

CATCHMENT SCALE WATER QUALITY AND ECOLOGICAL MONITORING IN AUCKLAND'S MEOLA CREEK AND COASTAL ENVIRONMENT

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ABSTRACT

Urban stormwater and combined sewer overflows (CSO) discharging into the Meola Creek (Auckland, New Zealand) have potential risks for public health and aquatic ecology. Monitoring was carried out by Auckland Council at selected stream, marine and discharge sites over summer and autumn 2010/2011 to characterise stream and coastal water quality.

Continuous monitors were installed and synoptic dry-weather and wet-weather events were sampled for heavy metals, nutrients, suspended sediment, indicator bacteria and norovirus. Stream Ecological Valuations (SEV) were also carried out at four sites and biofilm assessments at two sites to assess stream ecological health.

Wet weather monitoring provided evidence of the first flush phenomenon from CSO and stormwater inputs. Norovirus was detected during both wet and dry-weather monitoring. Dissolved oxygen in the upper catchment falls to levels below that of life-sustaining capacity (0 ppm) overnight during summer periods of low flow.

SEV values ranged from 0.574 to 0.645 revealing a trend of increasing ecological value moving from upper to lower catchment. Macroinvertebrate Community Index (MCI) values and bio-film sampling showed a similar trend highlighting the influence of water quality on aquatic ecology.

KEYWORDS

Monitoring, stormwater, urban runoff, water quality, combined sewer overflow (CSO), stream ecological valuation (SEV), macroinvertebrate community index (MCI), heavy metals, Auckland region, New Zealand

PRESENTER PROFILE

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Justine has extensive experience in environmental science and freshwater ecology. Focusing on urban stream ecology, she has surveyed streams in the Auckland region, gaining knowledge of stream assessment methodologies including development of Watercourse Management Plans. She graduated from the University of Auckland with a BSc (Biology) and PGDipSci (Environmental Science).

1 INTRODUCTION

This paper describes the water quality and ecological monitoring undertaken in the Meola Catchment, Auckland, over summer/autumn, 2010/11.

Urban stormwater and combined sewer overflows (CSO) discharging into the Meola Creek have potential risks for public health and aquatic ecology. Large scale capital works proposed in the catchment are being considered to significantly reduce the effects these discharges have on the receiving environments, as well as provide for flood mitigation and improve aesthetics.

The Watercare Services Central Interceptor (CI) proposes a 4-5 metre diameter, 13 kilometre tunnel to provide for growth, create resilience in its collection network and capture and take combined sewer flows to Mangere Wastewater Treatment Plant (Watercare Services Limited, 2011). The Auckland Council Central Auckland Stormwater Initiative (CASI) has identified Meola Creek as a catchment with significant stormwater management issues.

Monitoring has been undertaken to provide information to consider in addressing the objectives of the CI and CASI studies.

Previous monitoring had been restricted to single points within the mid to lower catchment for either dry or wet weather events including a single wet weather event sampling undertaken in April 2010 (Clarke, 2010), two wet weather events in 2006 (Moores, Reed, Pattinson, & McHugh, 2006), and two dry weather and wet weather events in 2004 (SKM, 2004).

The monitoring discussed in this paper, builds upon the earlier monitoring and contributes a more comprehensive depiction of the spatial characterisation of water quality along the creek under different conditions; quality in the stream and adjacent coastal zones; and contributions from stormwater and CSOs. The water quality information is supported with ecological assessments throughout the creek. These two key regimes are summarised following:

- Water quality monitoring was carried out in Meola Creek and the marine receiving environment between November 2010 and June 2012. This programme included baseline, wet weather and continuous monitoring within the receiving environment and at specific discharge points (Coup & Clarke, 2012).
- Stream Ecological Valuations (SEV) were carried out at four sites within Meola Creek between March and May 2011, to provide a baseline ecological value (Coup & Pearce, 2012).

The objectives of these monitoring regimes were defined by a variety of stakeholders. The information obtained provides the 'story' of existing conditions within the creek and can inform where improvements can be made.

1.1 MEOLA CREEK

Meola Creek is an urban stream which flows from Mt Albert through to Point Chevalier, in the western suburbs of Central Auckland. The creek flows through a highly modified urban watershed (1518 ha) with approximately 45% catchment imperviousness made up of primarily residential landuse (Miselis, Sharman, Ursem, & Captain, 2012). Approximately 5 km of open watercourse remains, with nearly 1.8 km of the main channel piped. In its upper reaches Meola Creek is highly modified and has been lined in many locations to improve stormwater conveyance and minimise erosion (Coup, Young,

& Eivers, 2009). The degree of naturalness increases as the watercourse gets closer to the sea.

The Meola Creek catchment is located in an old part of the city with approximately 20% of the catchment containing a dedicated stormwater network. The remainder of the catchment is serviced by a combined sewer network or soakage where stormwater is directed to the underlying basalt aquifer (Western Springs Aquifer).

Discharges from the creek enter the Waitemata Harbour and influence the quality of coastal water including the Point Chevalier bathing beach. Two of the city's largest combined sewer overflows (Haverstock and Lyons) operate within the upper catchment, discharging more than 100 times per year in the order of 1 million cubic metres (Cantrell, 2011; Miselis et al., 2012). Accumulation of heavy metals at the Meola Creek mouth (ARC, 2010); community access and amenity value of the Meola Creek and reserves; and recreational beach usage at Point Chevalier make the catchment and its issues a focal point within the city and Auckland region (Coup et al., 2009). In addition, a significant flood risk exists in the catchment (Miselis et al., 2012).

1.2 PROJECT SCOPE AND OBJECTIVES

Sampling of an isolated wet weather event was carried out within Meola Creek in April 2010 (Clarke, 2010). With less than 24 hours' notice three teams mobilised to capture the effects of the 'first big rain' following approximately five dry months. This sampling was limited in terms of the number of sites, however provided valuable insight into the dynamics of CSOs within Meola Creek. The monitoring programme developed for the 2010/11 sampling was based on the learnings of this initial sampling effort. The objectives of the programme were varied and the result of multiple workshops with various stakeholders. Ultimately the objectives of the water quality monitoring programme (Coup & Clarke, 2012) were to:

- gather sufficient information to inform future monitoring in other catchments.
- support modelling of the contaminant loading and water quality processes for the stream and harbour receiving environments for the Meola catchment.
- provide information regarding the baseline state of the receiving environment, and the impact that stormwater and combined sewer overflow discharges have on the receiving environment during wet weather events.

2 MONITORING

Between November 2010 and June 2011, four monitoring regimes were carried out within the freshwater and marine receiving environment of the Meola Catchment. These were continuous monitoring, baseline monitoring, wet weather monitoring and ecological assessments. These are discussed in the following sections.

2.1 SITES

Figure 1 provides an overview of sites sampled during the monitoring programme.

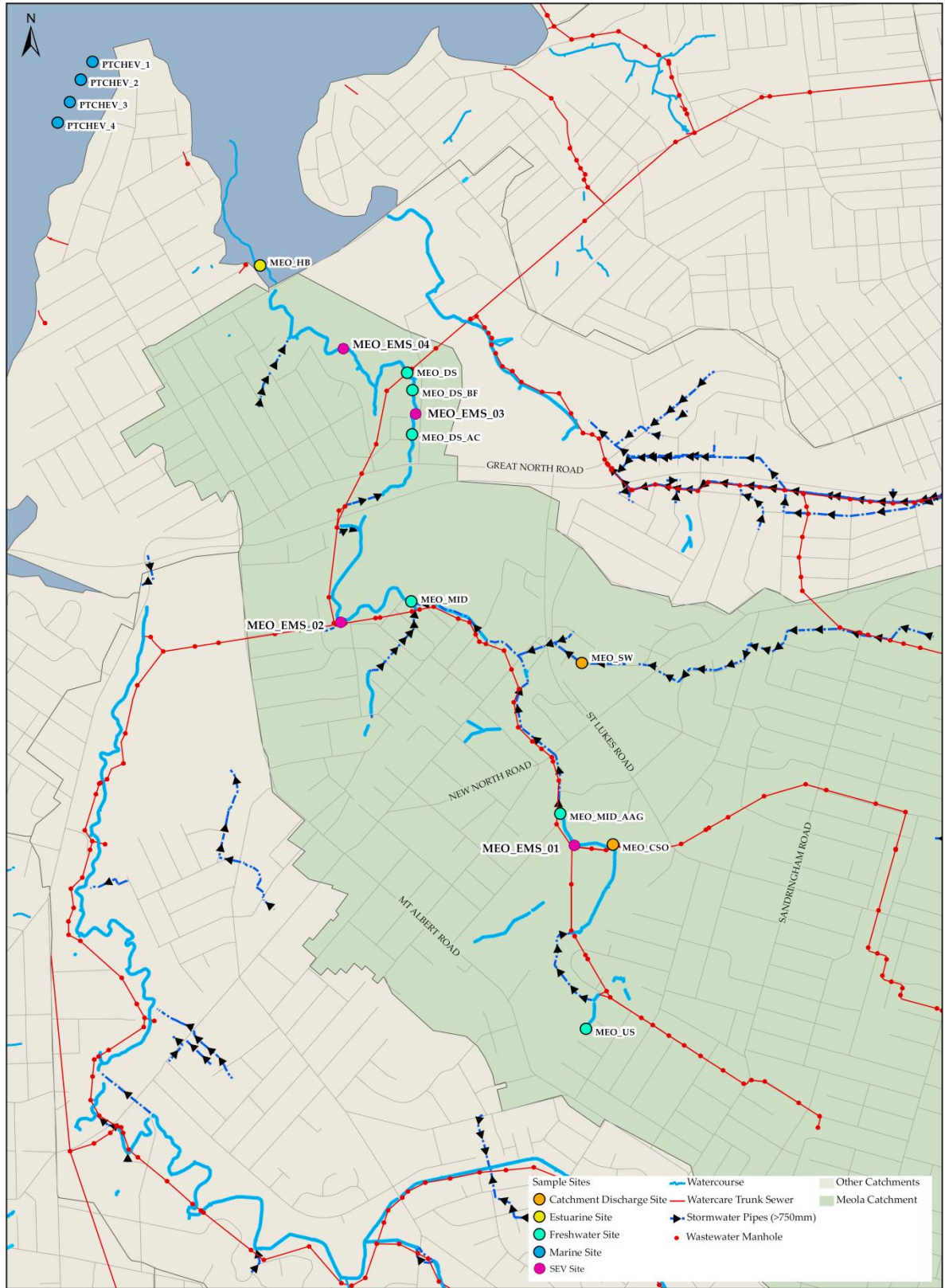


Figure 1: Meola Catchment Monitoring Sites 2010/11

2.2 CONTINUOUS MONITORING

Continuous monitors were located at selected sites (MEO_DS, MEO_MID_AAG, MEO_SW, MEO_US) within the catchment to measure a combination of flow, water level, temperature, dissolved oxygen (DO) and pH.

2.2.1 RESULTS

Dissolved oxygen and temperature exhibit clear diurnal patterns at both the MEO_DS and MEO_MID_AAG sites (Figure 2). Of concern was that the MEO_MID_AAG site in the upper catchment experienced an exaggerated diurnal variation, with dissolved oxygen periodically falling to 0 ppm at night which is below the life-supporting capacity for aquatic fauna (NIWA, 2010).

Dissolved oxygen increased following rainfall as increased flow provided turbulence re-introducing oxygen into the system. A DO sag (reduction in dissolved oxygen) was observed in some instances and was particularly evident when the rain event was small, and lacked sufficient flow to flush suspended contaminants through the system. Several examples of the CSO effects on DO are shown in Figure 2. Following a small rain event in mid-January the Lyons Ave CSO overflowed; dissolved oxygen decreased to zero and took several days to recover, during which time the CSO overflowed again (Note 1). After several days of rain the baseflow fluctuated resulting in higher nocturnal dissolved oxygen however lower daytime peaks due to less plant biomass (Note 2). Two larger rain events in late-January provided enough rain to increase baseflow water level resulting in higher dissolved oxygen and lower stream temperatures (Note 3). A small CSO lasting only 20 minutes can be sufficient to significantly reduce dissolved oxygen in the creek (Note 4).

A diurnal pattern was observed for pH, which was also influenced by rainfall, causing a lower pH. The MEO_MID_AAG site showed a more pronounced diurnal pH fluctuation which is likely to be a result of the higher levels of algae present influencing photosynthesis which subsequently affects pH (Chapman, 1996).

Turbidity monitoring was largely unsuccessful due to sensor interference from excessive, rapid algal growth and grazing *Potamopyrgus* snails. In some instances the results obtained for turbidity show the pattern of peaks and troughs associated with rain events although the values may not be consistent.

Flow monitoring provided insight into the relationship between rainfall and groundwater level in the catchment which is dominated by the Western Springs Aquifer. Higher groundwater levels following rainfall increased baseflow within the stream. This was particularly evident in the upper Meola Creek where the difference between the ground water inputs ranged from almost 2 l s⁻¹ to over 50 l s⁻¹ of baseflow in periods of higher groundwater during the monitoring.

Continuous monitoring revealed a clear distinction between the upper and lower catchment. The difference in DO and temperature can be attributed to high volumes of groundwater inputs in the lower catchment.

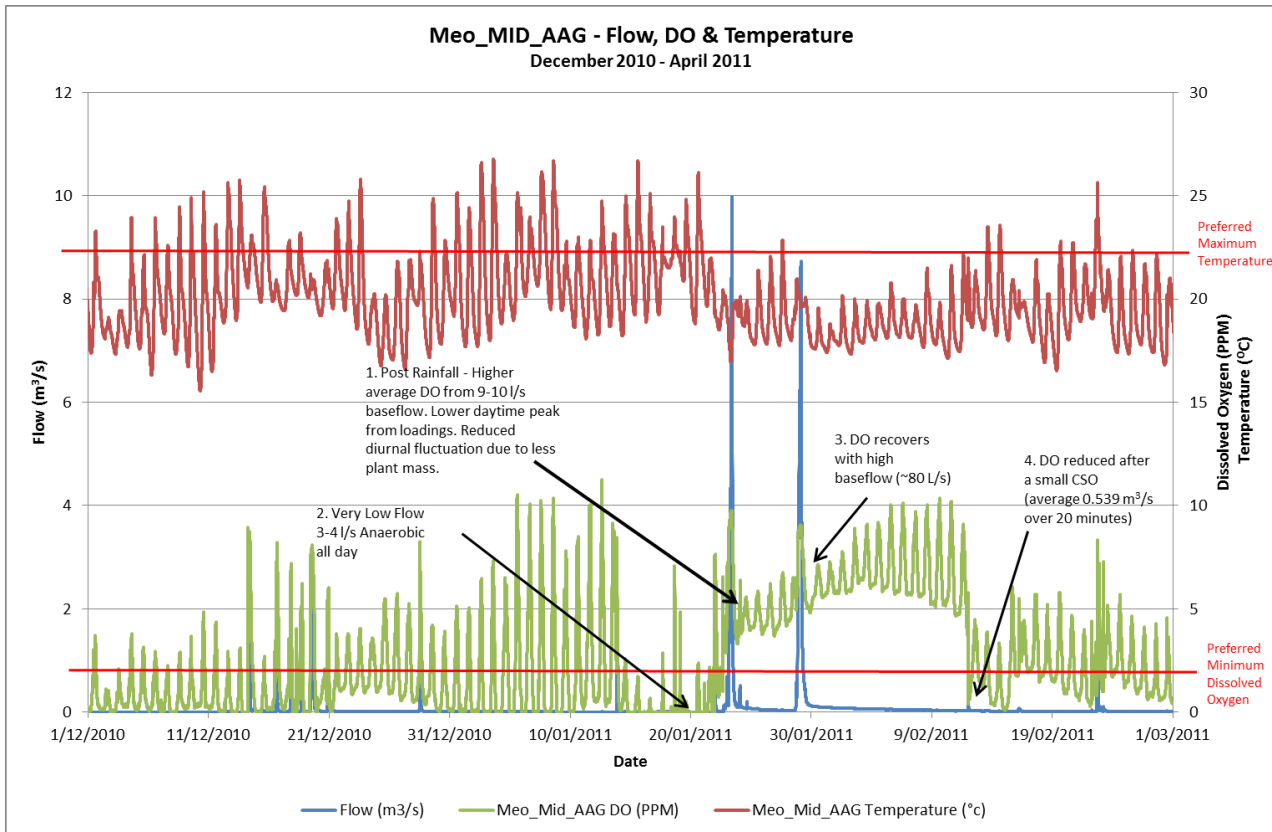


Figure 2: Three month trends identified for dissolved oxygen and temperature in relation to flow and Meo_MID_AAG site.

2.3 BASELINE MONITORING

Baseline monitoring of water quality was carried out at three freshwater sites (MEO_DS, MEO_MID, MEO_US), one estuarine (MEO_HB) and four marine sites (PTCHEV1-4) during dry weather once per month between November 2010 and January 2011. Samples were taken at the same time at each site, and were tested for microbiology, nutrients, hydrocarbons, suspended solids and oxygen demand. Some samples were also tested for campylobacter and norovirus. Following site sampling, the stream was walked between sites to identify possible sources of contamination that may affect results. Potential contamination sources (i.e. dry weather overflows (DWO)) were also sampled and tested for similar parameters. In addition, biofilm and biofilm metals were sampled at two freshwater sites (MEO_DS_BF, MEO_US) in November 2010 and January 2011.

2.3.1 RESULTS

Baseline monitoring revealed that all freshwater sites were at risk of microbiological contamination for contact recreation, exceeding the 550 cfu/100mL contact recreation guideline level (MfE, 2003). During the baseline stream walk, a DWO was observed on two occasions, with *E. coli* levels of 1-3 million cfu/100mL, influencing downstream water quality. This was reported and the issue subsequently remedied.

None of the marine sites had *E. coli* or Enterococci levels of concern during baseline with all but two below detection levels. However, norovirus was detected at one Point Chevalier Beach sampling point during December baseline sampling, which is when the dry weather overflow inputs were present.

Zinc was present above the ANZECC guideline value for ecosystem protection for slightly to moderately disturbed aquatic or freshwater ecosystems for 50% of samples (ANZECC, 2000). Metals in biofilm were higher at the upstream site, with values up to 20 times

higher than sediment quality guidelines. Biofilm Community Index (BCI) scores indicate that the downstream site is in better health than the upstream site (Lewis & Washington, 2011).

Most other parameters were considered to be within the expected regional average (Neale, 2010) or below detection limits. Baseline monitoring revealed that during baseflows the residual effects of CSO are still apparent. Other typical urban contaminants (metals, TPH) were less evident in water, but may still be present in sediment, which was not sampled.

2.4 WET WEATHER MONITORING

Wet weather monitoring was carried out in January and April 2011 to understand water quality dynamics in the stream during storm events. Synoptic monitoring, triggered by the commencement of discharge from a large CSO, was undertaken. Sample sites were located at two freshwater sites (MEO_DS, MEO_US), one estuarine (MEO_HB) and four marine sites (PTCHEV1-4). In addition, catchment discharge points were sampled during the initial stage of the storms (one stormwater (MEO_SW) and one CSO (MEO_CS0)). Manual sampling was selected over the use of auto-samplers as it enabled greater flexibility to sample special parameters that required large volumes of sample (e.g. norovirus). Samples were tested for similar parameters as for baseline sampling, with the addition of volatile matter and particle size distribution.

Sample timing within the marine environment was heavily influenced by tides. The Coastal Receiving Environment Assessment (CREA) model (Croucher, Bogle, & O'Sullivan, 2005) was consulted to determine appropriate sampling timing to ensure the CSO contaminant peaks were captured.

2.4.1 RESULTS

Two wet weather events were sampled during the course of the monitoring programme (refer to Table 1 for details).

Table 1: Summarised wet weather event characteristics.

	Wet Weather Event 1 (WW1)	Wet Weather Event 2 (WW2)
Date	28/01/2011	16/04/2011
Antecedent dry period	3 days	8 days
Peak Rainfall Intensity	12 mm/hr between 1:00 am and 2:00 am 29-01-2011 (after sampling)	1.7mm/10mins. The peak intensity prior to CSO overflowing was 1mm/10minutes at 8:30am.
Rainfall prior to overflow	7.5 mm of rain had fallen in the 3.5 hours prior to the CSO overflowing	3.5 mm of rain had fallen in the 1hr 20 minutes prior to the CSO overflowing.
CSO Overflow Time and Duration	5:50 pm, overflowed for 110 minutes.	8:55 am, overflowed for 50 minutes.

During wet weather events a significant volume of untreated combined sewage entered the receiving environment, with concentrations in excess of 2 million E. coli released in the first flush of the WW2 CSO overflow at the MEO_CS0 site. There was evidence of an increased concentration of many contaminants in the first flush from discharge points (MEO_CS0, MEO_SW and MEO_US) (e.g. Table 2, Figure 3). Samples taken in the lower

catchment provide an indication of the mixing and delay in the catchment, with contaminant concentrations peaking approximately 2 hours after the CSO started.

As the second event followed a longer dry period, and had a steeper rising arm of the initial overflow, contaminant concentrations, including E. coli and total suspended sediments (TSS), were generally higher and exhibited a more exaggerated 'first flush' effect (e.g. Figure 3).

Monitoring confirmed that during WW2, heavy metal concentrations were significantly higher in the stormwater discharge, while microbiological indicators were significantly higher in the CSO discharge. A higher proportion of TSS was volatile (VSS) in the CSO discharge (average of 77%) than in the stormwater (average of 50%). High concentrations of microbiological indicators were observed in the creek and subsequently within the marine receiving environment along Point Chevalier Beach.

Table 2: E. coli (cfu/100mL) comparison across three wet weather event samples.

Site Name	Time after CSO Minutes	WW1 E.coli cfu/100mL	WW2 E.coli cfu/100mL	April 2010 E.coli cfu/100mL
Meo_CS0	0	82000	2270000	2400000
	10	88000	1780000	1300000
	20	64000	1350000	520000
	30	50000	1130000	550000
	60	54000	960000	200000
	120	540000	Overflow Stopped	Not sampled

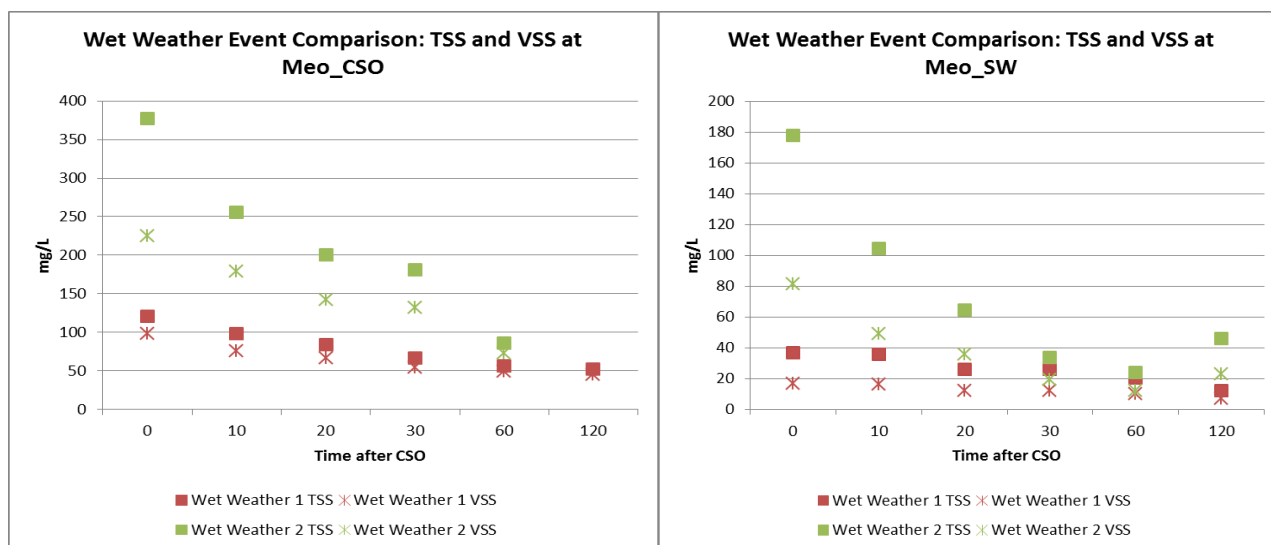


Figure 3 Total Suspended Solids (TSS) and Volatile Matter (VSS) for two wet weather events at the representative catchment discharge sites.

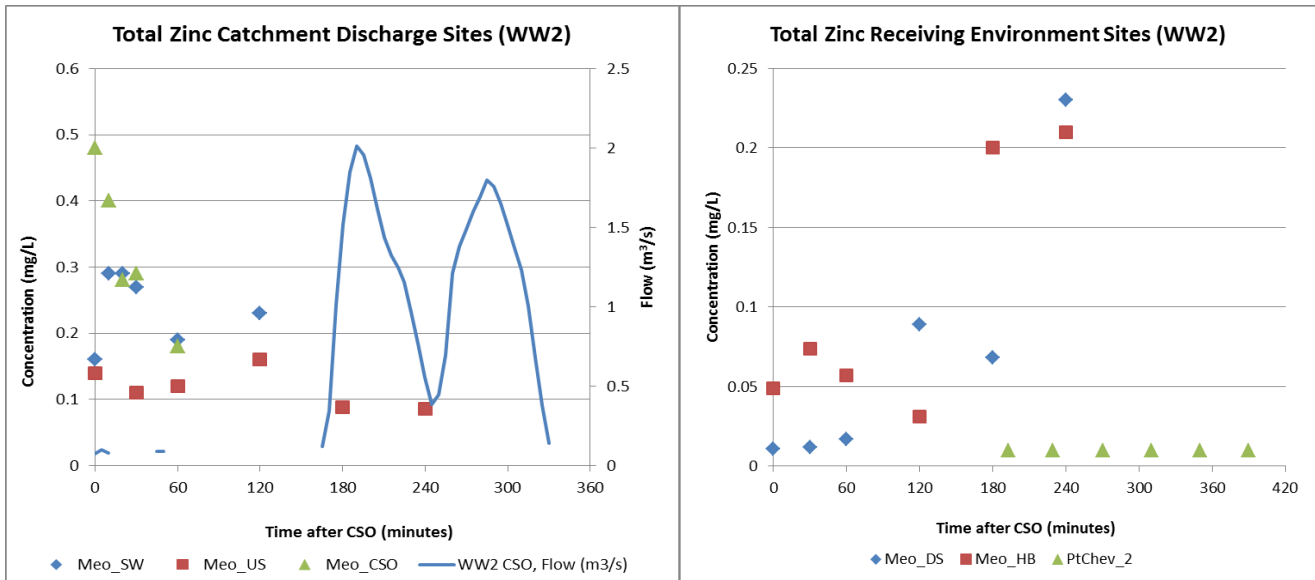


Figure 4: Total zinc concentration during WW2 exhibiting first flush peaks at discharge sites and the peak in the receiving environment approximately two hours later.

During this study, soluble zinc concentration was found to be highest from the stormwater discharge while total zinc showed a more varied pattern, particularly during WW2 where it was higher from the CSO (Figure 4). Like other metals zinc showed evidence of a first flush effect. This first flush occurred from the stormwater and CSO sites, and the peak concentration moved through the creek, with evidence of peaks at the downstream sites approximately two hours after the CSO started (e.g. Figure 4).

Total petroleum hydrocarbons (TPH) were assessed during both wet weather events. Typically TPH results were <0.3 mg/L for most sites, including the stormwater discharge site. An exception to this was the CSO site, which measured TPH of <0.3 mg/L for wet weather event 1, however had results ranging from 0.56 to 1.96 mg/L in the second wet weather event.

The presence and concentration of contaminants from these discharge points is likely to vary significantly depending on time between rainfall and catchment characteristics.

Particle size distribution (PSD) was analysed as a means of identifying the relative amount of particles within samples by particle size. Figure 5 illustrates the PSD of Wet Weather Event 2 as an average for each site. The graphs below relate to percentage of TSS volume smaller than the given size. This shows a pattern of larger particle size in the discharge and reduced particle size further downstream, potentially reflecting settlement of larger particles within the stream system.

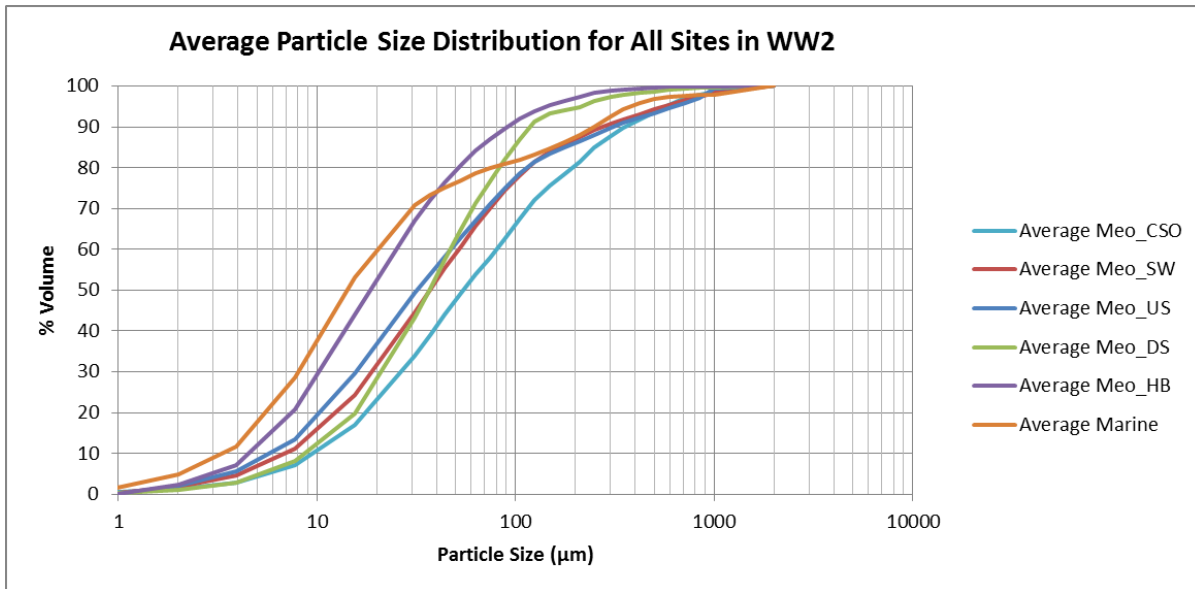


Figure 5: Average particle size distribution for each of the sites sampled for WW2 (nb: PtChev1-4 have been averaged together to produce the Average Marine data).

Figure 6 below illustrates the Enterococci indicator bacteria results for the marine sites on Point Chevalier Beach from the WW1 event. This indicates a peak in contaminant concentrations on the low incoming tide following the discharge.

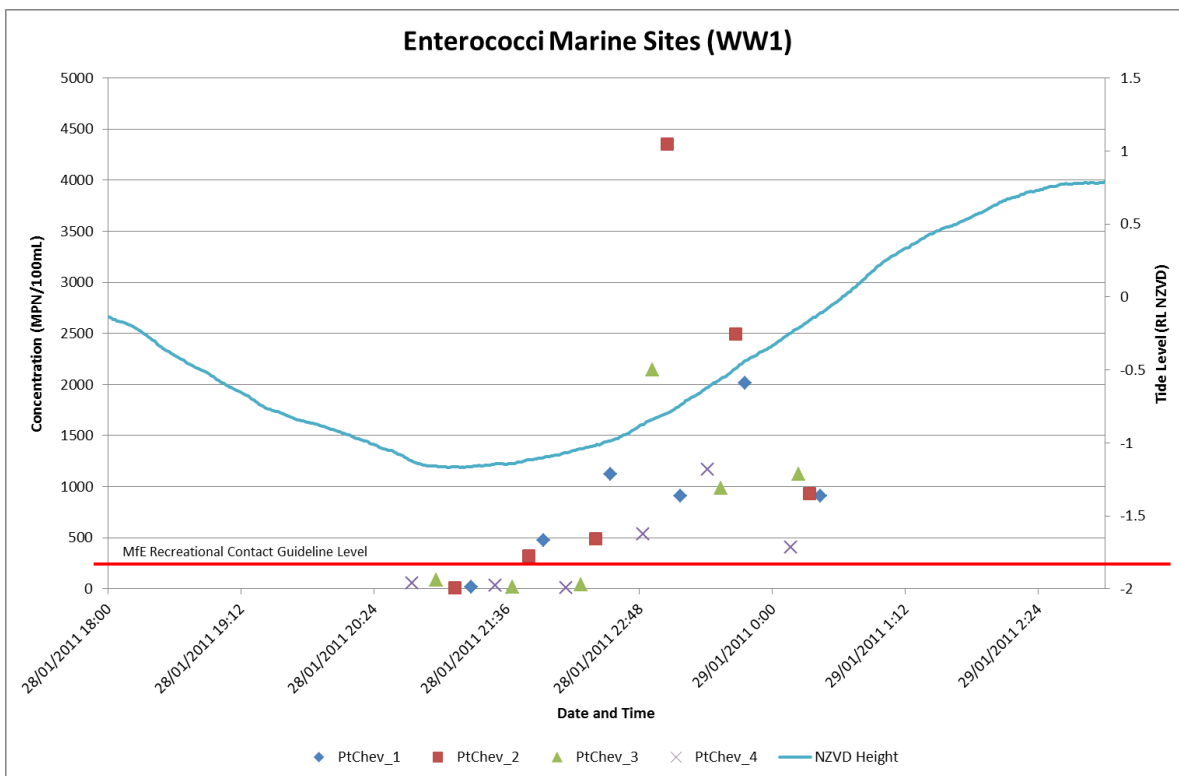


Figure 6: Enterococci concentration across four marine sites during WW1 in relation to tide (NZVD). The red line indicates MfE recreational contact level guidelines for enterococci (280 MPN/100mL).

2.5 ECOLOGICAL ASSESSMENT

Stream Ecological Valuations (SEV) (Rowe et al., 2008) were carried out at four sites along Meola Creek between April and June 2011 (Coup & Pearce, 2012). These were

located in the upper reaches within Roy Clements Treeway (Meo_EMS_01), below Rawalpindi Reserve (Meo_EMS_02), adjacent to Motions Road (Meo_EMS_03), and below Te Mahurehure Marae (Meo_EMS_04) (refer Figure 1).

The SEV method involves the assessment of 16 functions to determine ecological value of a stream reach. Scores range from 0 to 1, where 1 indicates an ideal stream (reference streams typically score in the order of 0.85 to 0.95). The 16 functions are summarised in Table 3 below.

The biodiversity function includes assessment of macroinvertebrate and fish fauna. Sites were determined as either hard or soft bottomed and macroinvertebrates were sampled accordingly. Macroinvertebrate fauna was scored using the Macroinvertebrate Community Index (MCI) and EPT (Ephemeroptera, Plecoptera, Tricoptera) methods for pollution sensitivity (Stark & Maxted, 2004, 2007).

Electric fishing was carried out to assess the fish population present. Where this was not possible due to site restrictions (excessive macrophytes, high conductivity or excessive silt) reference was made to previous studies and the NIWA New Zealand Freshwater Fish Database (Richardson, 2005). An Index of Biotic Integrity (IBI) score was calculated to determine the rating of the fish population at each site.

Table 3: Summary of ecological functions assessed in the SEV method (Rowe et al., 2008).

<p><u>Hydraulic function:</u></p> <p>Processes associated with water storage, movement and transport.</p>	<ul style="list-style-type: none"> • Natural flow regime • Connectivity to flood plain • Connectivity for species migration • Connectivity to groundwater
<p><u>Biogeochemical function:</u></p> <p>Relates to the processing of minerals, particulates and water chemistry.</p>	<ul style="list-style-type: none"> • Water temperature control • Dissolved oxygen levels • Organic matter inputs • In-stream particle retention • Decontamination of pollutants • Flood-plain particle retention
<p><u>Habitat provision functions:</u></p> <p>The types, amount and quality of habitats that the stream reach provides.</p>	<ul style="list-style-type: none"> • Fish spawning habitat • Habitat for aquatic fauna
<p><u>Native biodiversity function:</u></p> <p>The occurrences of diverse populations of flora and fauna that would normally be associated with the stream reach.</p>	<ul style="list-style-type: none"> • Fish fauna • Invertebrate fauna • Aquatic biodiversity • Riparian vegetation

2.5.1 RESULTS

SEV scores within Meola Creek increased from 0.574 at the most upstream site (Meo_EMS_01) to 0.645 at the most downstream site (Meo_EMS_04). This pattern of decreasing ecological value upstream is contrary to 'typical' catchments, as frequently, headwaters are less impacted than downstream reaches. All SEV values obtained are indicative of moderate ecological value. Biodiversity function was the lowest scoring function for all sites (Figure 7), likely a result of poor water quality restricting MCI scores.

Macroinvertebrate Community Index (MCI) scores, showed a similar pattern to the SEV values, indicating decreasing water quality moving upstream. Scores ranged from 55 at

Meo_EMS_01 to 75 at Meo_EMS_04. MCI scores of less than 80 are indicative of poor water quality indicating probable severe pollution (Stark, 1998; Stark & Maxted, 2004, 2007). The scores show an obvious improvement in the lower reaches where water quality is likely to be cleaner based on aquifer inputs providing dilution.

Several fish species were observed during the survey and others were recorded in the NIWA New Zealand Freshwater Fish Database. Meo_EMS_01 had the lowest scoring IBI with only eels present. It is expected that many other fish species are unable to live in the upper reaches due to oxygen depletion overnight.

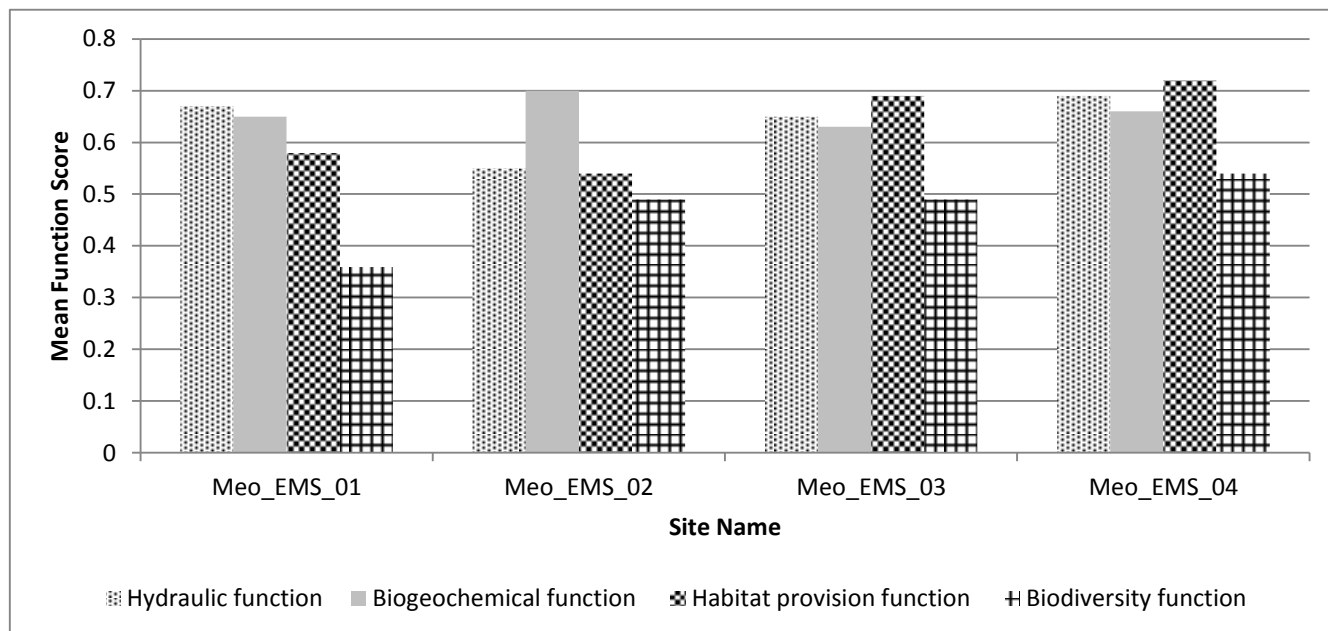


Figure 7: Mean Scores for each of the SEV Functions.

2.6 LEARNINGS

Large scale monitoring programmes are complex and can be difficult to implement. This may seem obvious, but is important to consider when developing a monitoring method and developing a timeline. As multiple stakeholders, working to different objectives and priorities, become involved in programme development added benefit can be attained, however may result in dilution of the original objectives.

Due to the reactive nature of wet weather sampling, auto-samplers could be considered as an alternative means of taking samples. However, most auto-samplers cannot collect the required volumes of sample for particular parameters. For example, norovirus alone needs a minimum of 10 litres, which must remain at <4°C. As such, field staff would be required regardless to ensure bottles were replaced fast enough.

The sample timing for wet weather events is very difficult to predict. WW1 for this project hit on a Friday afternoon before a long weekend. This has implications not only for staff resource capacity, but also receipt and processing of the large number of samples at the laboratory.

The provision of an integrated program of baseline, continuous and wet weather monitoring provides for synergy benefits. In particular the continuous monitoring including flow and dissolved oxygen provides an important context indicating the antecedent conditions and the impacts on stream processes from the sampled wet weather event.

3 DISCUSSION

The patterns of catchment scale discharges within Meola are complex, influenced by volumes, concentrations, timing, dilution and sediment transport. While a principal feature within this catchment is the wastewater from CSO discharges, the stormwater discharges (and the stormwater component of the CSO discharges) contain elevated levels of some contaminants. Modelling and assessment is underway to better define the potential changes to both dry and wet weather water quality and quantity in the Meola Creek under potential catchment management solutions.

3.1 PUBLIC HEALTH RISK

Wastewater in the receiving environment can pose a significant health hazard due to bacteria, pathogens and viruses that may be present. Public health risk is a factor of the likelihood of human contact with these pathogens and the impact of resultant illness if these pathogens enter the body (through ingestion, inhalation or skin abrasions).

Meola Creek is not typically used for direct recreational contact. However, indirect contact can occur along the walkways and banks which can be inundated during stormwater events. Point Chevalier Beach is influenced by the Meola catchment discharges. It is one of the 'central' bathing beaches (MfE, 2003) and is used for swimming and boating (Stacey et al., 2001). Auckland Council undertakes regular beach monitoring as part of the Safeswim programme (Auckland Council, 2012) to assess the beach for Enterococci to ensure it meets recreational contact guidelines (the Guidelines) (MfE, 2003).

During dry weather sampling levels of indicator bacteria within the freshwater environment were up to five to ten times above recreational contact 'alert' guidelines (MfE, 2003) on several occasions. Elevated levels of bacteria above guidelines were not observed in the marine environment at any of the Point Chevalier Beach sites during dry weather. However, norovirus was detected at potentially infectious levels at one of the beach sites and was a likely result of a dry weather overflow (DWO) in the catchment.

During wet weather events of any size, there is currently a risk that substantial volumes and high concentrations of bacteria, as well as viruses, enter the receiving environment. The studies undertaken in the Meola Catchment demonstrate the public health risk from combined sewer overflows. Reducing the occurrence of wastewater inputs into Meola Creek would have positive impacts on water quality and public health, particularly in the recreational areas of Point Chevalier Beach.

3.2 GROUNDWATER INPUTS

The high permeability of the basalt aquifers in large parts of the Meola Catchment has a significant influence on the flow regimes in Meola Creek. Aquifer inputs are key to maintaining relatively good water quality in the creek.

This study has shown that over summer when there is little rain and low aquifer levels, the baseflow becomes very low, and the upper Meola Creek can become a stagnant, almost anaerobic environment. As shown in this study, when rain does occur, it is possible an overflow will result. In these small events, often there is insufficient flow to ensure the 'first flush' contaminants are washed downstream.

Continuous monitoring shows that as the groundwater level increases, so do baseflows within the stream. This has positive effects on dissolved oxygen and temperature, improving the capacity of the stream to support aquatic fauna. The lower catchment has larger and more reliable groundwater input and as such exhibits a higher water quality as

demonstrated through the continuous monitoring results and the SEV and MCI scores obtained.

The importance of groundwater within this catchment cannot be understated. It is considered to be an important factor for the biodiversity value in the lower reaches and when aquifer levels are high, it ensures flushing of the upper reaches.

3.3 FIRST FLUSH OF CONTAMINANTS

The concept of 'first flush' has faced scepticism due to the variable nature in which different parameters react during different storm events and catchment dynamics (Bach, McCarthy, & Deletic, 2010). First flush refers to the initial volume or concentration of contaminants that are transported during the early stages of a storm event. In the Meola water quality monitoring project, the reference to first flush relates directly to the initial contaminant concentration entering the receiving environment from a discharge point (e.g., stormwater pipe or combined sewer overflow). The effect these 'dirty' flows have on the receiving environment is dependent on many factors including baseflow level, antecedent dry period and catchment location.

Both typical stormwater and wastewater contaminant concentrations exhibited a strong first flush pattern in the network discharge sites, while the lower catchment stream sites appeared to follow more of a dilution or slow accumulation pattern in the receiving environments. This observation is consistent with recent analysis of historical data in the Auckland region that supports evidence of the first flush phenomena (Shamseldin & Fassman, 2010).

The magnitude of these effects does appear to be event specific, depending on the antecedent dry period, size of the rain event and time of the day. In general the first flows discharging into the receiving environment are likely to have higher contaminant concentrations.

3.4 IMPORTANCE OF WET WEATHER FLOWS

Aquifer inputs form the dominant source of baseflow within Meola Creek and provide the dominant hydrological regime for most of the time. However the hydrographs generated from rainfall-runoff are an important part of the aquatic ecosystem function or conversely can lead to negative effects if too great or frequent for the receiving environments assimilative capacity.

Wet weather flows are able to provide temporarily increased velocities (relative to channel morphology), providing re-oxygenation, sediment transport, dilution of unwanted discharges, and flushing algae and accumulated organic sediments that could otherwise have a negative impact on water quality (including dissolved oxygen). Elevated water levels during wet weather also allow interaction with riparian vegetation and groundwater as well as facilitating some organism life cycles, such as inanga spawning.

This study found that during periods of the monitoring with low baseflow, no rainfall, and following very small overflow events (that provide nutrients and promote algae growth) dissolved oxygen was seen to drop to very low levels. A relatively small storm can improve the situation, flushing contaminants downstream and increasing the dissolved oxygen concentrations. In the upper Meola this is often followed by an increase in baseflow that can continue the re-oxygenation process.

Biotic indicators of an extreme example of this process were observed during the April 2010 rain event (Clarke, 2010). Prior to the event a pool of soupy brown water was observed in the mid catchment below the Alberton Ave Culvert. Low flows meant that

this pool had not been flushed for at least several days. The small scale rain event washed through the site over several hours. Within 12 hours of the rain event starting, baseflow through the pool had increased and the water was running clear. A school of inanga (*Galaxias maculatus*) had inhabited the pool, enjoying the clear, oxygenated water.

In the lower reaches, where greater and more frequent groundwater inputs are apparent, the biodiversity is significantly better and the stream does not appear to be as vulnerable to the same intermittent low flow effects.

4 SUMMARY

Meola Creek has an interesting catchment dynamic heavily influenced by stormwater, combined sewer and groundwater inputs. The water quality and ecological studies commissioned by Auckland Council portray the type of information that can be gleaned from combining baseline, wet weather and synoptic monitoring with ecological assessment. This information is important to consider when developing management intervention to improve stream and receiving environmental health.

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