns of accumulation in the estuary for the release conditions simulated in Scenarios 1 and 2, with potentially higher concentrations accumulating at the following locations:
 - A. The reach downstream of Release Point W3 and upstream of Parrearra Weir
 - B. Mid estuarine reaches near the Brightwater Eastern Conservation Area
 - C. Foreshore areas between Mooloolah Island and Minyama Island
- While not explicitly shown in the maximum concentration plots, the model results, viewed as a time lapse animation, also indicate the potential for greater accumulation in reach “A”, immediately following a release event. Depending on the magnitude of the release and the relative strength of tidal currents against the freshwater flows driven by runoff in the upstream catchments, particles are predicted to be retained in this area and deposited within the intertidal zones and into the embayment near the Parrearra Weir. These particles have the potential to be retained in this vicinity until the following wet weather event which effectively flushes the particles downstream.
- Further downstream the predicted areas of accumulation “B” and “C” appear to predominantly correlate with intertidal zones along the mid-estuarine river banks and the more artificially developed foreshores in the lower estuary.
- Scenario 3 represents a significant one-hour release of particles, occurring during an extreme rainfall/release event. The results for this scenario (PT3_6mm) represent similar distributions but with a greater accumulation predicted near the Parrearra Weir relative to the sites downstream. This perhaps indicates the prediction of higher concentrations near the weir prior to subsequent weather events that flush the particles downstream with sufficient magnitude to avoid deposition on the intertidal areas of the middle and lower estuary.
- As discussed previously in Section 3.2.1, this scenario has been included to investigate the potential dispersion of particles from the previous basket screen configuration. With the current basket screen configuration, this scenario is no longer possible.

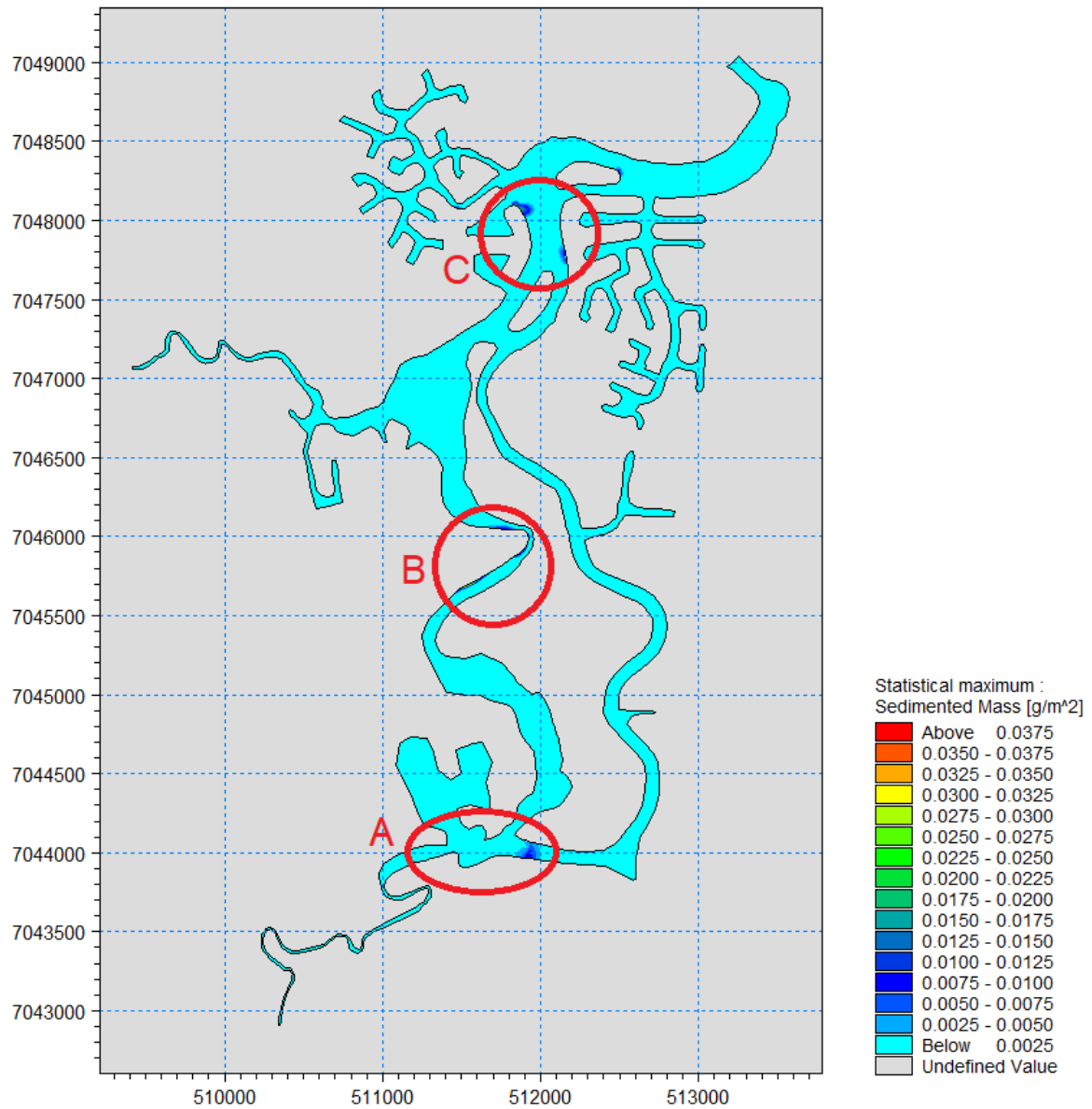


Figure 21 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm)

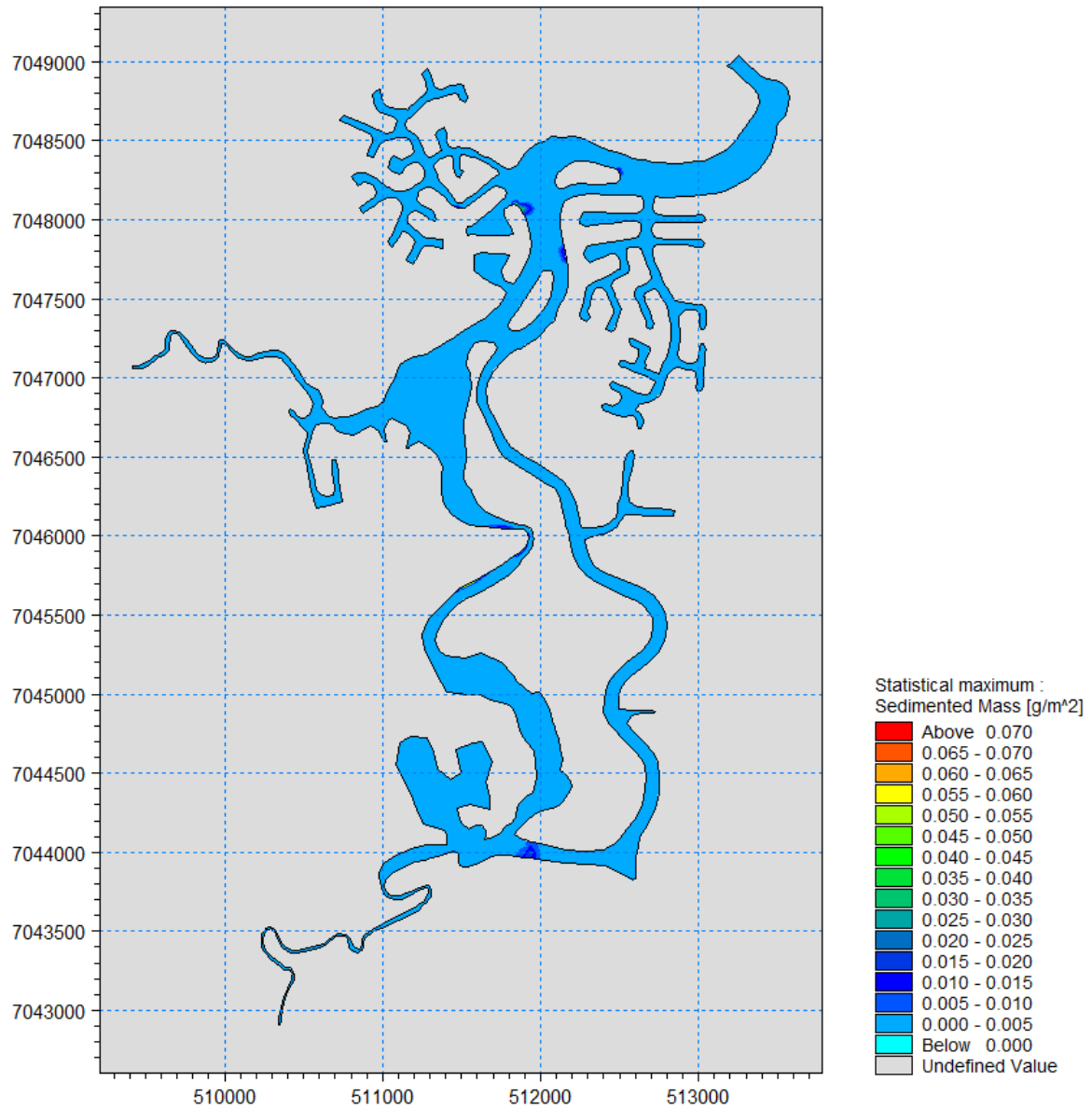


Figure 22 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_6mm)

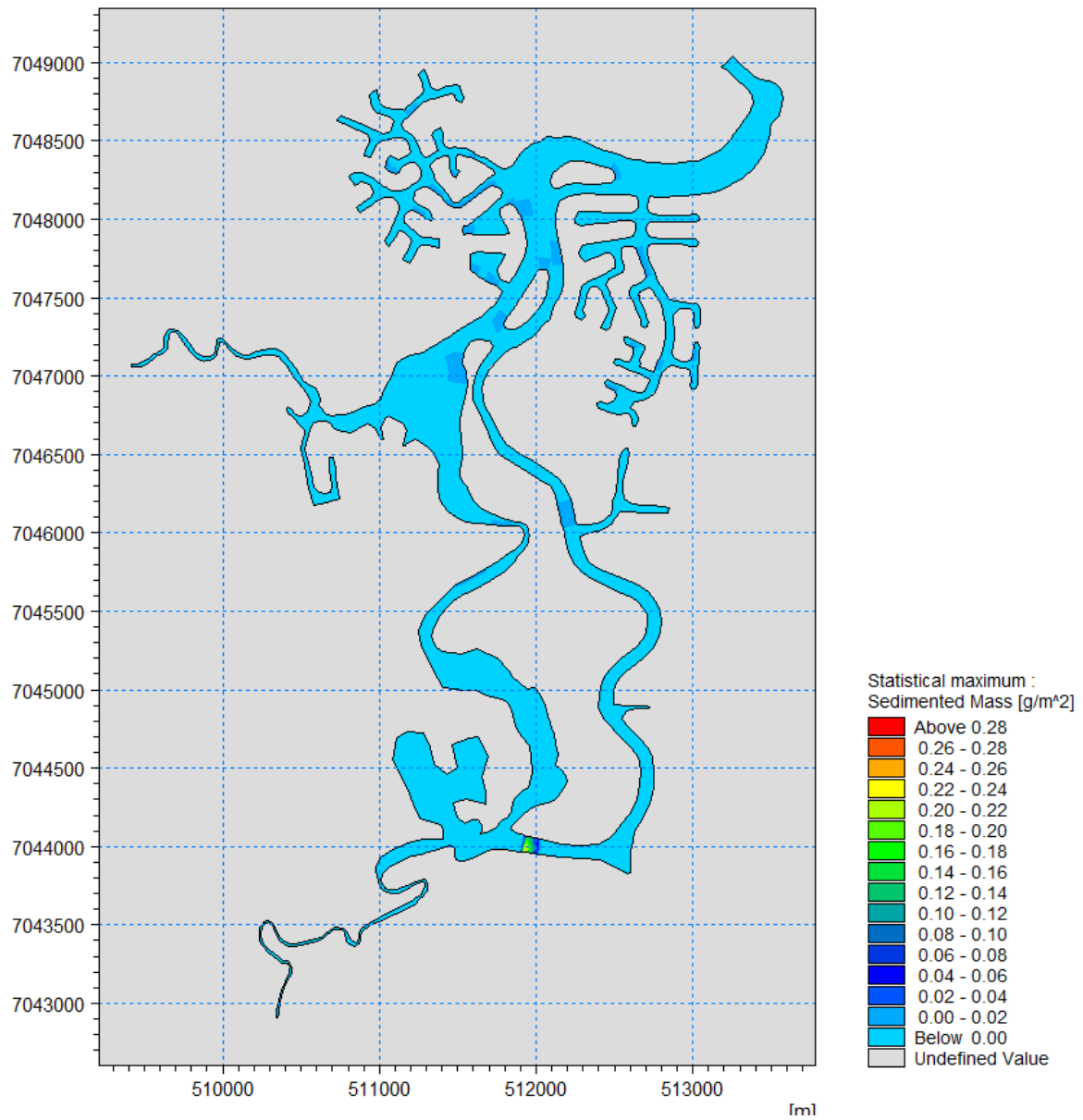


Figure 23 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_6mm)

3.3 Pacific Ocean assessment

3.3.1 Scenario descriptions

3.3.1.1 Scenario types

The scenario types applied to the Pacific Ocean releases replicated those applied to the Mooloolah River assessment. For ease of reference, the descriptions are repeated below.

The application of this particle age was deemed necessary to avoid excessive run times or simulation failures due to ever increasing number of particles generated in scenarios that simulate continuous release.

Scenario 1: Discharge of MBBR particles < 2 mm.

This is a scenario potentially expected under the current operating regime where smaller particles below 2 mm in size pass through the effluent basket screens. A single particle type was simulated in this size range:

- PT1_1mm: Nominal size of 1 mm, with an assumed mass of 0.45 mg/particle

Scenario 2: Hypothetical undetected release of a portion of all sizes of MBBR particles.

In this hypothetical scenario, it is assumed the basket screens have been breached by damage to the screens that goes undetected, despite regular screen inspections. It is assumed that 10% of particles pass through this breach in the screens. The following particle types were simulated:

- PT2_2mm: Nominal size range of 1.18 to 2.36 mm, with an assumed mass of 20.4 mg/particle
- PT2_4mm: Nominal size range of 2.36 to 4.75 mm, with an assumed mass of 25.9 mg/particle
- PT2_6mm: Nominal size range of 4.75 to 6.7 mm, with an assumed mass of 52.5 mg/particle
- PT2_8mm: Nominal size range of 6.7 to 9.5 mm, with an assumed mass of 74.5 mg/particle
- PT2_11mm: Nominal size range of 9.5 to 13 mm, with an assumed mass of 453.1 mg/particle

It is noted that these releases are not expected to occur under normal operating practice but have been included as a hypothetical scenario to assist understanding of the fate of released particles.

Scenario 3: Overtopping of the basket screens during an extreme wet weather event and associated release to the Pacific Ocean and Mooloolah River outfalls assuming the previous basket screen configuration at the STP.

This scenario has been included to provide insight into potential releases from overtopping of basket screens in the plant configuration prior to May 2021. This scenario represents a rain event that occurs just prior to the basket screens being emptied in line with maintenance schedules, and the contents captured on the screens released within one hour as they overtop. The following particle types were simulated in this scenario:

- PT3_2mm: Nominal size range of 1.18 to 2.36 mm, with an assumed mass of 20.4 mg/particle
- PT3_4mm: Nominal size range of 2.36 to 4.75 mm, with an assumed mass of 25.9 mg/particle
- PT3_6mm: Nominal size range of 4.75 to 6.7 mm, with an assumed mass of 52.5 mg/particle
- PT3_8mm: Nominal size range of 6.7 to 9.5 mm, with an assumed mass of 74.5 mg/particle
- PT3_11mm: Nominal size range of 9.5 to 13 mm, with an assumed mass of 453.1 mg/particle

It is noted that these releases are no longer possible under the current screen configuration but have been included in the assessment as an extreme wet weather scenario to assist understanding of the fate of particles that could have been released under the previous plant configuration.

With consideration of the prevailing hydrodynamic and meteorological conditions, in combination with the continuous nature of the releases, all particle types applied within the Pacific Ocean assessment were assumed to have a maximum particle age of 2 weeks. Adoption of this setting allowed for removal of particles from the simulation following a period of 14 days after their release. This period was considered to be an appropriate length of time for particles to become deposited on the foreshore following their release from the offshore diffuser (release point W1).

3.3.1.2 Release conditions

Release of treated effluent to the Pacific Ocean (Release Point W1) occurs continuously under normal operational conditions. However, the discharge rates from the offshore diffuser vary dependent on rainfall conditions and the corresponding volumes of influent reporting to the STP inlet works. The location of Release Point W1 is presented in Figure 24.

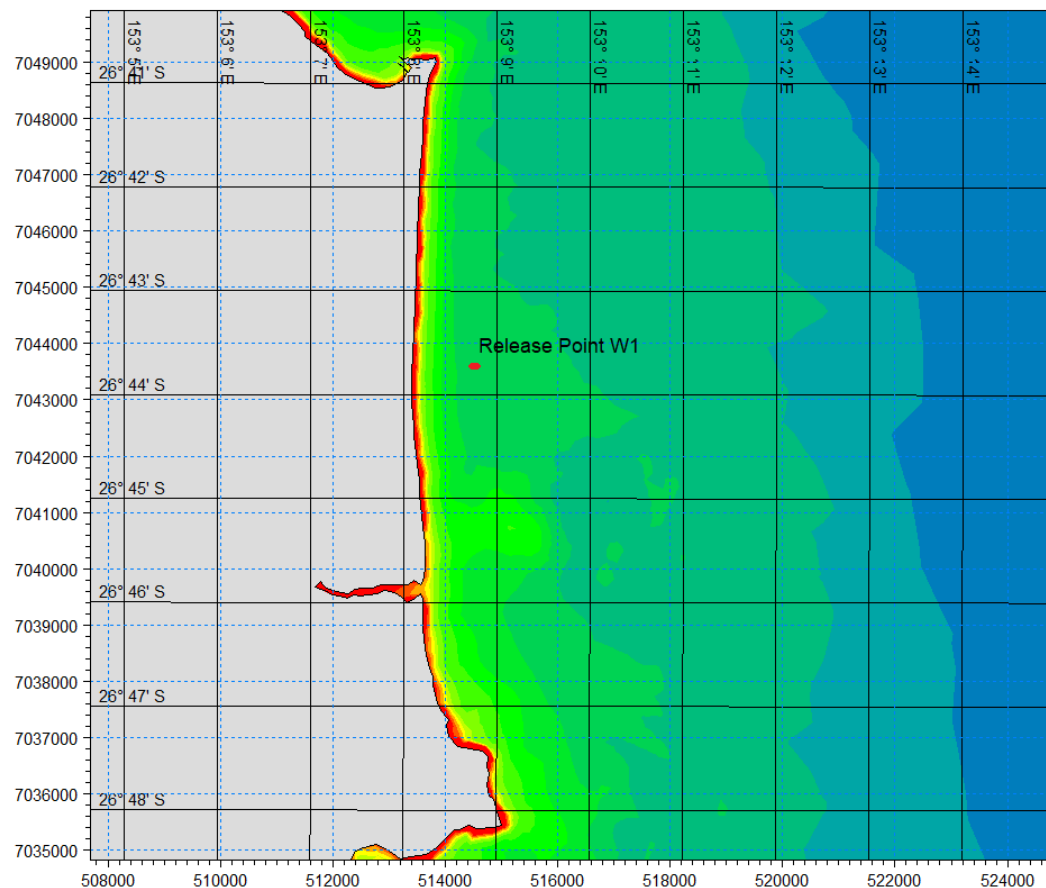


Figure 24 Location of Release Point W1

As discussed in Section 3.2.1.2, predictions regarding the flow splitting between release points W1 and W3 have been determined through the use of the previously developed water balance model (Intrawater, 2020). The primary objective of this model was to allow estimation of expected short-period, sub-daily, effluent flow patterns over a range of different climatic conditions as well as for various population scenarios.

Assuming a hydraulic capacity of 1,050 L/s for the ocean outfall, and an influent ADWF of 33 ML/d, the predicted release rates for the ocean outfall are presented in Figure 25.

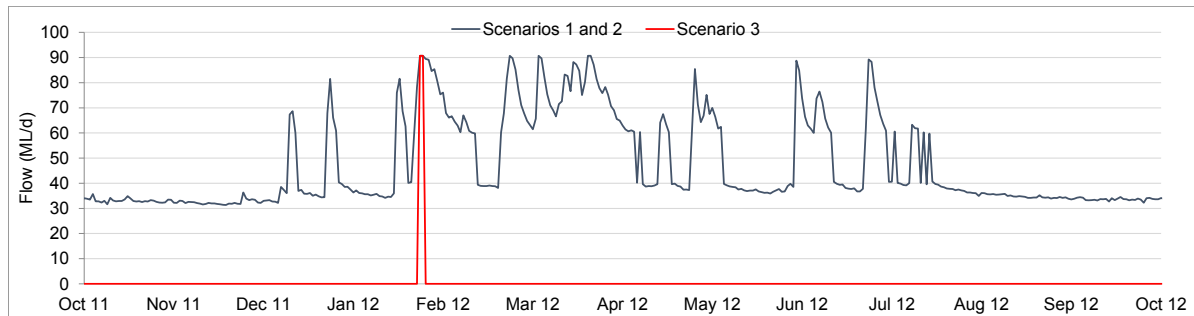


Figure 25 Predicted release rates for release point W1

For Scenario 2, the release rates were adapted to address the software limitations discussed in Section 3.1.3.2. Therefore, a release rate of one particle per 30 seconds (or 120 per hour) was applied continuously throughout the scenario simulations.

For Scenario 3, the following quantities of particles per time step were released over the one-hour release period presented in Figure 25. These values account for the volume of particles assumed to be collected on the screens over a 14-day period as well as the predicted level of flow splitting between the river and ocean outfalls.

- PT3_2mm: 72 per 30 seconds (or 8,640 per hour)
- PT3_4mm: 538 per 30 seconds (or 64,560 per hour)
- PT3_6mm: 187 per 30 seconds (or 22,440 per hour)
- PT3_8mm: 15 per 30 seconds (or 1,800 per hour)
- PT3_11mm: 486 per 30 seconds (or 58,320 per hour)

3.3.2 Scenario results and interpretation

The results of the Pacific Ocean scenarios are presented spatially as distributions of maximum sedimented/deposited mass concentrations calculated over the year-long simulation period.

For brevity, only one particle type per scenario has been presented below. For Scenarios 2 and 3, this includes mid-sized (~6 mm) particle types.

Figure 26, Figure 27 and Figure 28 present the results for Scenario 1 (PT1_1mm), at three alternate levels of zoom, while Figure 29 and Figure 30 present the distributions for Scenario 2 (PT2_6mm) and Scenario 3 (PT3_6mm) respectively.

A full set of the scenario results are provided in Attachment C2.

In summary, the modelling predicts that:

- Particles accumulate in the intertidal and shallow subtidal areas between Currimundi Lake in the south, and the Point Cartwright headland in the north. This is a result of the simulation of key hydrodynamic forces (wind, waves and tides) as well as wind drift applied directly to buoyant particles on the sea surface
- More specifically, the following influences have been assumed in the modelling:
 - As a general rule, the tidal influence is relatively low and orientated along a north to south axis, parallel to the coast. There is a residual northerly current which may contribute to the higher concentrations being located slightly to the north of the offshore diffuser location.
 - The effect of wind and waves in the inshore coastal area can also be a significant influence on any buoyant material. As discussed in Section 2.2.4.3, while there are seasonal patterns, prevailing winds are generally onshore from either the south, south-east, east and north-east, including the development of onshore sea breezes.
 - Similarly, the wave climate presents an additional shoreward influence for buoyant material in this coastal region. The prevailing wave direction originates from between east-north-east to south-east with a higher influence for waves with a southerly component. In addition to the

oceanic wave climate, there are additional influences from more localised waves generated by the prevailing winds.

- The modelling results for Scenarios 1 and 2 (constant release) therefore correlate with the expected response of buoyant particles exposed to this suite of combined influences over a 12-month period. From Figures 27 to 29, the predicted distribution of deposited particles along the shoreline extends from the Currimundi Lake reserve and extends north to, and includes, the Point Cartwright headland. Higher concentrations are predicted between latitude 26°45'S (Wurtulla Beach) and latitude 26°42.5'S (near the southern end of Pacific Boulevard), with the highest concentration predicted between latitude 26°44'S (Wyanda Drive) and latitude 26°43'S (Currawan Street).
- The modelling results for Scenario 3 (one hour release) present a more southerly accumulation on the foreshore. This demonstrates the effect on the transport of buoyant media from a single release event and how the prevailing conditions can influence their fate. During and subsequent to this release, the influence of northerly winds, a southward tidal stream and also an easterly wave climate has provided for greater distributions on the shoreline south of the release point.
- As described in Section 3.3.1, this scenario has been included to investigate dispersion of particles from the previous basket screen configuration. With the current basket screen configuration, this scenario is no longer possible.

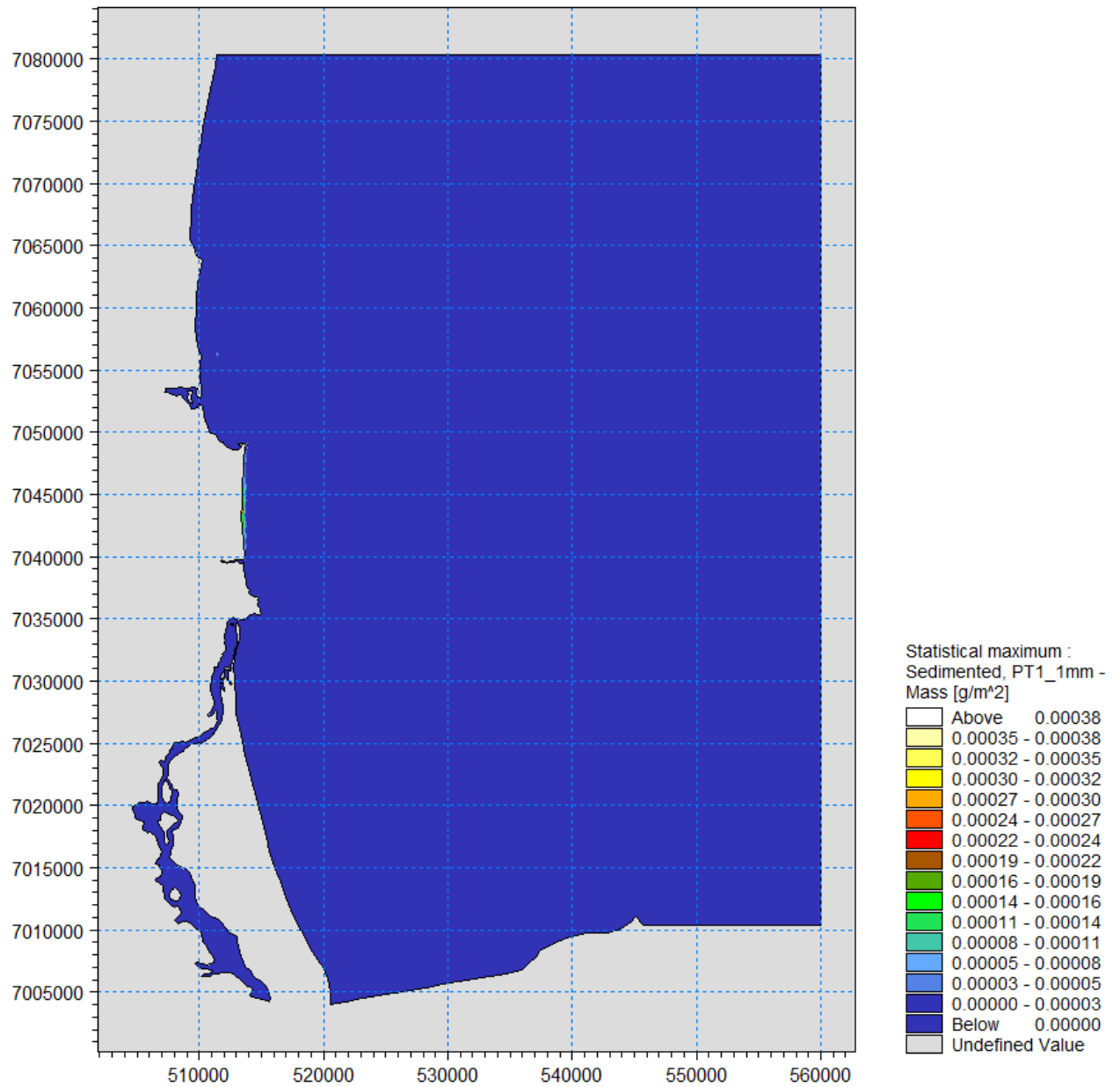


Figure 26 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm) (full model domain)

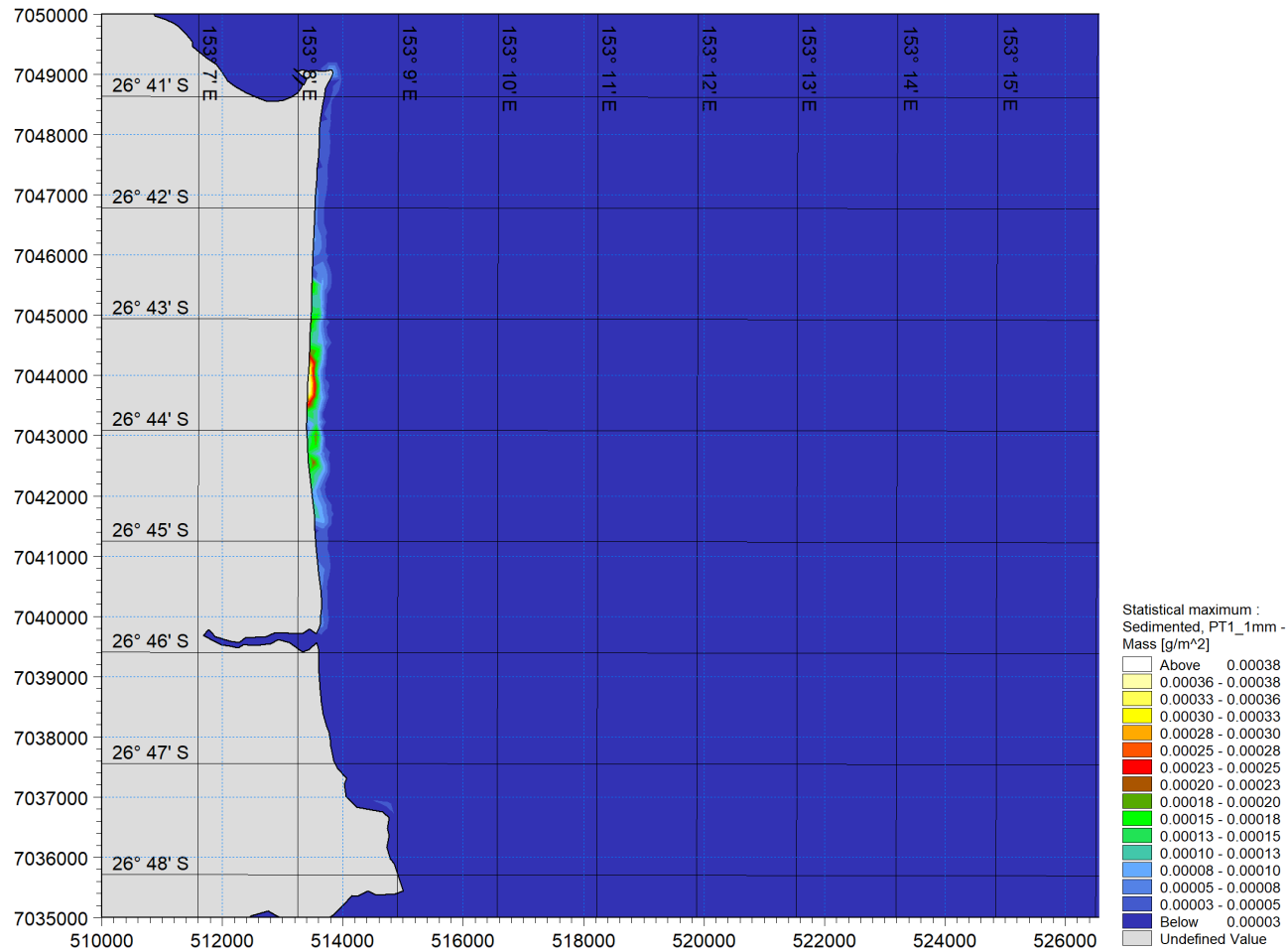


Figure 27 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm) (Caloundra to Mooloolaba)

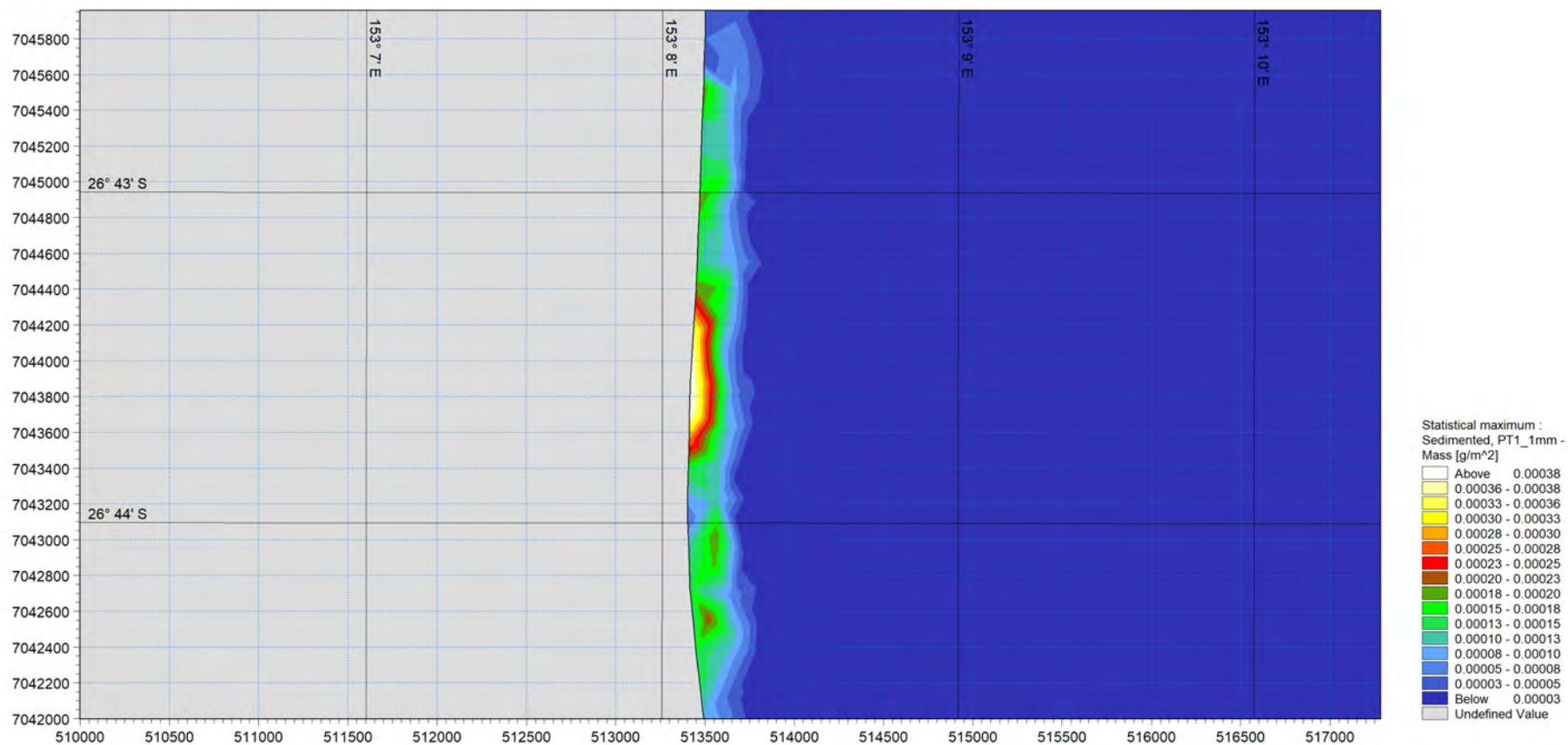


Figure 28 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm) (Warana Beach)

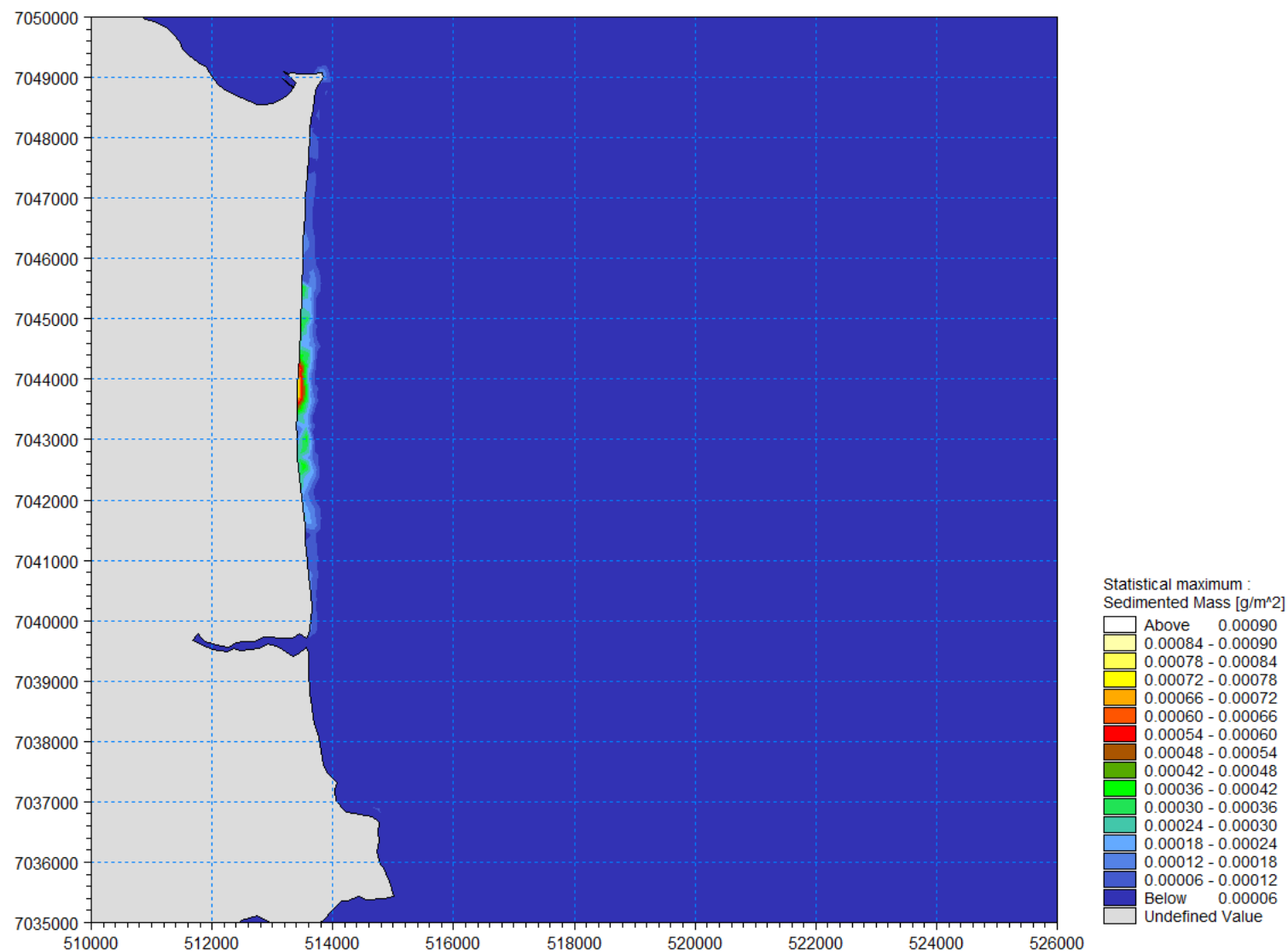


Figure 29 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_6mm) (Caloundra to Mooloolaba)

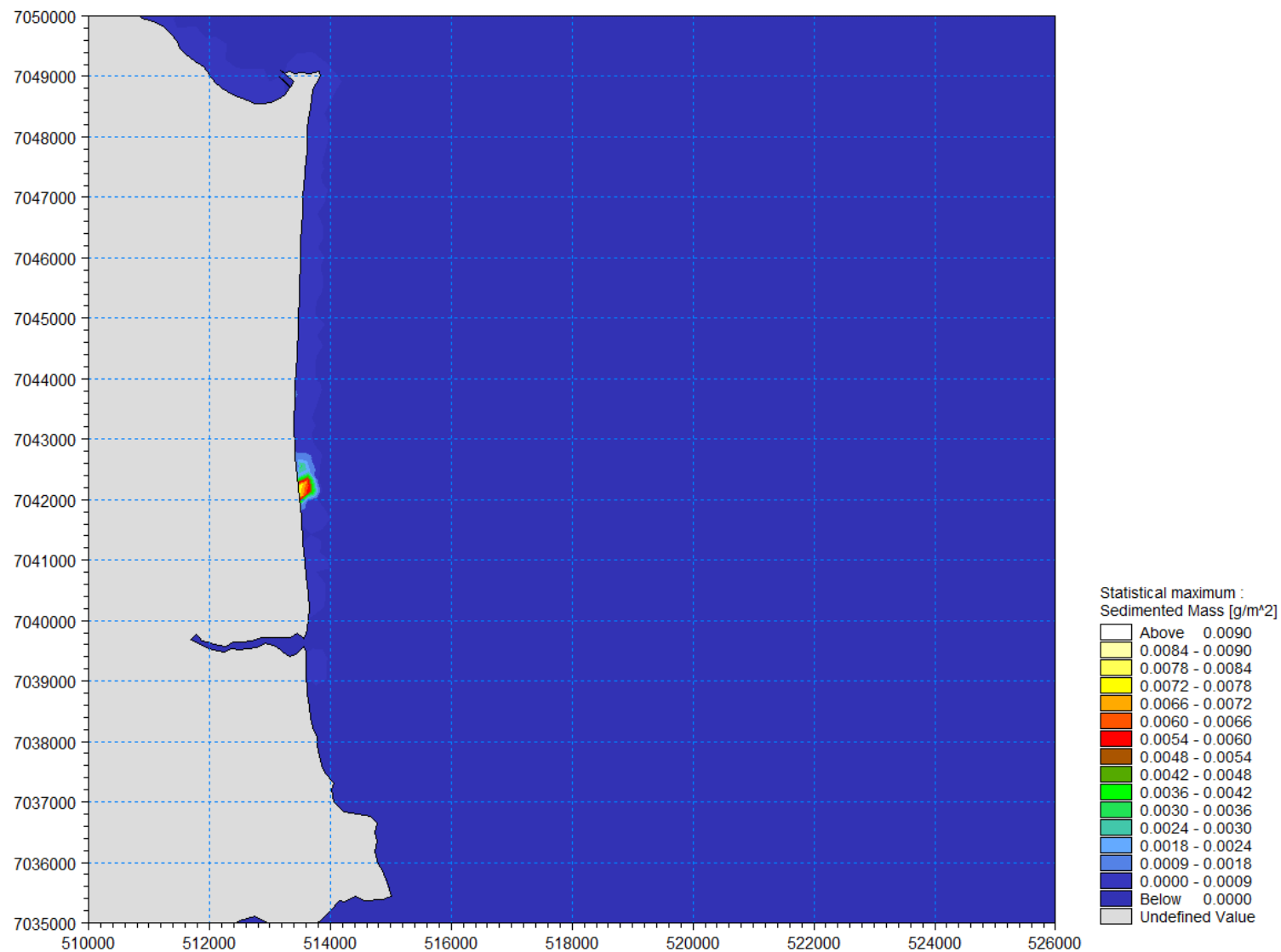


Figure 30 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_6mm) (Caloundra to Mooloolaba)

4 Conclusions

This report presents the findings of a hydrodynamic and particle tracking modelling assessment, developed to support and inform an Environmental Evaluation relating to the Kawana STP. The report consequently provides analysis of how the potential releases of particles from the STP's Moving Bed Biofilm Reactor (MBBR) may potentially be released and transported in the receiving waters of the Mooloolah River, as well as the coastal waters of the Pacific Ocean.

The primary objective of the modelling was to inform the design and implementation of the Sampling and Analysis Quality Plan by identifying potential zones of accumulation in the environment, thereby predicting the environmental fate of the media if released to either waterway.

Two hydrodynamic and advection/dispersion models were developed specifically for application in these assessments: a 2D model of the Mooloolah River estuary and a 3D model of the Pacific Ocean, extending from Moreton Island to Noosa. Each were developed using the MIKE suite of modelling software. Details regarding the structure, relevant datasets and calibration of these models are included in this report.

Following calibration and validation of both models, three scenarios were considered with simulation over a 12-month period to allow for a representative range of both release and ambient conditions.

The three scenarios represented the following potential release conditions:

- Discharge of MBBR particles < 2 mm where these smaller particles pass through the effluent basket screens
- Undetected release of a portion of all sizes of MBBR particles due to undetected damage to the basket screens
- Overtopping of the basket screens during an extreme wet weather event and associated release to both the Pacific Ocean and Mooloolah River outfalls. Although no longer possible with the current configuration of effluent basket screens, this scenario investigated the potential dispersion of particles from the previous plant configuration.

The following key findings were drawn from the modelling assessments:

Mooloolah River

There are similar patterns of accumulation in the estuary for the release conditions simulated in Scenarios 1 and 2, with potentially higher concentrations accumulating at the following locations:

- A. The reach downstream of Release Point W3 and upstream of Parrearra Weir
- B. Mid estuarine reaches near the Brightwater Eastern Conservation Area
- C. Foreshore areas between Mooloolah Island and Minyama Island

The modelling also indicates the potential for greater accumulation in reach "A", immediately following a release event. Depending on the magnitude of the release and the relative strength of tidal currents against the freshwater flows driven by runoff in the upstream catchments, particles are predicted to be potentially retained in this area and deposited within the intertidal zones and into the embayment near the Parrearra Weir. These particles have the potential to be retained in this vicinity until the following wet weather event which effectively flushes the particles downstream.

Further downriver the predicted areas of accumulation "B" and "C" appear to predominantly correlate with intertidal zones along the mid-estuarine river banks and the more artificially developed foreshores in the lower estuary.

The results for Scenario 3 represent similar distributions but with a greater accumulation predicted near the Parrearra Weir, relative to the sites downstream. This indicates the prediction of higher concentrations near the weir prior to subsequent weather events that flush the particles downstream with sufficient magnitude to avoid deposition on the intertidal areas of the middle and lower estuary.

Pacific Ocean

Regardless of the scenario, the predicted distribution of higher particle concentrations consistently lie in the intertidal and shallow subtidal areas between Currimundi Lake in the south, and the Point Cartwright headland in the north. This is a result of the simulation of the complex prevalent hydrodynamic conditions (wind, waves and tides) as well as wind drift applied directly to buoyant particles on the sea surface.

Higher concentrations are predicted between Wurtulla Beach and the southern end of Pacific Boulevard, with the highest concentration predicted between Wyanda Drive and Currawan Street.

The modelling results for Scenario 3 (one hour release) present a more southerly accumulation on the foreshore. This demonstrates the effect on the transport of buoyant media from a single release event and how the prevailing conditions can influence their fate. During, and subsequent to, this release, the influence of northerly winds, a southward tidal stream and also an easterly wave climate has provided for greater distributions on the shoreline south of the W3 release point.

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GHD, 2011. Report for Kawana Outfall Scoping Study, Briefing Paper - Kawana Outfall Upgrade. Technical paper for Unitywater dated December 2011

Attachment A: Assumed characteristics of MBBR particles

To	Ed Beling, Intrawater	From	Rickey Donald, Cardno now Stantec
CC	Ben Goodall, Unitywater	Date	10 March 2022
Project	Kawana STP Environmental Evaluation 304600296	Location	Kawana STP
Subject	MBBR plastic media particle release		
Action Required	Incorporate in dispersion modelling	Attachments	Nil

Calculation for MBBR Plastic Media Particle Release

This Technical Memorandum explains how the particle mass and rate of particle release from Kawana STP was calculated. The results are used in dispersion modelling Scenario 2 and 3 and focus on particle sizes caught in the effluent basket screens at Kawana STP.

Terminology

The following terms are used in this assessment:

- > Intra-particle voidage (%): portion of empty space inside the external surface of the particle
- > Inter-particle voidage (%): portion of empty space between particles when packed in a vessel

Method

The following method was used for calculating particle release rate, with results shown in Table 1

1. A representative MBBR carrier particle size distribution was obtained from samples of material removed from 2mm aperture basket screens (Figure 1).
2. A 100 g sample comprising mixed-size particles in the same portion as the particle size distribution was assembled, and the number of each particles per particle size counted.
3. Volume of 100 g mixed-size particles measured.
4. The intra-particle voidage of a whole unused carrier was calculated and used as a guide/benchmark when adjusting intra-particle voidage values of particles smaller than a whole carrier.
5. Initial inter-particle voidage selected.
6. For each particle size fraction:
 - a. A characteristic shape was selected that most represented the particle.
 - b. Shape dimensions were calculated based on minimum and maximum particle size within the size fraction range.
 - c. Volume of the solid particle was calculated.
 - d. Initial intra-particle voidage was selected for the particle size.
 - e. Mass of particle including effects of intra-particle voidage was calculated.
 - f. Number of particles in a 100 g sample of mixed particles in the same portion as the size distribution was calculated.
 - g. Intra-particle voidage was adjusted until number of particles from Step 4a equals number of particles from Step 2.

- h. Volume of particles was calculated, incorporating inter-particle voidage.
7. Inter-particle voidage of largest particle size was adjusted until volume of particles was approximately equal to volume of 100 g mixed size particles in Step 3.
 8. Inter-particle voidage of particles less than largest size fraction was adjusted down slightly
 9. For each particle size fraction, volume of particles in 100 g sample of mixed-size particles was calculated.
 10. Total volume in 100 g mixed-size particles was calculated
 11. Total mass release of carrier particles calculated using measured daily volume release of all size particles was calculated volume from Step 10
 12. For each size fraction, mass release rate of particles was calculated using particle size fraction and total mass from Step 11.
 13. Number of particles released per hour was calculated for each size fraction mass release rate in Step 12 and using calculated particle mass from Step 6e

Assumptions

- > 26.7 L/day MBBR plastic media particles > 1.18mm caught in basket screens, taken from plant records as the average volume collected from Fri 3/12/2021 to Thu 24/2/2022
- > Carrier material SG = 0.95 (from MBBR plastic media manufacturer's data sheet)
- > Negligible influence on particle SG from biofilm
- > For a sample of mixed-size particles, the small particles fall within the inter-particle voidage of larger size particles without consuming additional space
- > Inter-particle voidage of particles in largest size fraction is slightly higher than smaller sized particles

Volume of 100 g Mixed-Size Particles (Step 3 in Method)

- > Measured volume in 100 g sample = 616 mL

Whole Unused Carrier Intra-particle Voidage Calculation (Step 4 in Method)

- > Diameter = 13mm
- > Length = 13mm
- > Volume of solid carrier shape = $1.2 \times 10^{-6} \text{ m}^3$
- > Mass of solid carrier shape = 1.6 g
- > Measured carrier mass = 0.4567 g
- > Intra-particle voidage = $(1.6 - 0.4567) / 1.6 = 72\%$

Technical Memorandum

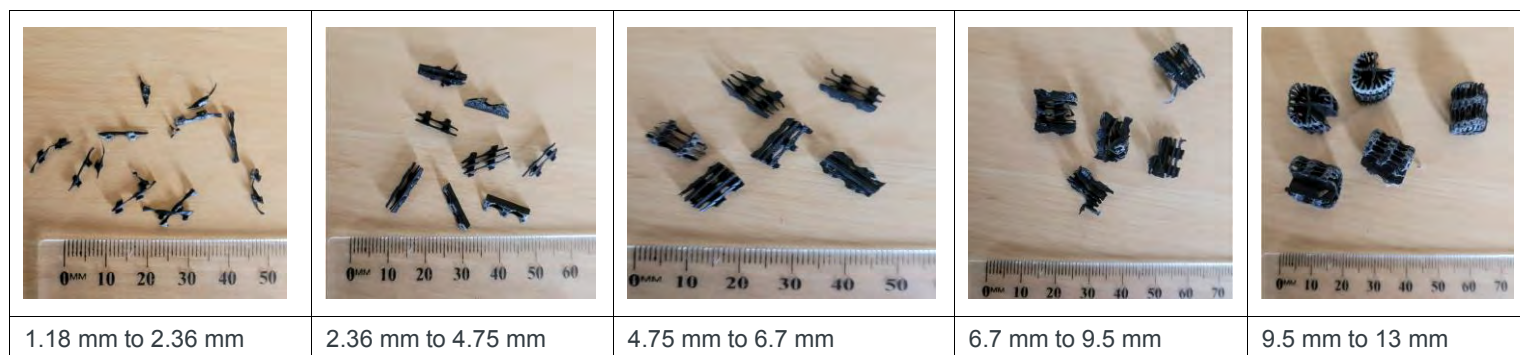


Figure 1 - Typical MBBR Plastic Media Particles per Size Fraction

Table 1 – Calculation Results

Particle Size Range (mm)		Particle Shape	Shape Dimensions (mm)			Intra-particle Voidage	Solid Particle Volume (mL)	Particle Mass (inc. intra-particle voidage) (g)	Particle Size Distn	Inter-particle Packing Voidage	Particles in 100g Sample		Vol (mL)	Mass Release (g/hr)	No. Particles Released/hr
			Width	Length	Depth						Number				
Min	Max										Calc.	Meas.			
1.18	2.36	Rectangular	1.8	1.8	13	47.4%	0.041	0.02	0.59%	25%	29	29	1.6	0.9	45
2.36	4.75	Rectangular	3.6	3.6	13	83.4%	0.164	0.026	5.65%	25%	218	218	47.8	8.8	339
4.75	6.7	Rectangular	5.7	5.7	13	87%	0.426	0.052	3.99%	25%	76	76	43.2	6.2	118
6.7	9.5	Rectangular	8.1	8.1	13	90.8%	0.853	0.075	0.45%	25%	6	6	6.9	0.7	9
9.5	13	Rectangular	13	13	13	78.3%	2.197	0.453	89.32%	25%	197.1	251	615.2	139.1	307
								Total =	100%	Vol. in 100 g sample (mL) =	714.5				

Attachment B: Water Balance Model

Approach

A predictive water balance model was developed to estimate release conditions to the Mooloolah River. The objective of this model was to allow estimation of expected effluent short-period flow conditions for Release Point W3 over a range of different climatic conditions as well as for various future population scenarios.

From this modelling, the volumes that would exceed the assumed hydraulic capacity of the ocean outfall could then be predicted. The proportion of flows expected to be directed to the Mooloolah River and those discharging to the ocean could therefore also be estimated.

Methodology

From analysis of influent (daily time step – refer Figure C1 below) and effluent (11.5 minutes – refer Figure C2 below) SCADA datasets recorded concurrently from 2008 to 2010, robust correlations were found between the daily influent data and the maximum and minimum short-term flow rates. These correlations allowed for development of reliable predictive algorithms for both daily maximum and daily minimum flows.

These predictive algorithms in turn allowed analysis of representative rainfall years where no SCADA data was readily available. Similarly, the algorithms could be used to predict effluent flow behaviour in future years by progressively increasing the base flows in line with future population estimates.

With respect to inflow and infiltration patterns, it was assumed that existing wet weather responses in influent flows will change over time due to new sewerage catchments coming on line, and/or existing catchments being diverted and/or pump station works. However, for the purposes of the flow model, it was assumed that there would be a linear relationship between ADWF growth and increases in inflow and infiltration. In consultation with Unitywater this was considered to be a conservative approach.

To determine the proportion of flows that would be released from the ocean and river outfalls, further analysis of diurnal patterns shown in the short-term effluent data was undertaken. From this analysis, it was found that, during dry weather, diurnal flow patterns were demonstrated to be very predictable as expected, but during wet weather, there were no discernible patterns demonstrated due to the significant influx of additional water.

The method of predicting how much flow may be diverted to the river and how much would be released to the ocean followed the steps below:

- Calculate the maximum and minimum short-term flows for each day
- Calculate the proportion of flow above the assumed hydraulic capacity of the ocean outfall
- Estimate the daily volume that would need to be diverted to the river based on the daily percentage of flow that exceeds the assumed outfall hydraulic capacity

Therefore, a linear daily profile between minimum and maximum short-term flows has been assumed for days that are affected by wet weather events. This was considered to be a robust assumption based on the fact that diversions to the Mooloolah River outfall would only occur during wet weather events over the time horizons assumed in this assessment i.e. up to 46 ML/d ADWF STP capacity.

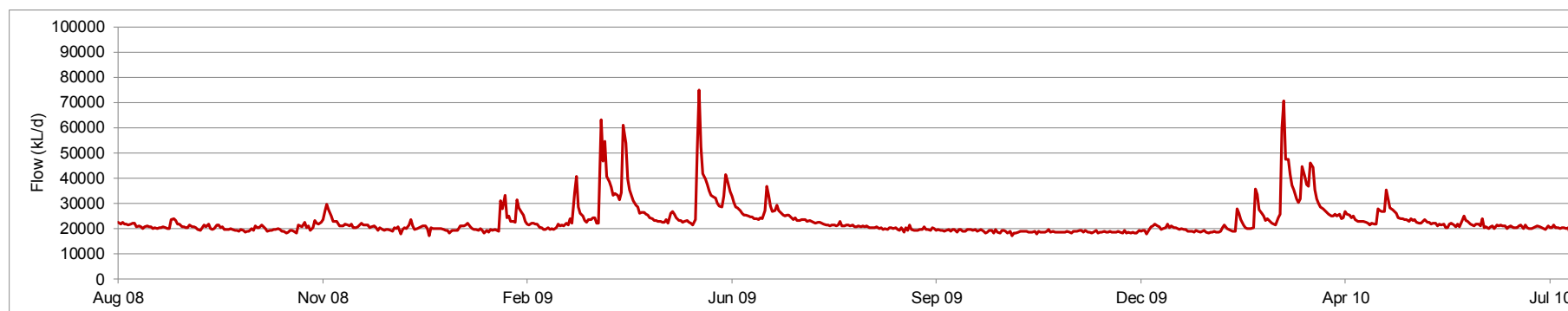


Figure C1 Influent flow rates (daily time-step)

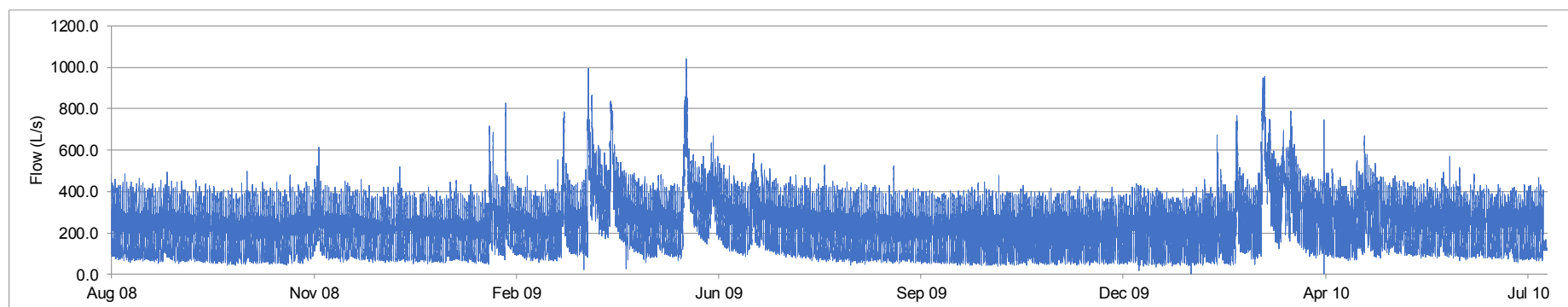


Figure C2 Effluent flow rates (11.5 minute time-step)

Attachment C: Scenario results

Model results from the Mooloolah River and Pacific Ocean assessments are presented in Appendices C1 and C2 respectively. As discussed in Sections 3.2.2 and 3.3.2, the results from each scenario are presented spatially as distributions of maximum sedimented/deposited mass concentrations calculated over the simulation period.

The release rates for the following scenarios were adapted to address the software limitations discussed in Section 3.1.3.2:

- Mooloolah River Scenarios 1 and 2
- Pacific Ocean Scenario 1

Therefore, a release rate of one particle per 30 seconds (or 120 per hour) was applied continuously throughout the scenario simulations.

To address these modifications to the release rates, scaling factors were applied to the results from Scenarios 1 and 2. As presented in Table C1, these scaling factors were derived from comparison of the release rates estimated in Attachment A, relative to the release rates adopted in the scenario modelling.

Table C1 Derivation of scaling factors for Scenarios 1 and 2

Scenario/ Particle type	Estimated number of particles released per year*	Simulated number of particles released per year**	Scaling factor applied
PT1_1mm	6,324,720	1,051,200	6.0167
PT2_2mm	39,540	1,051,200	0.0376
PT2_4mm	297,332	1,051,200	0.2829
PT2_6mm	103,656	1,051,200	0.0986
PT2_8mm	8,233	1,051,200	0.0078
PT2_11mm	268,853	1,051,200	0.2558

Notes

* Refer to Attachment A for estimated release rates

** Assumed a release rate of 1 particle per 30 s time-step

Attachment C1: Mooloolah River model results

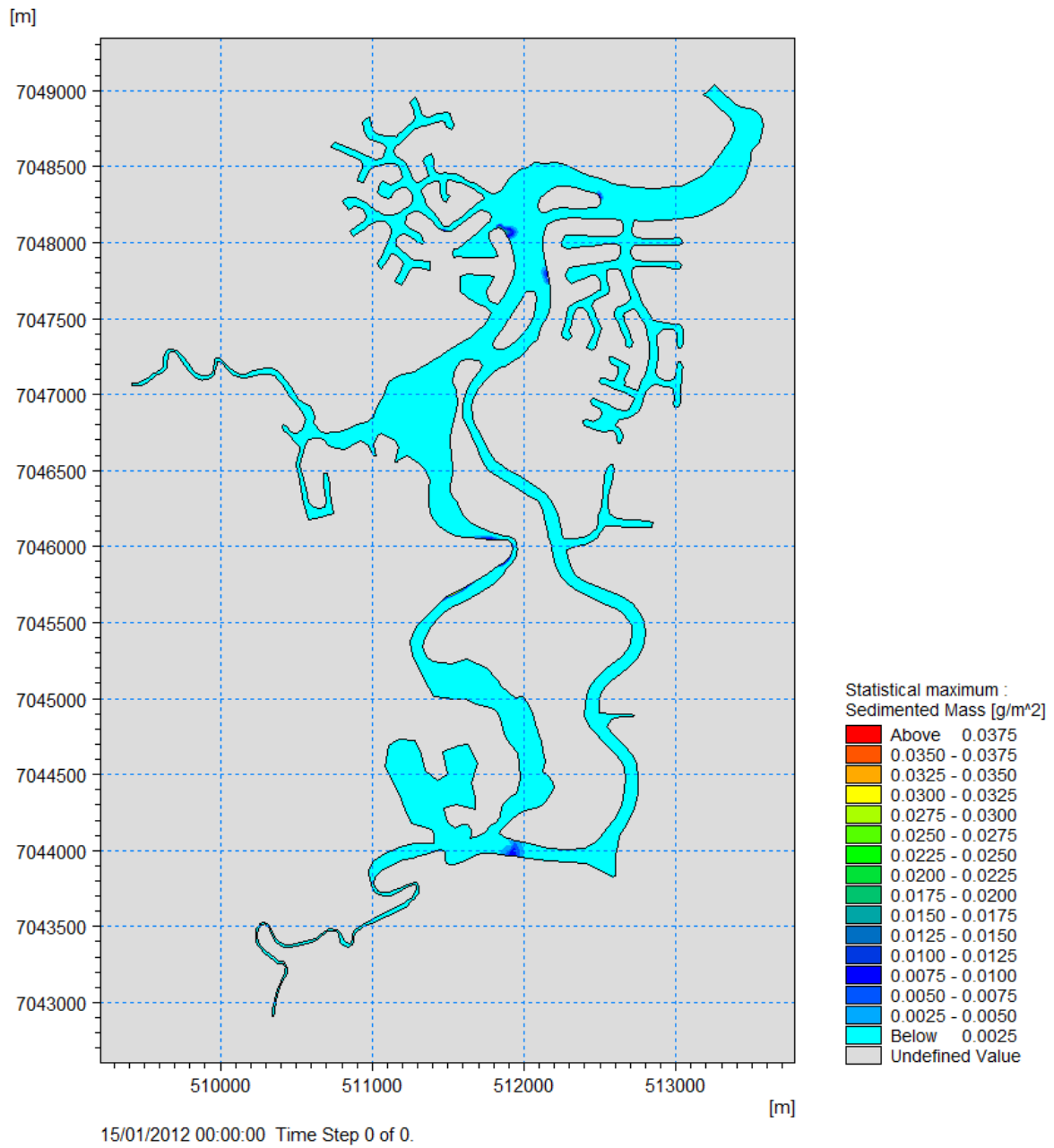


Figure C1 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm)

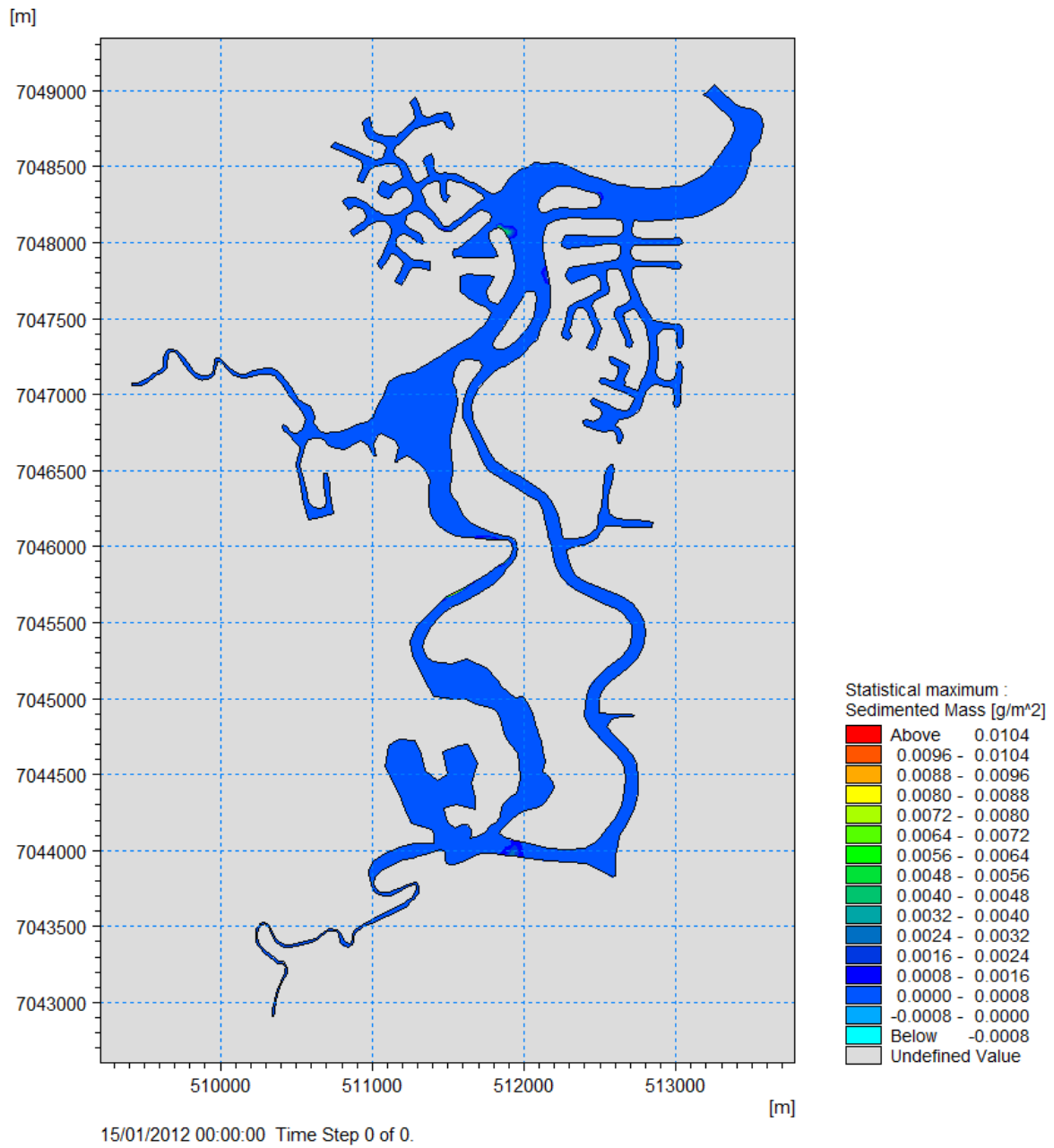


Figure C2 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_2mm)

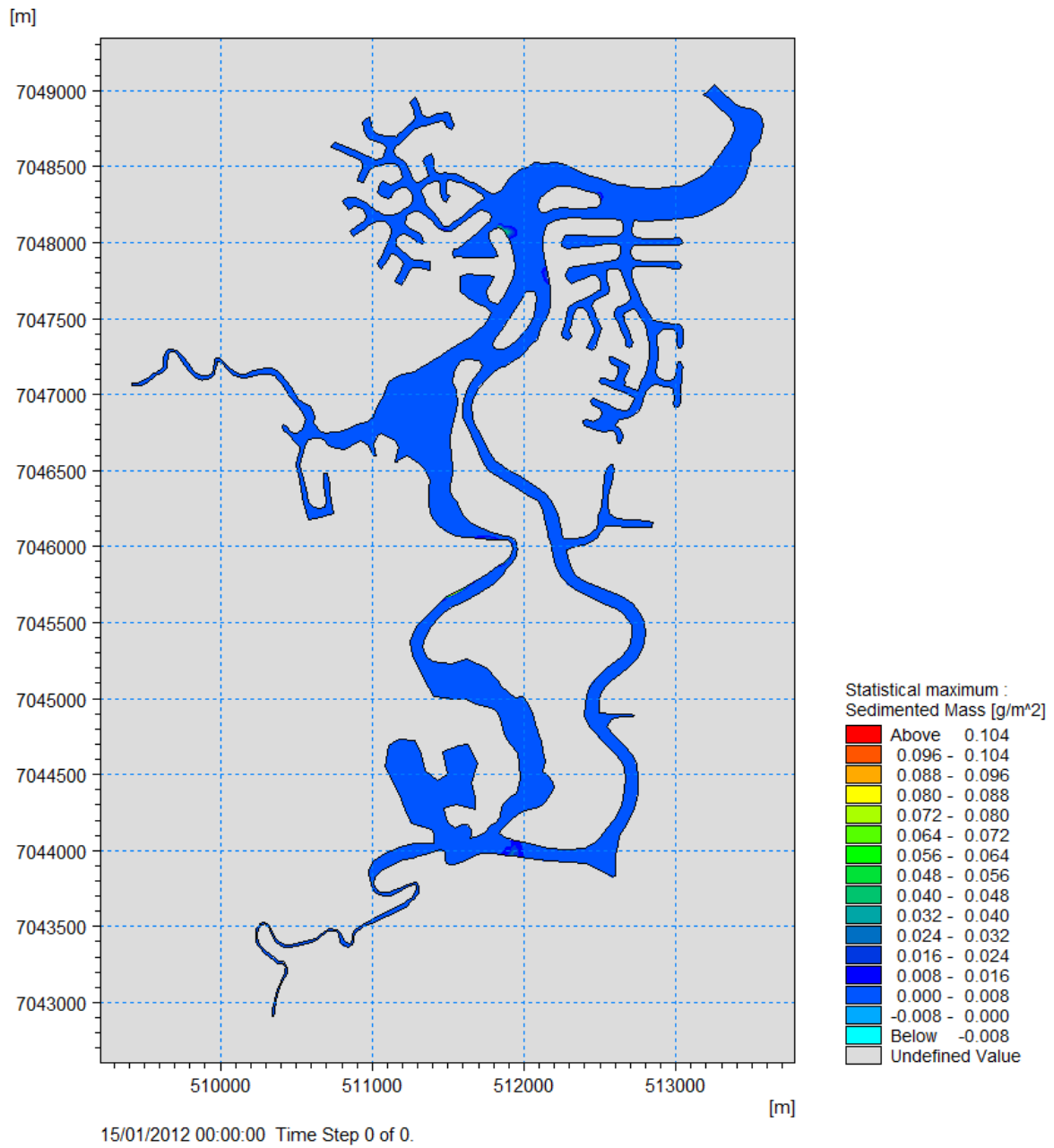


Figure C3 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_4mm)

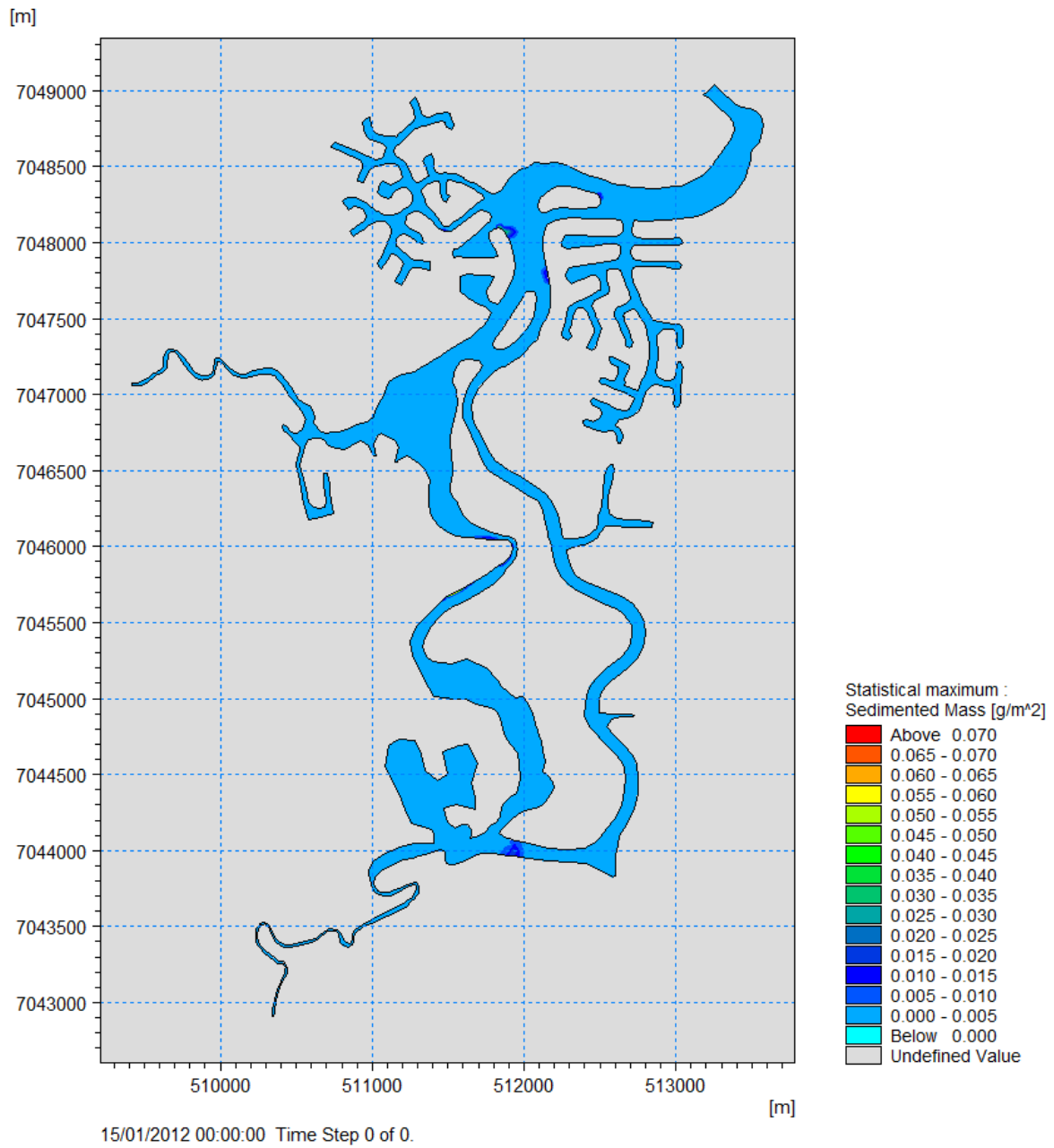


Figure C4 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_6mm)

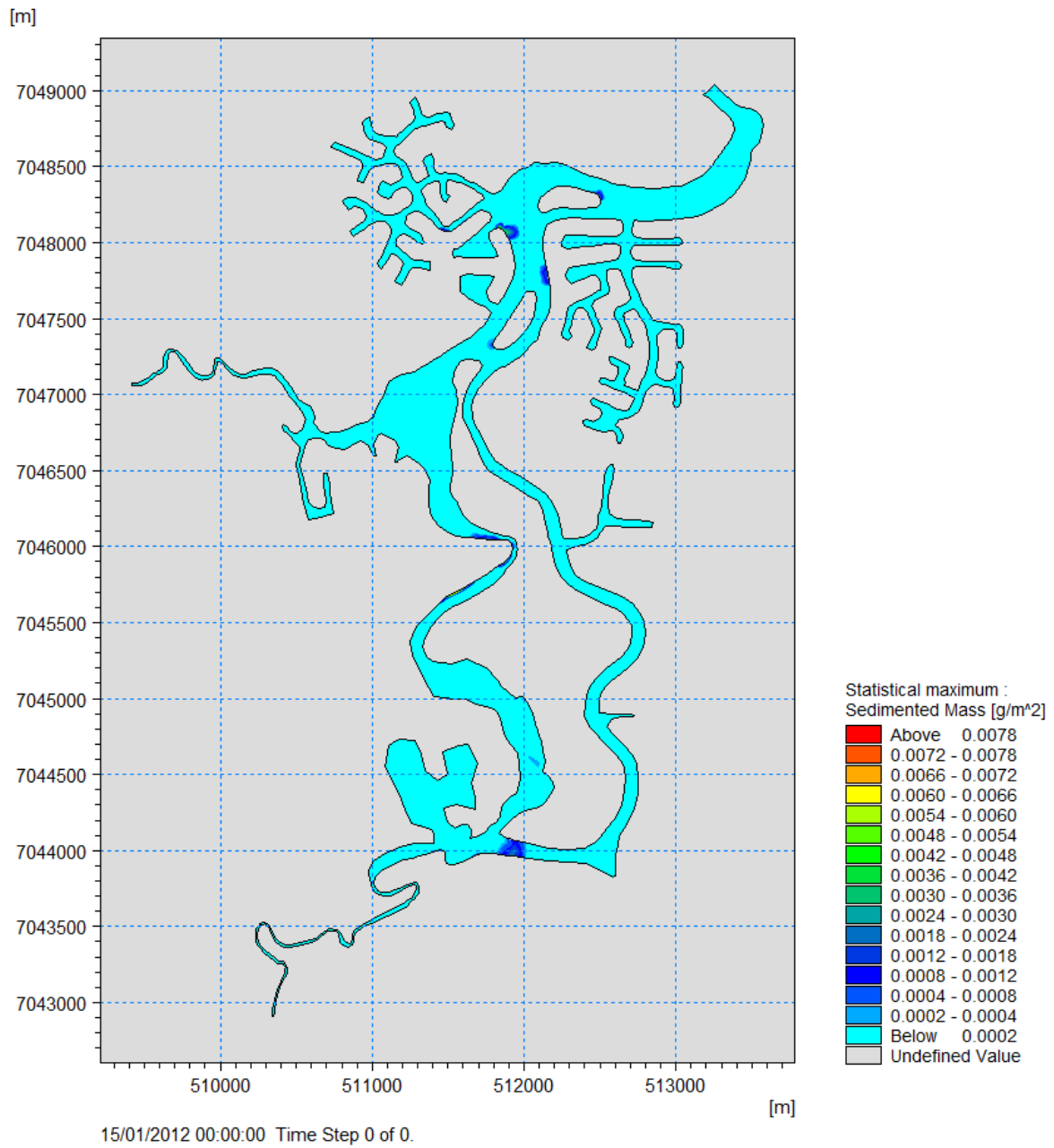


Figure C5 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_8mm)

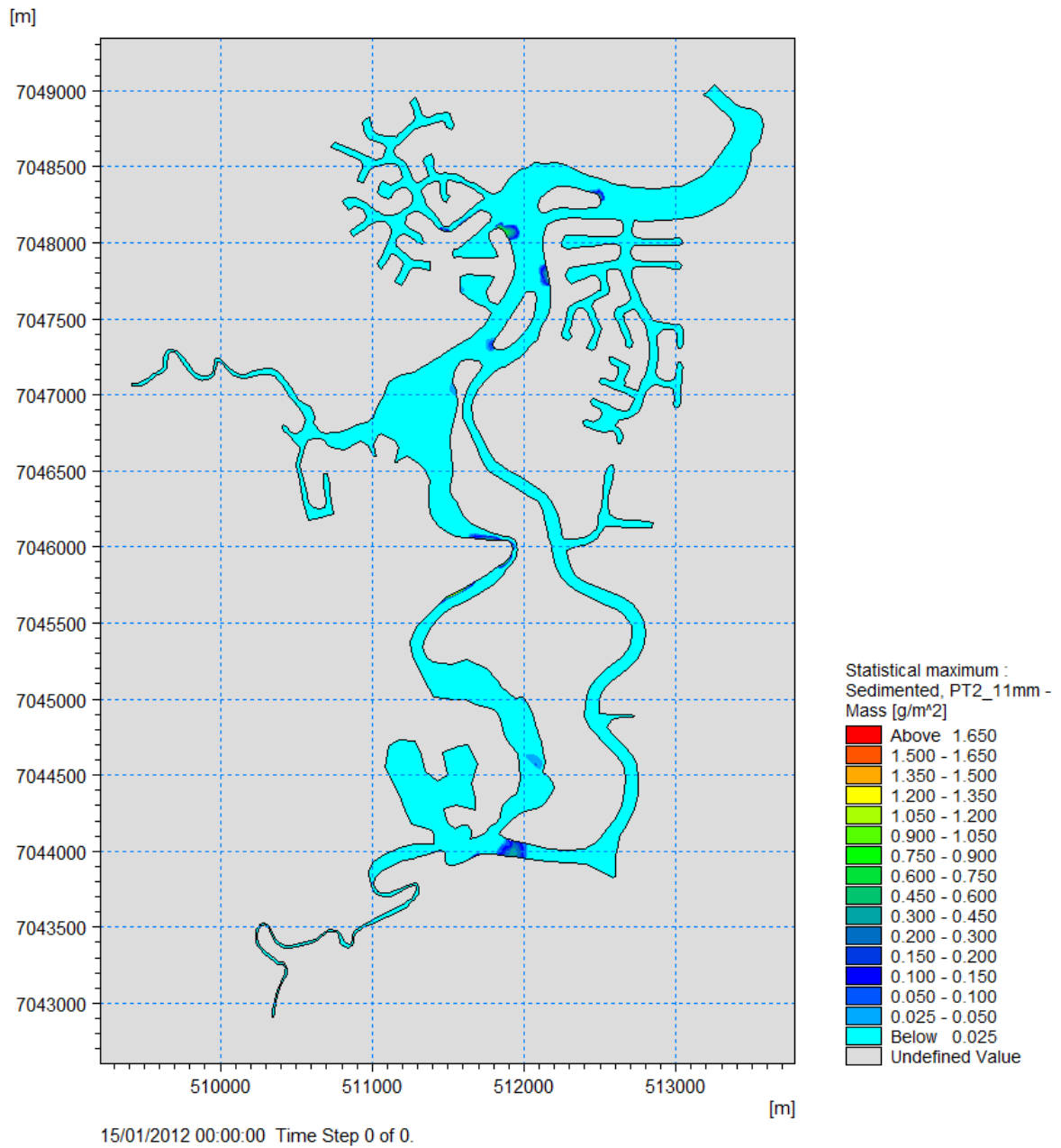


Figure C6 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_11mm)

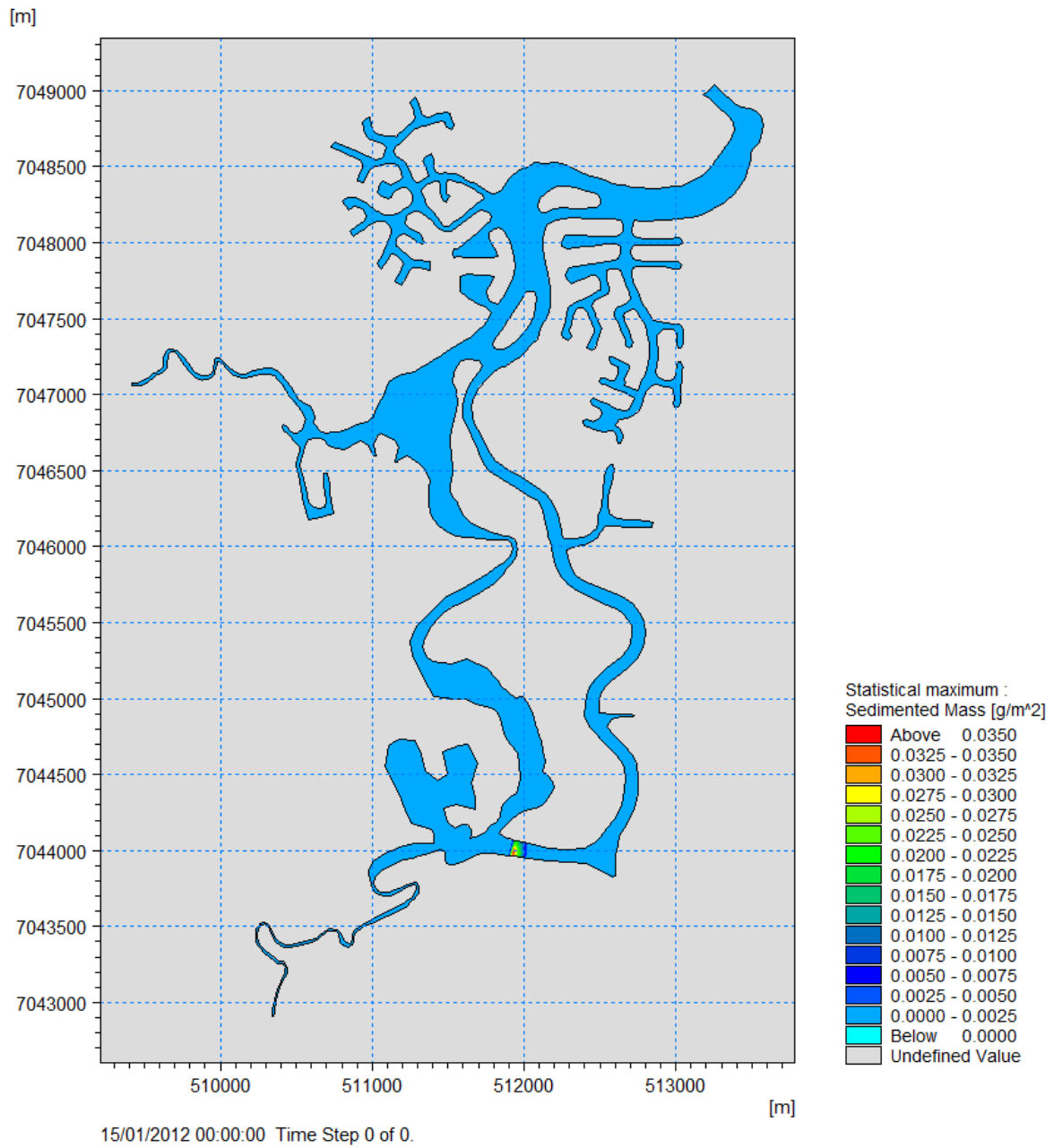


Figure C7 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_2mm)

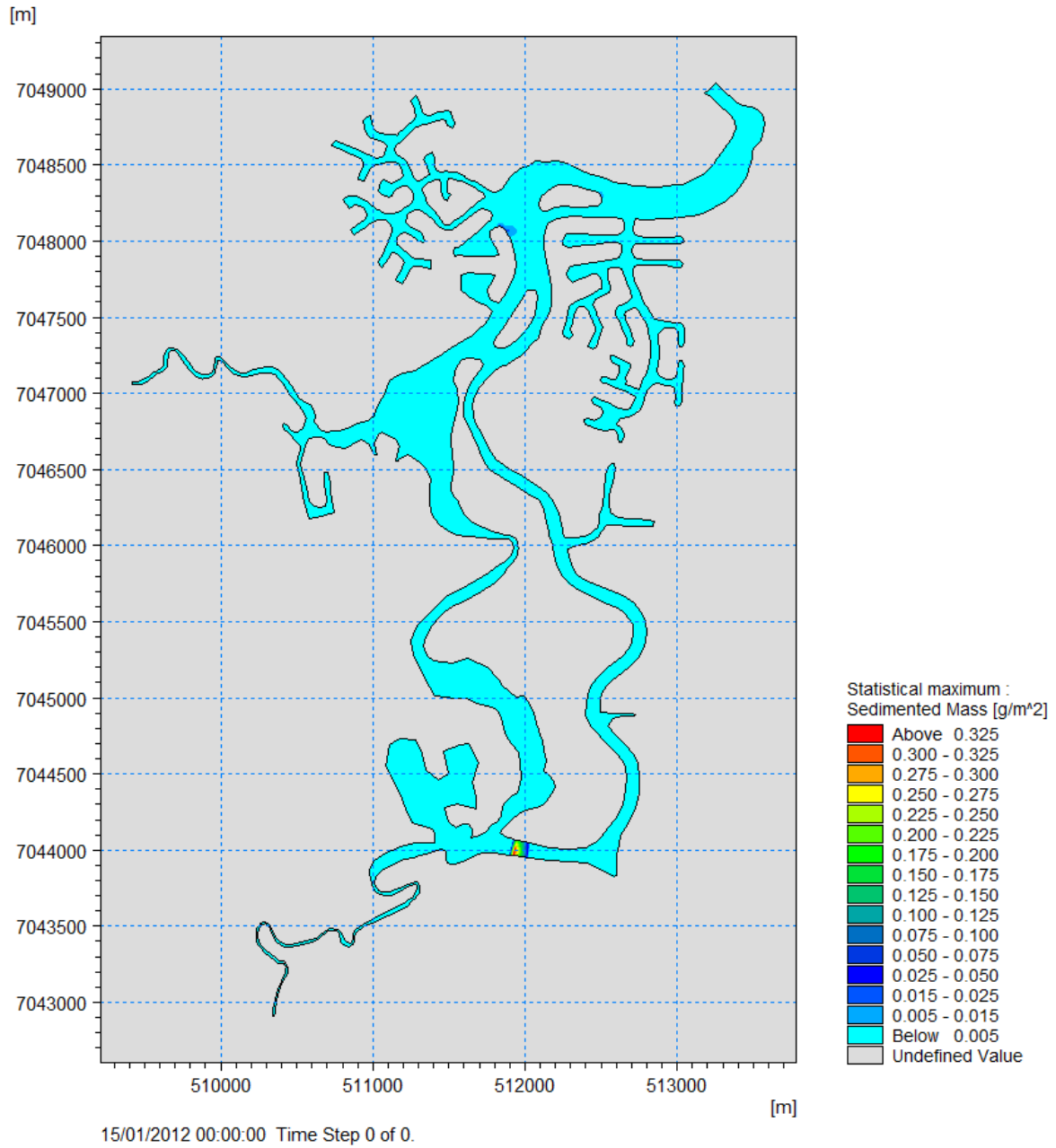


Figure C8 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_4mm)

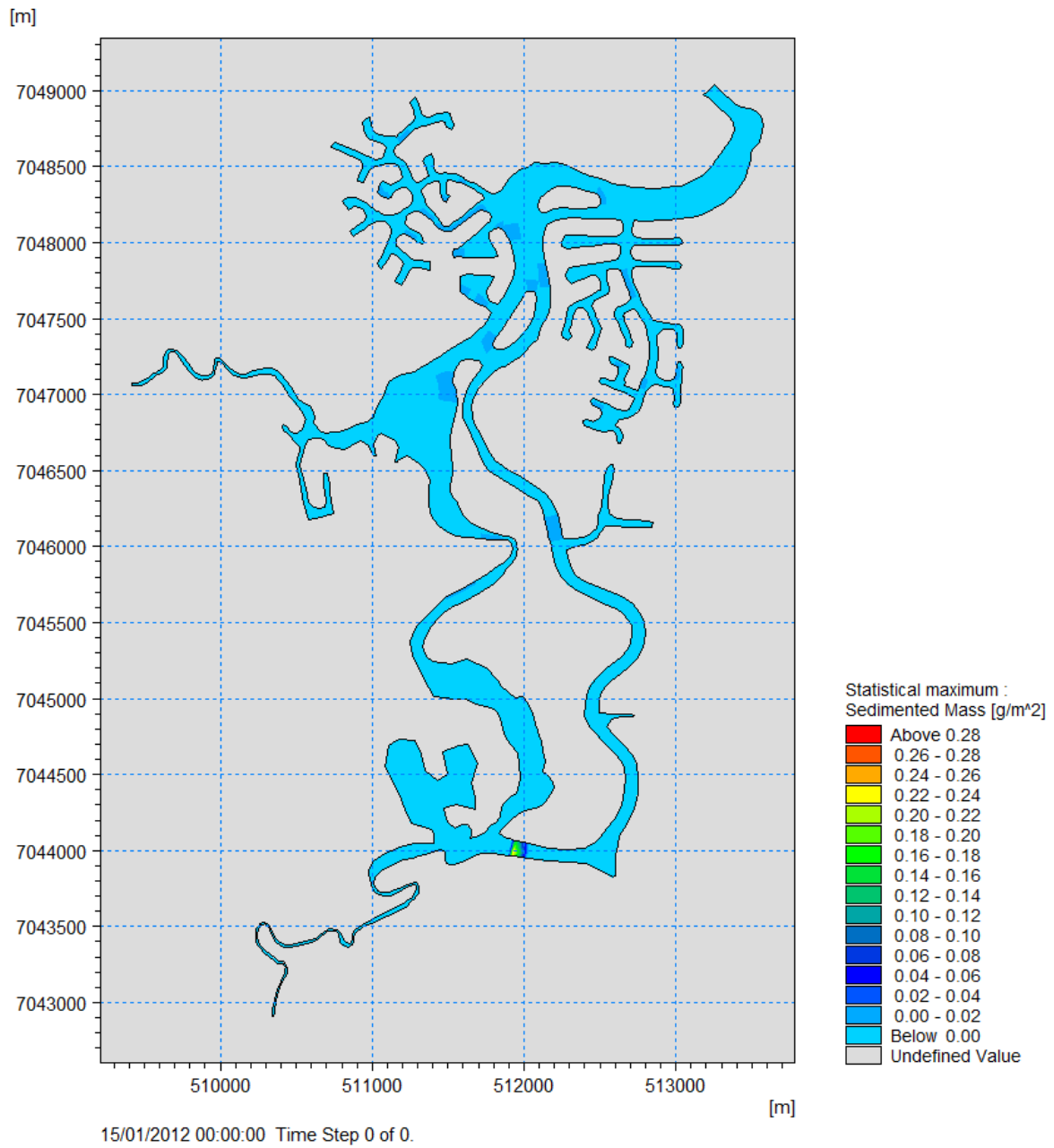


Figure C9 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_6mm)

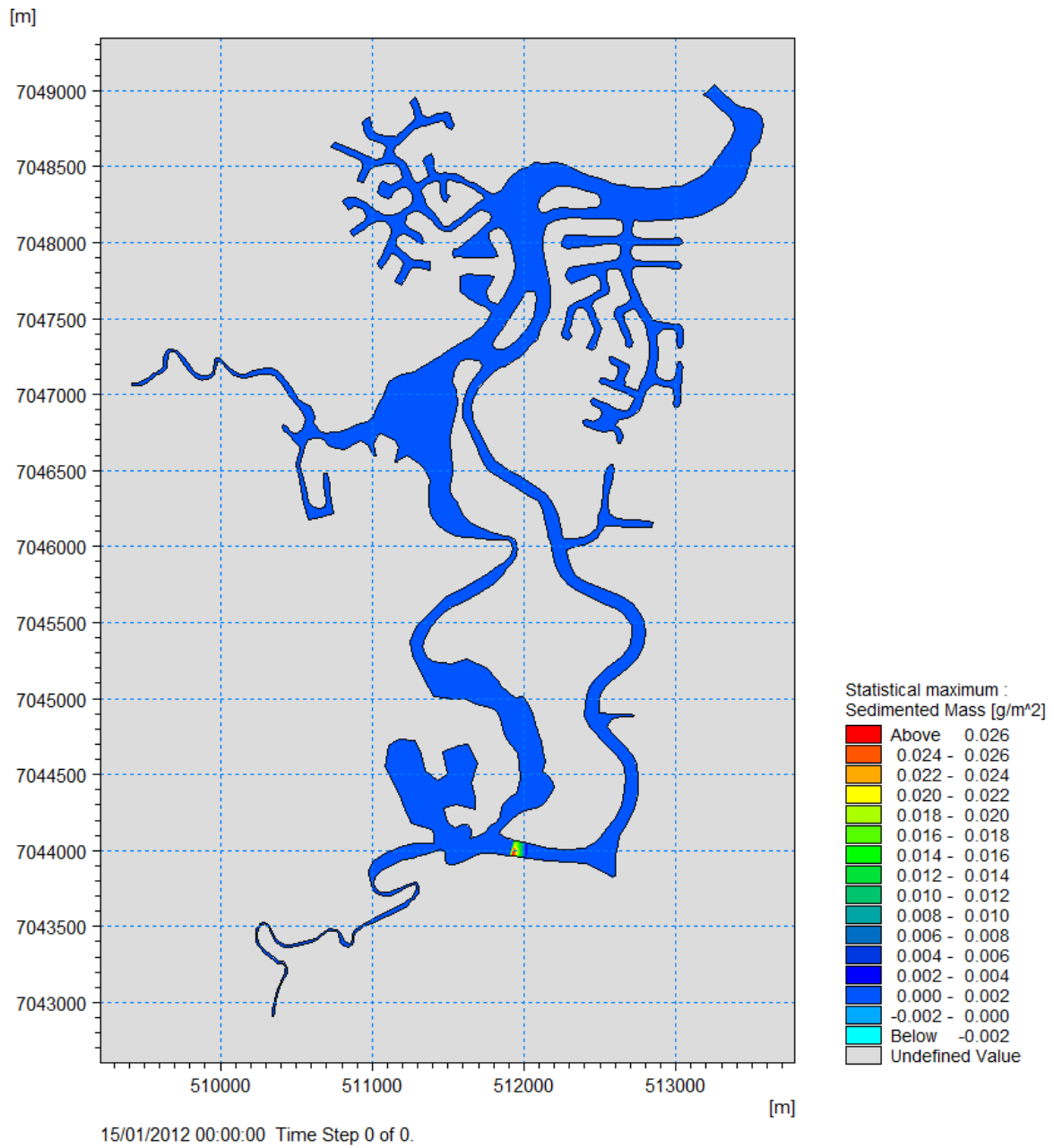


Figure C10 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_8mm)

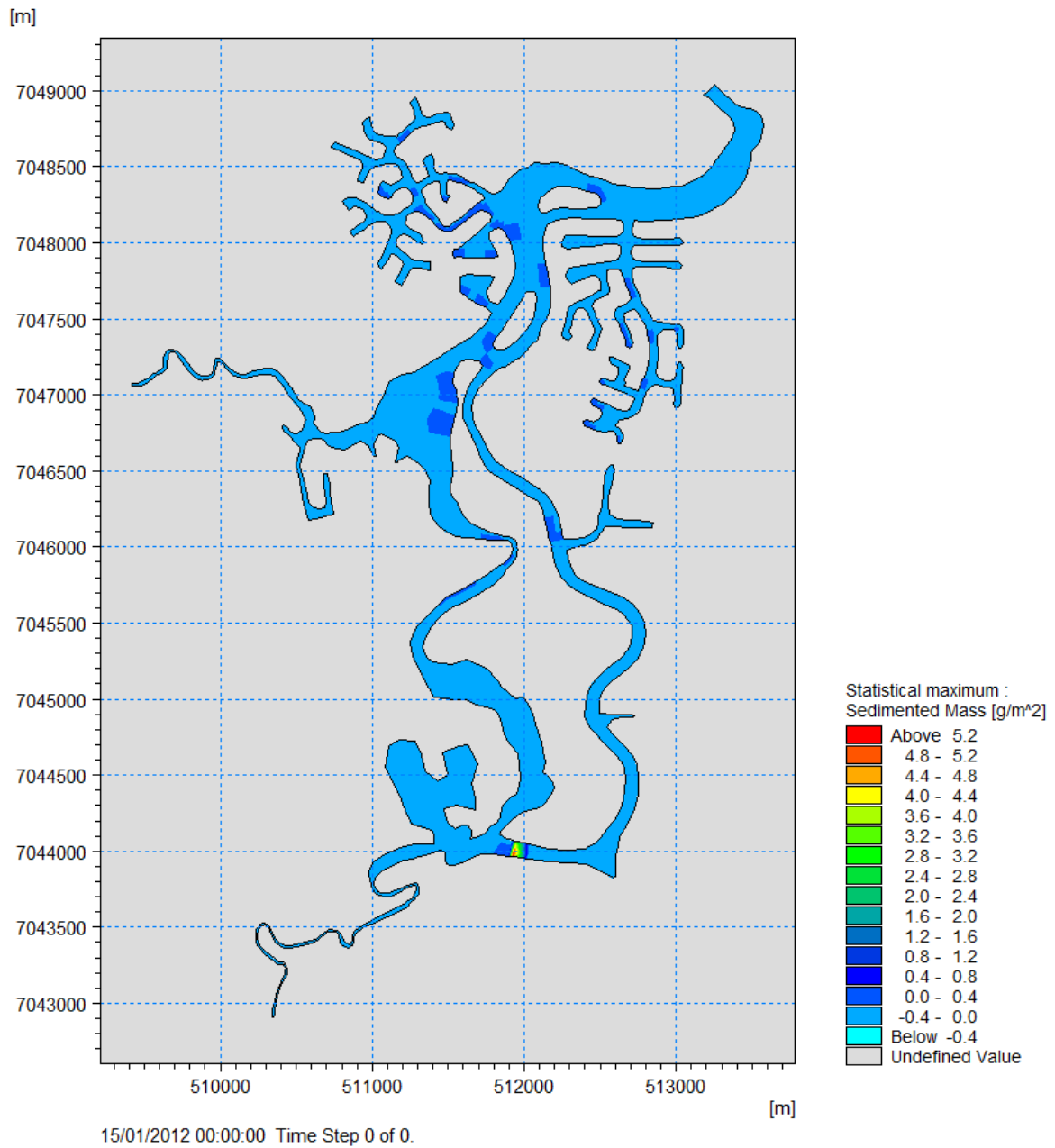


Figure C11 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_11mm)

Attachment C2: Pacific Ocean model results

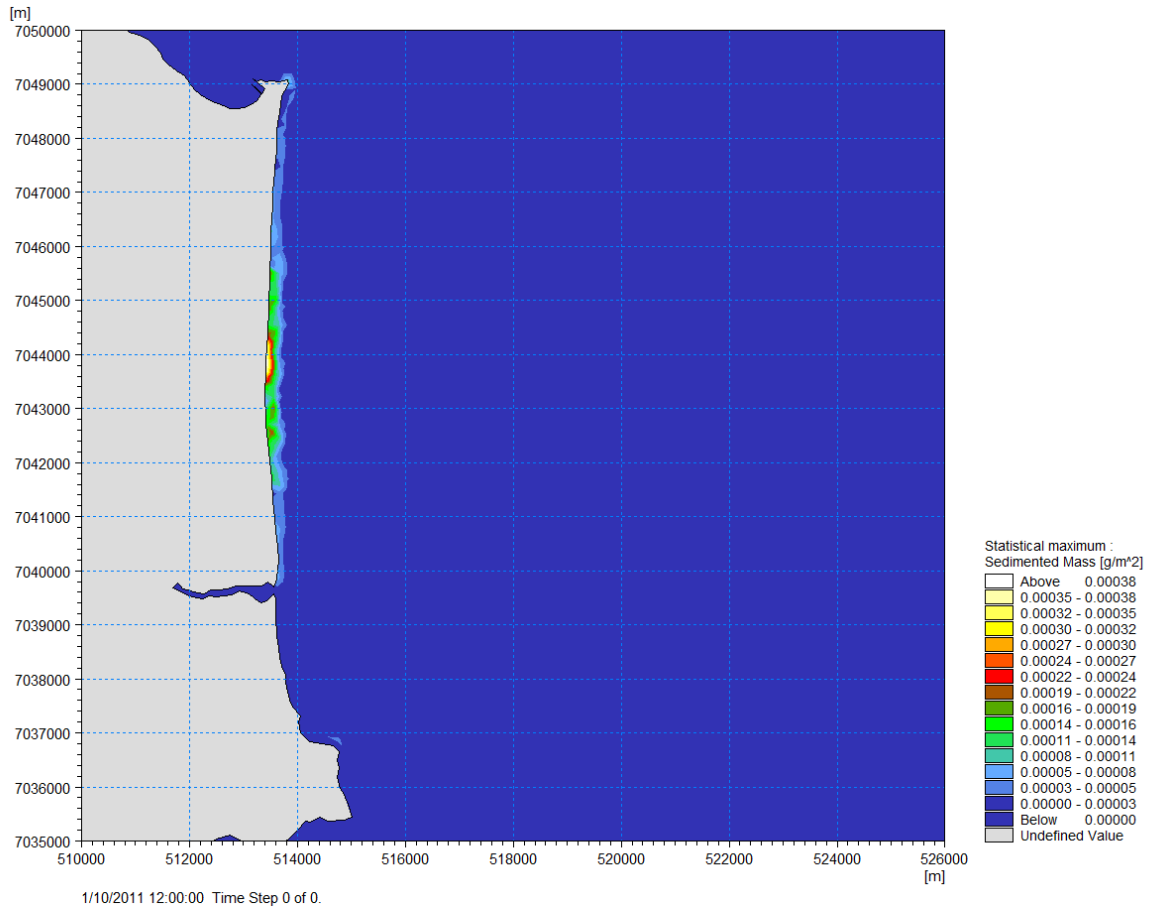


Figure C12 Predicted distribution of maximum sedimented particles – Scenario 1 (PT1_1mm)

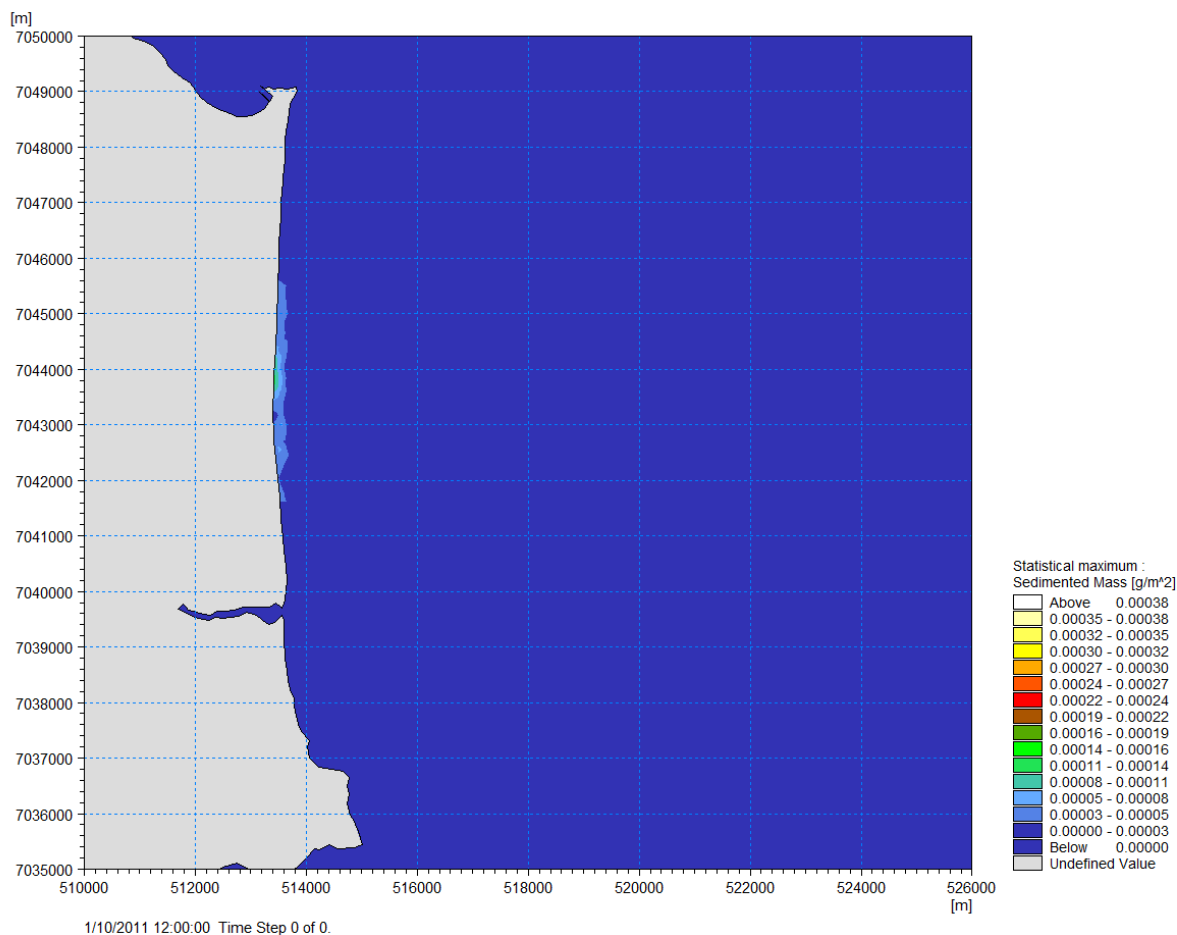


Figure C13 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_2mm)

1/10/2011 12:00:00 Time Step 0 of 0.

Figure C14 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_4mm)

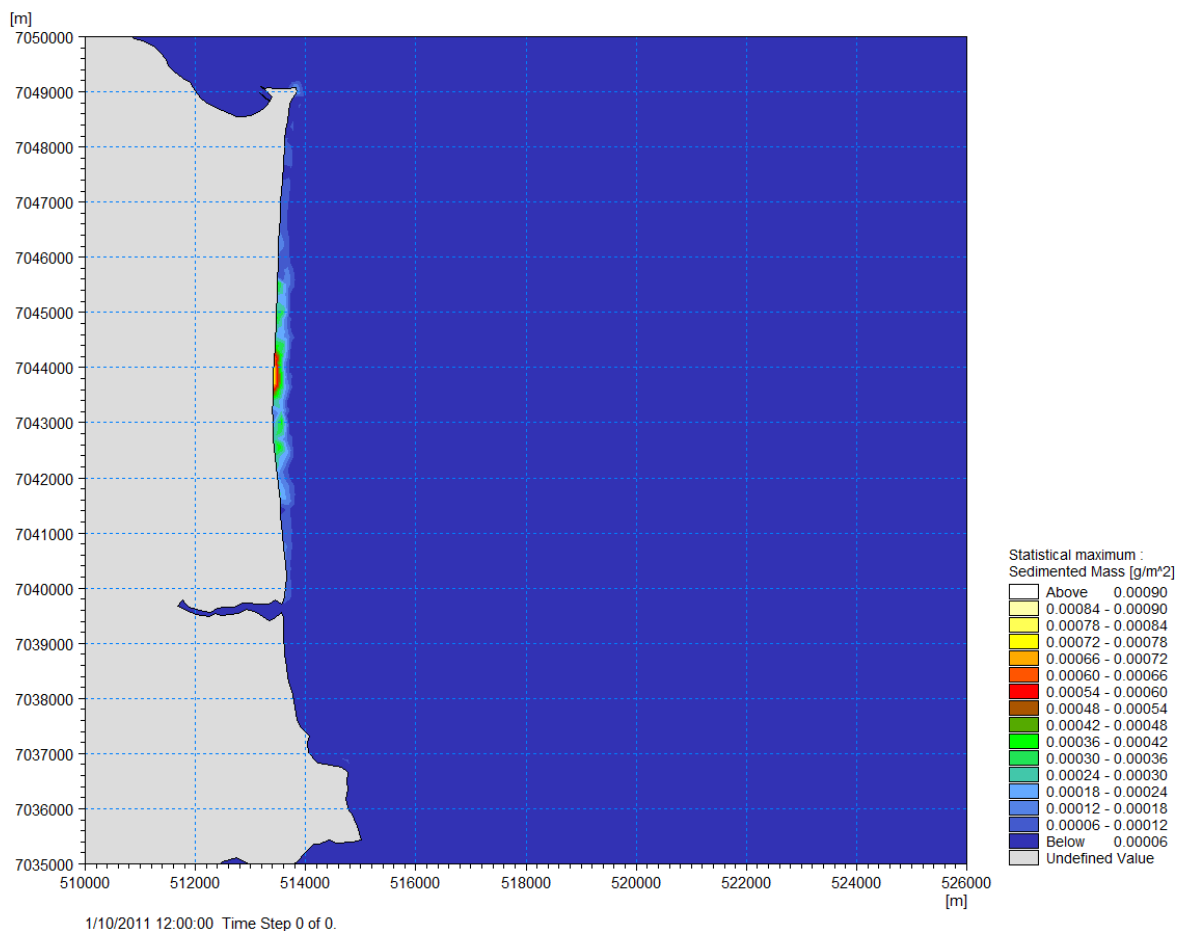


Figure C15 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_6mm)

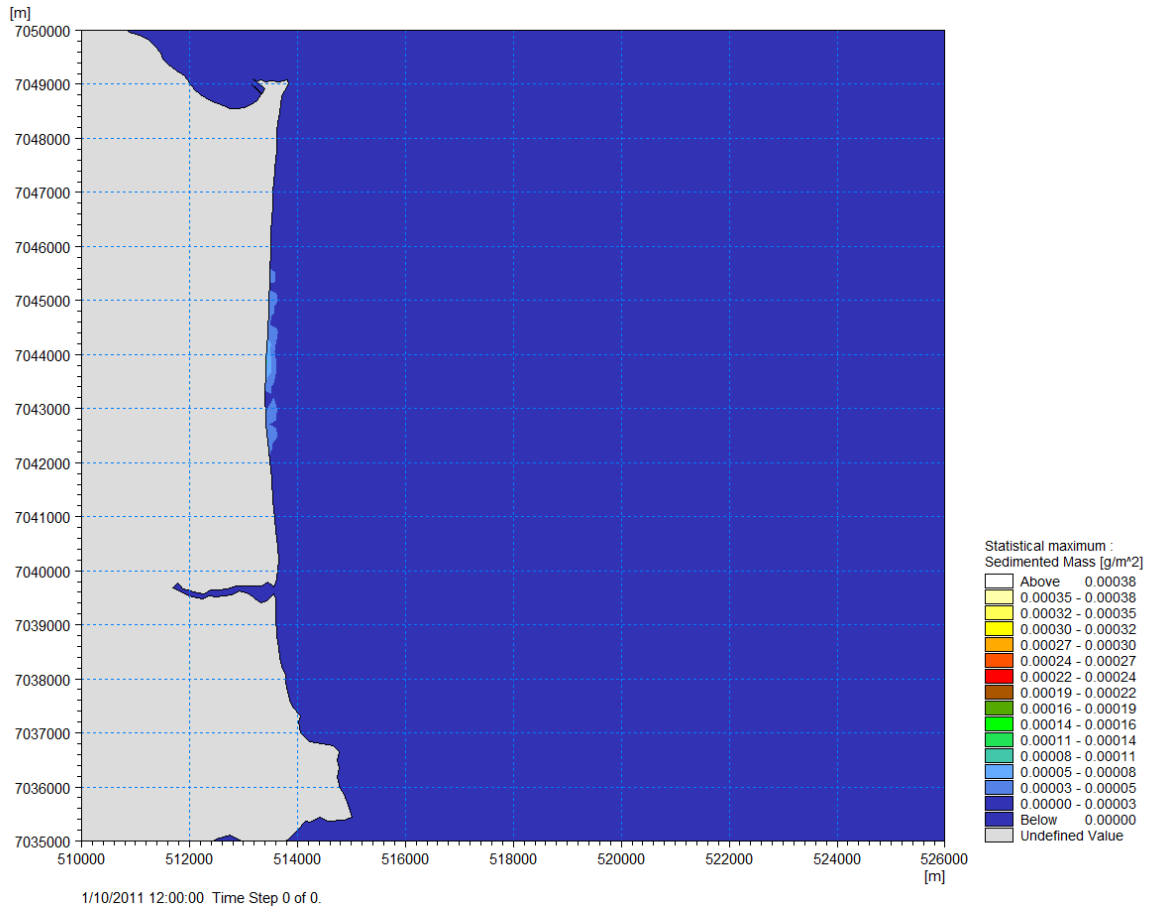


Figure C16 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_8mm)

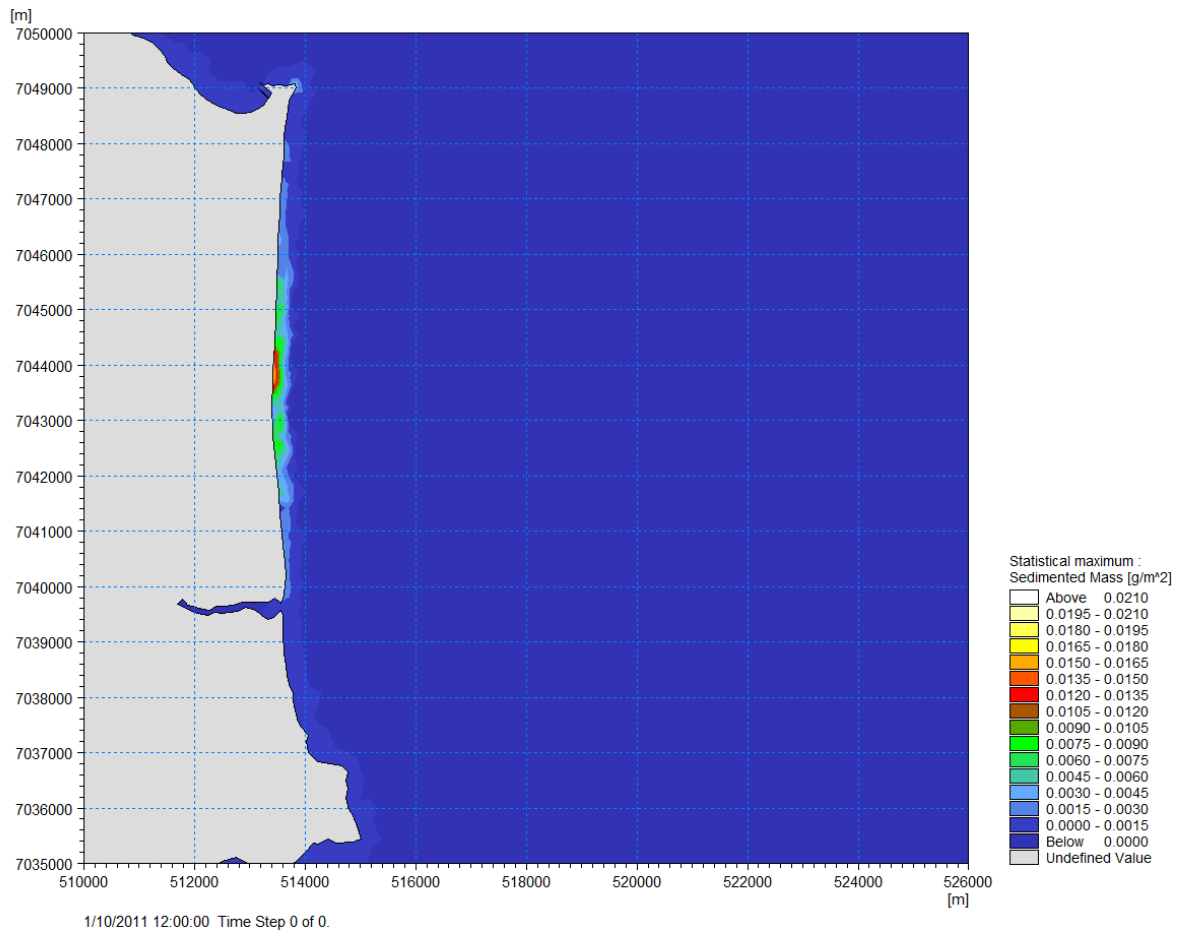


Figure C17 Predicted distribution of maximum sedimented particles – Scenario 2 (PT2_11mm)

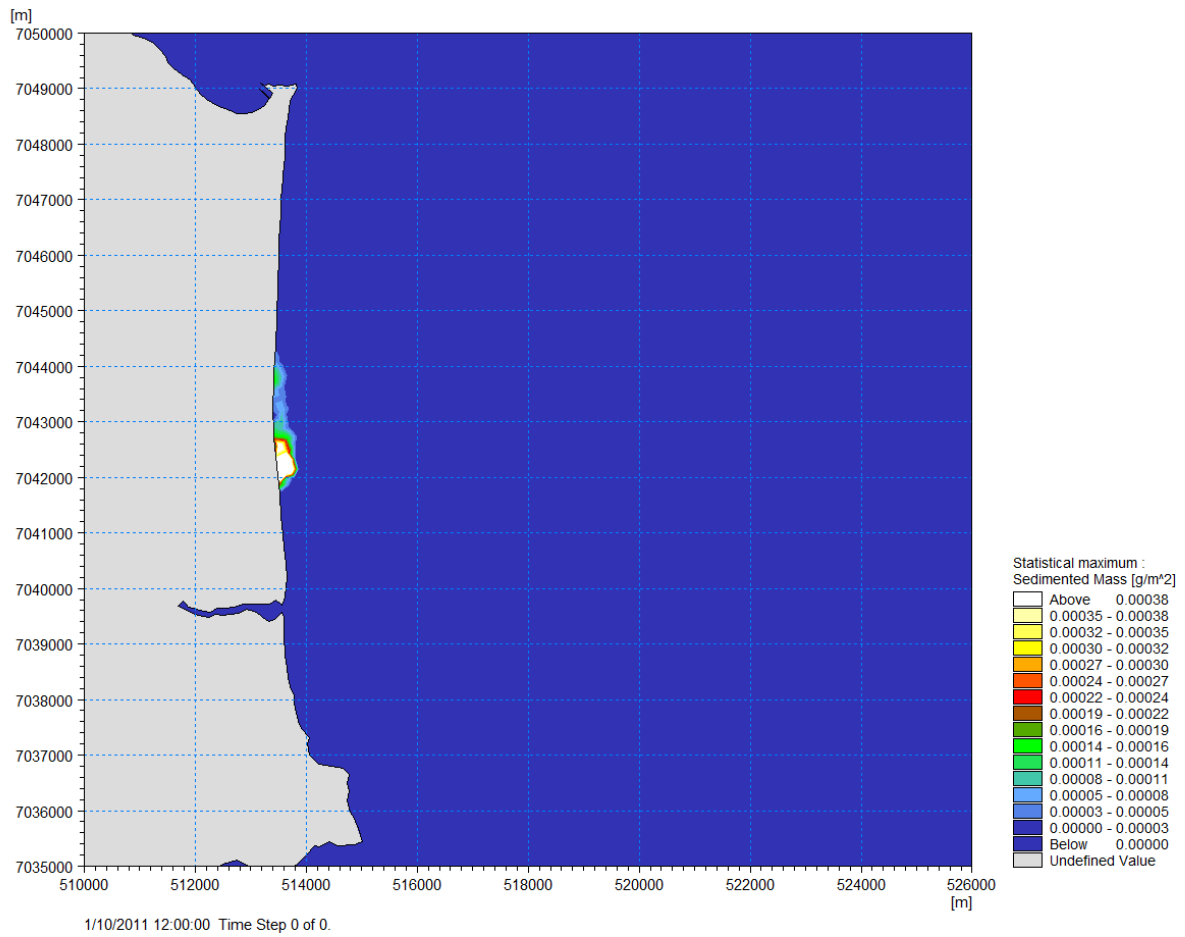


Figure C18 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_2mm)

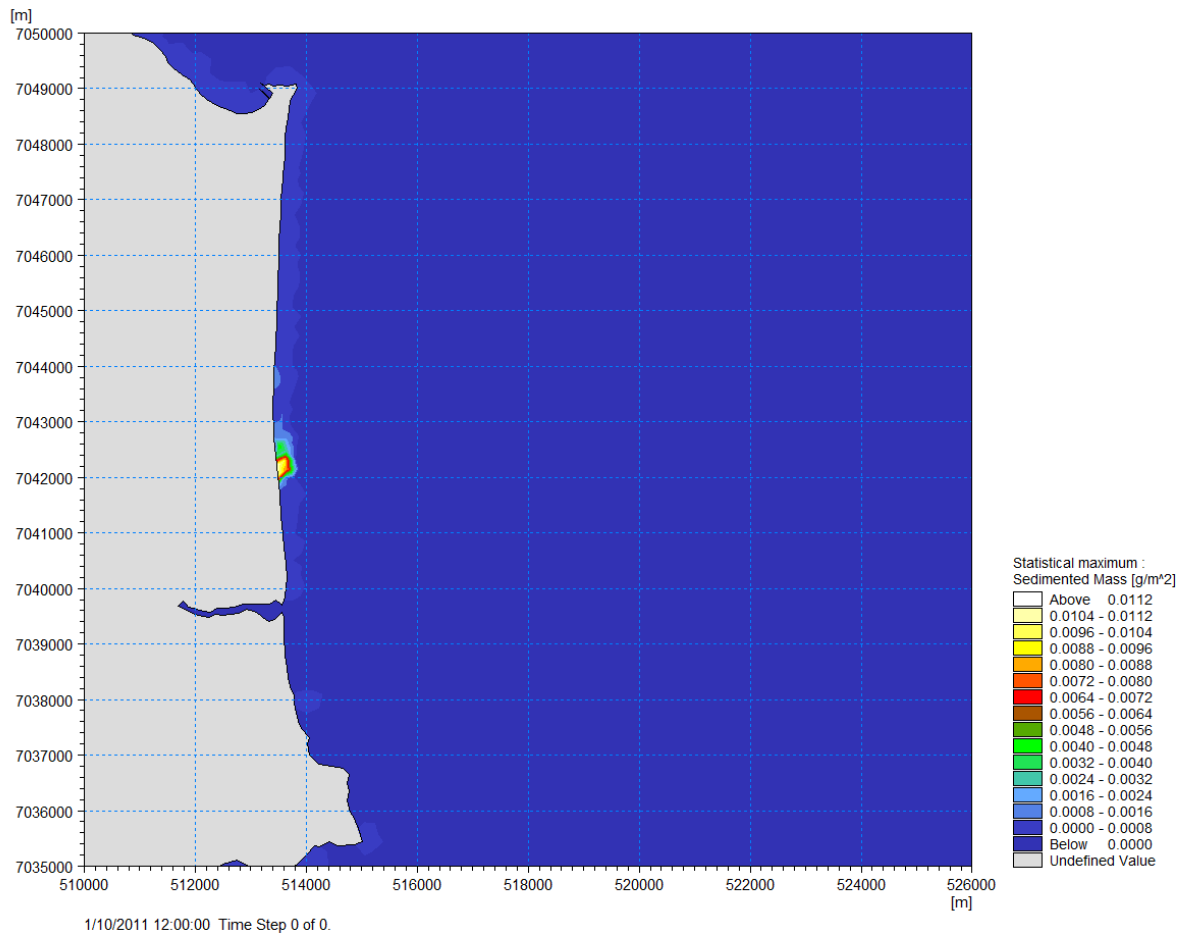


Figure C19 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_4mm)

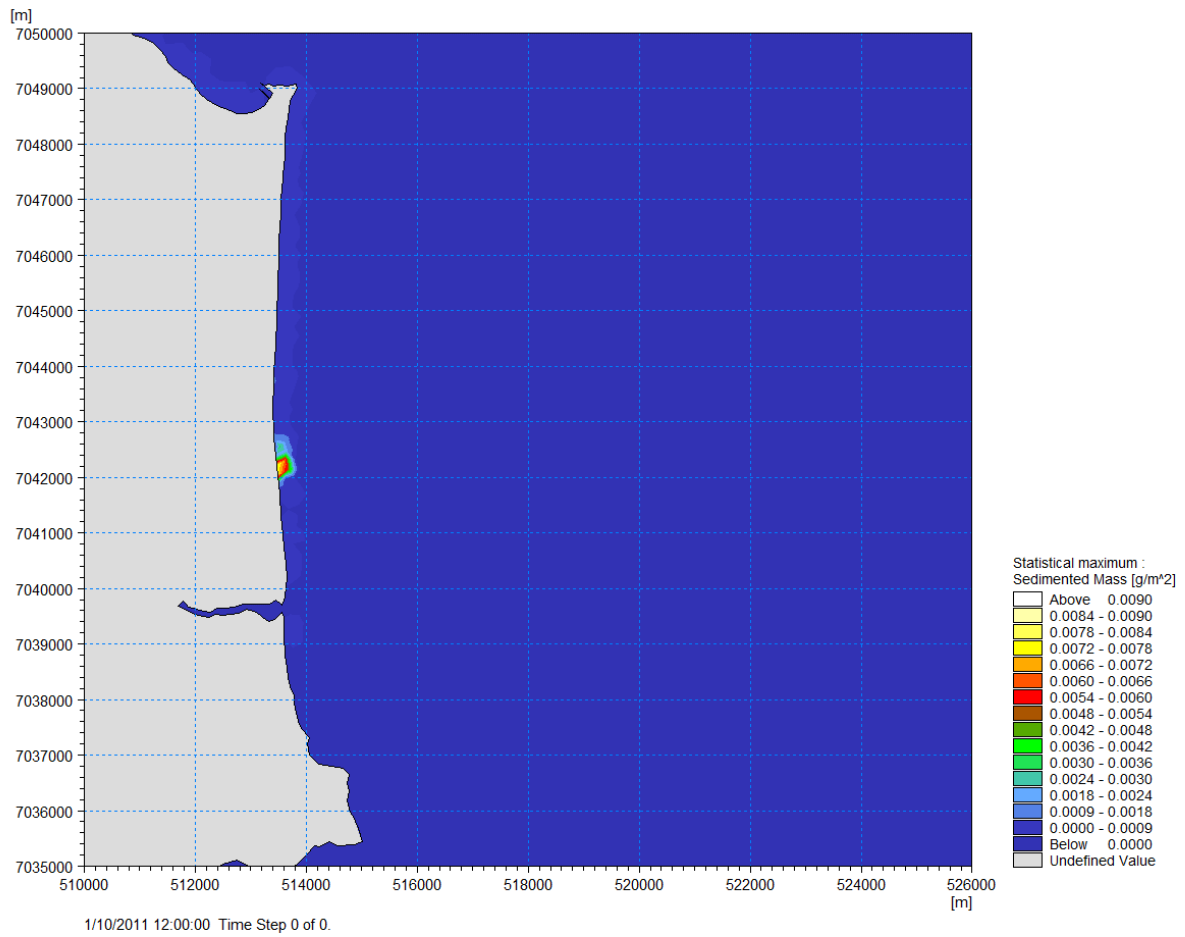


Figure C20 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_6mm)

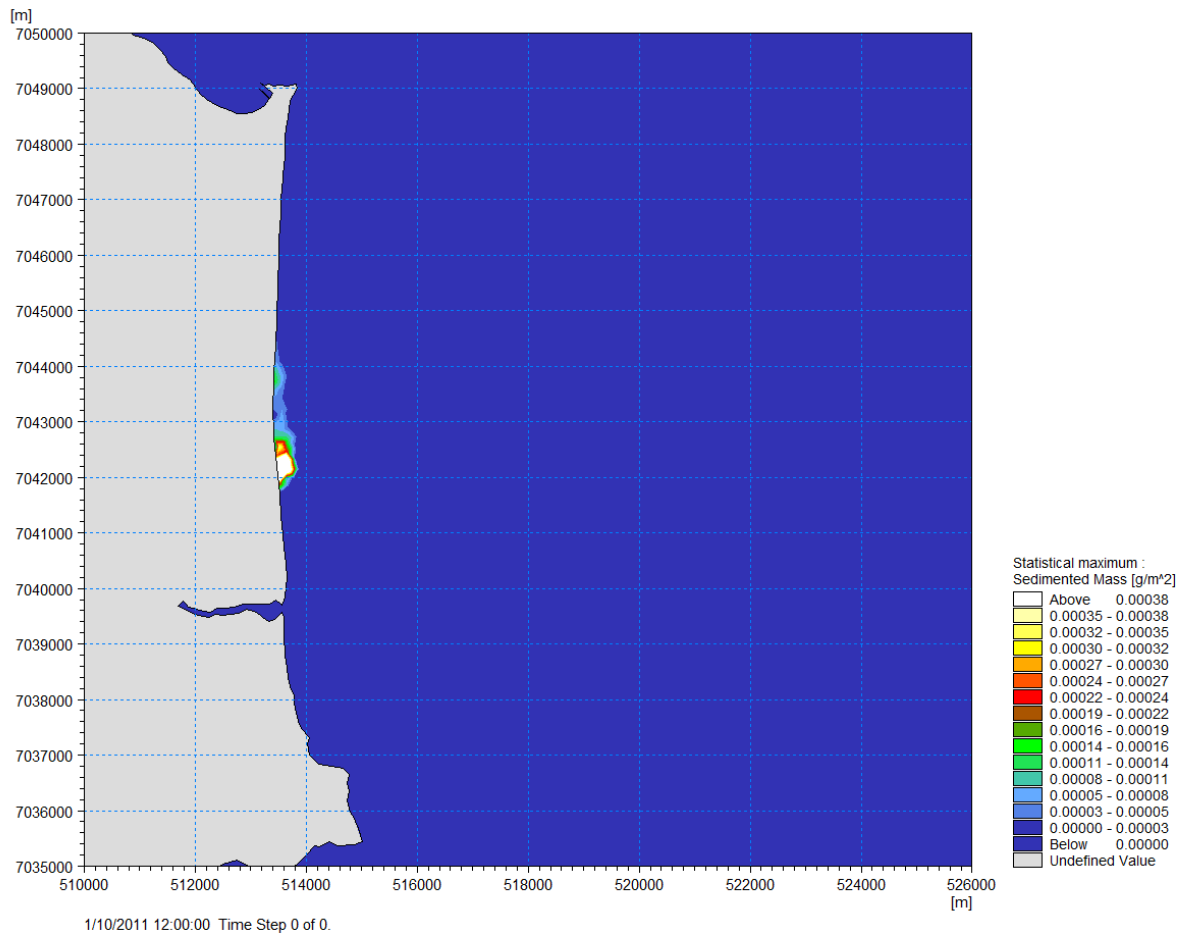


Figure C21 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_8mm)

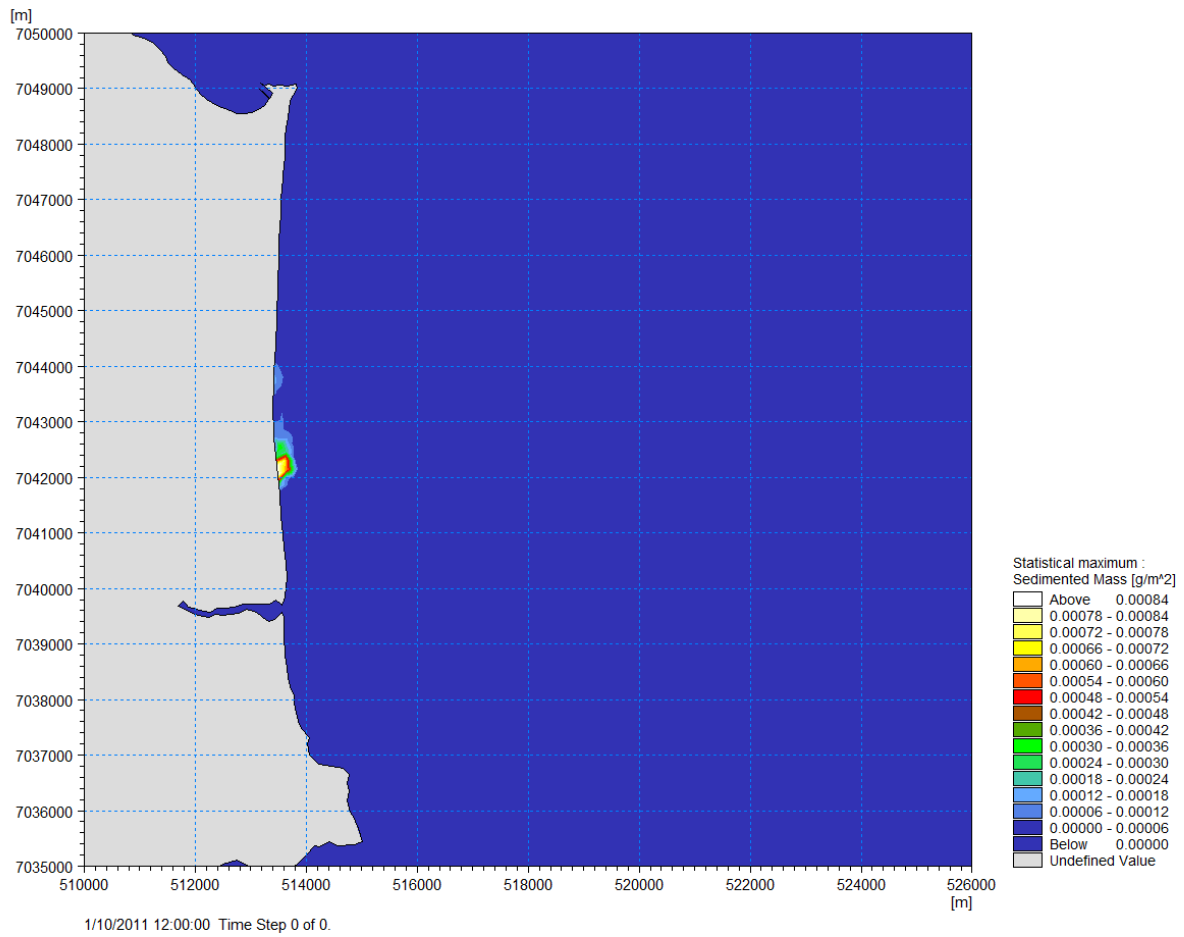
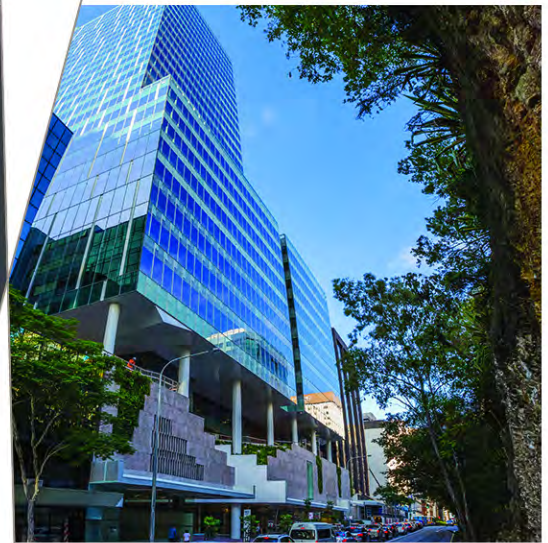


Figure C22 Predicted distribution of maximum sedimented particles – Scenario 3 (PT3_11mm)

Appendix I SAQP E1 to E6: Assessment of visual recreational amenity, during ambient conditions and following a wet weather event.

Appendix I: SAQP E3 to E6 Investigation of MBBR plastic media on land adjacent to waterways

KAWSTP Project Management
Services



*Prepared for
Unitywater*

28 June 2022



now



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2	9 June 2022	Update after comments	R.Donald	R.Donald
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Summary

The objective of this study was to determine whether plastic had been deposited in areas of recreational amenity and in particular to determine whether MBBR media were in areas likely to collect contaminants from the STP outfalls.

Kawana Beach, inshore of the ocean diffuser, and a control beach (Mount Coolum Beach) were surveyed every month for 6 months. In addition, these locations and the banks of the Mooloolah River were surveyed following a wet weather event.

A total of 63 samples were collected and analysed from Kawana Beach and 21 samples from Mount Coolum Beach. In addition, 15 samples were collected along the banks of the Mooloolah River following the severe wet weather event.

Of the samples collected surrounding the Pacific Ocean Outfall and Mooloolah River Overflow outfall, only one piece of MBBR plastic media particle was found in approximately 1500 plastic particles collected. Therefore, based on visual observations for the occurrence of MBBR plastic media, any previous release of these particles from Kawana STP is unlikely to have a significant impact on coastal regions surrounding the outfalls.

Table of Contents

1	Purpose	1
2	Methodology	2
2.1	Sampling Procedure	2
2.2	Beach Sampling	2
2.3	River Sampling	3
2.4	Sample Analysis	8
3	Results: Beach Sampling	9
3.1	Results	9
3.2	Analysis of Results	9
4	Results: River Sampling	12
4.1	Results	12
5	Conclusion	13
6	Attachments	14

Attachments

Attachment 1: Monthly Beach Sampling Results

Attachment 2: Wet Weather Beach Sampling Results

Attachment 3: Wet Weather River Sampling Results

Tables

Table 1: Coastal Site Information	6
Table 2: River Site Information	7
Table 3: Sampling Item List	8
Table 4 - Total Number of Particles Found at Kawana Beach North Transects 1 to 3	9
Table 5 - Total Number of Particles Found at Kawana Beach Central Transects 1 to 3	10
Table 6 - Total Number of Particles Found at Kawana Beach South Transects 1 to 3	10
Table 7 - Total Number of Particles Found at Control Beach (Mt Coolum) Transects 1 to 3	10
Table 8 - Total Mass Found at All Beach Locations	11
Table 9 - Total Number of Particles Found at River Locations Following Wet Weather	12
Table 10 - Total Mass Found at River Locations Following Wet Weather	12
Table 11: December Site Information Kawana Beach	14
Table 12: December Site Information Control Beach	15
Table 13: December Transect Data Central Kawana Beach	16
Table 14: December Transect Data North Kawana Beach	17
Table 15: December Transect Data South Kawana Beach	18
Table 16: December Transect Data Control Beach	19
Table 17: January Site Information Kawana Beach	20
Table 18: January Site Information Control Beach	21
Table 19: January Transect Data Central Kawana Beach	22
Table 20: January Transect Data North Kawana Beach	23
Table 21: January Transect Data South Kawana Beach	24
Table 22: January Transect Data Control Beach	25
Table 23: February Site Information Kawana Beach	26
Table 24: February Site Information Control Beach	27
Table 25: February Transect Data Central Kawana Beach	28

Table 26: February Transect Data North Kawana Beach	29
Table 27: February Transect Data South Kawana Beach	30
Table 28: February Transect Data Control Beach	31
Table 29: March Site Information Kawana Beach	32
Table 30: March Site Information Control Beach	33
Table 31: March Transect Data Central Kawana Beach	34
Table 32: March Transect Data North Kawana Beach	35
Table 33: March Transect Data South Kawana Beach	36
Table 34: March Transect Data Control Beach	37
Table 35: April Site Information Kawana Beach	38
Table 36: April Site Information Control Beach	39
Table 37: April Transect Data Central Kawana Beach	40
Table 38: April Transect Data North Kawana Beach	41
Table 39: April Transect Data South Kawana Beach	42
Table 40: April Transect Data Control Beach	43
Table 41: May Site Information Kawana Beach	44
Table 42: May Site Information Control Beach	45
Table 43: May Transect Data Central Kawana Beach	46
Table 44: May Transect Data North Kawana Beach	47
Table 45: May Transect Data South Kawana Beach	48
Table 46: May Transect Data Control Beach	49
Table 47: Wet Weather Event Site Information: Kawana Beach	50
Table 48: Wet Weather Event Site Information: Control Beach	51
Table 49: Wet Weather Event Transect Data: Central Kawana Beach	52
Table 50: Wet Weather Event Transect Data: North Kawana Beach	53
Table 51: Wet Weather Event Transect Data: South Kawana Beach	54
Table 52: Wet Weather Event Transect Data: Control Beach	55
Table 53: Wet Weather Event Site Information: Upstream of the Mooloolah River Outfall and at the Outfall Sampling Sites of Mooloolah River	56
Table 54: Wet Weather Event Site Information: Industrial Estate, Kawana Way and Brightwater Sampling Sites of Mooloolah River	57
Table 55: Wet Weather Event Transect Data: Upstream of the Mooloolah River Outfall, Mooloolah River	58
Table 56: Wet Weather Event Transect Data: At Mooloolah River Outfall, Mooloolah River	59
Table 57: Wet Weather Event Transect Data: Industrial Estate Site, Mooloolah River	60
Table 58: Wet Weather Event Transect Data: Kawana Way Site, Mooloolah River	61
Table 59: Wet Weather Event Transect Data: Brightwater Site, Mooloolah River	62

Figures

Figure 1 - Kawana Beach Sampling Locations	2
Figure 2 - Kawana Beach Sampling Locations Overlayed on Dispersion Modelling Results	3
Figure 3 - River Sampling Locations (Red Markers)	4
Figure 4 – Areas in the Mooloolah River Estuary where plastic debris is likely to accumulate.	5

1 Purpose

This report describes an investigation into MBBR plastic media particles on land adjacent to waterways. It provides a baseline for plastics found on land and compares areas around the Pacific Ocean Outfall of Kawana STP to another ocean location further away from the outfall that would be unlikely impacted by any release of MBBR particles. Additional sampling was undertaken following a defined weather event in February 2022, comparing areas surrounding the Mooloolah River discharge point. The purpose of this investigation was to determine whether plastic had been deposited in areas of recreational amenity where modelling suggests they are likely to be found. In particular to determine whether MBBR media were in areas likely to collect contaminants from the STP outfalls. This investigation was initiated to provide information in response to the Notice to conduct or commission an environmental evaluation EPPR00869113 issued by Department of Environment and Science on 14 December 2021. In particular, the study intended to address Items E3 to E6 of the Sampling and Quality Plan to assess the discharge of MBBR plastic media into the environment with specific reference to current containment controls (existing 2mm screen aperture).

2 Methodology

2.1 Sampling Procedure

The sampling procedure for this investigation was developed based on the methods in the CSIRO Handbook of Survey Methodology, Plastics Leakage, Version 1.4 (2020). [CSIRO Research Publications Repository - Handbook of Survey Methodology: Plastics Leakage](#)

2.2 Beach Sampling

Kawana Beach, the potentially impacted beach inshore of the Pacific Ocean Outfall of Kawana STP was sampled at 3 sites, identified as North, Central and South. At each site 3 transects were surveyed (Figure 1). The sites were selected based on the preliminary dispersion modelling which indicated which areas MBBR particles were most likely to accumulate in. All debris that appeared not to be natural, and that had a plastic appearance was collected along each transect.

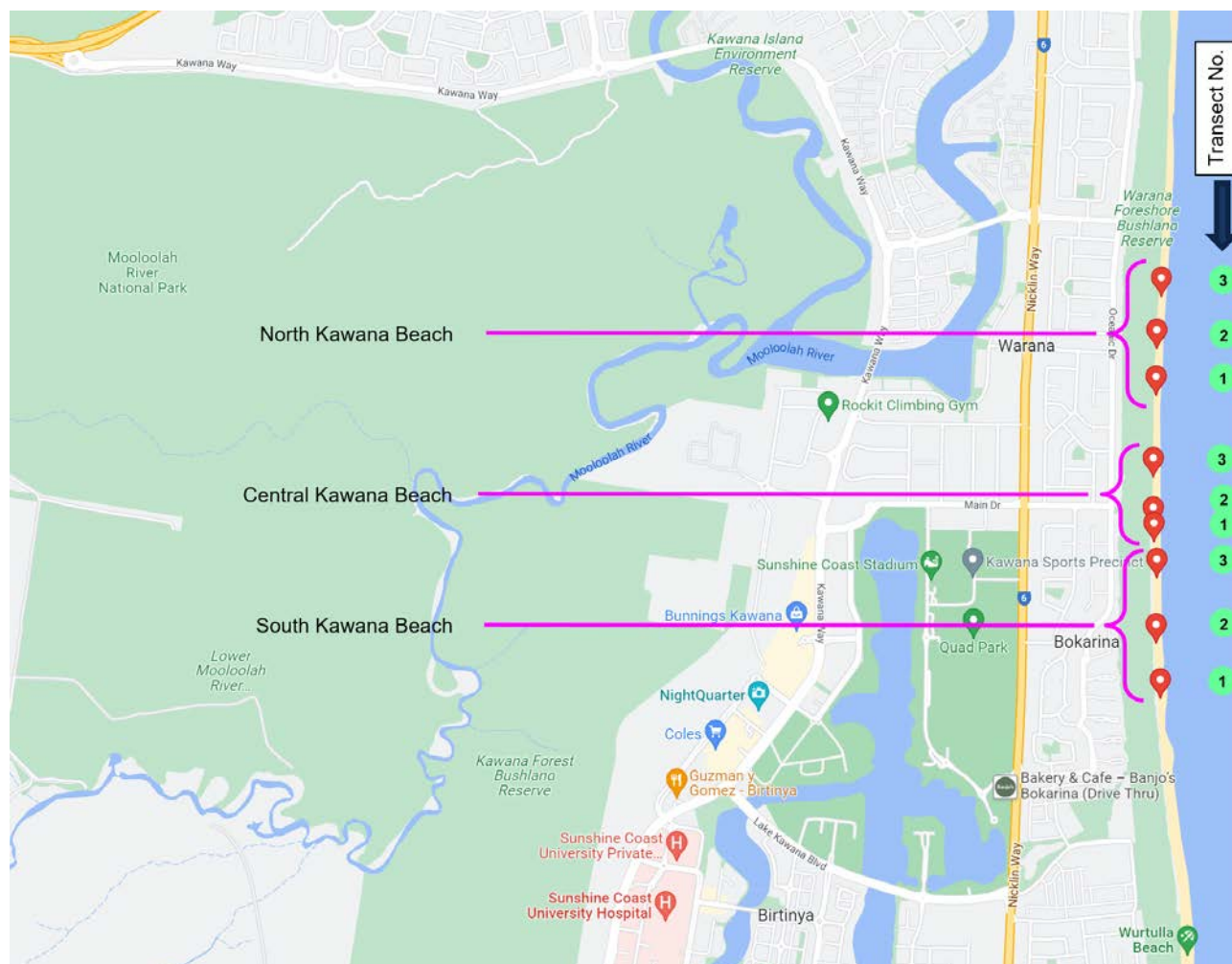


Figure 1 - Kawana Beach Sampling Locations

The CSIRO sampling procedure was followed for beach sampling, with some minor adjustments as follows:

- Sampling both sides of the Pacific Ocean Outfall rather than choosing one side as advised. At the time of developing the sampling procedure, early insight into likely ocean dispersion indicated that it would be prudent to take samples either side of the outfall.

- Where the procedure recommended an upright posture when visually identifying plastics in the environment, a bending / crouching position was used to ensure small plastic particles could be identified and collected.
- The area between the dune and the waterline was sampled, rather than two metres past the continuous vegetation. This was done to focus on MBBR plastic media particles washed up from the ocean onto the beach area. In addition, microplastics could not be easily identified amongst vegetation and walking through sensitive dune areas may have resulted in unnecessary environmental damage.

Samples were collected and analysed each month from December 2021 to May 2022. In addition, samples were collected and analysed in early March 2022 following the extreme wet weather even in February 2022.

A Coastal Site Information sheet was completed prior to sampling at each transect location (Table 1).

Kawana Beach sampling locations were selected using preliminary insights into particle dispersion from the Pacific Ocean Outfall. Detailed dispersion modelling by considering scenarios was completed at a later stage of the project (refer Appendix B).

Figure 2 shows the Kawana Beach sampling locations compared to the final results of the dispersion modelling for Scenario 2 which described the case of the effluent basket screens having lost part of their contents, such as being breached by a hole or other damage. This scenario was used because Scenario 1 considers small MBBR plastic media particles that would be very difficult to identify during beach sampling, and Scenario 3 release to the Pacific Ocean Outfall is considered unlikely to occur based on the current configuration of the effluent basket screens. As shown in Figure 2, the beach was sampled where the dispersion modelling indicated there would be the highest concentration of MBBR carriers released under Scenario 2.

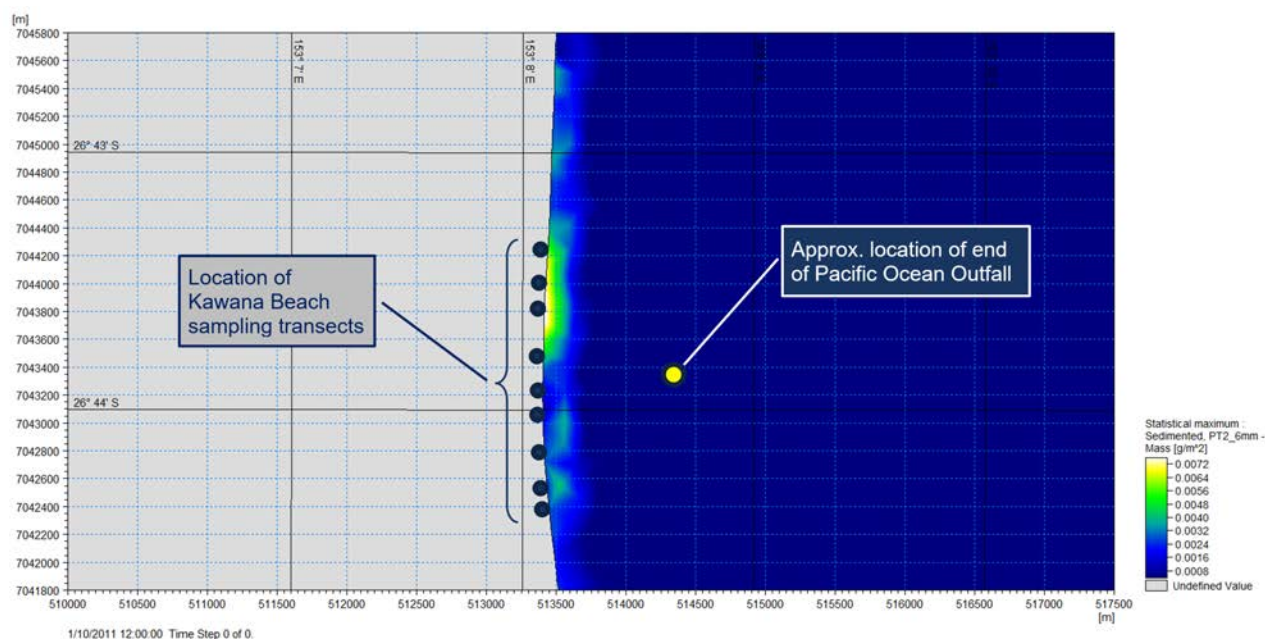


Figure 2 - Kawana Beach Sampling Locations Overlayed on Dispersion Modelling Results

2.3 River Sampling

Sites on the banks of the Mooloolah River were sampled in early March 2022, just after the extreme wet weather event in February 2022, and once the river levels had subsided to allow access to the river banks (Figure 3). Sites were selected based on safety of access, and in areas where MBBR plastic media particles were most likely to accumulate (Figure 4).

The same method was used as for beach sampling, with the collection of all debris that appeared not to be natural, and that had a plastic appearance. If in doubt, the material was collected for closer examination. A River Site Information sheet was completed prior to sampling at each transect location (Table 2).

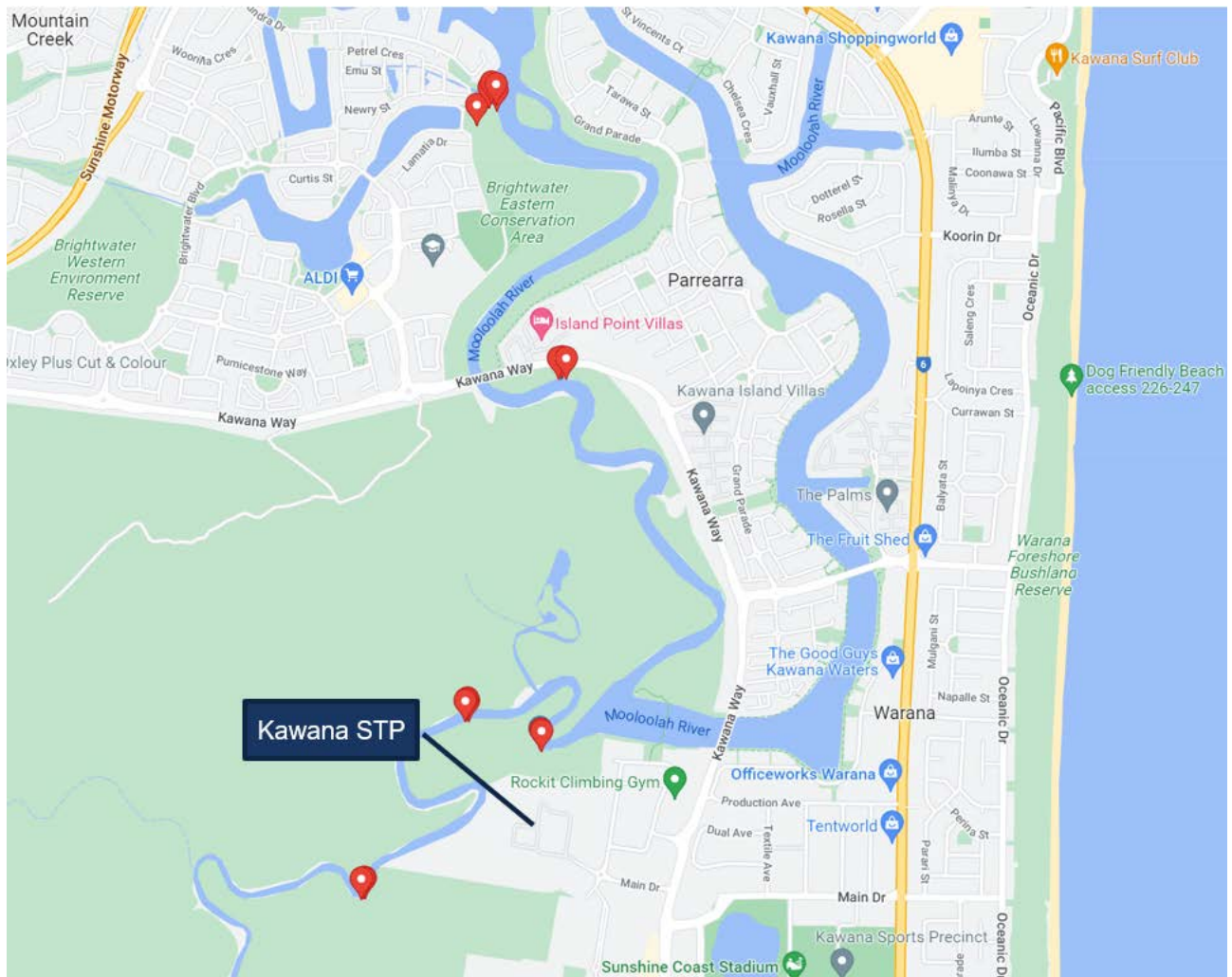


Figure 3 - River Sampling Locations (Red Markers)



Figure 4 – Areas in the Mooloolah River Estuary where plastic debris is likely to accumulate.
Source: Jock Mackenzie & Dr Norm Duke, 2017, Mooloolah River Baseline Mangrove & Saltmarsh Condition Assessment

Table 1: Coastal Site Information

Surveyor Details:		
Surveyor name:		
Site Details:		
Site name:		
Current Weather:	Clear, Rain/Storm, Overcast, Drizzle	Best option to describe the weather
Wind Speed:	0 1 2 3 4 5	0: calm (flat ocean) 1: light breeze (wavelets, <10km/h , <6 knots) 2: moderate breeze (small waves braking crests, 10-25km/h, 6-20 knots) 3: strong breeze (waves and many white caps, 25-49km/h, 21- 26 knots) 4: high wind (white caps and airborne spray, 50-65 km/h , 27-35 knots) 5: gale (high waves, foam and spray present, 65-85 km/h, 35-45 knots)
Wind Direction:	N, NE, E, SE, S, SW, W, NW, N/A	Direction from which wind is coming measured by the compass. N/A if no wind.
Wind Direction (Relative to Shore):	onshore, offshore, sideshore, side-on, side-off	Onshore: wind blowing towards shore Offshore: wind blowing towards sea Sideshore: wind blowing parallel to shore Side-onshore: wind blowing sideways and towards shore Side-offshore: wind blowing sideways and towards sea
Cleanliness at first glance:	No debris visible, Scattered debris visible, Lots of debris visible, Large amounts of dumped debris	

Transect Number:
Date:
Transect length (m):
Transect width (m):
Name of Surveyor(s):

Transect Start	Latitude: Longitude: Start Time: Photo:	Latitude and longitude recorded in decimal degrees (dd.dddd). Record Start Time of Transect. Photographer name and number of photo, taken from transect start point
Transect End	Latitude: Longitude: Start Time: Photo:	Latitude and longitude recorded in decimal degrees (dd.dddd). Record End Time of Transect. Photographer name and number of photo, taken from transect start point
Distance to dominant debris line (m):		Distance from water edge to major debris line (in meters) at time of survey. If no obvious debris line use NA
Beach Gradient:	A B C D E	Difference in elevation from start to end of transect. A = < 1 m (less than hip height) B = 1-2 m (hip to head height) C = 2-4 m (1-2 body length) D = 4-8 m (2-4 body lengths) E = > 8 m (more than 4 body lengths)
Substrate type:	Mud, Sand, Pebble / Gravel, Boulders, Rock slab, Mangrove	Major substrate type
Substrate colour (if visible):	White /cream, Yellow, Orange, Brown, Black, Grey, Red, Green	Predominant colour of substrate (not vegetation)
Backshore type:	Cliff, Seawall, Urban building, Forest / Tree (> 3m), Shrub (< 3m), Dune, Grass - tussock, Grass - pasture, Mangrove	Physical structure of backshore, where beach meets terrestrial vegetation
Shore exposure or shape:	Cove/bay, Straight, Headland	Shape of beach where survey is conducted. Based on 50m each side of transect.
Aspect:	N NE E SE S SW W NW	Direction when you are facing the water
Evidence of dumping:	None, Construction, Household, Other(specify)	
Evidence of recent activities within transect area: (one or more)	None, Clean-up or removal of rubbish, Apparent spilled trash or rubbish, Storm or flood, High winds, Public event, Mowing	
Comments:		

Table 2: River Site Information

Site name:	Mooloolah River Samples		
Current Weather:	Clear, Rain/Storm, Overcast, Drizzle	Best option to describe the weather	
Wind Speed:	0 1 2 3 4 5	0: calm (flat ocean) 1: light breeze (wavelets, <10km/h , <6 knots) 2: moderate breeze (small waves braking crests, 10-25km/h, 6-20 knots) 3: strong breeze (waves and many white caps, 25-49km/h, 21- 26 knots) 4: high wind (white caps and airborne spray, 50-65 km/h , 27-35 knots) 5: gale (high waves, foam and spray present, 65-85 km/h, 35-45 knots)	
Wind Direction:	N, NE, E, SE, S, SW, W, NW, N/A	Direction from which wind is coming measured by the compass. N/A if no wind.	
Wind Direction (Relative to Shore):	onshore, offshore, sideshore, side-on, side-off	Onshore: wind blowing towards shore Offshore: wind blowing towards sea Sideshore: wind blowing parallel to shore Side-onshore: wind blowing sideways and towards shore Side-offshore: wind blowing sideways and towards sea	
Cleanliness at first glance :	No debris visible, Scattered debris visible, Lots of debris visible, Large amounts of dumped debris		
Transect Number:			
Date:			
Transect length (m):			
Transect width (m):			
Name of Surveyor(s):			
Transect Start	Latitude: Longitude: Start Time: Photo:	Latitude and longitude recorded in decimal degrees (dd.dddd). Record Start Time of Transect. Photographer name and number of photo, taken from transect start point	
Distance to dominant debris line (m):	Distance from water edge to major debris line (in meters). If not obvious debris line use NA		
Distance to top of bank (m):	Distance from water edge to top of the bank		
Distance of river influence/erosion line (m):	Height that water comes up the bank/erosion line		
River Gradient:	A B C D E	Difference in elevation from start to end of transect. A = < 1 m (less than hip height) B = 1-2 m (hip to head height) C = 2-4 m (1-2 body length) D = 4-8 m (2-4 body lengths) E = > 8 m (more than 4 body lengths)	
Bank type:	Mud, Sand, Pebble/Gravel, Cobble, Boulders, Rock slab, Mangrove, Dirt bank, Vegetated, Cement	Circle the best option to describe the type of vegetation on the transect	
Bank Substrate colour (if visible):	White /cream, Yellow, Orange, Brown, Black, Grey, Red, Green	Predominant colour of substrate (not vegetation)	
Bank Vegetation:	Grass/Reeds, Broadleaf/herb, Shrub (< 3m), Tree (> 3m), Forest, None	Physical structure of backshore, where beach meets terrestrial vegetation	
Vegetation Height	No vegetation, 0 – 5cm, 5 – 50cm, 50 – 100cm, 100 – 200cm, >200cm	Height of the vegetation on the transect	
Percent (%) Bare ground %	How much of the transect is bare ground (i.e. unvegetated) (in 10% intervals)		
Percent (%) of area surveyed:	If unable to survey the whole area, what was sampled (in 10% intervals)		
Shore exposure or shape:	Cove/bay, Straight, Headland	Shape of river where survey is conducted. Based on 50m each side of transect.	
Aspect:	N NE E SE S SW W NW	Direction when you are facing the water	
Evidence of dumping:	None, Construction, Household, Other(specify)		
Evidence of recent activities within transect area: (one or more)	None, Clean-up or removal of rubbish, Apparent spilled trash or rubbish, Storm or flood, High winds, Public event, Mowing		
Comments:			

2.4 Sample Analysis

The samples collected at each transect were assessed using an item list, where materials found were classified as plastic types, size range and mass (Table 3). For example, if one 15 mm piece of a bottle cap/lid was found at a transect, the code "D" would be entered on the fourth row of the Class Size column in Table 3 and the mass of that item after weighing entered in the same row of the Mass (g) column. Another example, if 4 pieces of 6mm polystyrene foam and 3 pieces of 12mm polystyrene foam was found, the code "4C 3D" would be placed in the matching row and the total mass of those items entered in the mass column.

Table 3: Sampling Item List

		Class Size					Mass (g)
		A	B	C	D	E	
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard						
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft						
	Other plastic bag						
Plastic Straps	String/rope/ribbon						
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
Cloth	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene						
	Unknown/other						
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
Other	Unknown/other						
	Sponge						
	Paint						
	MBBR Plastic						
	Other items as identified						
TOTAL							
Class Size A: <1.5x1.5mm; B: 1.5-5mm; C: 5-10mm; D: 10-20mm; E: >20mm							

3 Results: Beach Sampling

3.1 Results

3.1.1 Site Information and Transect Data

The data for each month of the beach sampling and analysis is presented in Table 11 to Table 46 of Attachment 1, with data for the wet weather beach sampling in Table 47 to Table 52 of Attachment 2. The Site Information sheets in Attachment 1 provide data only, without field titles, and therefore should be read in conjunction with Table 1 and Table 2. Most of the material collected was easily identified as plastic, although some material required closer examination and was found to be non-plastic, for example metal and clear stone.

3.1.2 Observations

General observations from the beach sampling indicated there was:

- Hard plastics dominated the material collected.
- Particles in size category B (1.5 to 5 mm) were usually more common than other sizes.
- In the months following the wet weather event in March 2022, there was a significant shift in sand and severe erosion along the coastline.
- In March and May 2022, there was a significant increase in the proportion of polystyrene foam collected in the sample. This appeared to result from damage caused to structures such as jetties and rafts during the wet weather events.
- The amount of debris collected in April 2022 significantly decreased compared to March 2022.
- Significant dune erosion in beach samples from March to May, following the severe wet weather events. Debris may have been buried beneath the dunes and sand during this period.
- The distribution of debris type at Kawana Beach was similar to the distribution at the control site at Mount Coolum Beach.

3.2 Analysis of Results

The total number of plastic particles found at Kawana Beach location is shown in Table 4 to Table 6 and the results for the control beach (Mt Coolum) is provided in Table 7. Note that, to a very minor extent, some particles were subsequently identified as being non-plastic as noted in the detailed data in Attachment 1 and 2. Out of over 1200 particles collected at Kawana Beach locations in the 6-month sampling period, only one particle was identified as originating from MBBR plastic media in January 2022. This particle was in the 5 to 10 mm size range weighing 0.084 g and was found at transect number 1 at the Kawana Beach North site (Table 20).

Table 4 - Total Number of Particles Found at Kawana Beach North Transects 1 to 3

Month	MBBR Plastic	Hard Plastic	Soft Plastic	Foam	Other (including plastic strap, rubber, cloth, fishing and other)	TOTAL
December	0	41	4	1	5	51
January	0	95	0	0	6	101
February	0	38	2	0	0	40
March	0	4	0	47	1	52
April	0	7	0	0	0	7
May	0	13	0	31	0	44
Wet Weather	0	52	5	21	5	83
TOTAL	0	250	11	100	17	378

Table 5 - Total Number of Particles Found at Kawana Beach Central Transects 1 to 3

Month	MBBR Plastic	Hard Plastic	Soft Plastic	Foam	Other (including plastic strap, rubber, cloth, fishing and other)	TOTAL
December	0	30	2	1	2	35
January	1	104	1	1	0	107
February	0	70	1	0	3	74
March	0	9	2	16	0	27
April	0	1	0	0	0	1
May	0	1	0	0	0	1
Wet Weather	0	147	6	32	4	189
TOTAL	1	362	12	50	9	434

Table 6 - Total Number of Particles Found at Kawana Beach South Transects 1 to 3

Month	MBBR Plastic	Hard Plastic	Soft Plastic	Foam	Other (including plastic strap, rubber, cloth, fishing and other)	TOTAL
December	0	25	5	0	2	32
January	0	81	1	0	1	83
February	0	8	0	0	1	9
March	0	6	0	18	1	25
April	0	1	0	0	0	1
May	0	5	0	34	0	39
Wet Weather	0	164	3	27	2	196
TOTAL	0	290	9	79	7	385

Table 7 - Total Number of Particles Found at Control Beach (Mt Coolum) Transects 1 to 3

Month	MBBR Plastic	Hard Plastic	Soft Plastic	Foam	Other (including plastic strap, rubber, cloth, fishing and other)	TOTAL
December	0	14	2	0	0	16
January	0	65	0	0	1	66
February	0	40	1	0	2	43
March	0	13	1	1	0	15
April	0	0	0	0	0	0
May	0	39	0	35	0	74
Wet Weather	0	24	1	20	0	45
TOTAL	0	195	5	56	3	259

Table 8 presents the total mass of plastic material at all beach locations. Note that mass can be highly variable that is often dominated by one or more large particles.

Table 8 - Total Mass Found at All Beach Locations

Month	Total mass (g)			
	Kawana Beach North	Kawana Beach Central	Kawana Beach South	Control Beach (Mt Coolum)
December	7.0	3.1	7.0	3.2
January	6.8	4.4	9.5	5.6
February	2.7	0.96	0.6	4.3
March	3.3	2.2	14.4	0.2
April	0.06	1.4	0.9	0
May	27.4	7.2	1.4	13.4
Wet Weather	22.4	18.3	13.3	13.5
TOTAL	69.7	37.6	47.1	40.2

4 Results: River Sampling

4.1 Results

4.1.1 Site Information

Data for river sampling following the wet weather event is presented in Table 53 to Table 59 of Attachment 3.

4.1.2 Observations

Some of the general observations from the wet weather river sampling included:

- Sample material predominantly hard and soft plastics and microplastics.
- Accessible regions contained more debris, possibly due to recreational activities.

4.1.3 Analysis of Results

A summary of the total number of particles is provided in Table 9 and the mass of those particles shown in Table 10. No MBBR plastic media particles were recorded in the sampling of the Mooloolah River.

Table 9 - Total Number of Particles Found at River Locations Following Wet Weather

River Location	MBBR Plastic	Hard Plastic	Soft Plastic	Foam	Other (including plastic strap, rubber, cloth, fishing and other)	TOTAL
Upstream Outfall W3	0	5	3	0	1	9
Outfall W3	0	5	2	0	0	7
Industrial Estate	0	0	1	0	0	1
Kawana Way	0	8	4	0	3	15
Brightwater	0	3	10	0	2	15
TOTAL	0	21	20	0	6	47

Table 10 - Total Mass Found at River Locations Following Wet Weather

Total mass (g)				
Upstream Outfall W3	Outfall W3	Industrial Estate	Kawana Way	Brightwater
6.0	1.2	0.4	6.5	22.8

5 Conclusion

Over the 6-month sampling period, a total of 63 samples were collected and analysed from Kawana Beach, and 21 samples from the control location at Coolum Beach. In addition, 15 samples were collected along the banks of the Mooloolah River following the severe wet weather event. The location of sample sites on the beach and in the river was based on dispersion modelling, which indicated which areas any MBBR particles were likely to accumulate in.

Only one piece of MBBR plastic media was recorded in all of the sampling which contained over 1500 plastic particles. This was at Kawana Beach, inshore of the outfall diffuser and was in the 5 to 10mm size range. No MBBR plastic media were found in the Mooloolah River near, nor at the control beach at Mount Coolum Beach. That is, the visual impact of any previous release of MBBR plastic media particles from Kawana STP on coastal recreational amenities in the regions around Kawana STP is negligible.

6 Attachments

ATTACHMENT 1: MONTHLY BEACH SAMPLING RESULTS

Table 11: December Site Information Kawana Beach

Central Kawana Beach			South Kawana Beach			North Kawana Beach		
Clear								
3								
NE								
Side-onshore								
No debris visible			No debris visible			No debris visible		
1	2	3	1	2	3	1	2	3
21/12/2021			21/12/2021			21/12/2021		
50			50			50		
2m			2m			2m		
Liana Walsh			Liana Walsh			Liana Walsh		
-26.73228	-26.73167	-26.729776	-26.738284	-26.736175	-26.733664	-26.726655	-26.724847	-26.722849
153.134771	153.134732	153.134754	153.135031	153.134857	153.13488	153.134876	153.134888	153.135089
2:40	2:53	3:05	3:15	3:22	3:29	3:38	3:45	3:55
-26.73358	-26.73228	-26.72976	-26.74	-26.73822	-26.73608	-26.7267	-26.7249	-26.72296
153.13514	153.13518	153.13517	153.13552	153.13541	153.1352	153.1352	153.13525	153.13541
2:49	3:03	3:12	3:20	3:27	3:34	3:43	3:50	4:00
10			10			10		
B								
Sand								
Cream								
Dune								
Straight								
E								
None								
None								
Minimal rainfall throughout previous week with Northerly to North Easterly winds. Medium Beach activity (School Holiday Season); some but minimal activity at time of sampling.								

Table 12: December Site Information Control Beach

Liana Walsh		
Control - Mount Coolum Beach		
Overcast		
2		
SE		
Side-onshore		
No debris visible		
1	2	3
2/01/2022		
2m		
Liana Walsh		
2:20	2:30	2:40
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
2:30	2:40	2:50
15-20		
B		
Sand		
Cream		
Dune		
Straight		
E	E	E
None		
None		
Significant rainfall throughout previous week with Southerly to South Easterly winds. Minimal Beach activity (School Holiday Season but beaches closed due to big swell); minimal activity at time of sampling.		

Table 13: December Transect Data Central Kawana Beach

		Central KB 1		Central KB 2		Central KB 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	2A, 11B, 9C, 2D	0.9473	4B, 2C	0.6397	6B, 5C	0.3202
Soft Plastic	Thin film carry bag						
	Food wrapper/label	E	0.0995	D	0.0174		
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft					2B	0.072
	Other plastic bag						
Plastic Straps	String/rope/ribbon	B,C, D	0.0573			D	0.0506
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap						
	Clothing/towel			E	0.8016		
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene						
	Unknown/other			D	0.0748		
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other							
TOTAL			1.1041		1.5335		0.4428

Table 14: December Transect Data North Kawana Beach

		North KB 1				North KB 2				North KB 3						
		Class Size				Mass (g)	Class Size				Mass (g)	Class Size				
		A	B	C	D E		A	B	C	D E		A	B	C	D E	Mass (g)
Hard Plastic	Pipe/PVC															
	Beverage bottle <1L															
	Other bottle															
	Bottle cap/lid															
	Food Container															
	Utensil/plate/bowl															
	Bucket/crate															
	Lighter															
	Lollipop stick/earbud	E				0.5										
	Unknown/ other hard	4A, 4B, 2C, 3D, E				3.3843	2B, 3C, D			0.399	6B, 2C, E				2.431	
Soft Plastic	Thin film carry bag															
	Food wrapper/label															
	Sheeting	E				0.1436										
	Cup/lid															
	Straw															
	Unknown/other soft						B		0.0598							
	Other plastic bag															
Plastic Straps	String/rope/ribbon	B, C				0.0049										
	Packing strap															
	Cable ties															
	Unknown/other strap															
Rubber	Thong/Shoe															
	Tyre															
	Balloon															
	Rubber band															
	Unknown/other															
Cloth	String/rope/strap															
	Clothing/towel															
	Wipes/cloths															
	Insulation/stuffing															
	Unknown/other															
Foam	Food container															
	Cup/plates/bowls															
	Polystyrene															
	Unknown/other	D				0.0363										
Fishing	Net															
	Fishing line															
	Fishing lures															
	Buoys/floats															
	Glow stick															
	Fishhook/sinker															
	Unknown/other															
Other																
TOTAL						4.0691					0.4588					2.431

Table 15: December Transect Data South Kawana Beach

		South KB 1					South KB 2					South KB 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid	E					5.1351	D				0.337						0.5707	
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud													E				0.3604	
	Unknown/ other hard	11B, 2D					0.2263	3C				0.0551	4B, 2D						
Soft Plastic	Thin film carry bag																		
	Food wrapper/label	C					0.0097												
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft							C			0.0201	B					0.0014		
	Other plastic bag	B, E					0.1906												
Plastic Straps	String/rope/ribbon	2C					0.082												
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other																			
TOTAL							5.6437					0.4122						0.9325	

Table 16: December Transect Data Control Beach

		CONTROL 1					CONTROL 2					CONTROL 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid							E					1.7601						
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud							E					0.2092						
	Unknown/ other hard	B, 6C, D					0.9159	C,D					0.1768	2B					0.0304
Soft Plastic	Thin film carry bag																		
	Food wrapper/label							C				0.0288							
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft													E					0.065
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other																			
TOTAL							0.9159						2.1749						0.0954

Table 17: January Site Information Kawana Beach

Central Kawana Beach			South Kawana Beach			North Kawana Beach		
Clear								
2								
ENE								
Side-onshore								
No debris visible			No debris visible			No debris visible		

1	2	3	1	2	3	1	2	3
19/01/2022			19/01/2022			19/01/2022		
50			50			50		
2m			2m			2m		
Liana Walsh			Liana Walsh			Liana Walsh		

-26.73228	-26.73167	-26.729776	-26.738284	-26.736175	26.733664	-26.726655	-26.724847	-26.722849
153.134771	153.134732	153.134754	153.135031	153.134857	153.13488	153.134876	153.134888	153.135089
2:40	2:53	3:05	3:15	3:22	3:29	3:38	3:45	3:55
-26.73358	-26.73228	-26.72976	-26.74	-26.73822	-26.73608	-26.7267	-26.7249	-26.72296
153.13514	153.13518	153.13517	153.13552	153.13541	153.1352	153.1352	153.13525	153.13541
2:49	3:03	3:12	3:20	3:27	3:34	3:43	3:50	4:00
30			40			40		
C								
Sand								
Cream								
Dune								
Straight								
E								
None								
None								

Big swell throughout week and big high tides due to Full Moon, resulting in signs of significant beach erosion along the dunes of Kawana Beach. Mild Beach activity (School Holiday Season but beaches mostly closed due to big swell throughout last week).

Table 18: January Site Information Control Beach

Control - Mount Coolum Beach		
Clear		
2		
ENE		
Side-onshore		
No debris visible		

1	2	3
19/01/2022		
40		
2m		
Liana Walsh		

4:30	4:45	5:00
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
4:40	4:56	5:10
25		
C		
Sand		
Cream		
Dune		
Straight		
E	E	E
None		
None		
Big swell throughout week and big high tides due to Full Moon. Medium Beach activity (School Holiday Season but big swell caused beaches to be closed last week). N.B. Dog Beach.		

Table 19: January Transect Data Central Kawana Beach

		Central KB 1		Central KB 2		Central KB 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	1E, 9D, 16C, 38B, 2A	4.9082	D, 8C, 11B, A	0.5591	5C, 2B, A	0.1874
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft						
	Other plastic bag						
Plastic Straps	String/rope/ribbon			E	0.1596	E	0.8624
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap			D	0.124		
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene						
	Unknown/other						
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other	Sponge	2B	0.0055				
	Paint	B	0.0018				
	MBBR Plastic						
TOTAL			4.9155		0.8427		1.0498

Table 20: January Transect Data North Kawana Beach

		North KB 1		North KB 2		North KB 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	E, 6D, 23C, 35B, A	2.0322	E, 3D, 8C, 6B	1.5092	E, D, 8C, 6B, 4A	0.7312
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft						
	Other plastic bag	C	0.0052				
Plastic Straps	String/rope/ribbon						
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene						
	Unknown/other			C	0.0401		
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other	Sponge						
	Paint						
	MBBR Plastic	C	0.084				
TOTAL			2.1214		1.5493		0.7312

Table 21: January Transect Data South Kawana Beach

		South KB 1					South KB 2					South KB 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid							E				1.2734							
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	B, C					0.0761	E, 16D, 21C, 31B, A				7.9592	C,6B, A					0.1166	
Soft Plastic	Thin film carry bag																		
	Food wrapper/label							C				0.0155							
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge							C				0.0232							
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL							0.0761						9.2713						0.1166

Table 22: January Transect Data Control Beach

		CONTROL 1		CONTROL 2		CONTROL 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid					D	0.8295
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	8D, 19C, 11B, 2A	3.1549	D, 2C, 6B	0.3748	2E, 2D, 7C, 4B	1.2288
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft						
	Other plastic bag						
Plastic Straps	String/rope/ribbon						
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene						
	Unknown/other						
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other	Sponge					D	0.011
	Paint						
	MBBR Plastic						
	Metal						
	Cigarette Butt						
	Tape						
TOTAL			3.1549		0.3748		2.0693

Table 23: February Site Information Kawana Beach

Central Kawana Beach			South Kawana Beach			North Kawana Beach		
Clear								
2								
SE								
Side-onshore								
No debris visible			No debris visible			No debris visible		
1	2	3	1	2	3	1	2	3
16/02/2022								
50			50			50		
2m			2m			2m		
Liana Walsh			Liana Walsh			Liana Walsh		
-26.73228	-26.73167	-26.729776	-26.738284	-26.736175	26.733664	-26.726655	-26.724847	-26.722849
153.134771	153.134732	153.134754	153.135031	153.134857	153.13488	153.134876	153.134888	153.135089
3:00	1:45	2:05	3:37	3:25	3:15	2:20	2:35	2:45
-26.73358	-26.73228	-26.72976	-26.74	-26.73822	-26.73608	-26.7267	-26.7249	-26.72296
153.13514	153.13518	153.13517	153.13552	153.13541	153.1352	153.1352	153.13525	153.13541
3:05	1:55	2:10	3:40	2:30	3:20	2:25	2:40	2:50
5			5			5		
B								
Sand								
Cream								
Dune								
Straight								
E								
None								
None								
Beach fairly quiet. Less plastic perceived in comparison to previous two beach samples. School holidays over and wind swell of approximately 2-3ft								

Table 24: February Site Information Control Beach

Liana Walsh		
Control - Mount Coolum Beach		
Clear		
2		
SE		
Side-onshore		
No debris visible		
1	2	3
16/02/2022		
40		
2m		
Liana Walsh		
4:40	4:15	4:30
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
4:45	4:20	4:35
15		
B		
Sand		
Cream		
Dune		
Straight		
E	E	E
None		
None		
Beach fairly quiet. Less plastic perceived in comparison to previous two beach samples. School holidays over and wind swell of approximately 2-3 foot.		

Table 25: February Transect Data Central Kawana Beach

		Central KB 1		Central KB 2		Central KB 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	A, 21B, 3C, D	0.5281	2B, C	0.1736	A, 7B, D	0.2193
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft						
	Other plastic bag	C	0.0064	D	0.0301		
Plastic Straps	String/rope/ribbon						
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene						
	Unknown/other						
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other	Sponge						
	Paint						
	MBBR Plastic						
	Metal						
	Cigarette Butt						
	Tape						
TOTAL			0.5345		0.2037		0.2193

Table 26: February Transect Data North Kawana Beach

		North KB 1		North KB 2		North KB 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	2A, 11B, 3C	0.3014	A, 9B	0.085	4A, 29B, 8C, 3D	1.399
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw			E	0.4868		
	Unknown/other soft						
	Other plastic bag						
Plastic Straps	String/rope/ribbon						
	Packing strap						
	Cable ties						
	Unknown/other strap			C, D	0.0731		
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene						
	Unknown/other						
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other	Sponge						
	Paint						
	MBBR Plastic						
	Metal			C	0.1563	E	0.2232
	Cigarette Butt						
	Tape						
TOTAL			0.3014		0.8012		1.6222

Table 27: February Transect Data South Kawana Beach

		South KB 1						South KB 2						South KB 3					
		Class Size						Class Size						Class Size					
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard							2B, C, 2D					0.5152	3B					0.0379
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap													D					0.0163
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL		0						0.5152						0.0542					

Table 28: February Transect Data Control Beach

		CONTROL 1					CONTROL 2					CONTROL 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	2A, 11B, 6C					0.6235	3B, 2C					0.2604	2A, 12B, 2D					0.5749
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag													D					0.4386
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap	D					0.0464												
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape	E					2.3599												
	TOTAL							3.0298						0.2604					

Table 29: March Site Information Kawana Beach

Central Kawana Beach	South Kawana Beach	North Kawana Beach
Clear		
2		
S		
Side-shore		
No debris visible		

1	2	3	1	2	3	1	2	3
16/03/2022								
15	20	20	5	20	35	20	25	30
2m			2m			2m		
Liana Walsh			Liana Walsh			Liana Walsh		

-26.73228	-26.73167	-26.729776	-26.738284	-26.736175	-26.73366	26.726655	26.724847	26.722849
153.134771	153.13473	153.13475	153.13503	153.134857	153.1348	153.13487	153.13488	153.13508
3:00	3:10	3:25	2:00	2:20	2:35	3:45	3:55	4:05
-26.73358	-26.73228	-26.72976	-26.74	-26.73822	-26.73608	-26.7267	-26.7249	-26.72296
153.13514	153.13518	153.13517	153.13552	153.13541	153.1352	153.1352	153.13525	153.13541
2:10	2:20	2:35	1:15	1:30	1:45	2:50	3:00	3:10
-	20	19	-	18	30	-	24	28

B								
Sand								
Cream								
Dune								
Straight								
E								
None								
None								
High tide at approximately 7:00 pm. It is quite likely that the majority of debris was buried beneath the sand. Severe erosion evident on dunes.								

Table 30: March Site Information Control Beach

Liana Walsh		
Control - Mount Coolum Beach		
Cloudy		
2		
S		
Side-shore		
No debris visible		
1	2	3
16/03/2022		
18	8	20
2m		
Liana Walsh		
17:00	17:10	17:20
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
17:05	17:15	17:30
-	-	18
B		
Sand		
Cream		
Dune		
Straight		
E	E	E
None		
None		
High tide at approximately 7:00 pm. It is quite likely that the majority of debris was buried beneath the sand. Erosion evident on dunes.		

Table 31: March Transect Data Central Kawana Beach

		Central KB 1					Central KB 2					Central KB 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	B, C					0.0571							B, D					0.5498
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other							E				1.242							
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene	B					0.0024	4B, C, D				0.0946	2A,31B,5C,D,E					0.2946	
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL							0.0595						1.3366						0.8444

Table 32: March Transect Data North Kawana Beach

		North KB 1					North KB 2					North KB 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard							A, B, 2C					0.3082	2C, 2D, E					2.6718
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft	D					0.0017							E					0.0883
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene	2C					0.061	3C					0.0307	7B, C, D, E					0.1558
	Unknown/other													C					0.0098
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL							0.0627						0.3389						2.9257

Table 33: March Transect Data South Kawana Beach

		South KB 1					South KB 2					South KB 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard							B, C					0.0366	2C, D, E					3.2988
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene	2B, C, D					0.0194	2A, 7B, C					0.0147	2B, D					0.0842
	Unknown/other							D					0.0371						
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Toothbrush													E					10.9051
TOTAL							0.0194						0.0884						14.2881

Table 34: March Transect Data Control Beach

		CONTROL 1					CONTROL 2					CONTROL 3										
		Class Size					Class Size					Class Size										
		A	B	C	D	E	Mass (g)		A	B	C	D	E	Mass (g)		A	B	C	D	E	Mass (g)	
Hard Plastic	Pipe/PVC																					
	Beverage bottle <1L																					
	Other bottle																					
	Bottle cap/lid																					
	Food Container																					
	Utensil/plate/bowl																					
	Bucket/crate																					
	Lighter																					
	Lollipop stick/earbud																					
	Unknown/ other hard								5B					0.079		2A, 6B						0.1161
Soft Plastic	Thin film carry bag																					
	Food wrapper/label																					
	Sheeting																					
	Cup/lid																					
	Straw																					
	Unknown/other soft	E					0.0262															
	Other plastic bag																					
Plastic Straps	String/rope/ribbon																					
	Packing strap																					
	Cable ties																					
	Unknown/other strap																					
Rubber	Thong/Shoe																					
	Tyre																					
	Balloon																					
	Rubber band																					
	Unknown/other																					
Cloth	String/rope/strap																					
	Clothing/towel																					
	Wipes/cloths																					
	Insulation/stuffing																					
	Unknown/other																					
Foam	Food container																					
	Cup/plates/bowls																					
	Polystyrene	B					0.0003															
	Unknown/other																					
Fishing	Net																					
	Fishing line																					
	Fishing lures																					
	Buoys/floats																					
	Glow stick																					
	Fishhook/sinker																					
	Unknown/other																					
Other	Sponge																					
	Paint																					
	MBBR Plastic																					
	Metal																					
	Cigarette Butt																					
	Tape																					
TOTAL							0.0265							0.079							0.1161	

Table 35: April Site Information Kawana Beach

Central Kawana Beach			South Kawana Beach			North Kawana Beach		
Clear								
3								
SE								
Side-onshore								
No debris visible								
1	2	3	1	2	3	1	2	3
14/04/2022								
15	25	35	15	25	30	15	20	20
2m			2m			2m		
Liana Walsh			Liana Walsh			Liana Walsh		
-26.73228	-26.73167	-	-26.738284	-26.736175	-26.73366	-	-	-
153.134771	153.13473	153.13475	153.13503	153.134857	153.1348	153.13487	153.13488	153.13508
2:00	2:10	2:25	1:00	1:20	1:35	2:45	2:55	3:05
-26.73358	-26.73228	-26.72976	-26.74	-26.73822	-26.73608	-26.7267	-26.7249	-26.72296
153.13514	153.13518	153.13517	153.13552	153.13541	153.1352	153.1352	153.13525	153.13541
2:10	2:20	2:35	1:15	1:30	1:45	2:50	3:00	3:10
-	-	-	-	-	30	-	-	-
C								
Sand								
Cream								
Dune								
Straight								
E								
None								
None								
Build-up of sand along Eastern Beaches; it is expected that the majority of debris has been buried beneath the sand. Severe erosion evident on dunes.								

Table 36: April Site Information Control Beach

Control - Mount Coolum Beach		
Clear		
3		
SE		
Side-onshore		
No debris visible		
1	2	3
14/04/2022		
15	10	20
2m		
Liana Walsh		
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
17:00	17:10	17:20
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
17:05	17:15	17:30
-	-	-
C		
Sand		
Cream		
Dune		
Straight		
E	E	E
None		
None		
Build-up of sand along Eastern Beaches; it is expected that the majority of debris has been buried beneath the sand. Severe erosion evident on dunes.		

Table 37: April Transect Data Central Kawana Beach

		Central KB 1					Central KB 2					Central KB 3							
		Class Size					Mass (g)	Class Size					Mass (g)	Class Size					Mass (g)
		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E	
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard							2D				0.9821		5C				0.4051	
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL		0					0.9821					0.4051							

Table 38: April Transect Data North Kawana Beach

		North KB 1					North KB 2					North KB 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard													B					0.0602
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL							0						0						0.0602

Table 39: April Transect Data South Kawana Beach

		South KB 1					South KB 2					South KB 3							
		Class Size					Mass (g)	Class Size					Mass (g)	Class Size					
		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid												E					0.8982	
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard																		
	Soft Plastic	Thin film carry bag																	
Food wrapper/label																			
Sheeting																			
Cup/lid																			
Straw																			
Unknown/other soft																			
Other plastic bag																			
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL																		0.8982	

Table 40: April Transect Data Control Beach

		CONTROL 1						CONTROL 2						CONTROL 3					
		Class Size						Class Size						Class Size					
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard																		
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL		0						0						0					

Table 41: May Site Information Kawana Beach

Central Kawana Beach	South Kawana Beach	North Kawana Beach
Clear		
2		
SSE		
Side-onshore		
Scattered Debris Visible		

1	2	3	1	2	3	1	2	3
18/05/2022								
25	25	20	25	25	25	30	20	25
2m			2m			2m		
Liana Walsh			Liana Walsh			Liana Walsh		

-26.73228	-26.73167	26.729776	-26.738284	-26.736175	-26.73366	26.726655	26.724847	26.722849
153.134771	153.13473	153.13475	153.13503	153.134857	153.1348	153.13487	153.13488	153.13508
16:10	16:20	16:30	15:15	15:40	16:00	16:45	16:55	17:00
-26.73358	-26.73228	-26.72976	-26.74	-26.73822	-26.73608	-26.7267	-26.7249	-26.72296
153.13514	153.13518	153.13517	153.13552	153.13541	153.1352	153.1352	153.13525	153.13541
24	23-35	-	24	-	25	20, 25-30	-	21-24
16:15	16:25	16:40	15:25	15:55	16:05	16:50	16:55	17:05
C								
Sand								
Cream								
Dune								
Straight								
E								
None								
None								
Severe erosion evident on dunes (2-5m drop) ; debris particles are foam dominant								

Table 42: May Site Information Control Beach

Control - Mount Coolum Beach		
Clear		
2		
SSE		
Side-onshore		
Scattered debris visible		
1	2	3
18/05/2022		
15	25	20
2m		
Liana Walsh		
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
17:30	17:40	17:50
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
17:35	17:45	17:55
-	-	-
C		
Sand		
Cream		
Dune		
Straight		
E	E	E
None		
None		
Severe erosion evident on dunes (2-4m drop); debris particles are foam dominant		

Table 43: May Transect Data Central Kawana Beach

		Central KB 1			Central KB 2			Central KB 3		
		Class Size			Class Size			Class Size		
		A	B	C D E	Mass (g)	A	B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC									
	Beverage bottle <1L									
	Other bottle									
	Bottle cap/lid	D			2.2936	D		0.7799		
	Food Container									
	Utensil/plate/bowl									
	Bucket/crate									
	Lighter									
	Lollipop stick/earbud									
	Unknown/ other hard	2B, C, D, 2E			1.8551	C		0.0086	A, 2B, C	0.062
Soft Plastic	Thin film carry bag									
	Food wrapper/label									
	Sheeting									
	Cup/lid									
	Straw									
	Unknown/other soft									
	Other plastic bag									
Plastic Straps	String/rope/ribbon									
	Packing strap									
	Cable ties									
	Unknown/other strap									
Rubber	Thong/Shoe									
	Tyre									
	Balloon									
	Rubber band									
	Unknown/other									
Cloth	String/rope/strap									
	Clothing/towel									
	Wipes/cloths									
	Insulation/stuffing									
	Unknown/other									
Foam	Food container									
	Cup/plates/bowls									
	Polystyrene	2B, 5C, 3D			0.1251	2B, 5C, 2D		0.4324	2B, C, D	0.0544
	Unknown/other	B, 2C, 2D			0.7548	C, 2D		0.79		
Fishing	Net									
	Fishing line									
	Fishing lures									
	Buoys/floats									
	Glow stick									
	Fishhook/sinker									
	Unknown/other									
Other	Sponge									
	Paint									
	MBBR Plastic									
	Metal									
	Cigarette Butt									
	Tape									
TOTAL					5.0286			2.0109		0.1164

Table 44: May Transect Data North Kawana Beach

		North KB 1					North KB 2					North KB 3							
		Class Size					Mass (g)	Class Size					Mass (g)	Class Size					Mass (g)
		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E	
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	3A, 6B, 17C, 7D, 4E					10.8978	B, 2C, 2D				0.2933	11B,23C,16D,8E					15.3091	
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel											D						0.1994	
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene	2B,2C,4D					0.3653					C, 5D						0.2152	
	Uknown/other	A,C,D					0.0559	B			0.0007	4B, 3D						0.064	
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
TOTAL							11.319					0.294						15.7877	

Table 45: May Transect Data South Kawana Beach

		South KB 1		South KB 2		South KB 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	2B,C	0.0993	B	0.0142	B	0.0124
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft						
	Other plastic bag						
Plastic Straps	String/rope/ribbon						
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene	2A, 3B	0.0034	2C	0.0179	2A,5B,7C,6D,E	1.0082
	Unknown/other					2C, 4D	0.2198
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other	Sponge						
	Paint						
	MBBR Plastic						
	Metal						
	Cigarette Butt						
	Tape						
TOTAL			0.1027		0.0321		1.2404

Table 46: May Transect Data Control Beach

		CONTROL 1		CONTROL 2		CONTROL 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud						
	Unknown/ other hard	5C, 2D, 2E	7.3498	9B,8C,4D	2.077	B,3C,5D	2.6841
Soft Plastic	Thin film carry bag						
	Food wrapper/label						
	Sheeting						
	Cup/lid						
	Straw						
	Unknown/other soft						
	Other plastic bag						
Plastic Straps	String/rope/ribbon						
	Packing strap						
	Cable ties						
	Unknown/other strap						
Rubber	Thong/Shoe						
	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Cloth	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
	Unknown/other						
Foam	Food container						
	Cup/plates/bowls						
	Polystyrene	D	0.0233	2A, 3B, 4C, D	0.0901	2B,12C,4D	0.5614
	Unknown/other	A,B,C	0.031	D, E	0.5652	C	0.0054
Fishing	Net						
	Fishing line						
	Fishing lures						
	Buoys/floats						
	Glow stick						
	Fishhook/sinker						
	Unknown/other						
Other	Sponge						
	Paint						
	MBBR Plastic						
	Metal						
	Cigarette Butt						
	Tape						
TOTAL			7.4041		2.7323		3.2509

ATTACHMENT 2: WET WEATHER BEACH SAMPLING RESULTS

Table 47: Wet Weather Event Site Information: Kawana Beach

Central Kawana Beach			South Kawana Beach			North Kawana Beach		
Clear								
2								
SSE								
Side-onshore								
Lots of debris visible								
1	2	3	1	2	3	1	2	3
03/03/2022								
15			20			20		
2m			2m			2m		
Liana Walsh			Liana Walsh			Liana Walsh		
-26.73228	-26.73167	-26.729776	-26.738284	-26.736175	-26.733664	-26.726655	-26.724847	-26.722849
153.134771	153.134732	153.134754	153.135031	153.134857	153.134808	153.134876	153.134888	153.135089
2:00	2:10	2:25	1:00	1:20	1:35	2:45	2:55	3:05
-26.73358	-26.73228	-26.72976	-26.74	-26.73822	-26.73608	-26.7267	-26.7249	-26.72296
153.13514	153.13518	153.13517	153.13552	153.13541	153.1352	153.1352	153.13525	153.13541
2:10	2:20	2:35	1:15	1:30	1:45	2:50	3:00	3:10
15			15			15		
B								
Sand								
Cream								
Dune								
Straight								
E								
None								
Clean-up or removal of rubbish, Storm and Flooding								
Storms and severe flooding throughout this and last week have caused large amounts of debris to be washed up along the beach. The beach has also withstood large swell (~1.5-2m).								

Table 48: Wet Weather Event Site Information: Control Beach

Liana Walsh		
Control - Mount Coolum Beach		
Clear		
2		
ENE		
Side-onshore		
Scattered debris visible		
1	2	3
3/03/2022		
25		
2m		
Liana Walsh		
4:20	3:45	4:00
-26.56583	-26.56771	-26.56886
153.09937	153.09919	153.09901
4:30	3:50	4:10
10		
B		
Sand		
Cream		
Dune		
Straight		
E	E	E
None		
Clean-up or removal of rubbish, Storm and Flooding		
Storms and severe flooding throughout this and last week have caused large amounts of debris to be washed up along the beach. The beach has also withstood large swell (~1.5-2m).		

Table 49: Wet Weather Event Transect Data: Central Kawana Beach

		Central KB 1				Central KB 2				Central KB 3			
		Class Size				Class Size				Class Size			
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC												
	Beverage bottle <1L											E	12.0242
	Other bottle												
	Bottle cap/lid												
	Food Container												
	Utensil/plate/bowl												
	Bucket/crate												
	Lighter												
	Lollipop stick/earbud												
	Unknown/ other hard	2A,20B,9C,D,2E					2.169	2B, 8C, 3D				A, B, C, D	0.5668
Soft Plastic	Thin film carry bag												
	Food wrapper/label							C, D				C	0.0066
	Sheeting												
	Cup/lid												
	Straw												
	Unknown/other soft							D					0.0453
	Other plastic bag											E	0.6029
Plastic Straps	String/rope/ribbon												
	Packing strap												
	Cable ties												
	Unknown/other strap	3D					0.055	D				D	0.019
Rubber	Thong/Shoe												
	Tyre												
	Balloon												
	Rubber band												
	Unknown/other												
Cloth	String/rope/strap												
	Clothing/towel												
	Wipes/cloths												
	Insulation/stuffing												
	Unknown/other												
Foam	Food container												
	Cup/plates/bowls												
	Polystyrene	C, 2D					0.1245	2D, E				5B, 2C, 4D, 2E	0.3493
	Unknown/other											C, E	0.94
Other	Sponge												
	Paint												
	MBBR Plastic												
	Metal												
	Cigarette Butt												
	Tape												
	Deformable material												
TOTAL							2.3485						14.5088

Table 50: Wet Weather Event Transect Data: North Kawana Beach

		North KB 1		North KB 2		North KB 3	
		Class Size		Class Size		Class Size	
		A B C D E	Mass (g)	A B C D E	Mass (g)	A B C D E	Mass (g)
Hard Plastic	Pipe/PVC						
	Beverage bottle <1L						
	Other bottle						
	Bottle cap/lid						
	Food Container						
	Utensil/plate/bowl						
	Bucket/crate						
	Lighter						
	Lollipop stick/earbud	E	0.5336				
	Unknown/ other hard	7B, 2C, E	1.5946	3A,17B11C,4D,E	7.6557	4A,30B,20C,5D,2E	8.0525
Soft Plastic	Thin film carry bag						
	Food wrapper/label	C	0.0021			D	0.1603
	Sheeting						
	Cup/lid						
	Straw					E	0.5176
	Unknown/other soft					2B, 2E	0.5512
Plastic Straps	Other plastic bag						
	String/rope/ribbon						
	Packing strap						
	Cable ties						
Rubber	Unknown/other strap	D	0.0232	D	0.0862	E	0.6969
	Thong/Shoe						
Cloth	Tyre						
	Balloon						
	Rubber band						
	Unknown/other						
Foam	String/rope/strap						
	Clothing/towel						
	Wipes/cloths						
	Insulation/stuffing						
Other	Unknown/other						
	Food container						
	Cup/plates/bowls						
	Polystyrene	9B, 2C, D, E	0.0705	7B, C, D, 2E	1.4245	A, 2B, C, 2D, 2E	1.0125
Other	Unknown/other						
	Sponge						
	Paint						
	MBBR Plastic						
	Metal						
	Cigarette Butt						
	Tape						
TOTAL	Deformable material			B	0.0305		
			2.224		9.1969		10.991

Table 51: Wet Weather Event Transect Data: South Kawana Beach

		South KB 1					South KB 2					South KB 3							
		Class Size					Mass (g)	Class Size					Mass (g)	Class Size					Mass (g)
		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E	
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud	E					0.1611							E				0.3881	
	Unknown/ other hard	2A,28B,10C,9D					4.8491	2A, 25B, 13C				1.976	56B, 11C,5D, E					3.8334	
Soft Plastic	Thin film carry bag																		
	Food wrapper/label							C			0.0074								
	Sheeting							B			0.0011								
	Cup/lid																		
	Straw																		
	Unknown/other soft												C				0.0104		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band												B				0.0164		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene	2B,C, 7D, E					0.771	2B, 3C, 4D			0.3998	2B, 2C, D, E					0.3515		
	Unknown/other	B					0.0014					E					0.493		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
	Deformable material												B				0.0125		
TOTAL							5.7826						2.3843						5.1053

Table 52: Wet Weather Event Transect Data: Control Beach

		CONTROL 1					CONTROL 2					CONTROL 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	7B, 9C, D					1.0458	2C, D					0.4196	B, 3C					0.3232
Soft Plastic	Thin film carry bag																		
	Food wrapper/label												E						0.8221
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene	B, E					0.8156	13B, C, 3E					10.0643	C					0.0411
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Cigarette Butt																		
	Tape																		
	Deformable material																		
	TOTAL							1.8614						10.4839					

ATTACHMENT 3: WET WEATHER RIVER SAMPLING RESULTS

Table 53: Wet Weather Event Site Information: Upstream of the Mooloolah River Outfall and at the Outfall Sampling Sites of Mooloolah River

Clear					
2					
ENE					
Side-onshore					
Upstream Outfall			Outfall		
1	2	3	1	2	3
10/03/2022					
3	4	3	5	3	8
Liana Walsh					
-26.730923	-26.730926	-26.730942	-26.725062	-26.72503	-26.725042
153.109282	153.109204	153.10913	153.112996	153.113035	153.113125
			-26.724991		-26.724973
			153.113011		153.113082
-					
3	4	3	5	3	8
-					
A			A		
Mangrove	Mangrove	Mud, Sand	Mangrove		
Brown			Brown		
Trees			Shrub, Trees		
>200cm			>200cm		
50%	50%	80%	50%	60%	40%
5%	5%	5%	10%	10%	10%
Riverbank/ Bend					
NW	NW	N	NW		
None					
Storm and flooding event last week					
Off main access track					

Table 54: Wet Weather Event Site Information: Industrial Estate, Kawana Way and Brightwater Sampling Sites of Mooloolah River

Clear								
2								
ENE								
Side-onshore								
Industrial Estate			Kawana Way			Brightwater		
1	2	3	1	2	3	1	2	3
2/03/2022								
4	4	3	5	4	5	15	30	10
1.5m								
Liana Walsh								
-26.726004	-26.725986	-26.726052	-26.713669	-26.713662	-26.713664	-26.704516	-26.704689	-26.705277
153.115766	153.115805	153.115823	153.116461	153.116461	153.116732	153.113975	153.113894	153.113434
4:00		4:40	3:20		3:55	2:15		3:05
-								
4	4	3	5	4	5	15	30	10
1			1.5			1.5		
A			A			A		
Mud			Rock/Sand/Mud			Mangrove		
Creamy/Brown								
Trees			Trees			Shrub & Trees		
>200cm			>200cm			100-200cm		
60%			95%			70%		
5%			5%			2%		
Riverbank/ Bend								
N			SW			ESE		
-								
Storm or flood			Storm or flood			Apparent spilled trash or rubbish, storm or flood		
Crabbing evident in the area						Boating and crabbing evident in the area		

Table 55: Wet Weather Event Transect Data: Upstream of the Mooloolah River Outfall, Mooloolah River

		Upstream Outfall 1					Upstream Outfall 2					Upstream Outfall 3							
		Class Size					Class Size					Class Size							
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl/etc																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	A, 2B					0.1259	2B					0.0993						
Soft Plastic	Thin film carry bag																		
	Food wrapper/label	D					0.1782							B, C				0.1882	
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Clear stone													C				5.3994	
	Cigarette Butt																		
	Tape																		
TOTAL							0.3041						0.0993					5.5876	

Table 56: Wet Weather Event Transect Data: At Mooloolah River Outfall, Mooloolah River

		Outfall 1					Outfall 2					Outfall 3							
		Class Size					Mass (g)	Class Size					Mass (g)	Class Size					Mass (g)
		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E	
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl/etc																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	B					0.044	A, 3B				0.7384							
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft	C					0.1055	E				0.2992							
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Clear stone																		
	Cigarette Butt																		
	Tape																		
TOTAL							0.1495						1.0376						0

Table 57: Wet Weather Event Transect Data: Industrial Estate Site, Mooloolah River

		Industrial Estate 1						Industrial Estate 2						Industrial Estate 3					
		Class Size						Class Size						Class Size					
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl/etc																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard																		
Soft Plastic	Thin film carry bag																		
	Food wrapper/label																		
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft																		
	Other plastic bag							E				0.4066							
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap																		
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Clear stone																		
	Cigarette Butt																		
	Tape																		
	TOTAL						0					0.4066							0

Table 58: Wet Weather Event Transect Data: Kawana Way Site, Mooloolah River

		Kawana Way 1					Kawana Way 2					Kawana Way 3							
		Class Size					Mass (g)	Class Size					Mass (g)	Class Size					Mass (g)
		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E	
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl/etc	E,					0.893												
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard	2B,C,D					1.6133	B,D				1.5844	C					0.5588	
Soft Plastic	Thin film carry bag																		
	Food wrapper/label							C			0.0531								
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft												D				0.6478		
	Other plastic bag																		
Plastic Straps	String/rope/ribbon																		
	Packing strap																		
	Cable ties							D			1.0951								
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap							C			0.0092								
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line							E			0.0314								
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Clear stone																		
	Cigarette Butt																		
	Tape																		
TOTAL		2.5063					2.7732					1.2066							

Table 59: Wet Weather Event Transect Data: Brightwater Site, Mooloolah River

		Brightwater 1						Brightwater 2						Brightwater 3					
		Class Size						Class Size						Class Size					
		A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)	A	B	C	D	E	Mass (g)
Hard Plastic	Pipe/PVC																		
	Beverage bottle <1L																		
	Other bottle																		
	Bottle cap/lid																		
	Food Container																		
	Utensil/plate/bowl/etc																		
	Bucket/crate																		
	Lighter																		
	Lollipop stick/earbud																		
	Unknown/ other hard							2C,E				2.6194							
Soft Plastic	Thin film carry bag																		
	Food wrapper/label	2E					7.3664	2D,E				2.742	2E					1.0747	
	Sheeting																		
	Cup/lid																		
	Straw																		
	Unknown/other soft												2E					2.5477	
	Other plastic bag							E				4.4345							
Plastic Straps	String/rope/ribbon												E					1.61	
	Packing strap																		
	Cable ties																		
	Unknown/other strap																		
Rubber	Thong/Shoe																		
	Tyre																		
	Balloon																		
	Rubber band																		
	Unknown/other																		
Cloth	String/rope/strap							D				0.3703							
	Clothing/towel																		
	Wipes/cloths																		
	Insulation/stuffing																		
	Unknown/other																		
Foam	Food container																		
	Cup/plates/bowls																		
	Polystyrene																		
	Unknown/other																		
Fishing	Net																		
	Fishing line																		
	Fishing lures																		
	Buoys/floats																		
	Glow stick																		
	Fishhook/sinker																		
	Unknown/other																		
Other	Sponge																		
	Paint																		
	MBBR Plastic																		
	Metal																		
	Clear stone																		
	Cigarette Butt																		
	Tape																		
	TOTAL						7.3664					10.1662						5.2324	

Appendix J SAQP E7 to E12: Assessment of background plastic in ocean water and sediment.



Kawana STP

Appendix J: SAQP E7 to E12 Assessment of Background Plastics in Ocean Water and Sediment.

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☐ freshwater

☐ estuarine

☐ marine

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Contents

1	Introduction	1
2	Methods	2
2.1	Surface and Bottom Water	2
2.2	Sediment Samples	6
2.3	Laboratory Analysis	8
3	Results and Discussion	9
3.1	Surface and Bottom Water Samples	9
3.2	Sediment Samples	12
3.3	Summary of Results	13
4	References	14

Attachment 1 E7 to E12 Laboratory Results

Tables

Table 2.1	Sample tracking log for surface and bottom water samples.	5
Table 2.2	Sample tracking log for sediment samples.	7
Table 3.1	Summary table of microplastics in ocean surface water.	10
Table 3.2	Summary table of microplastics in ocean bottom water.	11
Table 3.3	Summary table of microplastics in sediment samples collected from the ocean.	12
Table 3.4	Summary table of microplastics in sediment samples collected from the high tide mark at the beach.	13

Figures

Figure 2.1	Sampling locations for water and sediment samples in the ocean, and on the beach.	3
Figure 2.2	Release point W1: offshore diffuser site	4
Figure 2.3	Surface manta trawl in operation.	4
Figure 2.4	1L glass jar, used to hold sediment samples.	6

1 Introduction

This study investigated whether there was an accumulation of plastic, and in particular black polyethylene particles that may have originated from MBBR carriers, in water and sediment near the diffuser.

Water was sampled near the diffuser at the water surface and near the bottom. The Modelling report (Appendix H) indicated that the majority of plastic particles were likely to move to the north, and consequently a control site to the south was chosen (Intrawater 2022).

Modelling indicated that buoyant particles would likely accumulate at the high tide mark inshore of the diffusers (Intrawater 2022). However, while MBBR particles float, once they become covered in biofilms they may sink, in which case they are likely to accumulate near the diffuser. Consequently sediment was sampled near the high tide mark, and near the diffuser.

2 Methods

2.1 Surface and Bottom Water

A 'manta' net was used to sample surface and bottom water near the diffuser and at the control site at Raper Shoal (Figure 2.1 and Figure 2.2). The mouth of the manta net was 50 by 90 cm and it was towed for 1 km in a series of loops focussed on each site (Figure 2.3). Two 1 km long samples of surface and bottom water were collected at each site, a total of 8 trawls. The total volume of water sampled in each trawl was approximately 450,000 L (Table 2.1). All samples from potentially impacted sites were analysed. Where there was a positive identification of black polyethylene fragments in a sample from a potentially impacted site, then the equivalent sample from a control site was analysed. The samples that were analysed are listed in Table 2.1.



Figure 2.1 Sampling locations for water and sediment samples in the ocean, and on the beach.

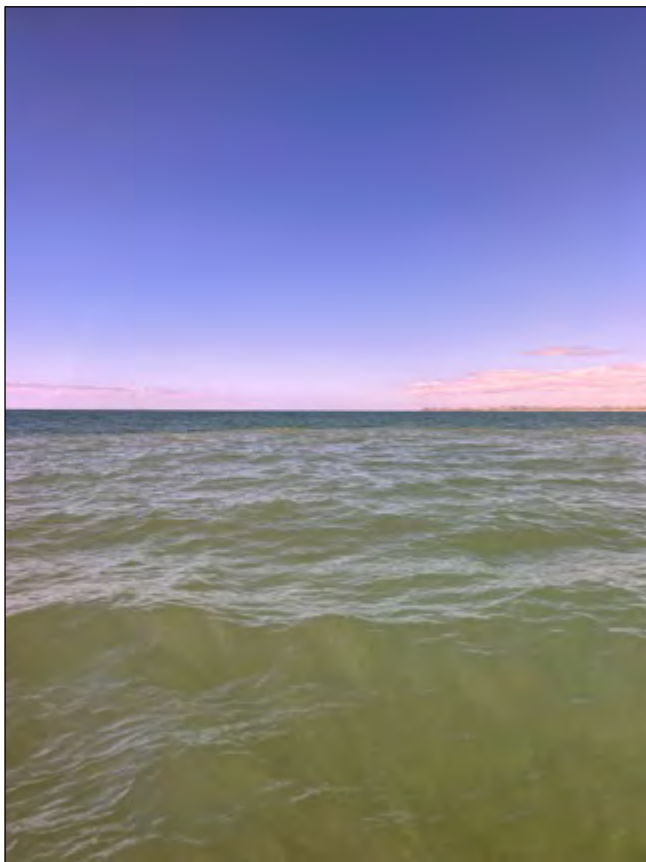


Figure 2.2 Release point W1: offshore diffuser site



Figure 2.3 Surface manta trawl in operation.

Table 2.1 Sample tracking log for surface and bottom water samples.

Sample #	Date Sampled	Analysed	Latitude	Longitude	Position	Water Depth (m)	Time In	Time Out	Speed (knots)	Weather and Sea Conditions
Potentially Impacted Site										
OW1	12-Apr-22	Yes	26°43.8725'S	153°08.8075'E	Surface	17.5	7:50	8:07	2	Clear and sunny, 2 m swell
OW2	12-Apr-22	Yes	26°43.8726'S	153°08.8075'E	Bottom	17.3	9:45	10:01	2	Clear and sunny, 2 m swell
OW5	19-Apr-22	Yes	26°45.881'S	153°09.075'E	Surface	17	14:28	15:20	2.5	Clear and sunny, 1 m swell
OW6	19-Apr-22	Yes	26°43.887'S	153°08.636'E	Bottom	16.8	10:17	10:45	2.5	Clear and sunny, 1 m swell
Control Site										
OW3	12-Apr-22	No	26°45.6157'S	153°08.3872'E	Surface	17.5	8:23	8:39	2	Clear and sunny, 2 m swell
OW4	12-Apr-22	Yes	26°45.6160S	153°09.2526'E	Bottom	17.4	9:06	9:23	2	Clear and sunny, 2 m swell
OW7	19-Apr-22	Yes	26°45.881'S	153°09.075'E	Surface	17	13:28	13:43	2.5	Clear and sunny, 1 m swell
OW8a*	19-Apr-22	No	26°45.618'S	153°08.848'E	Bottom	15.5	9:35	10:01	2	Clear and sunny, 1 m swell
OW8b*	19-Apr-22	No	26°45.618'S	153°08.848'E	Bottom	15.5	9:35	10:01	2	Clear and sunny, 1 m swell

* OW8a and OW8b comprise one sample that was split into 2 jars due to its size.

2.2 Sediment Samples

Two sediment samples were collected from each site. Beach sediment samples were collected at the high tide mark using a metal trowel, on 17 April 2022 (Table 2.2). Ocean sediment samples were collected on SCUBA on 19 April 2022, at similar depths at both the impact and control sites (Table 2.2). The top 2 to 5 cm of sediment was collected and placed in sealed 1 L glass jars (Figure 2.4). All samples from potentially impacted sites were analysed. Where there was a positive identification of black polyethylene fragments in a sample from a potentially impacted site, then the equivalent sample from a control site was analysed. The samples that were analysed are listed in Table 2.2.



Figure 2.4 1L glass jar, used to hold sediment samples.

Table 2.2 Sample tracking log for sediment samples.

Sample #	Date Sampled	Site Location	Analysed	Latitude	Longitude	Position	Water Depth (m)	Weather and Sea Conditions
Beach								
B1	17-Apr-22	Impact	Yes	26°43.784'S	153°08.095'E	High tide mark	0	Sediment was collected from areas of accumulation, however there was steep scarp erosion on most of the beach at the high tide mark.
B2	17-Apr-22	Impact	Yes	26°43.784'S	153°08.095' E	High tide mark	0	
B3	17-Apr-22	Control	No	26°33.984'S	153°05.9435' E	High tide mark	0	
B4	17-Apr-22	Control	No	26°33.984'S	153°05.9435' E	High tide mark	0	
Ocean								
B5	19-Apr-22	Impact	Yes	26°43.866'S	153°08.615' E	Bottom	16.8	Very low visibility (~30 cm), 1 m swell
B6	19-Apr-22	Impact	Yes	26°43.867'S	153°08.615' E	Bottom	16.8	
B7	19-Apr-22	Control	Yes	26°45.332'S	153°09.598' E	Bottom	17.0	Low visibility, 1 m swell
B8	19-Apr-22	Control	Yes	26°45.333'S	153°09.598' E	Bottom	17.0	

2.3 Laboratory Analysis

Laboratory methods are presented in Attachment 4 of Appendix D. In summary the samples were:

- digested using Fenton Agent
- sieved
- examined under a microscope coupled with image analysis, and microplastics extracted.

The microplastics were then collected and categorised according to their size class, colour and shape, and the polymer chemistry identified using spectral analysis. The likely polymer chemistry was assigned by matching to a Global polymer library, using the highest percent matching. Fragments that were black, and had the polymer type of 'black polyethylene' may have originated from MBBR plastic media.

Samples could not be directly compared to the plastic in MBBR carriers due to:

- the very small size of the microparticles
- the small number per sample
- the composition of the MBBR carriers: the carriers are made from recycled plastic, and consequently don't have a unique spectral signature, and as
- plastic particles in the environment chemically degrade and consequently the signature of a particle from an MBBR carrier would degrade.

Where there was a positive identification of black polyethylene fragments in a sample, then the equivalent samples from the control site was analysed.

3 Results and Discussion

3.1 Surface and Bottom Water Samples

- Results are summarised in Table 3.1 and Table 3.2.
- There was one black polyethylene particle, that may have originated from MBBR carriers, in one of the surface water samples from near the diffuser.
- There was one black polyethylene particle, that may have originated from MBBR carriers, in one of the bottom water samples from near the diffuser.
- There were not any black polyethylene particles in the remaining surface and bottom water samples collected near the diffuser, nor in the samples collected from the control sites.
- There were microplastic particles in all of the surface and bottom water samples that were analysed.
- In surface and bottom water samples from near the diffuser, one plastic particle in 22 was black polyethylene, that may have originated from MBBR carriers.

Table 3.1 Summary table of microplastics in ocean surface water.

Sample and Number	Type	Shape	Colour	Polymer Type*	Black Polyethylene	Library Match (%)
Potentially Impacted Samples from Near the Diffuser						
OW1		Fibre	White	PE	No	82.71
		Film	Clear	PVBC	No	36.96
		Fibre	Clear	PP	No	63.00
		Fibre	Clear	PE	No	81.89
		Rod Shaped	Green	PP	No	93.92
		Rod Shaped	Green	PP	No	58.47
		Fragment	Dark Green	PP	No	86.80
		Fibre	Black	Nylon/EVA	No	55.70
		Fibre	Black	PS resin	No	72.21
		Fibre	Blue	PSTIT	No	67.42
		Fibre	Black	PVPA	No	92.20
OW5		Rod Shaped	Blue	PP	No	95.53
		Rod Shaped	Green	PE	No	94.65
		Rod Shaped	Green	PE	No	91.23
		Rod Shaped	Green	PE	No	85.14
		Fragment	Black	Black PE	Yes	89.08
		Sphere	Pink	PE	No	97.86
		Fibre	Black	PP	No	88.72
		Fibre	Black	PP	No	81.08
		Fibre	Blue	PP	No	59.55
		Fibre	Blue	PE	No	68.33
		Fragment	Blue	PP	No	82.00
Control Samples						
OW7		Fibre	Blue	PE	No	36.96
		Fragment	Blue	PE	No	63.00

PA: Polyamide/Nylon, PE: Polyethylene, PE/EAC: Polyethylene/ Ethyl Acrylate Copolymer, PE-Chl: Chlorinated polyethylene, PEPD: Polyethylene Propylene Diene, PET: Polyethylene terephthalate, PP: Polypropylene, PS: Polystyrene, PSTIT: Polyester tere & isothalate, PVA: Polyvinyl alcohol, PVB: Polyvinyl butyral, PVBC: Polyvinyl butyl copolymer, PVC: Polyvinyl Chloride, PVPA: Polyvinyl Propionate Acrylate, SBCo: Styrene butadiene copolymer, PTFE: polytetrafluoroethylene, Black PE: Black polyethylene.

Table 3.2 Summary table of microplastics in ocean bottom water.

Sample and Number	Type	Shape	Colour	Polymer Type*	Black polyethylene	Library Match (%)
Potentially Impacted Samples from Near the Diffuser						
OW2		Fragment	Blue	PP	No	90.28
		Fibre	Blue	PE	No	86.60
		Fragment	Blue	PE	No	86.95
		Fragment	Black	Black PE	Yes	89.95
		Fragment	Dark blue	PE	No	89.61
		Fragment	Dark blue	PE	No	90.70
		Bead	White	PEPD	No	70.49
		Fibre	Blue	PA	No	46.67
		Fragment	Green	PP	No	89.50
		Fibre	Black	PE/EAC	No	78.00
		Fibre	Blue	PA	No	60.31
		Fibre	Black	PP	No	85.05
OW6		Rod shaped	Red	PE	No	87.64
		Fragment	Blue	PE	No	67.71
		Film	Yellow	PE	No	85.80
		Rod Shaped	Green	PE	No	76.50
		Fragment	Black	PA	No	66.18
		Rod Shaped	Black	PP	No	83.90
		Film	Clear	PE	No	93.59
		Fragment	White	PP:PE	No	69.34
		Fibre	Blue	PVC	No	39.31
		Fibre	Blue	PS	No	65.47
Control Samples						
OW4		Fragment	Green	PP	No	86.27

* Polymer types as in Table 3.1.

3.2 Sediment Samples

There were not any black polyethylene particles in sediment samples collected from near the diffuser nor at the high tide mark inshore of the diffuser, nor in any of the samples from the control sites (Table 3.3 and Table 3.4).

There were microplastic particles in all of the samples that were analysed.

Table 3.3 Summary table of microplastics in sediment samples collected from the ocean.

Sample and Number	Type	Shape	Colour	Polymer Type*	Black polyethylene	Library Match (%)
Potentially Impacted Samples from Near the Diffuser						
B5		Fibre	Blue	PA	No	40.04
		Fibre	Black	PET	No	79.95
B6		Fibre	Black	PVC	No	38.43
		Fibre	Black	PS	No	51.05
Control Samples						
B7		Fibre	Black	PVC	No	38.43
		Fibre	Black	PVC	No	39.68
B8		Fibre	Blue	PVC	No	31.44
		Fibre	Black	PTFE	No	36.11
		Fragment	Black	Styrene copolymer	No	22.47
		Fragment	Black	PP	No	36.80

* Polymer types as in Table 3.1.

Table 3.4 Summary table of microplastics in sediment samples collected from the high tide mark at the beach.

Sample and Number	Type	Shape	Colour	Polymer Type*	Black polyethylene	Library Match (%)
Potentially Impacted Samples						
B1		Fibre	Blue	PS	No	81.62
		Fibre	Blue	PVA	No	61.05
		Fibre	Blue	PVA	No	61.20
		Fibre	Blue	PVA	No	61.41
		Fibre	Red	PVPA	No	89.69
B2		Foam	White	PS	No	80.66

* Polymer types as in Table 3.1.

3.3 Summary of Results

There were black polyethylene particles in surface and bottom water near the diffuser, but not in any of the sediment samples near the diffuser, inshore of the diffuser near the high tide mark, or at the control sites.

4 References

frc environmental 2014, *Underwater inspection of the Kawana Sewage Treatment Plant (STP) ocean outfall*, report prepared for CH2M HILL.

Attachment 1 E7 to E12 Laboratory Results

MICROPLASTICS - REPORT OF ANALYSIS

Job description	: Investigating the Characteristics of Microplastics in Oceanic Sediment and Water		
Job status	: Completed		
Work order	:	Laboratory	: Microplastics Laboratory - GICAN
Client Contact	: Carol Conacher	Contact	: thavapalanisami@newcastle.edu.au
Address	: Unit 1, 7-9 Grant St Cleveland QLD 4163	Address	: Global Innovative Centre for Advanced Nanomaterials (GICAN) College of Engineering, Science and Environment THE UNIVERSITY OF NEWCASTLE UNIVERSITY DRIVE CALLAGHAN NSW 2308
Telephone	: +61 7 3286 3850		
Order number	:		
C-O-C number	:		
Sampler	:		
Site	: Pacific Ocean	Telephone	: + 61 431 300 521
No. of samples analysed	: 12	Report ID and issue date	: E7-E12 Ocean_Sediment_Water_2022-06-30

This certificate of analysis contains the following information:

- General comments
- Laboratory Report

ABBREVIATIONS:

g – grams, μm – micrometer; MPs – Microplastics; kL – kilolitres

Abbr.	Polymer Type
Black PE	Black Polyethylene fragments
Nylon/EVA tie layer	Nylon/Ethylene vinyl acetate
PA	Polyamide
PE	Polethylene
PE/EAC	Polyethylene/ Ethyl Acrylate Copolumer
PEPD	Polyethylene Propylene Diene
PET	Polethylene terephthalate
PP	Polypropylene
PP:PE	Polypropylene:Polyethylene
PS	Polystyrene
PSTIT	Polyester tere & isothalate
PTFE	Polytetrafluroethylene
PVA	Polyvinyl alcohol
PVBC	Polyvinyl butryl copolymer
PVC	Polyvinyl Chloride
PVPA	Polyvinyl Propionate Acrylate
Styrene copolymer	Styrene

Data Sheet of Water Metadata

Sample #	Sample Code	Sample Type	Date Sampled	Sample Volume (kL)
1	OW1	Water	12/04/2022	45
2	OW2	Water	12/04/2022	45
3	OW4	Water	12/04/2022	45
4	OW5	Water	19/04/2022	45
5	OW6	Water	19/04/2022	45
6	OW7	Water	19/04/2022	45

The labels are given according to the suppliers file name "211109 COC Plastics 22-04-24 DS".

*The labels are given as such from the sample containers as per the advice from the suppliers.

Data Sheet of Sediment Metadata

Sample #	Sample Code	Sample Type	Date Sampled	Sample Weight (g)
7	B1	Sediment	17/04/2022	100
8	B2	Sediment	17/04/2022	100
9	B5	Sediment	19/04/2022	100
10	B6	Sediment	19/04/2022	100
11	B7	Sediment	19/04/2022	100
12	B8	Sediment	19/04/2022	100

The labels are given according to the suppliers file name "211109 COC Plastics 22-03-15 EH".

*The labels are given as such from the sample containers as per the advice from the suppliers.

Data Sheet of Microplastic Abundance In Water

Sample #	Sample Code	Sample Volume (kL)	Total No. of MPs	Mean No. MPs (total/kL)
1	OW1	45	11	0.24
2	OW2	45	11	0.24
3	OW4	45	1	0.02
4	OW5	45	11	0.24
5	OW6	45	11	0.24
6	OW7	45	2	0.04

Data Sheet of Microplastic Characterisation in Water

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
1	OW1	1	0	1	White	fibre	PE	82.71
	OW1	1	0	1	Clear	film	PVBC	36.96
	OW1	1	0	1	Clear	film	PP	63.00
	OW1	1	0	1	Clear	film	PE	81.89
	OW1	1	0	1	Green	Rod shaped	PP	93.92
	OW1	1	0	1	Green	Rod shaped	PP	58.47
	OW1	1	0	1	Dark green	fragment	PP	86.80
	OW1	1	1	0	Black	fibre	Nylon/EVA tie layer	55.70
	OW1	1	1	0	Black	fibre	PS resin	72.21
	OW1	1	1	0	Blue	fibre	PSTIT	67.42
	OW1	1	1	0	Black	fibre	PVPA	92.20
	OW2	1	0	1	Blue	fragment	PP	90.28
2	OW2	1	0	1	Blue	fibre	PE	86.60
	OW2	1	0	1	Blue	fragment	PE	86.95
	OW2	1	0	1	Black	fragment	Black PE	89.95

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
	OW2	1	0	1	Dark blue	fragment	PE	89.61
	OW2	1	0	1	Dark blue	fragment	PE	90.70
	OW2	1	1	0	White	bead	PEPD	70.49
	OW2	1	1	0	Blue	fibre	PA	46.67
	OW2	1	1	0	Green	fragment	PP	89.50
	OW2	1	1	0	Black	fibre	PE/EAC	78.00
	OW2	1	1	0	Blue	fibre	PA	60.31
3	OW4	1	0	1	Green	fragment	PP	86.27
4	OW7	1	1	0	Blue	fibre	PE	36.96
	OW7	1	1	0	Blue	fragment	PE	63.00
5	OW5	1	0	1	Blue	Rod shaped	PP	95.53
	OW5	1	0	1	Green	Rod shaped	PE	94.65
	OW5	1	0	1	Green	Rod shaped	PE	91.23
	OW5	1	0	1	Green	Rod shaped	PE	85.14
	OW5	1	0	1	Black	fragment	Black PE	89.08
	OW5	1	0	1	Pink	sphere	PE	97.86

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
	OW5	1	0	1	Black	fibre	PP	88.72
	OW5	1	0	1	Black	fibre	PP	81.08
	OW5	1	1	0	Blue	fibre	PP	59.55
	OW5	1	1	0	Blue	fibre	PE chlorinated	68.33
	OW5	1	1	0	Blue	fragment	PP	82.00
6	OW6	1	0	1	Black	fibre	PP	85.05
	OW6	1	0	1	Red	Rod shaped	PE	87.64
	OW6	1	0	1	Blue	fragment	PE	67.71
	OW6	1	0	1	Yellow	film	PE	85.80
	OW6	1	0	1	Green	Rod shaped	PE	76.50
	OW6	1	0	1	Black	fragment	PA	66.18
	OW6	1	0	1	Black	Rod shaped	PP	83.90
	OW6	1	0	1	Clear	film	PE	93.59
	OW6	1	0	1	White	fragment	PP:PE	69.34
	OW6	1	1	0	Blue	fibre	PVC	39.31
	OW6	1	1	0	Blue	fibre	PS	65.47

Data Sheet of Microplastic Abundance in Sediment

Sample #	Sample Code	Sample Weight (g)	Total No. of MPs	Mean No. MPs (total/g)
7	B1	100	5	0.05
8	B2	100	1	0.01
9	B5	100	2	0.02
10	B6	100	2	0.02
11	B7	100	2	0.02
12	B8	100	4	0.04

Data Sheet of Microplastic Characterisation in Sediment

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
7	B1	1	0	1	Blue	fibre	PS	81.62
		1	1	0	Blue	fibre	PVA	61.05
		1	1	0	Blue	fibre	PVA	61.20
		1	1	0	Blue	fibre	PVA	61.41
		1	1	0	Red	fibre	PVPA	89.69
8	B2	1	0	1	White	foam	PS	80.66
9	B5	1	1	0	Blue	Fibre	PA	40.04
		1	1	0	Black	fibre	PET	79.95
10	B6	1	1	0	Black	fibre	PVC	38.43
		1	1	0	Black	fibre	PS	51.05
11	B7	1	1	0	Black	fibre	PVC	38.43
		1	1	0	Black	fibre	PVC	39.68
12	B8	1	1	0	Blue	Fibre	PVC	31.44
		1	1	0	Black	Fibre	PTFE	36.11
		1	1	0	Black	fragment	Styrene copolymer	22.47
		1	1	0	Black	fragment	PP	36.8

Appendix K SAQP E19 to E22: Assessment of plastic in river water and sediment, following a wet weather event.



Kawana STP

Appendix K: SAQP E19 to E22: Assessment of Plastic in River Water and Sediment, Following a Wet Weather Event.

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Contents

1	Introduction	1
2	Methods	2
2.1	Surface Water	2
2.2	Sediment	2
2.3	Laboratory Analysis	3
3	Results and Discussion	6
4	References	10

Attachment 1 E19 to E22 Laboratory Results

1 Introduction

The Mooloolah River Catchment is between the coast and the Blackall Ranges, covering a total area of approximately 223 km². The River flows in a general east north-easterly direction with the mouth discharging into the Pacific Ocean west of Point Cartwright (Healthy Waterways 2015).

Release point W3 is licensed under the Environmental Authority (the EA) as the secondary outfall of the Kawana STP. Release point W3 is in the upper estuary, approximately 15 km upstream of the river mouth.

During significant rainfall events wet weather overflows can overwhelm the stormwater network and spill over into the sewer system. Under the EA additional effluent can be released from W3 during wet weather flows (Figure 1.1).

This study investigated whether plastic particles, and in particular black polyethylene particles that may have originated from MBBR carriers, accumulated in water and sediment in the Mooloolah River during a designated wet weather overflow when treated effluent was released into the Mooloolah River. The purpose was to identify the scale of plastics occurring in the aquatic environment and quantify the contribution that may have been made by MBBR media plastic following a wet weather release.



Figure 1.1 Release site W3 during following a wet weather release.

2 Methods

On 24 February 2022, river water and sediment were sampled during a known release of treated effluent into the Mooloolah River from W3 (Map 2.1).

Sample sites were based on preliminary modelling indicated that any plastic particles discharged in the effluent from W3 would likely accumulate in the upper estuary. Dispersion modelling was completed after the wet weather event, and indicated that plastic would accumulate in this general vicinity, and in particular above Parrearra Weir (Appendix H: Dispersion Modelling; Map 2.1).

2.1 Surface Water

Surface water was sampled using a circular plankton trawl net, with a sampling area of 0.033m². One surface water sample was collected at each of three sites downstream of W3 and at an upstream control site (Map 2.1, Table 2.1). The net was towed for approximately 500 m against the flow of current, sampling between approximately 3000 to 6000 L of water. A blank elutriate sample was also collected from the net.

Samples were sent to the designated laboratory and analysed for the number and weight of plastic particles and of black polyethylene particles > 330 micron per litre of sample. The samples that were analysed are listed in Table 2.1.

2.2 Sediment

Sediment samples were collected from five sites along the Mooloolah River downstream of W3 (Map 2.1, Table 2.1). One control sample was taken from a site 500 m upstream of W3. Each sample was collected from a depositional bank in approximately 10 cm of water.

Metal trowels were used to collect 1 kg of the top 5 cm of sediment. The sediment was placed in glass jars and labelled with paper labels.

Samples were sent to the designated laboratory and analysed for the number and weight of plastic particles and of black polyethylene particles > 330 micron per litre of sample. The samples that were analysed are listed in Table 2.1.

Where there was a positive identification of black polyethylene particles in a sample, then the sample from the control site, the blank, and from sites further downstream were analysed.

2.3 Laboratory Analysis

Laboratory methods are presented in Attachment 4 of Appendix D. In summary the samples were:

- digested using Fenton Agent
- sieved
- examined under a microscope coupled with image analysis, and microplastics extracted.

The microplastics were then collected and categorised according to their size class, colour and shape, and the polymer chemistry identified using spectral analysis. The likely polymer chemistry was assigned by matching to a Global polymer library, using the highest percent matching. Fragments that were black, and had the polymer type of 'black polyethylene' may have originated from MBBR plastic media.



Map 2.1 Sample sites for river water and sediment, following a wet weather event, overlain on dispersion modelling results for a wet weather overflow.

Table 2.1 E19 to E22: Surface water and sediment samples collected in the Mooloolah River following a wet weather release.

Sample #	Date Sampled	Analysed	Location	Latitude	Longitude
Surface Water					
Potentially Impacted Sites					
DST1	24-Feb-22	Yes	At release site W3	26°43'33.5"S	153°06'59.1"E
DST2	24-Feb-22	No	Downstream 4-5km	26°42'30.7"S	153°07'06.9"E
DST3	24-Feb-22	Yes	Downstream 1.5-2.5 km	26°43'04.4"S	153°07'09.5"E
Control Site					
UST	24-Feb-22	No	Upstream 1km	26°43'31.6"S	153°06'40.6"E
Blank					
CT	24-Feb-22	No	-	-	-
Sediment					
Potentially Impacted Sites					
DS1_R1	24-Feb-22	Yes	Downstream 300m	26°43'25.0"S	153°06'58.7"E
DS1_R2	24-Feb-22	No	Downstream 300m	26°43'25.0"S	153°06'58.7"E
DS2_R1	24-Feb-22	Yes	Downstream 600m	26°43'33.5"S	153°06'57.4"E
DS2_R2	24-Feb-22	No	Downstream 600m	26°43'33.5"S	153°06'57.4"E
DS3	24-Feb-22	No	Downstream 1.5km	26°43'15.6"S	153°07'21.6"E
DS4	24-Feb-22	No	Downstream 2.5km	26°42'58.0"S	153°07'01.5"E
DS5	24-Feb-22	No	Downstream 4km	26°42'29.8"S	153°07'07.5"E
Control Sites					
US_R1	24-Feb-22	No	Upstream 500m	26°43'40.2"S	153°06'39.2"E
US_R2	24-Feb-22	No	Upstream 500m	26°43'40.2"S	153°06'39.2"E

3 Results and Discussion

Results of the analyses are presented in Table 3.1 and Table 3.2. In summary:

- Black polyethylene particles were not found in surface water or sediment samples in the Mooloolah River.
- All surface water samples had microplastics, most of fragment shape (~75%).
- There were more microplastics in surface water at the release site W3 (88 particles) than 4-5 km downstream (17 particles).
- All sediment samples had microplastics, most of fragment shape (72-97%).
- There were more microplastics in sediment 300 m downstream from the release site (39 particles) than 600 m downstream (33 particles)
- Fibres comprised a higher proportion of the microplastics in surface water and sediment samples closer to the release point.

Thus, although there was a higher number of microplastics in close proximity to release point W3, no black polyethylene particles were found. This indicates that MBBR-particles are unlikely to have accumulated within the surface water and sediment of the Mooloolah River during a release event.

Table 3.1 Summary table of microplastic size and shape found in river surface water and sediment.

Sample Type and Number	Sample Size	Microplastic Shape	Size Class						Total
			≥1mm	≥500 µm	≥250 µm	≥125 µm	≥63 µm	≤63-11 µm	
Surface Water									
Potentially Impacted Sites									
DST1	2 Litres	Fibres	1	1	2	2	2	12	20
		Fragments	1	7	25	23	10	0	66
		Microbead	0	0	1	1	0	0	2
DST3	2.5 Litres	Fibres	0	0	0	0	0	4	4
		Fragments	1	1	0	6	1	4	13
		Microbead	0	0	0	0	0	0	0
Sediment									
Potentially Impacted Sites									
DS1_R1	100 grams	Fibres	0	0	0	3	6	0	9
	(58.8 grams dry weight)	Fragments	1	2	2	7	12	4	28
		Microbead	0	0	0	2	0	0	2
DS2_R1	100 grams	Fibres	0	0	0	1	0	0	1
	(88.02 grams dry weight)	Fragments	3	2	4	6	1	16	32
		Microbead	0	0	0	0	0	0	0

Table 3.2 Summary table of microplastic types in river surface water and sediment.

Sample and Number	Type	Shape	Colour	Polymer Type*	Black polyethylene	Library Match (%)
Surface Water						
Potentially Impacted Sites						
DST1	Fragment	Black		PP	No	85.21
	Fragment	Dark		PEPDM	No	73.7
	Fragment	Dark		PE	No	71.77
	Fragment	Dark		PEPDM	No	70.83
	Fragment	Dark		PEPDM	No	65.89
	Fragment	Dark		PE	No	61.14
	Fragment	White		PEPDM	No	60.95
	Fragment	White		PAA	No	51.11
	Fragment	Black		PTFE	No	50.97
	Microbead	Yellow		PA	No	<50
	Fragment	Transparent		PTFE	No	<50
	Fragment	White		PAA	No	<50
	Fragment	Green		PTO	No	<50
	Fiber	Black		PTFE	No	<50
	Fragment	White		PECA	No	<50
	Microbead	Yellow		PANMMA	No	<50
	Fragment	White		PVC	No	61.38
	Fiber	Black		PE/PEA	No	59.35
	Fragment	Black		PMPO	No	57.08
DST3	Fragment	Black		PMPI	No	54.82
	Fragment	Black		PVB	No	54.31
	Fragment	White		PVA	No	51.52
	Fiber	Blue		N	No	49.59
Sediment						
Potentially Impacted Sites						
DS1_R1	Fragment	Black		SMA	No	<50
	Fragment	White		PIIR	No	<50

Sample Type and Number	Shape	Colour	Polymer Type*	Black polyethylene	Library Match (%)
DS2_R1	Fiber	Blue	PA	No	<50
	Fiber	Black	PA	No	<50
	Fragment	White	PU	No	<50
	Microbead	White	PVDF	No	<50
	Fragment	White	PVDF	No	<50
	Microbead	White	R	No	<50
	Fiber	Blue	R	No	<50
	Fragment	Green Blue	PVB	No	<50
	Fragment	White	PVB	No	<50
	Fragment	Black	R	No	<50
	Fragment	Black	PSSM	No	<50
	Fragment	Black	PP	No	<50
	Fragment	Creamy White	R	No	<50
	Fragment	Creamy White	PP	No	<50
	Fragment	Creamy White	R	No	<50
	Fragment	Creamy White	R	No	<50
	Fragment	Black	PSSM	No	50.11
	Fragment	Transparent	PEU	No	<50
	Fragment	Creamy White	PSSM	No	<50
	Fragment	Black	PA	No	<50
	Fragment	Black	PET	No	<50
	Fragment	Black	PSSM	No	<50
	Fragment	Black	PVA	No	<50
	Fragment	Black	A	No	<50

* A: Acrylate, N: Nylon, PA: Polyamide, PAA: Poly(Acrylic Acid), PANMMA: Poly(acrylonitrile:MMA), PE: Poly(Acrylic Acid), PEA: Poly(ethyl acrylate), PECA: Poly(ethyl cyanoacrylate), PEPDM: Poly(ethylene:propylene:diene), PET: Polyethylene terephthalate, PEU: Polyetherurethane, PIIR: Poly(isobutene:isoprene), PMPI: Poly(2-methylphenylisocyanate), PMPO: Poly(4-methyl-1-penten-3-one), PP: Polypropylene, PSSM: Poly(styrene-4-sulfonate, Magnesium), PTFE: Polytetrafluoroethylene, PTO: Poly(terephthaloyl oxamidrazone), PU: Polyurethane, PVA: Polyvinyl alcohol, PVB: Polyvinyl butyral, PVC: Polyvinyl Chloride, PVDF: Poly(vinylidene fluoride), R: Rayon, SMA: Styrene/maleic anhydride

4 References

Healthy Waterways 2015, *Mooloola Condition 2015*, viewed 17 April 2017, <https://hlw.org.au/download/2015-healthy-waterways-report-card/>.

Attachment 1 E19 to E22 Laboratory Results

MICROPLASTICS - REPORT OF ANALYSIS

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This certificate of analysis contains the following information:

- General comments
- Laboratory Report

ABBREVIATIONS:

g – grams, μm – micrometer; MPs – Microplastics; kL – kilolitres

Abbr.	Polymer Type
A	Acrylate
N	Nylon
PE	Polyethylene
PEA	Poly(ethyl acrylate)
Black PE	Black Polyethylene fragments
PA	Polyamide
PAA	Poly(Acrylic Acid)
PANMMA	Poly(acrylonitrile:MMA)
PECA	Poly(ethyl cyanoacrylate)
PE-Chl	Chlori-ated polyethylene
PEPDM	Poly(ethylene:propylene:diene)
PET	Polyethylene terephthalate
PEU	Polyetherurethane
PIIR	Poly(isobutene:isoprene)
PMPI	Poly(2-methylphenylisocyanate)
PMPO	Poly(4-methyl-1-penten-3-one)
PP	Polypropylene
PS	Polystyrene
PSSM	Poly(styrene-4-sulfonate, Magnesium)
PTFE	Polytetrafluoroethylene
PTO	Poly(terephthaloyl oxamidrazone)
PU	Polyurethane
PVA	Polyvinyl alcohol
PVB	Polyvinyl butyral
PVC	Polyvinyl Chloride
PVDF	Poly(vinylidene fluoride)
R	Rayon
SBCo	Styrene butadiene copolymer
SMA	Styrene/maleic anhydride copolymer
PS	Polystyrene
PSSM	Poly(styrene-4-sulfonate, Magnesium)
PTFE	Polytetrafluoroethylene

Data Sheet of Water Metadata

Sample #	Sample Code	Sample Type	Date Sampled	Sample Volume (kL)
1	DST1	Water	24/02/2022	64.76
2	DST3	Water	24/02/2022	31.98

The labels are given according to the suppliers file name "211109 COC Plastics 22-03-15 EH".

*The labels are given as such from the sample containers as per the advice from the suppliers.

Data Sheet of Sediment Metadata

Sample #	Sample Code	Sample Type	Date Sampled	Sample Weight (g)
3	DS1_R1	Sediment	24/02/2022	100
4	DS2_R2	Sediment	24/02/2022	100

The labels are given according to the suppliers file name "211109 COC Plastics 22-03-15 EH".

*The labels are given as such from the sample containers as per the advice from the suppliers.

Data Sheet of Microplastic Abundance In Water

Sample #	Sample Code	Sample Volume (kL)	Total No. of MPs	Mean No. MPs (total/kL)
1	DST1	64.76	88	1.36
2	DST3	31.98	17	0.53

Data Sheet of Microplastic Size and Shape in Water

Sample #	Sample Code	MP Shape	No. of MPs (≥1mm)	No. of MPs (≥500 µm)	No. of MPs (≥250 µm)	No. of MPs (≥125 µm)	No. of MPs (≥63 µm)	No. of MPs (≤63-11 µm)	Total No. MPs
1	DST1	Fibres	1	1	2	2	2	12	20
		Fragments	1	7	25	23	10	0	66
		Microbead	0	0	1	1	0	0	2
2	DST3	Fibres	0	0	0	0	0	4	4
		Fragments	1	1	0	6	1	4	13
		Microbead	0	0	0	0	0	0	0

Data Sheet of Microplastic color and polymer types in water samples

Sample #	Sample Code	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
1	DST1	Black	Fragment	PP	85.21
		Dark	Fragment	PEPDM	73.7
		Dark	Fragment	PE	71.77
		Dark	Fragment	PEPDM	70.83
		Dark	Fragment	PEPDM	65.89
		Dark	Fragment	PE	61.14
		White	Fragment	PEPDM	60.95
		White	Fragment	PAA	51.11
		Black	Fragment	PTFE	50.97
		Yellow	Microbead	PA	<50
		Transparent	Fragment	PTFE	<50
		White	Fragment	PAA	<50
		Green	Fragment	PTO	<50
		Black	Fiber	PTFE	<50
		White	Fragment	PECA	<50

Sample #	Sample Code	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
		Yellow	Microbead	PANMMA	<50
2	DST3	White	Fragment	PVC	61.38
		Black	Fiber	PE/PEA	59.35
		Black	Fragment	PMPO	57.08
		Black	Fragment	PMPI	54.82
		Black	Fragment	PVB	54.31
		White	Fragment	PVA	51.52
		Blue	Fiber	N	49.59

Data Sheet of Microplastic Abundance in Sediment samples

Sample #	Sample Code	Sample Weight (g)	Total No. of MPs	Mean No. MPs (total/g)
3	DS1_R1	100	39	0.39
4	DS2_R2	100	33	0.33

Data Sheet of Microplastic Size and Shape in Sediment

Sample #	Sample Code	MP Shape	No. of MPs (≥1mm)	No. of MPs (≥500 µm)	No. of MPs (≥250 µm)	No. of MPs (≥125 µm)	No. of MPs (≥63 µm)	No. of MPs (≤63-11 µm)	Total No. MPs
3	DS1_R1	Fibres	0	0	0	3	6	0	9
		Fragments	1	2	2	7	12	4	28
		Microbead	0	0	0	2	0	0	2
4	DS2_R2	Fibres	0	0	0	1	0	0	1
		Fragments	3	2	4	6	1	16	32
		Microbead	0	0	0	0	0	0	0

Data Sheet of Microplastic color and polymer types in Sediment samples

Sample #	Sample Code	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
3	DS1_R1	Black	Fragment	SMA	<50
		White	Fragment	PIIR	<50
		Blue	Fiber	PA	<50
		Black	Fiber	PA	<50
		White	Fragment	PU	<50
		White	Microbead	PVDF	<50
		White	Fragment	PVDF	<50
		White	Microbead	R	<50
		Blue	Fiber	R	<50
		Green Blue	Fragment	PVB	<50
		White	Fragment	PVB	<50
		Black	Fragment	R	<50
DS2_R1	DS2_R1	Black	Fragment	PSSM	<50
		Black	Fragment	PP	<50
		Creamy White	Fragment	R	<50

Sample #	Sample Code	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
		Creamy White	Fragment	PP	<50
		Creamy White	Fragment	R	<50
		Creamy White	Fragment	R	<50
		Black	Fragment	PSSM	50.11
		Transparent	Fragment	PEU	<50
		Creamy White	Fragment	PSSM	<50
		Black	Fragment	PA	<50
		Black	Fragment	PET	<50
		Black	Fragment	PSSM	<50
		Black	Fragment	PVA	<50
		Black	Fragment	A	<50

Appendix L SAQP E23 to E32: Assessment of plastic in biota in the river.



Kawana STP

Appendix L: SAQP E23 to E32: Assessment of Plastic in Biota in the River, Including Biota Available for Human Consumption

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Contents

1	Introduction	5
2	Species, Habitats and Environmental Values that May be Impacted	6
2.1	Habitats in the Mooloolah River	6
2.2	Target Species for Collection	10
3	Methods	13
3.1	Filter Feeding Invertebrates	13
3.2	Other Invertebrates	14
3.3	Fin Fish	15
3.4	Laboratory Analysis	23
4	Results and Discussion	24
4.1	Black Polyethylene Particles	24
4.2	Total Plastic Particles	24
5	References	30

Attachment 1: E23 to E32 Lab Results

Tables

Table 2.1	Ray-finned fish that occur in the estuary, and that may be suitable for sampling.	11
Table 3.1	Summary of sample collection methods	15
Table 3.2	Biota collected at potentially impacted sites and at control sites.	18
Table 4.1	Summary table of microplastics that were found in river biota samples.	26

Figures

Figure 2.1	Coastal wetlands vegetation mapping of the Mooloolah River (modified from Stephens & Dowling 1998).	8
Figure 2.2	Habitat near Release point 3 in the Mooloolah River.	9
Figure 2.3	Habitat in the middle estuary of the Mooloolah River, 4 km downstream of W3.	9
Figure 2.4	Rocky shoreline habitat at the mouth of the Mooloolah River.	10
Figure 3.1	Oysters collected 3.5 downstream of site W3.	13
Figure 3.2	Crabs (<i>Uca coarctata</i>) hand collected at the release site W3.	14
Figure 3.3	Sea Mullet (<i>Mugil cephalus</i>) collected at the release site W3 by cast netting.	15

Maps

Map 3.1	Mooloolah River biota sampling sites, overlain on results of dispersion modelling for dry weather discharge (Scenario 1).	16
Map 3.2	E23 to E32 Maroochy River biota sampling sites	17

1 Introduction

The Mooloolah River Catchment is between the coast and the Blackall Ranges covering a total area of 223 km² (Healthy Waterways 2015). The Mooloolah River flows in a general east north-easterly direction with the mouth discharging into the Pacific Ocean west of Point Cartwright.

Under their Environmental Authority (EA) Unitywater are authorised for the restricted discharge of treated effluent from Kawana STP via release point W3. Release point W3 is approximately 15 km upstream of the mouth of the river.

The STP is currently designed for a treatment capacity of 200,000 EP. Release point W3 can only be used when Release point W1 is not available due to maintenance, or when there is excessive rainfall resulting in excess of three times average dry weather flow reporting to the Kawana sewage treatment plant and storage of the effluent is no longer possible.

This study investigated whether black polyethylene particles, that may have originated from MBBR, particles accumulate in biota in the river, with both stationary filter feeders, and more mobile fish species targeted for collection.

2 Species, Habitats and Environmental Values that May be Impacted

2.1 Habitats in the Mooloolah River

The Mooloolah River outfall (W3) is approximately 9 km upstream from the mouth of the river, in the upper reaches of the estuary. It consists of an outfall pipe with an internal diameter of approximately 900 mm that was constructed on the south bank of the Mooloolah River in 2015 (Intrawater 2020). Much of the sub catchment is wetland, including extensive palustrine wetlands and constructed waterbodies (canals and the ring tank reservoir).

Environmental values, water quality objectives and existing condition of the Mooloolah River Estuary are presented in (Intrawater 2020) and EHMP 2021. In summary:

- applicable Water Quality Objectives (WQO) according to the Queensland Water Quality Guidelines (QWQG) in the vicinity of the discharge are for the upper estuary, and for downstream of W3 are for the mid estuary and remains in “fair” condition.
- compliance with water quality objectives is relatively high
- land clearing and run-off in the upper catchment has increased sediment and nutrient loads
- freshwater health is deemed excellent
- pollutant loads increased significantly in 2021 to very high. Sediment (mud) loads increased from 556 kg/ha in 2020 to 723 kg/ha in 2021. Mooloolah is susceptible to hillslope erosion and landslips in the upper catchment with the significant rainfall events in December 2020 and March 2021 potentially activating these high-risk areas, and
- estuarine water quality remains excellent despite a slight decrease in dissolved oxygen in the mid estuary. Total nitrogen improved in the mid estuary within the Mooloolah River National Park.

The outfall is in the upper reaches of the Estuary, with nearby riparian vegetation consisting of *Casuarina* forest and mangroves (*Bruguiera gymnorhiza* and mixed mangrove forests) (Figure 2.1 and Figure 2.2). From the outfall downstream to Kawana Way, the Estuary winds through the Mooloolah River National Park, where vegetation is essentially unaltered. The Parrearra Bypass canal has weirs at both ends, and a loch at the northern end, and provides flood storage. The condition of habitat is assessed each year in the Ecosystem Health Monitoring Program (EHMP) for South East Queensland with the last EHMP report card issued in 2021 (HLW 2021).

In summary:

- Stream bank vegetation remains in good condition (85% cover), with high levels of stream bank vegetation preventing erosion of sediments (Figure 2.3).
- Wetland extent remains in poor condition (30% cover) in the freshwater reaches of the catchment.
- extent of wetland habitat in the estuary remains in fair condition, with 48% of mangroves and saltmarshes remaining in the catchment.

From Kawana Way to the Sunshine Motorway mangroves line the foreshore, however downstream of the Sunshine Motorway the Estuary is highly modified with canal estates and a marina, and little to no riparian vegetation (Figure 2.4)(DES 2017). Clearing of mangroves reduces habitat for fish communities and shoreline stability, and while the upper estuary has moderate mangrove cover it is still low compared to nearby estuaries (Mackenzie & Duke 2017).

The catchments are underlain by mostly low permeability rock in the north, and sedimentary rock in the south. There is basalt in the upper reaches of both catchments, which is prone to slumping and landslips, together with small areas of fractured metamorphic rock. On lower lying lands there is alluvium and other unconsolidated sediments.

The unconsolidated sediments across the catchments enable high amounts of water infiltration and recharge of groundwater. This provides an important contribution to springs, creeks, wetlands and terrestrial vegetation year round.

Fish communities in the river are anticipated to be typical of estuaries in south east Queensland with urbanised foreshores, with opportunistic species such as bream likely dominating (Yabsley et al. 2018).

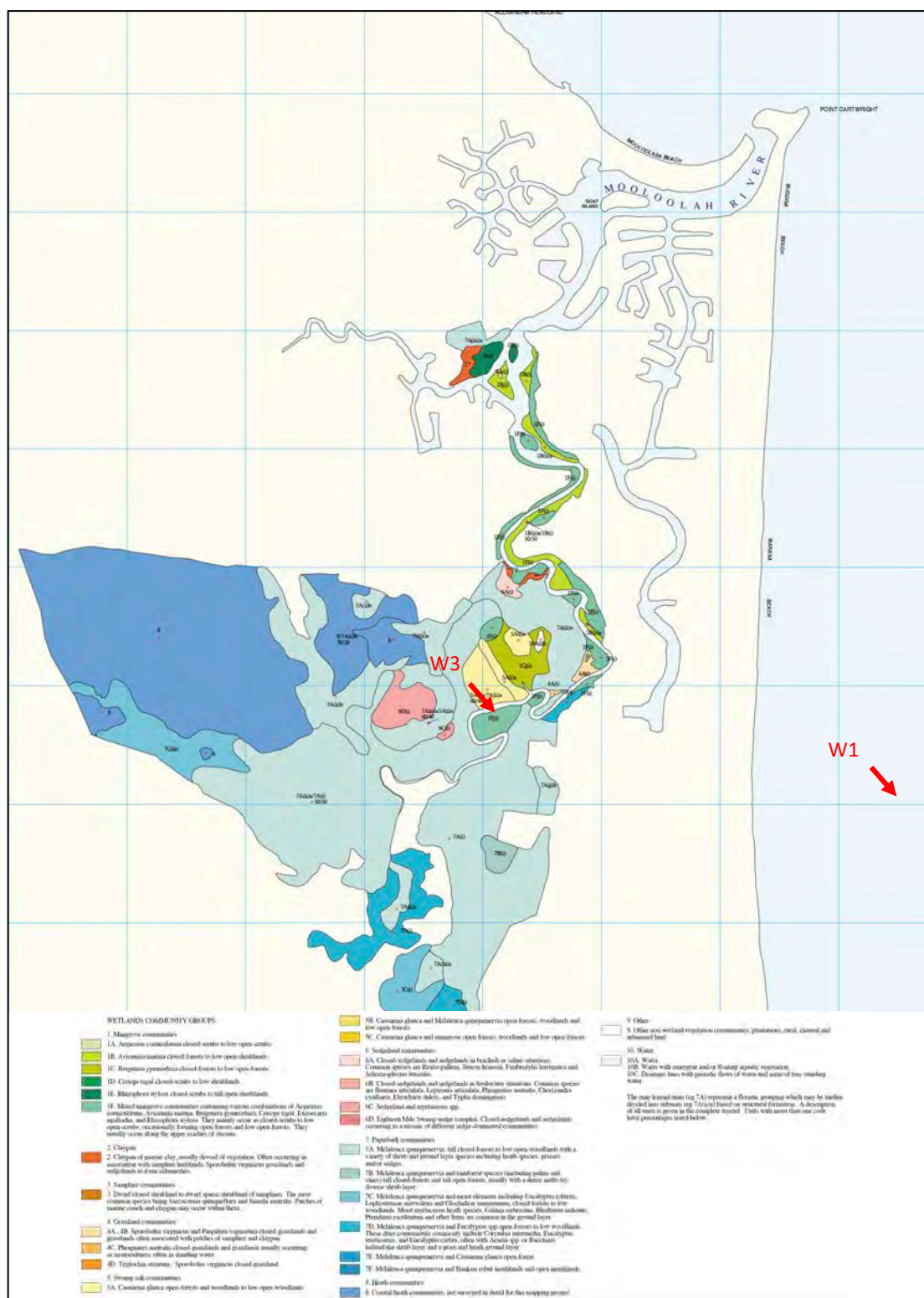


Figure 2.1 Coastal wetlands vegetation mapping of the Mooloolah River (modified from Stephens & Dowling 1998).



Figure 2.2 Habitat near Release point 3 in the Mooloolah River.



Figure 2.3 Habitat in the middle estuary of the Mooloolah River, 4 km downstream of W3.



Figure 2.4 Rocky shoreline habitat at the mouth of the Mooloolah River.

2.2 Target Species for Collection

Immobile filter feeders such as oysters (*Saccostrea cucullata glomerata*) were targeted. These species filter large quantities of water to feed, and consequently can bioaccumulate contaminants. As they are stationary they provide a good indication of contaminants within an area.

More mobile benthic feeders such as prawns (*Metapenaeus bennettiae*) were also targeted as they may bioaccumulate contaminants as they sift through the sediment to feed upon crustaceans, molluscs, and plant material.

Ray-finned and cartilaginous fish were also targeted to provide an indication of whether microplastics were accumulating in these species. There are many species of ray-finned and cartilaginous fish in the Mooloolah River estuary (Table 2.1), each with a different distribution and in different feeding guilds.

Table 2.1 Ray-finned fish that occur in the estuary, and that may be suitable for sampling.

Family	Species	Common Name	Freshwater/Estuary/Coastal Marine
Ambassidae	<i>Ambassis marianus</i>	Estuary glassfish	Estuary
Anguillidae	<i>Anguilla australis</i>	Southern shortfin eel	Freshwater/estuary/coastal marine
Anguillidae	<i>Anguilla reinhardtii</i>	Longfin eel	Freshwater/estuary/coastal marine
Carangidae	<i>Caranx sexfasciatus</i>	Bigeye trevally	Estuary/coastal marine
Carangidae	<i>Trachurus novaezelandiae</i>	Yellowtail horse mackerel	Estuary/coastal marine
Chanidae	<i>Chanos chanos</i>	Milkfish	Freshwater/estuary/coastal marine
Cichlidae	<i>Oreochromis mossambicus*</i>	Mozambique mouthbrooder	Freshwater/estuary
Clupeidae	<i>Nematalosa erebi</i>	Bony bream	Freshwater/estuary
Eleotridae	<i>Gobiomorphus australis</i>	Striped gudgeon	Freshwater/estuary
Eleotridae	<i>Gobiomorphus coxii</i>	Cox gudgeon	Freshwater/estuary
Eleotridae	<i>Philypnodon grandiceps</i>	Flathead gudgeon	Freshwater/estuary
Elopidae	<i>Elops hawaiiensis</i>	Hawaiian Giant Herring	Freshwater/estuary/coastal marine
Gerreidae	<i>Gerres filamentosus</i>	Threadfin silverbiddy	Estuary/coastal marine
Kyphosidae	<i>Microcanthus strigatus</i>	stripey	Estuary/coastal marine
Lutjanidae	<i>Lutjanus argentimaculatus</i>	Mangrove jack	Freshwater/estuary/coastal marine
Lutjanidae	<i>Lutjanus russellii</i>	Moses' Snapper	Estuary/coastal marine
Megalopidae	<i>Megalops cyprinoides</i>	Oxeye herring	Freshwater/estuary/coastal marine
Mugilidae	<i>Mugil cephalus</i>	Sea mullet	Estuary/coastal marine
Mugilidae	<i>Trachystoma petardi</i>	Pinkeye mullet	Estuary/coastal marine
Orectolobidae	<i>Orectolobus maculatus</i>	Spotted wobbegong	Estuary/coastal marine
Myliobatidae	<i>Aetobatus ocellatus</i>	Whitespotted eagle ray	Estuary/coastal marine
Percichthyidae	<i>Percolates novemaculeata</i>	Australian bass	Freshwater/estuary
Platycephalidae	<i>Platycephalus fuscus</i>	Dusky flathead	Estuary/coastal marine
Polynemidae	<i>Polydactylus multiradiatus</i>	Australian Threadfin	Estuary/coastal marine
Polynemidae	<i>Polydactylus macrochir</i>	King Threadfin	Freshwater/estuary/coastal marine
Pseudomugilidae	<i>Pseudomugil signifer</i>	Pacific blue eye	Freshwater/estuary

Family	Species	Common Name	Freshwater/Estuary/Coastal Marine
Scatophagidae	<i>Scatophagus argus</i>	Spotted Scat	Freshwater/estuary/coastal marine
Scatophagidae	<i>Selenotoca multifasciata</i>	Striped Scat	Freshwater/estuary/coastal marine
Scorpaenidae	<i>Notesthes robusta</i>	Bullrout	Freshwater/estuary/coastal marine
Serranidae	<i>Epinephelus malabaricus</i>	Malabar grouper	Estuary/coastal marine
Siganidae	<i>Siganus fuscescens</i>	Black rabbitfish	Estuary/coastal marine
Sparidae	<i>Acanthopagrus australis</i>	Yellowfin bream	Estuary/coastal marine
Sparidae	<i>Rhabdosargus sarba</i>	Goldlined seabream	Estuary/coastal marine
Terapontidae	<i>Leiopotherapon unicolor</i>	Spangled perch	Freshwater/estuary
Terapontidae	<i>Terapon jarbua</i>	Crescent grunter	Freshwater/estuary/coastal marine
Tetraodontidae	<i>Tetractenos hamiltoni</i>	Common toadfish	Estuary/coastal marine
Tetraodontidae	<i>Torquigener pleurogramma</i>	Weeping toadfish	Estuary/coastal marine

* Introduced pest species

3 Methods

River biota was collected at six sites. Samples were collected from:

- three potentially impacted sites in the Mooloolah River (Map 3.1):
 - at the Release Point W3
 - in the middle estuary, and
 - at the river mouth, and from
- three equivalent control sites in the Maroochy River (Map 3.2).

Site selection was based on preliminary dispersion modelling, with final dispersion modelling not complete until after the sampling was completed.

Collection methods are summarised below and in Table 3.1. The biota that was collected is summarised in Table 3.2.

3.1 Filter Feeding Invertebrates

Oysters were hand collected at low tide using a metal shucking knife and metal buckets. Approximately ten individuals were collected per sample, with two samples collected from each site. Oysters were obtained at all sites apart from at the release site W3, and were wrapped in foil and frozen (Figure 3.1).



Figure 3.1 Oysters collected 3.5 downstream of site W3.

3.2 Other Invertebrates

A yabbie pump was used at each site to collect benthic invertebrates, however, this was only successful at the mouth of the Maroochy River. Additional crustaceans were collected at each site by hand. Samples were placed in glass jars and frozen (Figure 3.2).



Figure 3.2 Crabs (*Uca coarctata*) hand collected at the release site W3.

3.3 Fin Fish

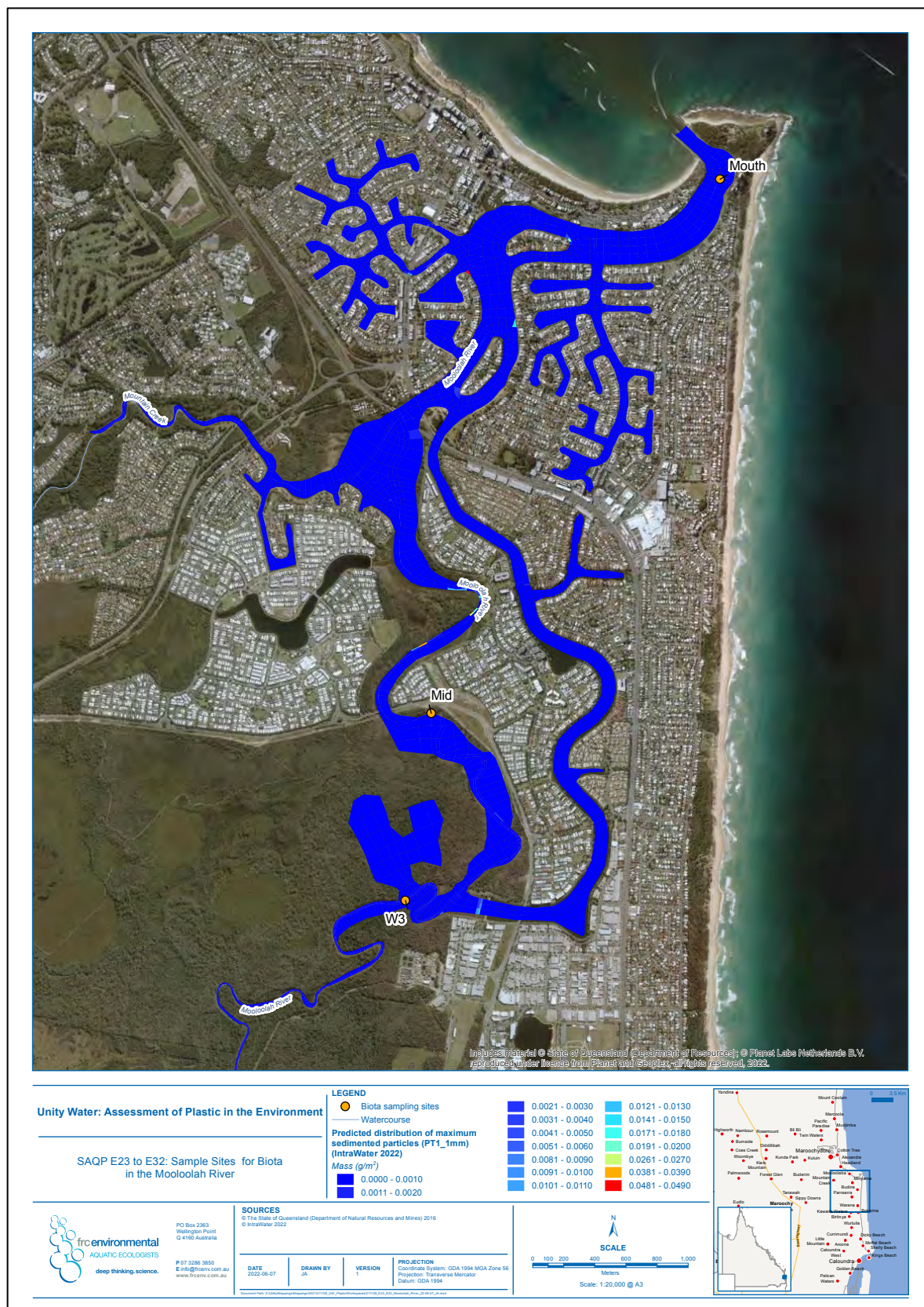
Fyke nets, baited box traps and cast nets were used to collect samples of fin fish within the estuary at all six sites. Fish were kept whole to prevent possible contamination by other plastic sources and wrapped in foil and frozen (Figure 3.3).

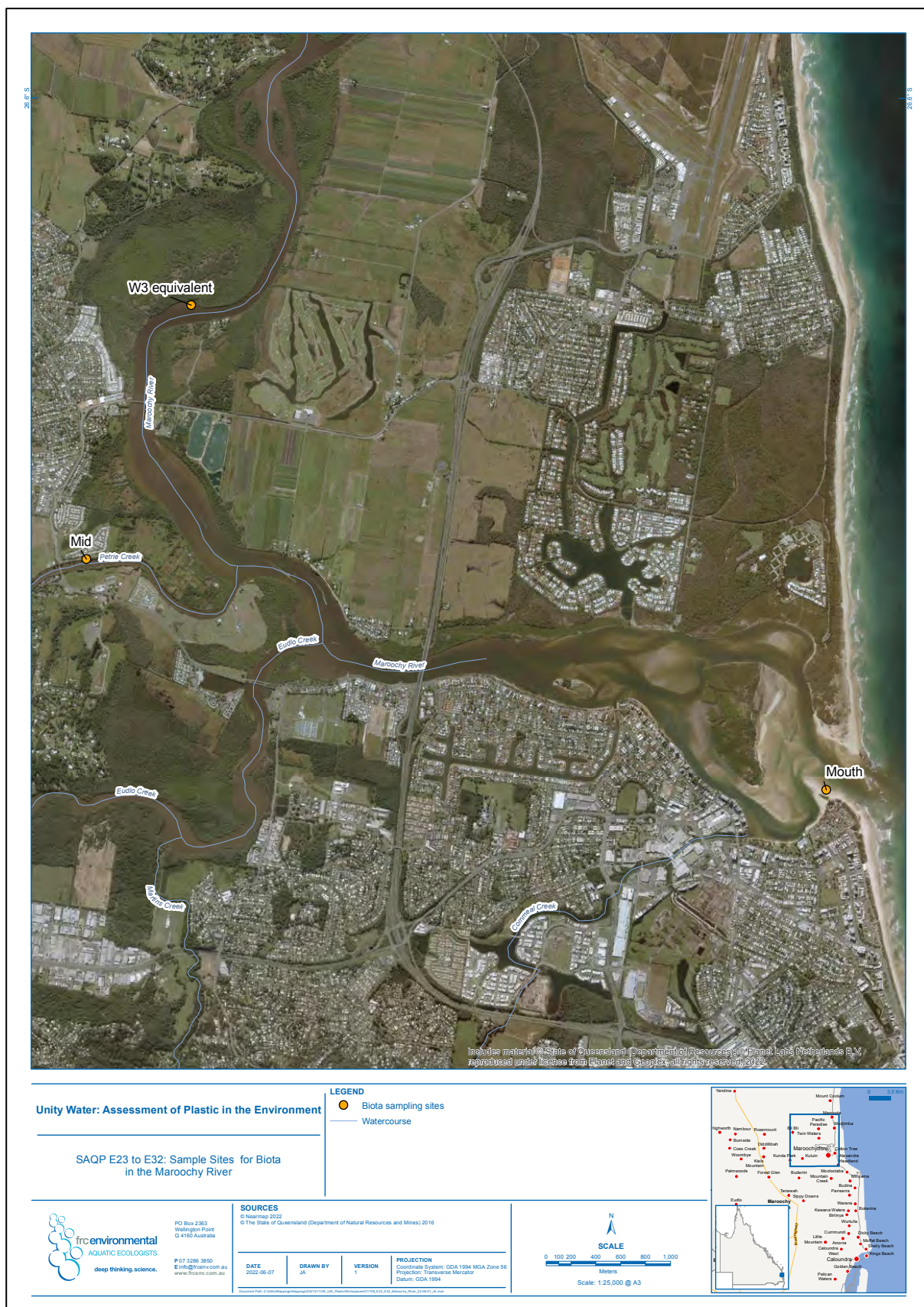


Figure 3.3 Sea Mullet (*Mugil cephalus*) collected at the release site W3 by cast netting.

Table 3.1 Summary of sample collection methods

	Hand Collection	Yabbie Pump	Fyke Net	Box Trap	Cast Net
Potentially Impacted					
Mooloolah Mouth	x	x	x	x	x
Mid Mooloolah River	x	—	x	—	x
Outfall Mooloolah River	x	—	—	x	x
Control					
Maroochy Mouth	x	x	x	x	x
Mid Maroochy River	x	x	x	x	x
'Outfall' Maroochy River	x	x	—	x	x





Map 3.2 E23 to E32 Maroochy River biota sampling sites

Table 3.2 Biota collected at potentially impacted sites and at control sites.

Sample #	Date sampled	Analysed	Count	Species Name	Common Name	Location	Latitude	Longitude
Fish								
Potentially Impacted Sites								
Release Point W3								
MO_Out_S3_R4	22-Mar-22	Yes	4	<i>Acanthopagrus australis</i>	Yellowfin bream	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R5	22-Mar-22	Yes	2	<i>Mugil cephalus</i>	Sea mullet	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R9	22-Mar-22	Yes	1	<i>Tetractenos hamiltoni</i>	Common toadfish	Downstream 100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R3	22-Mar-22	Yes	1	<i>Acanthopagrus australis</i>	Yellowfin bream	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R6	22-Mar-22	Yes	2	<i>Mugil cephalus</i>	Sea mullet	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R10	22-Mar-22	Yes	2	<i>Ambassis marianus</i>	Bony bream	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
Mid Estuary								
MO_Mid_S2_R5	22-Mar-22	Yes	2	<i>Marilyna pleurosticta</i>	Banded toadfish	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R7	22-Mar-22	Yes	4	<i>Acanthopagrus australis</i>	Yellowfin bream	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R9	22-Mar-22	Yes	2	<i>Platycephalus fuscus</i>	Dusky flathead	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R11	22-Mar-22	Yes	3	<i>Mugil cephalus</i>	Sea mullet	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R6	22-Mar-22	Yes	2	<i>Marilyna pleurosticta</i>	Banded toadfish	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R8	22-Mar-22	Yes	4	<i>Acanthopagrus australis</i>	Yellowfin bream	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R10	22-Mar-22	Yes	2	<i>Platycephalus fuscus</i>	Dusky flathead	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R14	22-Mar-22	Yes	4	<i>Ambassis marianus</i>	Glassfish	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E

Sample #	Date sampled	Analysed	Count	Species Name	Common Name	Location	Latitude	Longitude
River Mouth								
MO_Mouth_S1_R6	24-Mar-22	Yes	4	<i>Mugil cephalus</i>	Sea mullet	Downstream 8km	26°41'06.6"S	153°08'06.5"E
MO_Mouth_S1_R7	24-Mar-22	Yes	1	<i>Acanthopagrus australis</i>	Yellowfin bream	Downstream 8km	26°41'06.6"S	153°08'06.5"E
MO_Mouth_S1_R8	24-Mar-22	Yes	1	<i>Tetractenos hamiltoni</i>	Common toadfish	Downstream 8km	26°41'06.6"S	153°08'06.5"E
MO_Mouth_S1_R5	24-Mar-22	Yes	3	<i>Mugil cephalus</i>	Sea mullet	Downstream 8km	26°41'06.6"S	153°08'06.5"E
Control Sites								
Maroochy River W3 Equivalent								
MA_Out_S1_R2	25-Mar-22	No	5	<i>Acanthopagrus australis</i>	Yellowfin bream	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R4	25-Mar-22	No	4	<i>Mugil cephalus</i>	Sea mullet	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R7	25-Mar-22	No	3	<i>Platycephalus fuscus</i>	Dusky flathead	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R8	25-Mar-22	No	2	<i>Tetractenos hamiltoni</i>	Common toadfish	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R3	25-Mar-22	No	5	<i>Acanthopagrus australis</i>	Yellowfin bream	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R5	25-Mar-22	No	3	<i>Mugil cephalus</i>	Sea mullet	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R6	25-Mar-22	No	2	<i>Platycephalus fuscus</i>	Dusky flathead	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R10	25-Mar-22	No	2	<i>Marilyna pleurosticta</i>	Banded toadfish	W3 equivalent	26°36'58.2"S	153°02'45.7"E
Mid Estuary								
MA_Mid_S2_R1	24-Mar-22	No	2	<i>Marilyna pleurosticta</i>	Banded toadfish	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
MA_Mid_S2_R2	24-Mar-22	No	1	<i>Platycephalus fuscus</i>	Dusky flathead	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
MA_Mid_S2_R6	24-Mar-22	No	5	<i>Mugil cephalus</i>	Sea mullet	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
MA_Mid_S2_R7	24-Mar-22	No	3	<i>Acanthopagrus australis</i>	Yellowfin bream	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
MA_Mid_S2_R3	24-Mar-22	No	2	<i>Tetractenos hamiltoni</i>	Common toadfish	Downstream equivalent	26°37'18.6"S	26°37'18.6"S

Sample #	Date sampled	Analysed	Count	Species Name	Common Name	Location	Latitude	Longitude
MA_Mid_S2_R4	24-Mar-22	No	1	<i>Platycephalus fuscus</i>	Dusky flathead	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
MA_Mid_S2_R5	24-Mar-22	No	3	<i>Mugil cephalus</i>	Sea mullet	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
River Mouth								
MA_Mouth_S1_R5	24-Mar-22	No	4	<i>Acanthopagrus australis</i>	Yellowfin bream	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
MA_Mouth_S1_R7	24-Mar-22	No	3	<i>Tetractenos hamiltoni</i>	Common toadfish	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
MA_Mouth_S1_R9	24-Mar-22	No	1	<i>Platycephalus fuscus</i>	Dusky flathead	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
MA_Mouth_S1_R6	24-Mar-22	No	4	<i>Acanthopagrus australis</i>	Yellowfin bream	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
MA_Mouth_S1_R8	24-Mar-22	No	4	<i>Acanthopagrus australis</i>	Yellowfin bream	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
MA_Mouth_S1_R10	24-Mar-22	No	1		Whiting	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
MA_Mouth_S1_R5	24-Mar-22	No	4	<i>Acanthopagrus australis</i>	Yellowfin bream	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
MA_Mouth_S1_R7	24-Mar-22	No	3	<i>Tetractenos hamiltoni</i>	Common toadfish	Mouth equivalent	26°38'27.7"S	153°05'36.2"E
Filter Feeding Invertebrates								
Potentially Impacted Sites								
Release Point W3								
nil	-	-	-	-	-	-	-	-
Mid Estuary								
MO_Mid_S2_R12	22-Mar-22	Yes	13	<i>Saccostrea cucullata</i>	Rock Oyster	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R13	22-Mar-22	Yes	12	<i>Saccostrea cucullata</i>	Rock Oyster	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
River Mouth								
MO_Mouth_S1_R1	22-Mar-22	Yes	10	<i>Saccostrea cucullata</i>	Rock Oyster	Downstream 8km	26°41'06.6"S	153°08'06.5"E
MO_Mouth_S1_R2	22-Mar-22	Yes	10	<i>Saccostrea cucullata</i>	Rock Oyster	Downstream 8km	26°41'06.6"S	153°08'06.5"E

Sample #	Date sampled	Analysed	Count	Species Name	Common Name	Location	Latitude	Longitude
Control Sites								
Maroochy River W3 Equivalent								
MA_Out_S1_R1	25-Mar-22	Yes	10	<i>Saccostrea cucullata</i>	Rock Oyster	W3 equivalent	26°36'58.2"S	153°02'45.7"E
MA_Out_S1_R9	25-Mar-22	No	11	<i>Saccostrea cucullata</i>	Rock Oyster	W3 equivalent	26°36'58.2"S	153°02'45.7"E
Mid Estuary								
MA_Mid_S2_R9	24-Mar-22	Yes	6	<i>Saccostrea cucullata</i>	Rock Oyster	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
River Mouth								
MA_Mouth_S1_R2	23-Mar-22	No	13	<i>Saccostrea cucullata</i>	Rock Oyster	Mouth equivalent	26°39'14.5"S	153°05'51.2"E
MA_Mouth_S1_R1	24-Mar-22	No	13	<i>Saccostrea cucullata</i>	Rock Oyster	Mouth equivalent	26°39'14.5"S	153°05'51.2"E
Other Invertebrates								
Potentially Impacted Sites								
Release Point W3								
MO_Out_S3_R1	24-Mar-22	Yes	16	<i>Uca coarctata</i>	Fiddler Crab	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R7	24-Mar-22	Yes	4	<i>Metapenaeus bennettiae</i>	Greentail prawn	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R2	24-Mar-22	Yes	17	<i>Uca coarctata</i>	Fiddler Crab	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
MO_Out_S3_R8	24-Mar-22	Yes	4	<i>Metapenaeus bennettiae</i>	Greentail prawn	Downstream 0-100m	26°43'25.0"S	153°06'58.7"E
Mid Estuary								
MO_Mid_S2_R1	22-Mar-22	Yes	10	<i>Uca coarctata</i>	Fiddler Crab	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R4	22-Mar-22	Yes	19	<i>Metapenaeus bennettiae</i>	Greentail prawn	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R2	22-Mar-22	Yes	10	<i>Uca coarctata</i>	Fiddler Crab	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E
MO_Mid_S2_R3	22-Mar-22	Yes	12	<i>Metapenaeus bennettiae</i>	Greentail prawn	Downstream 3.5km	26°42'36.6"S	153°06'57.5"E

Sample #	Date sampled	Analysed	Count	Species Name	Common Name	Location	Latitude	Longitude
River Mouth								
MO_Mouth_S1_R3	22-Mar-22	Yes	12	–	Snails	Downstream 8km	26°41'06.6"S	153°08'06.5"E
MO_Mouth_S1_R4	24-Mar-22	Yes	12	–	Snails	Downstream 8km	26°41'06.6"S	153°08'06.5"E
Control Sites								
Maroochy River W3 Equivalent								
MA_Out_S1_R11	25-Mar-22	Yes	30	<i>Metapenaeus bennettiae</i>	Greentail prawn	W3 equivalent	26°36'58.2"S	153°02'45.7"E
Mid Estuary								
MA_Mid_S2_R8	25-Mar-22	Yes	5	<i>Metapenaeus bennettiae</i>	Greentail prawn	Downstream equivalent	26°37'18.6"S	26°37'18.6"S
River Mouth								
MA_Mouth_S1_R3	24-Mar-22	No	14	<i>Callinassa australiensis</i>	Ghost shrimp	Mouth equivalent	26°38'24.6"S	153°05'14.6"E
MA_Mouth_S1_R4	24-Mar-22	No	14	<i>Callinassa australiensis</i>	Ghost shrimp	Mouth equivalent	26°38'24.6"S	153°05'14.6"E

3.4 Laboratory Analysis

Biota samples were frozen and freighted to the laboratory for analysis. All samples from the Mooloolah River were analysed. Where there was a positive identification of likely MBBR particles in a sample from the Mooloolah River, then the equivalent samples from the Maroochy River were analysed.

Finfish samples were gutted and the gastrointestinal tract and remaining tissue analysed separately. Invertebrates were not gutted, and the whole tissue sample was analysed.

Laboratory methods are presented in Attachment 4 of Appendix D. In summary the samples were:

- digested using Fenton Agent as required
- examined under a microscope coupled with image analysis, and microplastics extracted.

The microplastics were then collected and categorised according to their size class, colour and shape, and the polymer chemistry identified using spectral analysis. The likely polymer chemistry was assigned by matching to a Global polymer library, using the highest percent matching. Fragments that were black, and had the polymer type of 'black polyethylene' may have originated from MBBR plastic media.

Samples could not be directly compared to the plastic in MBBR carriers due to:

- the very small size of the microparticles
- the small number per sample
- the composition of the MBBR carriers: the carriers are made from recycled plastic, and consequently don't have a unique spectral signature, and as
- plastic particles in the environment chemically degrade and consequently the signature of a particle from an MBBR carrier would degrade.

4 Results and Discussion

Results of the analyses are presented in Table 4.1, and summarised below.

4.1 Black Polyethylene Particles

Particles with a polymer type of 'black polyethylene' may have originated from MBBR plastic media.

- Black polyethylene particles were found in one oyster (*Saccostrea cucullata*) sample (comprised of 13 oysters) and one greentail prawn (*Metapenaeus bennettiae*) sample (comprised of 12 prawns) at the mid estuary site in the Mooloolah River. This site was close to where the dispersion modelling indicated particles were likely to accumulate.
- In the oyster sample that had black polyethylene particles, 9 of the 11 microplastic particles were black polyethylene.
- In the prawn sample that had black polyethylene particles, there was one microplastic particle, and it was black polyethylene.
- Black polyethylene particles were not found in biota from anywhere else in the Mooloolah River, including in the remaining 12 oysters or 19 prawns collected from the mid estuary of the Mooloolah River.
- Black polyethylene particles were not found in the oyster or greentail prawn samples from the mid estuary control site in the Maroochy River.

4.2 Total Plastic Particles

- Most samples had microplastic in them with up to 10 particles per sample (1.43 particles per gram).
- There was 1 microplastic particle per sample in oysters from the Maroochy River, and none in samples from the mouth of the Mooloolah River.
- Greentail prawn samples had between 0 and 3 microplastic particles in them.
- Of the fish samples collected in the Mooloolah River, yellowfin bream (*Acanthopagrus australis*), sea mullet (*Mugil cephalus*), common toadfish (*Tetractenos hamiltoni*), bony bream (*Ambassis marianus*), banded toadfish

(*Marilyna pleurosticta*) and dusky flathead (*Platycephalus fuscus*) had microplastic particles in their gut or tissue.

- The oyster samples from the mouth of the Mooloolah River were the only site / taxa combination where there were no microplastic particles in either sample.

That is, while there were microplastic particles in biota throughout the Mooloolah estuary (with the exception of oysters at the mouth of the estuary) black polyethylene particles were only found at one site in the River, where dispersion modelling indicated MBBR-particles were likely to accumulate. Black polyethylene particles were only found in one oyster and one prawn sample at this site. However, the concentration of black polyethylene particles was relatively high in the oyster sample. Oysters are filter feeders that bioaccumulate contaminants, and consequently it is likely that the oysters in this sample bioaccumulated these particles.

Table 4.1 Summary table of microplastics that were found in river biota samples.

Sample Type and Number	Species Name	Common Name	Sample weight (g)	Polymer Type	No. MPs in tissue	No. MPs in gut	Mean No. MPs/gram	Black polyethylene	Library Match (%)
Fish									
Release Point W3									
MO_Out_S3_R4	<i>Acanthopagrus australis</i>	Yellowfin bream	5.94	PP	0	2	0.34	No	77.00
				PE	0	3	0.51	No	76.00
MO_Out_S3_R5	<i>Mugil cephalus</i>	Sea mullet	9.13	PE	0	1	0.11	No	66.00
MO_Out_S3_R9	<i>Tetractenos hamiltoni</i>	Common toadfish	15.12	PE	1	0	0.07	No	81.00
				PE-Chl	1	0	0.07	No	87.72
MO_Out_S3_R3	<i>Acanthopagrus australis</i>	Yellowfin bream	11.85	PP	2	0	0.17	No	77.00
				PA	2	0	0.17	No	58.00
				PVC	2	0	0.17	No	75.00
MO_Out_S3_R6	<i>Mugil cephalus</i>	Sea mullet	7.54	-	0	0	0	-	0
MO_Out_S3_R10	<i>Ambassis marianus</i>	Bony Bream	6.18	PVC	1	0	0.16	No	70.00
Mid Estuary									
MO_Mid_S2_R5	<i>Marilyna pleurosticta</i>	Banded toadfish	10.64	PE	1	0	0.09	No	71.00
MO_Mid_S2_R7	<i>Acanthopagrus australis</i>	Yellowfin bream	8.21	-	0	0	0	-	
MO_Mid_S2_R9	<i>Platycephalus fuscus</i>	Dusky flathead	6.37	PVC	2	0	0.31	No	78.00

Sample Type and Number	Species Name	Common Name	Sample weight (g)	Polymer Type	No. MPs in tissue	No. MPs in gut	Mean No. MPs/gram	Black polyethylene	Library Match (%)
MO_Mid_S2_R11	<i>Mugil cephalus</i>	Sea mullet	11.87	PP	0	1	0.08	No	86.00
MO_Mid_S2_R6	<i>Marilyna pleurosticta</i>	Banded toadfish	10.20	PET	1	0	0.10	No	80.00
MO_Mid_S2_R8	<i>Acanthopagrus australis</i>	Yellowfin bream	8.66	PE	0	1	0.23	No	78.00
MO_Mid_S2_R10	<i>Platycephalus fuscus</i>	Dusky flathead	5.62	PA	0	4	0.71	No	48.00
				PE	1	0	0.18	No	77.00
				PET	0	1	0.18	No	66.00
River Mouth									
MO_Mouth_S1_R6	<i>Mugil cephalus</i>	Sea mullet	12.48	PVC	0	1	0.08	No	57.00
				PET	1	0	0.08	No	49.00
				PVA	1	0	0.08	No	70.00
MO_Mouth_S1_R7	<i>Acanthopagrus australis</i>	Yellowfin bream	7.27	-	0	0	0	-	-
MO_Mouth_S1_R8	<i>Tetractenos hamiltoni</i>	Common toadfish	3.54	PS	0	1	0.28	-	-
MO_Mouth_S1_R5	<i>Mugil cephalus</i>	Sea mullet	7.81	PA	1	0	0.13		64.00
Filter Feeding Invertebrates									
Mid Estuary									
MO_Mid_S2_R12	<i>Saccostrea cucullata</i>	Rock Oyster	6.29	SBCo	1	-	0.16	No	79.60
				PE	9	-	1.43	Yes	78.00
MO_Mid_S2_R13	<i>Saccostrea cucullata</i>	Rock Oyster	6.47		1	-	0.15	No	68.00

Sample Type and Number	Species Name	Common Name	Sample weight (g)	Polymer Type	No. MPs in tissue	No. MPs in gut	Mean No. MPs/gram	Black polyethylene	Library Match (%)
River Mouth									
MO_Mouth_S1_R1	<i>Saccostrea cucullata</i>	Rock Oyster	5.02	-	0	-	0	-	-
MO_Mouth_S1_R2	<i>Saccostrea cucullata</i>	Rock Oyster	5.02	-	0	-	0	-	-
Control Sites									
Maroochy River W3 Equivalent									
MA_Out_S1_R1	<i>Saccostrea cucullata</i>	Rock Oyster	6.02	PE	1	-	0.1	No	46.00
Mid Estuary									
MA_Mid_S2_R9	<i>Saccostrea cucullata</i>	Rock Oyster	4.86	PA	1	-	0.21	No	64.00
Other Invertebrates									
Potentially Impacted Sites									
Release Point W3									
MO_Out_S3_R1	<i>Uca coarctata</i>	Fiddler Crab	3.62	PP	2	-	0.55	No	86.00
MO_Out_S3_R7	<i>Metapenaeus bennettiae</i>	Greentail prawn	5.00	PVB	1	-	0.20	No	79.00
				PA	1	-	0.20	No	66.00
MO_Out_S3_R2	<i>Uca coarctata</i>	Fiddler Crab	2.49	-	0	-	0	-	-
MO_Out_S3_R8	<i>Metapenaeus bennettiae</i>	Greentail prawn	4.28	PVC	1	-	0.23	No	71.00
Mid Estuary									

Sample Type and Number	Species Name	Common Name	Sample weight (g)	Polymer Type	No. MPs in tissue	No. MPs in gut	Mean No. MPs/gram	Black polyethylene	Library Match (%)
MO_Mid_S2_R1	<i>Uca coarctata</i>	Fiddler Crab	5.48	-	0	-	0	-	-
MO_Mid_S2_R4	<i>Metapenaeus bennettiae</i>	Greentail prawn	5.24	-	0	-	0	-	-
MO_Mid_S2_R2	<i>Uca coarctata</i>	Fiddler Crab	3.00	PE	1	-	0.33	No	62.00
MO_Mid_S2_R3	<i>Metapenaeus bennettiae</i>	Greentail prawn	6.5	PE	4	-	0.61	Yes	78.00
River Mouth									
MO_Mouth_S1_R3		Snails	5.78	PVC	1	-	0.17	No	78.00
MO_Mouth_S1_R4		Snails	1.15	-	0	-	0	-	-
Control Sites									
Maroochy River W3 Equivalent									
MA_Out_S1_R11	<i>Metapenaeus bennettiae</i>	Greentail prawn	4.92	PE	2	-	2.46	No	58.00-63.00
				PA	1	-	0.20	No	43.40
Mid Estuary									
MA_Mid_S2_R8	<i>Metapenaeus bennettiae</i>	Greentail prawn	2.90	PA	1	-	0.34	No	64.00

5 References

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Attachment 1 E23 to E32 Lab Results

MICROPLASTICS - REPORT OF ANALYSIS

Job description	: Investigating the Characteristics of Microplastics in Riverine Biota		
Job status	: Completed		
Work order	:	Laboratory	Environmental Plastics Innovation Cluster(EPIC), Global Innovative Centre for Advanced Nanomaterials (GICAN), THE UNIVERSITY OF NEWCASTLE
Client Contact	: Carol Conacher	Contact	: thavapalanisami@newcastle.edu.au
Address	: Unit 1, 7-9 Grant St Cleveland QLD 4163	Address	Global Innovative Centre for Advanced Nanomaterials (GICAN) Level 1, ATC Building, UNIVERSITY DRIVE CALLAGHAN THE UNIVERSITY OF NEWCASTLE NSW 2308
Telephone	: +61 7 3286 3850		
Order number	:		
C-O-C number	:		
Sampler	:		
Site	: Mooloolah River, Maroochy River	Telephone	: + 61 431 300 521
No. of samples analysed	: 36	Report ID and issue date	: E23-E32_River_Biota_2022-06-06

This certificate of analysis contains the following information:

- General comments
- Laboratory Report

ABBREVIATIONS:

g – grams, μm – micrometer; MPs – Microplastics;

Abbr.	Polymer Type
Black PE	Black polyethylene
PA	Polyamide
PE	polyethylene
PE-Chl	Chlorinated polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVA	Polyvinyl alcohol
PVB	Polyvinyl butyral
PVC	Polyvinyl Chloride
SBCo	Styrene butadiene copolymer

Data Sheet of Metadata

Sample #	Sample Code	Biota Name	Date Sampled	Tissue weight (g)	Gut weight (g)	Sample Weight (g)
1	MO_Mouth_S1_R1	Commercial Rock Oyster	22/03/2022	5.02	-	5.02
2	MO_Mouth_S1_R3	Snails	22/03/2022	5.78	-	5.78
3	MO_Mouth_S1_R6	Sea mullet	22/03/2022	5.56	6.92	12.48
4	MO_Mouth_S1_R7	Yellowfin bream	22/03/2022	5.47	1.80	7.27
5	MO_Mouth_S1_R8	Common toadfish	22/03/2022	3.03	0.51	3.54
6	MO_Mid_S2_R1	Fiddler Crab	22/03/2022	3.93	-	3.93
7	MO_Mid_S2_R5	Banded toadfish	22/03/2022	6.62	4.02	10.64
8	MO_Mid_S2_R4	Greentail prawn	22/03/2022	5.24	-	5.24
9	MO_Mid_S2_R7	Yellowfin bream	22/03/2022	6.46	1.75	8.21
10	MO_Mid_S2_R9	Dusky flathead	22/03/2022	5.19	1.18	6.37
11	MO_Mid_S2_R11	Sea mullet	22/03/2022	6.87	5.00	11.87
12	MO_Mid_S2_R12	Commercial Rock Oyster	22/03/2022	6.29	-	6.29
13	MO_Out_S3_R1	Fiddler Crab	23/03/2022	3.62	-	3.62
14	MO_Out_S3_R4	Yellowfin bream	23/03/2022	5.03	0.91	5.94
15	MO_Out_S3_R5	Sea mullet	23/03/2022	5.11	4.02	9.13

Sample #	Sample Code	Biota Name	Date Sampled	Tissue weight (g)	Gut weight (g)	Sample Weight (g)
16	MO_Out_S3_R7	Greentail prawn	23/03/2022	5.00	-	5.00
17	MO_Out_S3_R9	Common toadfish	23/03/2022	6.07	9.05	15.12
27	MA_MID_S2_R8	Greentail Prawns	24/03/2022	2.90	-	2.90
28	MA_MID_S2_R9	Commercial Rock Oyster	24/03/2022	4.86	-	4.86
29	MA_OUT_S1_R1	Commercial Rock Oyster	25/03/2022	6.02	-	6.02
34	MA_OUT_S1_R11	Greentail Prawns	25/03/2022	4.92	-	4.92
35	MO_Mouth_S1_R2	Commercial Rock Oyster	22/03/2022	5.02	-	5.02
36	MO_Mouth_S1_R4	Snails	22/03/2022	1.15	-	1.15
37	MO_Mouth_S1_R5	Sea mullet	22/03/2022	5.58	2.23	7.81
38	MO_Mid_S2_R2	Fiddler Crab	22/03/2022	3.00	-	3.00
39	MO_Mid_S2_R3	Greentail prawn	22/03/2022	6.57	-	6.57
40	MO_Mid_S2_R6	Banded toadfish	22/03/2022	5.36	4.84	10.20
41	MO_Mid_S2_R8	Yellowfin bream	22/03/2022	5.26	3.40	8.66
42	MO_Mid_S2_R10	Dusky flathead	22/03/2022	4.97	0.65	5.62
44	MO_Mid_S2_R13	Commercial Rock Oyster	22/03/2022	6.47	-	6.47
45	MO_Out_S3_R2	Fiddler Crab	23/03/2022	2.49	-	2.49

Sample #	Sample Code	Biota Name	Date Sampled	Tissue weight (g)	Gut weight (g)	Sample Weight (g)
46	MO_Out_S3_R3	Yellowfin bream	23/03/2022	5.41	6.44	11.85
47	MO_Out_S3_R6	Sea mullet	23/03/2022	4.24	3.30	7.54
48	MO_Out_S3_R8	Green tail prawn	23/03/2022	4.28	-	4.28
49	MO_Out_S3_R10	Bony bream and Glassfish	23/03/2022	5.08	1.10	6.18

The labels are given according to the suppliers file name "211109 COC Plastics 22-04-04 EH".

*The labels are given as such from the sample containers as per the advice from the suppliers.

Data Sheet of Microplastic Abundance

Sample #	Sample Code	Tissue Weight (g)	Gut Weight (g)	Total Weight (g)	No. of MPs (Tissue)	No. of MPs (Gut)	Total No. of MPs	Mean No. MPs Tissue (total/g)	Mean No. MPs Gut (total/g)	Mean No. MPs (total/g)
1	MO_Mouth_S1_R1	5.02	-	5.02	0	-	0	0.00	-	0.00
2	MO_Mouth_S1_R3	5.78	-	5.78	1	-	1	0.17	-	0.17
3	MO_Mouth_S1_R6	5.56	6.92	12.48	2	1	3	0.36	0.14	0.24
4	MO_Mouth_S1_R7	5.47	1.8	7.27	0	0	0	0.00	0.00	0.00
5	MO_Mouth_S1_R8	3.03	0.51	3.54	0	1	1	0.00	1.96	0.28
6	MO_Mid_S2_R1	3.93	-	3.93	0	-	0	0.00	-	0.00
7	MO_Mid_S2_R5	6.62	4.02	10.64	1	0	1	0.15	0.00	0.09
8	MO_Mid_S2_R4	5.24	-	5.24	0	-	0	0.00	-	0.00
9	MO_Mid_S2_R7	6.46	1.75	8.21	0	0	0	0.00	0.00	0.00
10	MO_Mid_S2_R9	5.19	1.18	6.37	0	2	2	0.00	1.69	0.31
11	MO_Mid_S2_R11	6.87	5	11.87	0	1	1	0.00	0.20	0.08
12	MO_Mid_S2_R12	6.29	-	6.29	10	-	10	1.59	-	1.59
13	MO_Out_S3_R1	3.62	-	3.62	2	-	2	0.55	-	0.55
14	MO_Out_S3_R4	5.03	0.91	5.94	0	5	5	0.00	5.49	0.84
15	MO_Out_S3_R5	5.11	4.02	9.13	0	1	1	0.00	0.25	0.11

Sample #	Sample Code	Tissue Weight (g)	Gut Weight (g)	Total Weight (g)	No. of MPs (Tissue)	No. of MPs (Gut)	Total No. of MPs	Mean No. MPs Tissue (total/g)	Mean No. MPs Gut (total/g)	Mean No. MPs (total/g)
16	MO_Out_S3_R7	5	-	5	2	-	2	0.40	-	0.40
17	MO_Out_S3_R9	6.07	9.05	15.12	1	1	2	0.16	0.11	0.13
27	MA_MID_S2_R8	2.90	-	2.90	1	-	1	0.34	-	0.34
28	MA_MID_S2_R9	4.86	-	4.86	0	-	0	0.00	-	0.00
29	MA_OUT_S1_R1	6.02	-	6.02	1	-	1	0.17	-	0.17
34	MA_OUT_S1_R11	4.92	-	4.92	1	-	1	0.20	-	0.20
35	MO_Mouth_S1_R2	5.02	-	5.02	0	-	0	0.00	-	0.00
36	MO_Mouth_S1_R4	1.15	-	1.15	0	-	0	0.00	-	0.00
37	MO_Mouth_S1_R5	5.58	2.23	7.81	0	1	1	0.00	0.45	0.13
38	MO_Mid_S2_R2	3	-	3	1	-	1	0.33	-	0.33
39	MO_Mid_S2_R3	6.57	-	6.57	4	-	4	0.61	-	0.61
40	MO_Mid_S2_R6	5.36	4.84	10.2	1	0	1	0.19	0.00	0.10
41	MO_Mid_S2_R8	5.26	3.4	8.66	0	1	1	0.00	0.29	0.12
42	MO_Mid_S2_R10	4.97	0.65	5.62	1	5	6	0.20	7.69	1.07
44	MO_Mid_S2_R13	6.47	-	6.47	1	-	1	0.15	-	0.15

Sample #	Sample Code	Tissue Weight (g)	Gut Weight (g)	Total Weight (g)	No. of MPs (Tissue)	No. of MPs (Gut)	Total No. of MPs	Mean No. MPs Tissue (total/g)	Mean No. MPs Gut (total/g)	Mean No. MPs (total/g)
45	MO_Out_S3_R2	2.49	-	2.49	0	-	0	0.00	-	0.00
46	MO_Out_S3_R3	5.41	6.44	11.85	6	0	6	1.11	0.00	0.51
47	MO_Out_S3_R6	4.24	3.3	7.54	0	0	0	0.00	0.00	0.00
48	MO_Out_S3_R8	4.28	-	4.28	1	-	1	0.23	-	0.23
49	MO_Out_S3_R10	5.08	1.1	6.18	1	0	1	0.20	0.00	0.16

Data Sheet of Microplastic Characterisation

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
1	MO_Mouth_S1_R1	0	0	0	–	–	–	–
2	MO_Mouth_S1_R3	1	1	0	Black	fibre	PVC	78.00
3	MO_Mouth_S1_R6	1	0	1	Blue	fibre	PVC	57.00
	MO_Mouth_S1_R6	1	1	0	Black	fibre	PET	49.00
	MO_Mouth_S1_R6	1	1	0	Black	fragment	PVA	70.00
4	MO_Mouth_S1_R7	0	0	0	–	–	–	–
5	MO_Mouth_S1_R8	1	1	0	Brown	fragment	PS	57.00
6	MO_Mid_S2_R1	0	0	0	–	–	–	–
7	MO_Mid_S2_R5	1	1	0	Black	fibre	PE	71.00
8	MO_Mid_S2_R4	0	0	0	–	–	–	–
9	MO_Mid_S2_R7	0	0	0	–	–	–	–
10	MO_Mid_S2_R9	1	1	0	Black	fibre	PVC	78.00
	MO_Mid_S2_R9	1	1	0	Black	fibre	PVC	78.00
11	MO_Mid_S2_R11	1	1	0	Clear	fibre	PP	86.00
12	MO_Mid_S2_R12	1	1	0	Black	fibre	SBCo	79.60

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R12	1	1	0	Black	fragment	Black PE	78.00
13	MO_Out_S3_R1	1	1	0	Black	fragment	PP	86.00
	MO_Out_S3_R1	1	1	0	Black	fragment	PP	86.00
14	MO_Out_S3_R4	0	0	0	–	–	–	–
	MO_Out_S3_R4	1	1	0	Black	fibre	PP	77.00
	MO_Out_S3_R4	1	1	0	Black	fibre	PP	77.00
	MO_Out_S3_R4	1	1	0	Blue	fibre	PE	76.00
	MO_Out_S3_R4	1	1	0	Blue	fibre	PE	76.00

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
	MO_Out_S3_R4	1	1	0	Blue	fibre	PE	76.00
15	MO_Out_S3_R5	1	1	0	White	fibre	PE	66.00
16	MO_Out_S3_R7	1	1	0	Black	fibre	PVB	79.00
	MO_Out_S3_R7	1	1	0	Clear	fibre	PA	66.00
17	MO_Out_S3_R9	1	1	0	Black	fibre	PE	81.00
	MO_Out_S3_R9	1	1	0	Red	fibre	PE-Chl	82.72
27	MA_MID_S2_R8	1	0	0	Black	fibre	PA	64.00
28	MA_MID_S2_R9	1	1	0	Black	fibre	PA	75.00
29	MA_OUT_S1_R1	1	1	0	Black	fibre	PE	46.00
34	MA_OUT_S1_R11	1	1	0	Blue	fibre	PE	58.00
	MA_OUT_S1_R11	1	1	0	Blue	fibre	PE	63.00
	MA_OUT_S1_R11	1	1	0	Black	fibre	PA	43.40
35	MO_Mouth_S1_R2	0	0	0	–	–	–	–
36	MO_Mouth_S1_R4	0	0	0	–	–	–	–
37	MO_Mouth_S1_R5	1	1	0	Black	fibre	PA	64.00
38	MO_Mid_S2_R2	1	1	0	White	fibre	PE	62.00

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
39	MO_Mid_S2_R3	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R3	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R3	1	1	0	Black	fragment	Black PE	78.00
	MO_Mid_S2_R3	1	1	0	Black	fragment	Black PE	78.00
40	MO_Mid_S2_R6	1	1	0	Red	fibre	PET	80.00
41	MO_Mid_S2_R8	1	1	0	Black	fibre	PE	78.00
42	MO_Mid_S2_R10	1	1	0	Clear-white	fibre	PA	48.00
	MO_Mid_S2_R10	1	1	0	Clear-white	fibre	PA	48.00
	MO_Mid_S2_R10	1	1	0	Clear-white	fibre	PA	48.00
	MO_Mid_S2_R10	1	1	0	Clear-white	fibre	PA	48.00
	MO_Mid_S2_R10	1	1	0	Black	fibre	PE	77.00
	MO_Mid_S2_R10	1	1	0	Red	fibre	PET	66.00
44	MO_Mid_S2_R13	1	1	0	Red	fibre		68.00
45	MO_Out_S3_R2	0	0	0	–	–	–	–
46	MO_Out_S3_R3	1	1	0	Black	fragment	PP	77.00
	MO_Out_S3_R3	1	1	0	Black	fragment	PP	77.00

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
	MO_Out_S3_R3	1	1	0	Black	fibre	PA	58.00
	MO_Out_S3_R3	1	1	0	Black	fibre	PA	58.00
	MO_Out_S3_R3	1	1	0	Black	fragment	PVC	75.00
	MO_Out_S3_R3	1	1	0	Black	fragment	PVC	75.00
47	MO_Out_S3_R6	0	0	0	–	–	–	–
48	MO_Out_S3_R8	1	1	0	Black	fibre	PVC	71.00
49	MO_Out_S3_R10	1	1	0	Black	fibre	PVC	70.00

Appendix M SAQP E27 & E28: Assessment of plastic on oceanic fish and other invertebrates.

Kawana STP

Appendix M: SAQP E27 & E28: Assessment of Plastic in Oceanic Fish and Invertebrates

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Contents

1	Introduction and Background	1
1.1	Habitats Around the Potentially Impacted and Control Sites	1
1.2	Potential Impacts to Marine Biota	3
1.3	Impacts of Chemical Absorption	7
1.4	Accumulation of Contaminants in Plastic Particles	8
1.5	Bioaccumulation	9
2	Methods	10
2.1	Barrier Netting	10
2.2	Benthic Trawls	10
2.3	Laboratory Analysis	10
3	Results and Discussion	16
4	References	18

Attachment 1	E27 and E28 Laboratory Results
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Tables

Table 1.1	Ray-finned and cartilaginous fish that occur in offshore waters, and that may be suitable for sampling.	2
Table 1.2	Global studies of microplastic ingestion impacts on marine organisms	5
Table 2.1	Species caught using the trawl at the impact and control sites	12

Figures

Figure 2.1	Sampling locations for biota (near the diffuser and control), overlain on the results of the dispersion modelling.	13
Figure 2.2	Manta trawl used to collect benthic biota (yellow floats were removed for benthic sampling).	14
Figure 2.3	Fish caught with the benthic trawl.	14
Figure 2.4	Prawn caught with the benthic trawl.	15

1 Introduction and Background

This study investigated whether there was an accumulation of plastic, and in particular black polyethylene particles that may have originated from MBBR carriers, in fish and invertebrates in the vicinity of the diffuser at release point W1 in the Pacific Ocean.

1.1 Habitats Around the Potentially Impacted and Control Sites

The benthic habitats surrounding the pipeline and diffuser ports comprise bare sand with patches of macroalgal debris collecting in the corrugations of the sandy bed (frc environmental 2014b).

The diffuser heads and surrounding pylons function as artificial reefs and support a diverse community of algae, hard and soft corals, sponges, ascidians, and hydrozoans, with a variety of reef fish around each diffuser including Queensland groper (*Epinephelus lanceolatus*), stripey (*Microcanthus strigatus*), bannerfish (*Heniochus acuminatus*), yellowtail (*Trachurus novaezelandiae*), various wrasses (family Labridae), ring-tailed surgeonfish (*Acanthurus grammoptilus*), lionfish (*Pterois volitans*), and crested morwong (*Cheilodactylus vestitus*) (frc environmental 2014a). Other coastal fish that may occur in the vicinity of the diffuser heads are listed in Table 1.1.

In addition, invertebrates such as prawns (including banana prawns), shrimp and sand crabs are likely to use the bare sandy sediment in the surrounding area.

The habitats in the vicinity of the outfall do not provide habitat critical to the survival or reproduction of any threatened aquatic species that may be present in the area (frc environmental 2014a).

Modelling indicated that plastic particles are likely to move to the north, and be concentrated in the upper intertidal area (Intrawater 2022). Consequently the control site is to the south of the discharge, near Raper Shoals (Figure 2.1).

Along the coastal zone to the south of the release point, between Caloundra and Point Cartwright, there are some minor rocky outcrops on the foreshore. These reefs are dominated by macroalgae, with patches of sand, hard and soft coral, and sponges. Algal communities covered approximately 65% of the total surface of the reef and were dominated by species of *Padina gymnospora*, *Corallina*, *Halimeda*, *Sargassum*, *Lobophora* and *Dictyota* (frc environmental 2014b). These reefs are classified as rocky reefs, with rock forming the substrate upon which the corals attach and are an important source of refuge, nursery areas and food for marine organisms (Roelfsema et al. 2019).

Table 1.1 Ray-finned and cartilaginous fish that occur in offshore waters, and that may be suitable for sampling.

Family	Type	Species	Common Name	Freshwater/Estuary/Coastal Marine
Carangidae	ray-finned fishes	<i>Caranx sexfasciatus</i>	Bigeye trevally	Estuary/coastal marine
Carangidae	ray-finned fishes	<i>Trachurus novaezelandiae</i>	Yellowtail horse mackerel	Estuary/coastal marine
Chanidae	ray-finned fishes	<i>Chanos chanos</i>	Milkfish	Freshwater/estuary/coastal marine
Chaetodontidae	ray-finned fish	<i>Heniochus acuminatus</i>	Longfin bannerfish	Coastal marine
Elopidae	ray-finned fishes	<i>Elops hawaiiensis</i>	Hawaiian Giant Herring	Freshwater/estuary/coastal marine
Gerreidae	ray-finned fishes	<i>Gerres filamentosus</i>	Threadfin silverbiddy	Estuary/coastal marine
Kyphosidae	ray-finned fishes	<i>Microcanthus strigatus</i>	stripey	Estuary/coastal marine
Labridae	ray-finned fishes	<i>Various labrids</i>		Coastal marine
Latridae	ray-finned fishes	<i>Cheilodactylus vestitus</i>	Crested morwong	Coastal marine
Lutjanidae	ray-finned fishes	<i>Lutjanus argentimaculatus</i>	Mangrove jack	Freshwater/estuary/coastal marine
Lutjanidae	ray-finned fishes	<i>Lutjanus russellii</i>	Moses' Snapper	Estuary/coastal marine
Megalopidae	ray-finned fishes	<i>Megalops cyprinoides</i>	Oxeye herring	Freshwater/estuary/coastal marine
Mugilidae	ray-finned fishes	<i>Mugil cephalus</i>	Sea mullet	Estuary/coastal marine
Mugilidae	ray-finned fishes	<i>Trachystoma petardi</i>	Pinkeye mullet	Estuary/coastal marine
Orectolobidae	cartilaginous fishes	<i>Orectolobus maculatus</i>	Spotted wobbegong	Estuary/coastal marine
Myliobatidae	cartilaginous fishes	<i>Aetobatus ocellatus</i>	Whitespotted eagle ray	Estuary/coastal marine
Percichthyidae	ray-finned fishes	<i>Percolates novemaculeata</i>	Australian bass	Freshwater/estuary

Family	Type	Species	Common Name	Freshwater/Estuary/Coastal Marine
Platycephalidae	ray-finned fishes	<i>Platycephalus fuscus</i>	Dusky flathead	Estuary/coastal marine
Polynemidae	ray-finned fishes	<i>Polydactylus multiradiatus</i>	Australian Threadfin	Estuary/coastal marine
Polynemidae	ray-finned fishes	<i>Polydactylus macrochir</i>	King Threadfin	Freshwater/estuary/coastal marine
Scatophagidae	ray-finned fishes	<i>Scatophagus argus</i>	Spotted Scat	Freshwater/estuary/coastal marine
Scatophagidae	ray-finned fishes	<i>Selenotoca multifasciata</i>	Striped Scat	Freshwater/estuary/coastal marine
Scorpaenidae	ray-finned fishes	<i>Notesthes robusta</i>	Bullrout	Freshwater/estuary/coastal marine
Serranidae	ray-finned fishes	<i>Epinephelus malabaricus</i>	Malabar grouper	Estuary/coastal marine
Siganidae	ray-finned fishes	<i>Siganus fuscescens</i>	Black rabbitfish	Estuary/coastal marine
Sillaginidae	ray-finned fishes	<i>Sillago ciliata</i>	Sand whiting	Estuary/coastal marine
Sparidae	ray-finned fishes	<i>Acanthopagrus australis</i>	Yellowfin bream	Estuary/coastal marine
Sparidae	ray-finned fishes	<i>Rhabdosargus sarba</i>	Goldlined seabream	Estuary/coastal marine
Terapontidae	ray-finned fishes	<i>Leiopotherapon unicolor</i>	Spangled perch	Freshwater/estuary
Terapontidae	ray-finned fishes	<i>Terapon jarbua</i>	Crescent grunter	Freshwater/estuary/coastal marine
Tetraodontidae	ray-finned fishes	<i>Tetractenos hamiltoni</i>	Common toadfish	Estuary/coastal marine
Tetraodontidae	ray-finned fishes	<i>Torquigener pleurogramma</i>	Weeping toadfish	Estuary/coastal marine

1.2 Potential Impacts to Marine Biota

Plastic in the environment may impact marine ecology via ingestion, chemical absorption and bioaccumulation. Microplastics are difficult to remove and have been found in a wide range of locations including the human food chain, with long-term impacts widely undetermined (QldGov 2021).

Impacts of Ingestion

Due to its lightweight, durable nature, plastic has become a prevalent, widespread component of marine litter (Moore 2008; Thompson et al. 2009), with the most commonly produced and therefore encountered polymers being polypropylene (PP), polyethylene (PE) and polyvinylchloride (PVC) composing 24%, 21% and 19% of global plastic production (Andrady 2011). Microplastics can be ingested by low trophic level suspension, filter and deposit feeders, detritivores and planktivores, and can accumulate in organisms in higher trophic levels (Bergmann et al. 2015).

Ingestion of microplastics in small organisms may cause physical harm, such as by internal abrasions and blockages. In addition, contaminants such as monomers and plastic additives may leach from the ingested plastic and may cause carcinogenesis and endocrine disruption (Table 1.2).

Table 1.2 Global studies of microplastic ingestion impacts on marine organisms

Species	Common Name	Impacts	Reference
<i>Arenicola marina</i>	Lugworm	Reduced feeding activity, reduced energy reserves longer gut residence times of ingested material and inflammation	Wright et al. 2013a
<i>Mytilus edulis</i>	Mussel	Accumulation of plastic in the gut, translocation to circulatory system	Browne et al. 2008
<i>Lepidochelys olivacea</i>	Turtle	Obstruction of the oesophagus	Mascarenhas et al. 2004
<i>Phalaropus fulicarius</i>	Red Phalarope	Reduced food consumption, limiting ability to lay down fat deposits	Spear et al. 1995
<i>Sulidae sp</i>	Marine birds	Blockage of gastric enzyme secretion, diminished feeding stimulus, lowered steroid hormone levels, delayed ovulation and reproductive failure	Azzarello & Van Vleet 1987
<i>Proporus sp</i>	Sea Cucumber	Selectively ingest plastics over sediment grains, accumulation in lipid rich tissues, greater gut fluid release	Graham & Thompson 2009
<i>Balaenoptera physalus</i>	Baleen whale	High concentrations of endocrine disrupting toxicants found in the blubber of stranded fin whales	Fossi et al. 2012
<i>Nephrops norvegicus</i>	Norway Lobster	Ingested fibres forming spherical shapes in the gut and blocking passages	Wright et al. 2013b
<i>Mollusca sp.</i>	Suspension feeding bivalves	Feeding functions disrupted (cirral trapping)	Ward & Shumway 2004
<i>Acipenser transmontanus</i> ,	White Sturgeon	Protein levels and feeding behaviour altered	Rochman et al. 2017
<i>Ambassis dussumieri</i>	Glassfish	Growth, survival and body condition reduced	Naidoo & Glassom 2019
<i>Carassius auratus</i>	Goldfish	Reduced body weight; mouth and GIT damage, oxidative stress; altered growth/activity	Jabeen et al. 2018

Benthic Invertebrates

Prawns can be a good indicator for the contamination of plastics in the benthos. Banana prawns (*Penaeus merguensis*) and western king prawns (*Penaeus latisulcatus*) are benthic detrital feeders, that sift through the sand to feed upon crustaceans, molluscs and plant material (Alexander & Hindley, 1985; Rasheed & Bull 1992). Consequently, there is a high potential for the ingestion of plastics through the sediment that they feed upon, or from the food itself (i.e. trophic link) (Murray & Cowie 2011). In addition, plastic particles can be internalised by the prawns through respiration via gills (D'Costa 2022). Banana prawns and western king prawns in the coastal waters around Australia, have been reported to accumulate microplastics in various tissues such as their gastrointestinal tract (Ogunola et al. 2022). The consumption of plastics such as polystyrene and polyethylene, may affect the reproductive success, development and growth of prawns (Jaikumar et al. 2021; D'Costa 2022). Further, the plastic particles in prawns could bioaccumulate in animals higher in the trophic food chain, including humans.

Benthic holothurians (sea slugs) are an excellent model for studying plastic ingestion in deposit-feeding organisms. Holothurian's shovel, scoop, and rake large quantities of sediment into their mouths to extract nutrition from biofilms, organic debris, and microorganisms. However, it is unknown if plastic ingestion adversely affects the physiology behaviour or fitness of holothurians and crustaceans (Crump et al. 2020; Graham & Thompson 2009). The gut fluids of at least one deposit feeder (the polychaete *Arenicola marina*) release greater concentrations of polycyclic aromatic hydrocarbons (PAHs) than seawater, thereby potentially exposing them to PAHs adsorbed to ingested sediment (Voparil et al. 2009; Voparil & Mayer 2000).

Fish

Fish can ingest microplastics either via primary ingestion (i.e. the fish ingest the plastic directly, usually by mistaking it for food) (Worm et al. 2017); or by secondary digestion when prey that already contains plastic is ingested (Watts et al. 2014). Alternative exposure routes, such as gills, can also allow microplastic uptake in fish. Trophic level, feeding strategy, biogeography, habitat and ecological niche are likely to impact the amount and type of plastic ingested by fishes (Woodall et al. 2014). Following ingestion, the morphology of both the gastrointestinal tract (and ingested microplastics may affect the passage of plastic through the fish (Jabeen et al. 2018) and whether they temporarily or permanently lodge on gastrointestinal tract structures. Differences in gastrointestinal tract structure have been suggested as a driver of species-specific differences in concentrations of microplastics in fish (Jabeen et al. 2018).

Fine plastic particles can clog the gills, or the glands of the digestive system and thus disturb body functions such as respiration, the segregation of digestive enzymes, the absorption of nutrients, and the storage of energy reserves (Derraik 2002). Disruptions of these functions can lead to a decrease in the performance of the animals and to a decline in ecosystem services such as the processing of organic matter.

Marine Mammals and Reptiles

Macroplastics

Plastic pollution affects marine megafauna through entanglement (Tibbetts et al. 2018) ingestion (Alexiadou et al. 2019; Stephanis et al. 2013), habitat degradation (Pawar et al. 2016), and via ingestion, with ingestion causing severe negative effects such as intestinal blockages or malnutrition (Moore et al. 2013). Ingestion of macroplastics has been implicated in the mortality of a wide range of organisms including cetaceans sirenians and sea turtles (Santos & Duarte 2015).

Microplastics

Studies of microplastics in non-commercial large marine megafauna are less common. Microplastics may be ingested by marine megafauna, including marine turtles dugong and baleen whales (e.g. the humpback whale, *Megaptera novaeangliae*; (Simmonds 2012). Due to their non-selective feeding behaviour, macro filter feeders such as baleen whales can collect microplastics from the sea water column. Plastic particles have been found in the stomach of Franciscana dolphins, *Pontoporia blainvillei* in the gastrointestinal tract of True's beaked whales *Mesoplodon mirus* and in two baleen whale species, Minke (*Balaenoptera acutorostrata*), and Sei whales (*Balaenoptera borealis*) (Denucio et al. 2011).

1.3 Impacts of Chemical Absorption

Several of the ingredients associated with plastics are considered hazardous by regulatory agencies. (Browne et al. 2008; Linther et al. 2011; Rochman et al. 2013; USEPA 2013). Polymerization reactions are rarely complete and unpolymerized residual monomers can migrate off the plastic (Linther et al. 2011). Moreover, additive ingredients are not usually bound to the polymer matrix, and often account for the major leaching and emissions of chemical substances from plastic materials (Engler 2012; Ribeiro et al. 2019). Release of hazardous substances, including phthalates, brominated flame retardants, bisphenol A, formaldehyde, acetaldehyde, 4-nonylphenol and many volatile organic compounds, from plastic products has been shown (Crain et al. 2007). As such, these chemicals may be

bioavailable to marine life and thus there is potential for organisms to be impacted by the chemical ingredients associated with plastic debris. The dialkyl or alkyl/aryl esters of 1,2-benzenedicarboxylic acid, commonly known as phthalates, are high-production-volume synthetic chemicals; moreover, they are not covalently bound to plastic and migrate from the products to the environment, thus becoming ubiquitous contaminants (Latini & Rau 2009).

Marine plastics adsorb and transport chemicals, including high concentrations of organochlorines such as polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethane (DDT) and PAHs (Teuten et al. 2007).

Oxidative stress and histological damage are common impacts at the organ/tissue level where the processing of microplastics and/or any associated chemicals induce an immune response, resulting in localized cell damage and altered morphology of physiological structures and processes (Wang et al. 2020; Oliveira et al. 2013).

Microplastics can adsorb high concentrations of persistent organic pollutants. Once ingested these can eventually leak out into the organism's body; disrupting the function of their organs due to chronic exposure (Bakir et al. 2014). In addition, additives in their composition, such as phthalates, are suspected of endocrine disruption (European Commission DG ENV, 2000).

1.4 Accumulation of Contaminants in Plastic Particles

Because of their physical and chemical properties, plastics accumulate a complex mixture of chemical contaminants present in the surrounding seawater, including persistent organic pollutants in sea water. While plastics debris 'cleans' the sea water of pollutants, on being ingested, these pollutants can become bioavailable to the organism (Endo et al. 2005; Bowmer and Kershaw, 2010).

A study measuring the bioaccumulation of persistent organic pollutants absorbed to plastics demonstrated the transfer of chrysene, PCB 28 and several congeners of PBDEs to fish from the ingestion of polyethylene pellets (Rochman et al. 2013).

The accumulation of metals on marine plastic debris may be explained by both the chemical ingredients of the plastic (e.g. catalysts, fillers, plasticizers; (Robertson 1966) and the degradation and fouling of aquatic plastic debris via microbial biofilms and colonization by algae and invertebrates (Holmes et al. 2012; Lee et al. 2013) that may generate active sites for the sorption and/or bioaccumulation of metals.

1.5 Bioaccumulation

The uptake of microplastics has been confirmed in wild populations of numerous marine organisms across all trophic levels, with increased accumulation of microplastic in higher trophic level predators (Farrell & Nelson 2013; Provencher et al. 2018; Tao et al. 2019).

With their increased gape, body size, and high trophic order, microplastics may accumulate in apex predators. For example, populations of largemouth bass (*Micropterus salmoides*) (Hurt et al. 2020) and northern pike (*Esox lucius*) (Campbell et al. 2017) had higher concentrations of microplastics in their gastrointestinal tract than lower trophic order fishes in the same system.

There are limited studies linking microplastic accumulation in humans from seafood consumption, however, seafood is a vector for potential human exposure to microplastics (Danopoulos et al. 2020; Smith et al. 2018). A novel Australian wide study has recently published findings on the assessment of microplastics across a broad range of species from 25 different species (15 finfish, 6 crustacea, 3 bivalves, 1 cephalopod) investigating microplastics in commercially caught Australian fish and invertebrates. Samples were sourced from commercial fishers, seafood processors or sales outlets throughout Australia including from Perth, Adelaide, Melbourne, Hobart, Sydney, Brisbane and Darwin. Although around 44% of the ~1800 organisms examined contained microplastics, the average number of microplastics per organism was low, at around 1 particle per organism. Similarly, microplastic load (number of microplastic pieces per organism) also varied greatly among samples – ranging from 0 through to 29 pieces found in an oyster from South Australia (Gillanders et al. 2021), demonstrating the potential for filter feeders to contain greater levels.

2 Methods

Two methods were proposed for the collection of fish samples; barrier netting and benthic trawl.

2.1 Barrier Netting

In this method fish are collected on SCUBA by herding them into a 15 x 2 m barrier net. Each fish is quickly be captured with a hand net and immediately placed into a holding container. Good diving conditions and good visibility in the water are required for this method. Flooding, inclement weather and poor visibility in the first two quarters of 2022 prevented the use of this technique.

2.2 Benthic Trawls

Ocean biota were surveyed using a benthic trawl. The trawl was used to collect biota at similar depths at both the impact (diffuser) and control (Raper Shoal) sites (Figure 2.1). The benthic trawl was towed in a zig zag pattern, using 48 metres of rope, at a constant speed of 2 – 2.5 knots and for approximately 25 minutes at each site. The biota were then placed into a calico bag tied with a rubber band, a glass jar, or wrapped in foil (Figure 2.3 to Figure 2.5).

The biota that was collected is listed in Table 2.1. Collection of these samples was highly constrained due to inclement weather and consequent HSE concerns in the first two quarters of 2022.

2.3 Laboratory Analysis

Biota samples were frozen and freighted to the laboratory for analysis. All samples from the vicinity of the diffuser were analysed. Where there was a positive identification of likely MBBR particles in a sample from near the diffuser, then the equivalent samples from the control sites were analysed.

Laboratory methods are presented in Attachment 4 of Appendix D. In summary all fin-fish were gutted and tissue and gut analysed, while invertebrates were not gutted. Once prepared the samples were:

- digested using Fenton Agent
- examined under a microscope coupled with image analysis, and microplastics extracted.

The microplastics were then collected and categorised according to their size class, colour and shape, and the polymer chemistry identified using spectral analysis. The likely polymer chemistry was assigned by matching to a Global polymer library, using the highest percent matching. Fragments that were black, and had the polymer type of 'black polyethylene' may have originated from MBBR plastic media.

Table 2.1 Species caught using the trawl at the impact and control sites

Date Sampled	Location	Common name	Species	Sample type
Potentially Impacted Sites				
19/04/22	Diffuser	Dragonet	<i>Callionymus</i> sp.	Muscle
19/04/22	Diffuser	Dragonet	<i>Callionymus</i> sp.	Gut
19/04/22	Diffuser	Mixed prawns		Muscle
19/04/22	Diffuser	Shrimp	Unidentified shrimp	Muscle
Control Sites				
19/04/22	Raper Shoal	Cardinalfish	<i>Apogonid</i> sp.	Muscle
19/04/22	Raper Shoal	Cardinalfish	<i>Apogonid</i> sp.	Gut
19/04/22	Raper Shoal	–	Unidentified fish sp.	Muscle
19/04/22	Raper Shoal	–	Unidentified fish sp.	Gut
19/04/22	Raper Shoal	Mixed prawns		Muscle
19/04/22	Raper Shoal	Shrimp	Unidentified shrimp	Muscle

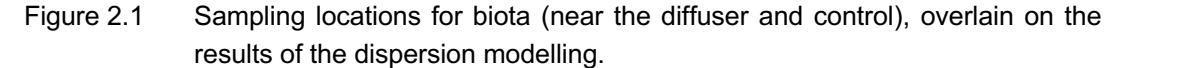




Figure 2.2 Manta trawl used to collect benthic biota (yellow floats were removed for benthic sampling).



Figure 2.3 Fish caught with the benthic trawl.



Figure 2.4 Prawn caught with the benthic trawl.



Figure 2.5 Shrimp caught with the benthic trawl.

3 Results and Discussion

Near the diffuser there were black polyethylene particles (that may have originated from the MBBR carriers) in one shrimp sample, and both shrimp samples had other microplastics in their tissue. Shrimp from the control site at Raper Shoal did not have any black polyethylene particles in their tissue, although one sample did have other microplastics (Table 3.1).

While one of the prawn samples, the limpet and the gastrointestinal tract of the dragonet sample from the diffuser site contained microplastics, none contained black polyethylene particles.

Overall, 2 of the 9 microplastic particles found in biota near the diffuser were black polyethylene, that may have originated from the MBBR carriers.

That is, black polyethylene particles, that may have originated from the MBBR carriers, may have been ingested or absorbed by some biota (i.e. the shrimp) near the diffuser, but were not prevalent in biota from this area. All biota sampled, other than the limpet, are mobile and are likely to feed in a variety of areas, and consequently any impact from the diffuser releasing microplastic particles would be diluted.

Table 3.1 Summary table of microplastic found in ocean biota samples

Sample #	Common name	Sample weight (g)	Polymer type	No. MPs in tissue	No. MPs in gut	Mean No. particles /gram	Black polyethylene	Library Match (%)
Potentially Impacted Sites								
Diffuser								
F1	Mixed prawns	3.61	PA	1	0	0.28	No	58.00
			PP	1	0	0.28	No	77.60
F2	Shrimps	5.04	PE	2	0	0.40	Yes	71.00-78.00
F3	Mixed prawns	2.33	-	0	0	0	-	-
F4	Shrimps	5.54	PA	1	0	0.18	No	66.00
			PE	1	0	0.18	No	72.00
F5	Limpet	0.35	PE	1	0	2.86	No	70.00
F12	Dragonet	1.43	PP	0	2	0.72	No	52.00
Control Sites								
Raper Shoal								
F6	Shrimps	4.15	-	0	0	0	-	-
F7	Mixed prawns	0.80	PVA	1	0	1.25	No	47.90
F10	Mixed prawns	9.07	PVA	1	0	0.11	No	83.00

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Attachment 1 Laboratory Results

MICROPLASTICS - REPORT OF ANALYSIS

Job description	: Investigating the Characteristics of Microplastics in Oceanic Biota		
Job status	: Completed		
Work order	:	Laboratory	Environmental Plastics Innovation Cluster(EPIC), Global Innovative Centre for Advanced Nanomaterials (GICAN), THE UNIVERSITY OF NEWCASTLE
Client Contact	: Carol Conacher	Contact	: thavapalanisami@newcastle.edu.au
Address	: Unit 1, 7-9 Grant St Cleveland QLD 4163	Address	Global Innovative Centre for Advanced Nanomaterials (GICAN) Level 1, ATC Building, UNIVERSITY DRIVE CALLAGHAN THE UNIVERSITY OF NEWCASTLE NSW 2308
Telephone	: +61 7 3286 3850		
Order number	:		
C-O-C number	:		
Sampler	:		
Site	: Pacific Ocean	Telephone	: + 61 431 300 521
No. of samples analysed	: 10	Report ID and issue date	: E27-E28 Ocean_Biota_2022-06-06

This certificate of analysis contains the following information:

- General comments
- Laboratory Report

ABBREVIATIONS:

g – grams, μm – micrometer; MPs – Microplastics;

Abbr.	Polymer Type
Black PE	Black Polyethylene fragments
PA	Polyamide
PE	Polyethylene
PP	Polypropylene
PVA	Polyvinyl alcohol

Data Sheet of Metadata

Sample #	Sample Code	Biota Name	Date Sampled	Sample Weight (g)
1	F1	Mixed prawns	19/04/2022	3.61
2	F2	shrimps	19/04/2022	5.04
3	F3	Mixed prawns	19/04/2022	2.33
4	F4	shrimps	19/04/2022	5.54
5	F5	limpet sp	19/04/2022	0.35
6	F6	Shrimps	19/04/2022	4.15
7	F7	Mixed prawns	19/04/2022	0.80
8	F10	Mixed prawns	19/04/2022	9.07
9	F12a	Dragonet sp.	19/04/2022	1.37
10	F12b	Dragonet sp.	19/04/2022	0.06

The labels are given according to the suppliers file name "211109 COC Plastics 22-04-24 DS".

*The labels are given as such from the sample containers as per the advice from the suppliers.

Data Sheet of Microplastic Abundance

Sample #	Sample Code	Sample Weight (g)	No. of MPs (Tissue)	No. of MPs (Gut)	Total No. of MPs	Mean No. MPs (total/g)
1	F1	3.61	2	–	2	0.55
2	F2	5.04	2	–	2	0.40
3	F3	2.33	0	–	0	0
4	F4	5.54	2	–	2	0.36
5	F5	0.35	1	–	1	2.86
6	F6	4.15	0	0	0	0
7	F7	0.80	1	–	1	1.25
8	F10	9.07	3	–	3	0.33
9	F12a	1.37	0	0	0	0
10	F12b	0.06	0	2	2	33.33

Data Sheet of Microplastic Characterization

Sample #	Sample Code	Total No. of MPs	No. of MPs (<500µm)	No. of MPs (>500µm)	MP Colour	MP Shape	MP Polymer Type (FTIR)	Library match (%)
1	F1	1	1	0	Black	Fibre	PA	58.00
		1	1	0	Black	Fibre	PP	77.60
2	F2	1	1	0	Black	fragment	Black PE	78.00
		1	1	0	Black	fragment	Black PE	71.00
3	F3	0	0	0				
4	F4	1	1	0	Black	fibre	PA	66.00
		1	1	0	White	fibre	PE	72.00
5	F5	1	1	0	White	fibre	PE	70.00
6	F6	0	0	0				
7	F7	1	1	0	Red	fibre	PVA	47.90
8	F10	1	1	0	Red	fibre	PVA	83.00
9	F12a	0	0	0				
10	F12b	1	1	0	Black	fragment	PP	48.00
		1	1	0	Black	fragment	PP	52.00

Appendix N Statutory Declarations

Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Science (the department).

Oaths Act 1867

**QUEENSLAND
TO WIT**

I Christopher James Conway

Insert the name of the person making this declaration

Of Beca – Hunter H2O Pty Ltd

Insert the street address of the person making this declaration

in the State of NSW do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled

Assessment of microplastics in Kawana Sewage Treatment Plant – Appendix D

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the *Environmental Protection Act 1994* (the Act) to:

Unitywater

14/12/2021

Insert name of recipient of the notice

Insert date of the notice

A copy of my report is attached to this statutory declaration.

I possess the following qualifications and experience relevant to this environmental evaluation:

BE Chem Eng, MIEAust

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

Statutory Declaration
Suitably qualified person

I certify that:

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at Newcastle

Insert location

this 23rd day of June in the year 2022
Insert day (e.g. 18th) Insert month Insert year

Signed

(Person making this declaration)

Signed

JP (Qual)

SCOTT R BARBEY
Printed name and registration number (if applicable) JP120269

Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Science (the department).

Oaths Act 1867

**QUEENSLAND
TO WIT**

I Ed Beling

Insert the name of the person making this declaration

of Intrawater Pty Ltd

Insert the street address of the person making this declaration

[REDACTED]

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled
Kawana Sewage Treatment Plant Environmental Investigation - Appendix H Dispersion Modelling /
Hydrodynamic and Particle Tracking Modelling Assessment

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the *Environmental Protection Act 1994* (the Act) to:

Unitywater

Insert name of recipient of the notice

14/12/2021

Insert date of the notice

A copy of my report is attached to this statutory declaration.

I possess the following qualifications and experience relevant to this environmental evaluation:

BEng (Civil Hons) MSc (Marine Science) CPEng RPEQ

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

Statutory Declaration
Suitably qualified person

I certify that:

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at The Gap Brisbane, Queensland

Insert location

this 24th day of June in the year 2022

Insert day (e.g. 18th)

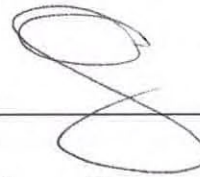
Insert month

Insert year



Signed

(Person making this declaration)



Signed

JP (Qual)

SOLICITOR.

Melissa Marie Demarco

Printed name and registration number (if applicable)

Statutory Declaration

Environmental Protection Act 1994

Environmental Evaluation

Suitably qualified person

A Statutory Declaration is a written statement of facts that is sworn or declared under the Oaths Act 1867. This Statutory Declaration must be completed by the person who conducted the environmental evaluation and accompany the environmental report submitted to the Department of Environment and Science (the department).

Oaths Act 1867

QUEENSLAND
TO WIT

Carol Conacher

Insert the name of the person making this declaration

of

frc environmental

Insert the street address of the person making this declaration

[REDACTED]

in the State of Queensland do solemnly and sincerely declare that:

- I am the suitably qualified person and author of an environmental report entitled
Kawana Sewage Treatment Plant Environmental Investigation, and Appendices J to M of that report

Insert title of the environmental report

In accordance with the environmental evaluation issued by the department under the *Environmental Protection Act 1994* (the Act) to:

Unitywater

Insert name of recipient of the notice

14/12/2021

Insert date of the notice

A copy of my report is attached to this statutory declaration.

I possess the following qualifications and experience relevant to this environmental evaluation:

BSc. CEnvP, FEIANZ

I have not knowingly included any false, misleading or incomplete information in the report; and

I have not knowingly failed to reveal any relevant information or document to the department.

Statutory Declaration
Suitably qualified person

I certify that:

- The report addresses the relevant matters for the evaluation and is factually correct; and
- The opinions expressed in it are honestly and reasonably held.

I make this solemn declaration conscientiously believing the same to be true, and by virtue of the *Oaths Act 1867*.

Taken and declared before me, at

Brisbane

Insert location

this 22 nd day of June in the year 2022

Insert day (e.g. 18th) Insert month Insert year

CA Thorogood
Signed
(Person making this declaration)

S Kooznetzoff
Signed
JP (Qual)

Sonya Kooznetzoff 108818
Printed name and registration number (if applicable)