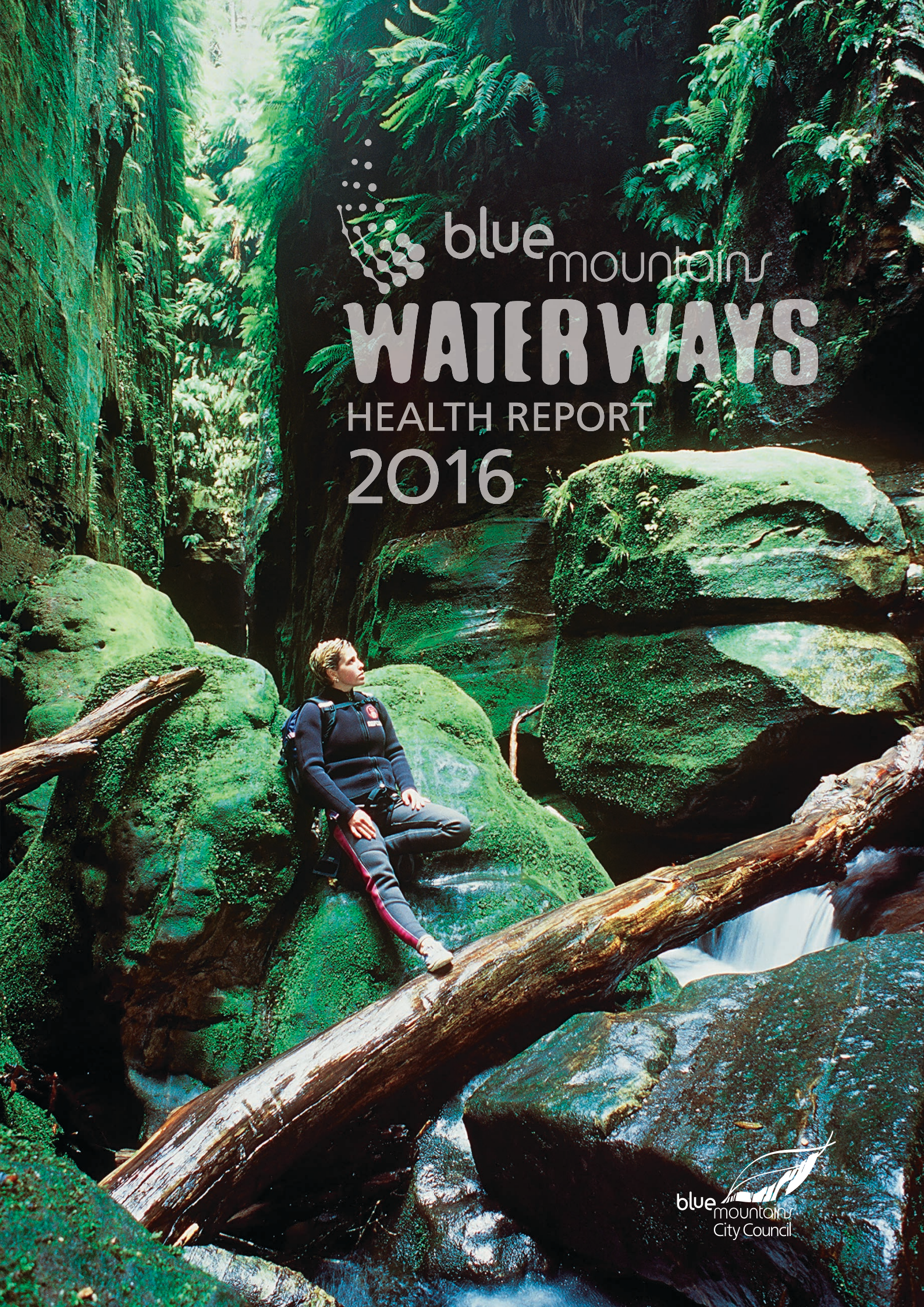
blue mountains
WATERWAYS
HEALTH REPORT
2016
blue mountains
City Council

healthy waterways

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Blue Mountains City Council acknowledges that the City of Blue Mountains is located within the Country of the Darug and Gundungurra peoples, who are the Traditional Owners of the land we now call the Blue Mountains. Council recognises the unique position of the Darug and Gundungurra peoples in the history and culture of the Blue Mountains and acknowledges the strong, unbroken and ongoing connections Aboriginal people have with their Country, cultures, heritage and history.

Report: Prepared by Blue Mountains City Council's Healthy Waterways team (Environment and Culture Branch) – Amy St Lawrence, Christina Day, Emma Kennedy, Jenny Hill and Geoffrey Smith.

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Summary

Blue Mountains waterways sustain an enormous diversity of life, provide opportunities for recreation and contribute to local and regional drinking water supplies. Yet many are at risk of degradation, especially due to stormwater runoff from urban areas.

The general pattern of development in the Blue Mountains makes stormwater a significant issue here. Ridgetop urban settlements drain to sensitive downstream environments: streams, rivers, lakes, swamps and bushland within the Greater Blue Mountains World Heritage Area and drinking water storages. Problems associated with stormwater include creekline erosion, sedimentation and pollution of water by contaminants such as pesticides, fertilisers, nutrients, rubbish, sewage, hydrocarbons and heavy metals.

Blue Mountains City Council works to protect and improve the health of waterways within our Local Government Area (LGA), and aquatic monitoring programs are fundamental to council's ability to prioritise waterways and catchments and to track progress over time. Each year council monitors more than 40 sites from Lapstone to Mount Wilson, to assess the health of local waterways.

Council rates waterway health by scoring each site's aquatic macroinvertebrate community, based on the average sensitivity of macroinvertebrates, the diversity of macroinvertebrate families, the number of mayfly, stonefly and caddisfly families and the proportion of all macroinvertebrates that were mayflies, stoneflies or caddisflies.

Of the 'urban' waterway sites sampled, 52.5% were rated as being in good or excellent health. Waterway health was rated 'fair' for 40% of sites, and 'poor' for the remaining 7.5%.

This report presents the 2016 Waterway Health Ratings for sites tested within council's aquatic monitoring program during 2013, 2014 and 2015.

Of the 'urban' waterway sites sampled, 52.5% were rated as being in good or excellent health. Waterway health was rated 'fair' for 40% of sites, and 'poor' for the remaining 7.5%.

Waterway health improved at Yosemite Creek (Katoomba) and Jamison Creek (Wentworth Falls); while the health of Leura Falls Creek deteriorated. A catchment improvement project (focused on stormwater) is underway in a bid to reverse this trend of degradation at Leura Falls Creek.

Council continues to deliver a range of programs to protect and enhance the health of local waterways and catchments, including constructing stormwater treatment systems, rehabilitating creeklines, delivering grant-funded subcatchment restoration programs and running engagement and education programs that build community water literacy. The Blue Mountains Water Sensitive City Strategy (in development) will help the city manage its water resources more holistically.

Blue Mountains residents and businesses can help protect our waterways, by making their properties more water sensitive (for example by installing rainwater tanks to capture and reuse stormwater at its source).

Council's aquatic monitoring programs will continue to assess the condition of local waterways over time, guiding catchment and waterway management and keeping our community up-to-date with reliable, science-based information.

Govetts Leap Brook, Blackheath, during the July 2015 snowfall

1 Introduction & Methods

blue mountains City Council

Introduction

Beautiful creeks and waterholes are great features of the Blue Mountains. These waterways sustain an enormous diversity of life, provide opportunities for recreation and contribute to local and regional drinking water supplies. Yet our waterways are at risk of degradation, especially due to stormwater runoff from urban areas.

Our waterways are at risk of degradation, especially due to stormwater runoff from urban areas.

The geography of the Blue Mountains makes urban runoff a particular focus here: stormwater management in this environment is challenging, but vitally important. Our city is characterised by a string of 27 ridgetop towns and villages. These urban areas drain to sensitive downstream environments: streams, rivers, lakes, swamps and bushland within the Greater Blue Mountains World Heritage Area and drinking water storages. More than 78% of the 135,000 hectare Blue Mountains Local Government Area (LGA) is protected within National Parks (Figure 1), however the impacts from urban settlements extend beyond the boundaries of land tenure, particularly in regards to waterways.

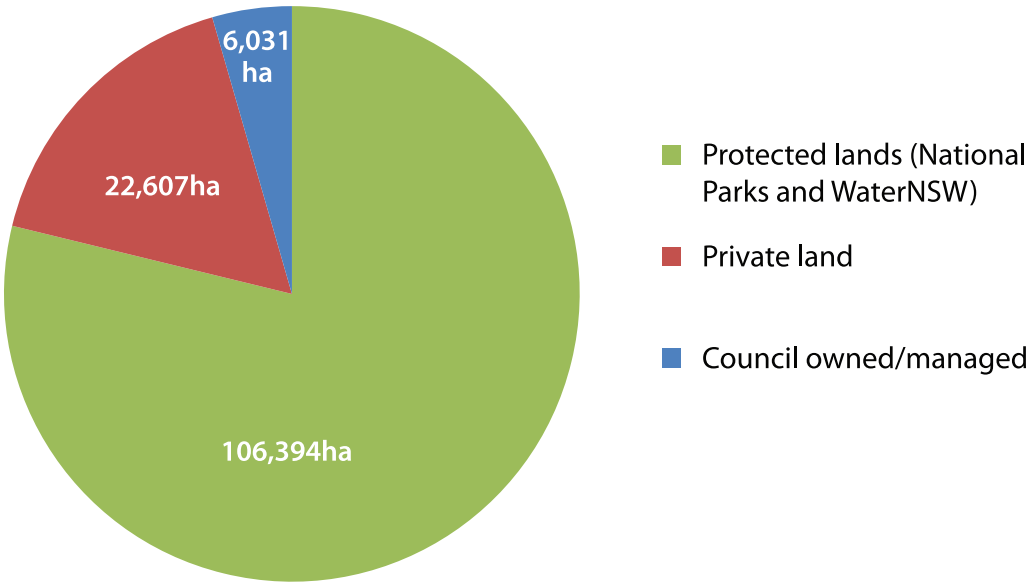


Figure 1: Land tenure in the Blue Mountains Local Government Area (LGA)

While many of our waterways are in excellent condition, some streams, particularly those with highly urbanised catchments, are in comparatively poor health (Wright, 2012). A 'healthy waterway' is characterised by high levels of aquatic biodiversity, including the presence of different types of sensitive macro-invertebrates such as mayflies, stoneflies and caddisflies; and good water quality, with high dissolved oxygen levels, clear water, appropriate pH and low levels of salt, nutrients and bacteria.

Urbanised catchments feature impervious surfaces such as roads, roofs and concreted areas, which can generate large amounts of runoff during rain. Unless managed using 'water sensitive' approaches, runoff from these catchments enters waterways at unnaturally large volumes and velocities. Conventional stormwater systems lead to problems such as creek-line erosion, sedimentation and pollution by contaminants: pesticides, herbicides, fertilizers, oil, petrol, sediment, sewage, animal faeces, garden waste, heavy metals, litter and others (Walsh et al 2004; Tippler et al 2012; Davies et al 2012; St Lawrence et al 2014).

Each year, an average (conventionally drained) Blue Mountains residence sends around 240 thousand litres of stormwater directly into natural waterways (adapted from Walsh, 2016b). In a typical Blue Mountains catchment this equates to over 300 million litres of polluted water hitting the creek each year, or more than two Olympic swimming pools every week, just from residential runoff alone (with road, industrial and commercial runoff additional to this). Capturing and using this water on each property would not only improve waterway health, it would prevent the waste of a valuable resource.

Water sensitive approaches capture and use rainwater as close to the source as possible, to mimic the natural (pre-development) water cycle, in which there is little or no surface runoff after rain. In an undisturbed catchment, the majority of water from rainfall is evapotranspired by vegetation, with the remainder soaking into soils and travelling slowly, sub-surface, to waterways.

Blue Mountains City Council aims to protect, enhance, advocate for and monitor the health of the City's natural waterways and water catchments (BMCC, 2013a; BMCC, 2013b). The local community endorses this approach, with 'looking after the environment' and 'clean creeks and waterways' consistently rated amongst the most important key directions and focus points for council during annual surveys of randomly selected Blue Mountains residents (IRIS Research, 2014).

Aquatic monitoring is fundamental to council's understanding of the condition and function of local waterways over time. Council uses the data to prioritise waterways, catchments and issues for protection, restoration and further study. With more than fifteen years of annual sampling, Council has developed one of the most extensive and long-running stream monitoring programs of its kind, enabling rigorous and detailed measurement of stream ecosystem condition (Wright, 2012).

This report is primarily focused on presenting the 2016 Waterway Health Ratings for sites tested within council's aquatic monitoring program during 2013, 2014 and 2015.

Blue Mountains Local Government Area: Waterway Statistics

- **More than 4,200 kilometres of creek-lines flow within the Blue Mountains LGA:**
  - 193 kilometres council-managed land
  - 567 kilometres private land
  - 3,524 kilometres National Parks
- **Nearly 1000 hectares of Temperate Highland Peat Swamps on Sandstone:**
  - 189 hectares council-managed land
  - 424 hectares private land
  - 348 hectares National Parks
- **Nearly 150 hectares of standing water bodies:**
  - 20 hectares council-managed land (Glenbrook Lagoon and Wentworth Falls Lake)
  - 12 hectares private land
  - 115 hectares National Parks and drinking water storages

More than 80% of Blue Mountains creek-lines lie within National Parks. However, the impacts from urban settlements at catchment headwaters can extend far into protected areas.

By implementing the Local Environment and Development Control Plans, along with a range of catchment and waterway restoration programs, Council aims to protect and enhance the health of the City's natural waterways.

Objectives: *why* does council monitor waterway health?

1. **To understand the condition and function of local aquatic ecosystems over time**

   Without a good understanding of our local waterways, we will be unable to effectively protect them. Sampling provides information about each waterway's unique values and threats.

   Regular monitoring can detect declining or improving water quality and aquatic ecosystem health. Catchment and waterway management can then be adapted in response to the trends and changes observed.

   It is likely that population growth, intensification of urban development and climate change will put increasing pressure on Blue Mountains waterways, and it is important to measure their condition and function over time.

2. **To help prioritise catchments, waterways and issues**

   Council's resources are limited: we have neither the quantity of staff nor the operational funds to address problems simultaneously in every catchment and waterway across the Local Government Area. Our aquatic monitoring programs help council target resources as effectively as possible. This may mean allocating budgets to waterways with very high conservation value that also have high risks of degradation from catchment activities, or identifying sites and issues that require more detailed investigation or strategic planning.

   Our monitoring and assessment programs help isolate problems and inform solutions (for example, during the investigation of the 2012 Jamison Creek pesticide contamination incident and mass crayfish kill. See the Jamison Creek case study on page 47 for further detail).

3. **To keep our community and other stakeholders up-to-date with reliable, science-based information on our waterways**

   Council publishes regular reports, such as State of the City, to communicate information about our assets and operations. Sound, science-based information is required for effective reporting on waterway condition and management.

Methods: *how* does council measure waterway health?

Council conducts annual monitoring at over 40 sites from Lapstone to Mount Wilson, to assess the health of local waterways. This is done using aquatic macroinvertebrates (water bugs) as biological indicators, as well as a range of other indicators of water quality (pH, dissolved oxygen, turbidity, electrical conductivity, salinity, temperature, nutrients, alkalinity, faecal coliforms and enterococci).

Sites are selected to:

- Represent the area's different altitudinal zones;
- Cover as many towns and villages as possible;
- Encompass representative reference sites in undeveloped catchments;
- Maximise the number of sites sampled within staff and budget constraints;
- Complement other projects, particularly on-ground works aimed at improving waterway health;
- Monitor key issues and high-risk land uses (e.g. industrial areas and landfills);
- Ensure continuity of data where possible.

Aquatic macroinvertebrates (water bugs)

Aquatic macroinvertebrates are excellent rapid indicators of waterway condition (Wright, et al 2007; NPWS, 1999). Changes in the type, diversity and abundance of macroinvertebrates found in a waterway can suggest declining or improving water quality and aquatic ecosystem health. Unlike a 'spot' water quality measurement, which provides information about the moment of sampling only, identifying a site's macroinvertebrate assemblage offers insight to the waterway's past and present water quality (Chessman, 2001; Gooderham and Tsyrlin, 2002).

Sampling of macroinvertebrates is based on the AUSRIVAS protocol for collecting and processing samples in NSW (DEC, 2004). A 0.25mm mesh net is used to sample 10 metres of edge habitat within a pre-determined 100 metres of reach at each site. "Edge habitat" includes trailing vegetation, overhanging banks/bedrock/boulders, submerged logs, detritus and aquatic plants. Duplicate macroinvertebrate samples are collected at reference sites (i.e. 20 metres of edge habitat, divided into two sub-samples).

Two field operators "pick" samples live on site for 40-60 minutes per sample per site. Invertebrates that are accurately identifiable to family level in the field are recorded and released; others are preserved in ethanol for laboratory identification.

Scientific keys are used to identify laboratory specimens, with most taxa identified to family level (Gooderham and Tsyrlin, 2002; The Waterbug Company, 2016; Murray-Darling Freshwater Research Centre, 2015; Dean et al 2004; Hawker and Theischinger, 1999). Binocular stereoscopes are used to examine the distinguishing features of closely related families.

Figure 2: Blue Mountains City Council staff sampling and sorting aquatic macroinvertebrates at Blue Mountains waterways

Water quality

At each site pH, dissolved oxygen, turbidity, temperature, electrical conductivity and salinity are recorded using a Hydrolab Quanta probe (triplicate readings). Water samples are collected and analysed in Council's Laboratory for Alkalinity, available Phosphorus, Nitrate-N and Faecal Coliforms, as per test kit manufacturers' instructions.

For particular project sites or special issues, additional water quality samples are tested by NATA accredited laboratories for a range of water quality parameters (e.g. total nitrogen, total phosphorus, pesticides, metals, hydrocarbons and others).

To aid interpretation of water quality results, a series of local trigger values have been developed (adapted from ANZECC, 2000, 7.4.4), using the 95th/5th percentile values from Blue Mountains reference site data (2010-2015). Separate trigger values are specified for upper (>500m ASL) and lower (<500m ASL) mountains sites in recognition of the underlying natural differences in some indicators due to geological variation etc. This system serves as an 'early warning' mechanism, where test results outside of trigger values can indicate potential problems (ANZECC, 2000).

The resulting trigger values are as shown in table 1 below.

Table 1: Local water quality – desirable ranges for Blue Mountains waterways

Altitudinal zone (m above sea level)	EC (us/cm2)	pH	DO (%sat)	Turbidity NTU	Alkalinity (ppm CaCO3)	Nitrate-nitrogen (mg/L)	Faecal coliforms (CFU/100ml)
>500	<65	4.37-7.24	63.28-100.38	<12.25	<10.9	<0.22	<20
<500	<208	5.21-7.73	72.99-108.37	<15.09	<27.6	<0.24	<64

Note: ranges based on trigger values derived from 95th/5th percentile values for Blue Mountains reference sites (2010-2015).

Waterway health rating system

The results presented in the 2016 Waterway Health Report were compiled from aquatic macroinvertebrate data collected annually between 2013 and 2015 (where available a three-year average was reported, if not a two-year average, or the results of a single year where a site was sampled only once during 2013-2015).

Aspects of the rating system were adapted from other stream/river health monitoring programs and assessment methods in Australia (Healthy Waterways, 2014; GRCCC, 2015; Index of Stream Condition, 2010; EHMP, 2010; Hornsby Shire Council, 2012; ANZECC, 2000; Chessman, 2001; Wright 2012; Barmuta, Chessman and Hart, 1998).

SIGNAL is a system that grades macroinvertebrate families depending on their sensitivity to or tolerance of pollution and disturbance (Chessman, 2003; 2001). SIGNAL-SF grades are specific to macroinvertebrate families as they occur in the Sydney region (Chessman, Williams and Besley, 2007). The system is designed to reflect human influences such as stormwater pollution, rather than natural factors such as altitude and stream size, and thus provides a useful tool for assessing the degree to which human activities impact on waterways (Growns et al. 1995).

The number of macroinvertebrate families found at a waterway reflects its ability to support diverse aquatic life. Assessing a site's mayfly, stonefly and caddisfly families and their abundance relative to other macroinvertebrate families can provide further understanding of waterway health, as these are the three orders most likely to disappear in the event of pollution or disturbance (Wright et al, 2007).

In this report, waterway health was rated by scoring each site on four factors:

1. SIGNAL-SF (a 'sensitivity score', reflecting the average sensitivity of families present);
2. Number of aquatic macroinvertebrate families present;
3. Number of mayfly/stonefly/caddisfly families present (# EPT families);
4. Percentage of individual macroinvertebrates recorded that were mayflies, stoneflies or caddisflies (% EPT).

Scores for these factors were based on comparisons with other Blue Mountains urban sites and pristine local reference sites. For each factor at each site, a score between 0 and 5 was allocated, to signify how the site's result compared with results from other urban sites. This process was repeated, with scores from 0 to 5 assigned to signify how the site's result compared with reference sites.

Table 2 below details the bands used to score each factor against both urban and reference comparisons. These bands were established using percentile values for data collected at urban sites and reference sites between 2012 and 2015 (score of 5 = 100th percentile, 4 = 80th percentile, 3 = 60th percentile, 2 = 40th percentile, 1 = 20th percentile, 0 score not percentile-based).

Table 2: Bands used for scoring macroinvertebrate factors at each site

Factor Score	Comparison with urban sites				Comparison with reference sites			
	SIGNAL-SF	# families	#EPT families	% EPT	SIGNAL-SF	# families	#EPT families	% EPT
0	<4.50	<3.00	0	0	<4.50	<3.00	0	0
1	4.50-5.00	3.00-8.00	0.01-2.00	0.01-6.06	4.51-6.63	3.00-14.60	0.01-4.60	0.01-59.44
2	5.01-6.04	8.01-11.00	2.01-3.00	6.07-34.62	6.64-6.92	14.61-16.00	4.61-5.00	59.45-67.05
3	6.05-6.51	11.01-14	3.01-4.00	34.63-58.48	6.93-7.05	16.01-17.00	5.01-6.00	67.06-76.20
4	6.52-7.00	14.01-18	4.01-6.00	58.49-71.79	7.06-7.20	17.01-18.00	6.01-7.00	76.21-80.85
5	>7.00	>18.00	>6.00	>71.79	>7.20	>18	>7	>80.85

Factor scores assigned to each site were then averaged, and an overall waterway health rating applied according to Table 3 below. Table 4 shows worked examples for Yosemite Creek, Katoomba and Cataract Creek, Lawson.

Table 3: Allocating waterway health ratings

Average factor score	Waterway health rating
0-0.99	Very Poor
1.00-1.99	Poor
2.00-2.99	Fair
3.00-3.99	Good
4.00-5.00	Excellent

Table 4: examples – allocating waterway health ratings to Yosemite Creek and Cataract Creek

Yosemite Creek, Katoomba	SIGNAL-SF	MACROINVERTEBRATE FACTORS # families	#EPT families	%EPT
Site result (3-yr average)	6.78	19.33	8.67	69.98
Factor score (urban comparison)	4	5	5	4
Factor score (reference comparison)	2	5	5	3
			Average factor score:	**4.13**
			Waterway health rating:	**Excellent**

Cataract Creek, Lawson	SIGNAL-SF	MACROINVERTEBRATE FACTORS # families	#EPT families	%EPT
Site result (3-yr average)	4.92	11.33	1.00	1.47
Factor score (urban comparison)	1	3	1	1
Factor score (reference comparison)	1	1	1	1
			Average factor score:	**1.25**
			Waterway health rating:	**Poor**

Walking in to sample an undisturbed Blue Mountains reference waterway

2 Results & Discussion

blue mountains City Council

Results

Waterway health ratings

Waterway health ratings are mapped in (figures 3 to 11) below. Figure 3 shows the locations of major catchments in the Local Government Area, while figures 4 to 11 map sites and their ratings by major catchment.

Only the portions of catchments that are within the Blue Mountains Local Government Area are shown on the maps.

Of the 'urban' waterway sites sampled in the Blue Mountains between 2013 and 2015, 52.5% were rated as being in good or excellent health. Waterway health was rated 'fair' for 40% of sites, and 'poor' for the remaining 7.5%.

The system used to assign these health ratings is specific to the Blue Mountains and is designed to allow differentiation between waterways in the local context. Streams rated under this system as 'fair' or 'poor' are still likely to be healthier than many urban streams in the Sydney area (Wright, 2012). However, when compared to other Blue Mountains waterways rated 'good' or 'excellent', they show signs of degradation.

Wentworth Falls

- Excellent
- Good
- Fair
- Poor

Colo Catchment

- Waterfall Creek

Coxs Catchment

- Fairy Dell Creek
- Centennial Glen Creek
- Pulpit Hill Creek
- Megalong Creek
- Pulpit Hill Creek tributary
- Megalong Creek tributary (Bonnie Doon)

Erskine Catchment

- Bedford Creek
- Terrace Falls Creek
- Lawson Creek
- Cataract Creek

Glenbrook Catchment

- Magdala Creek
- Glenbrook Creek

Figure 3: City-wide waterway health ratings - 2016

Grose Catchment

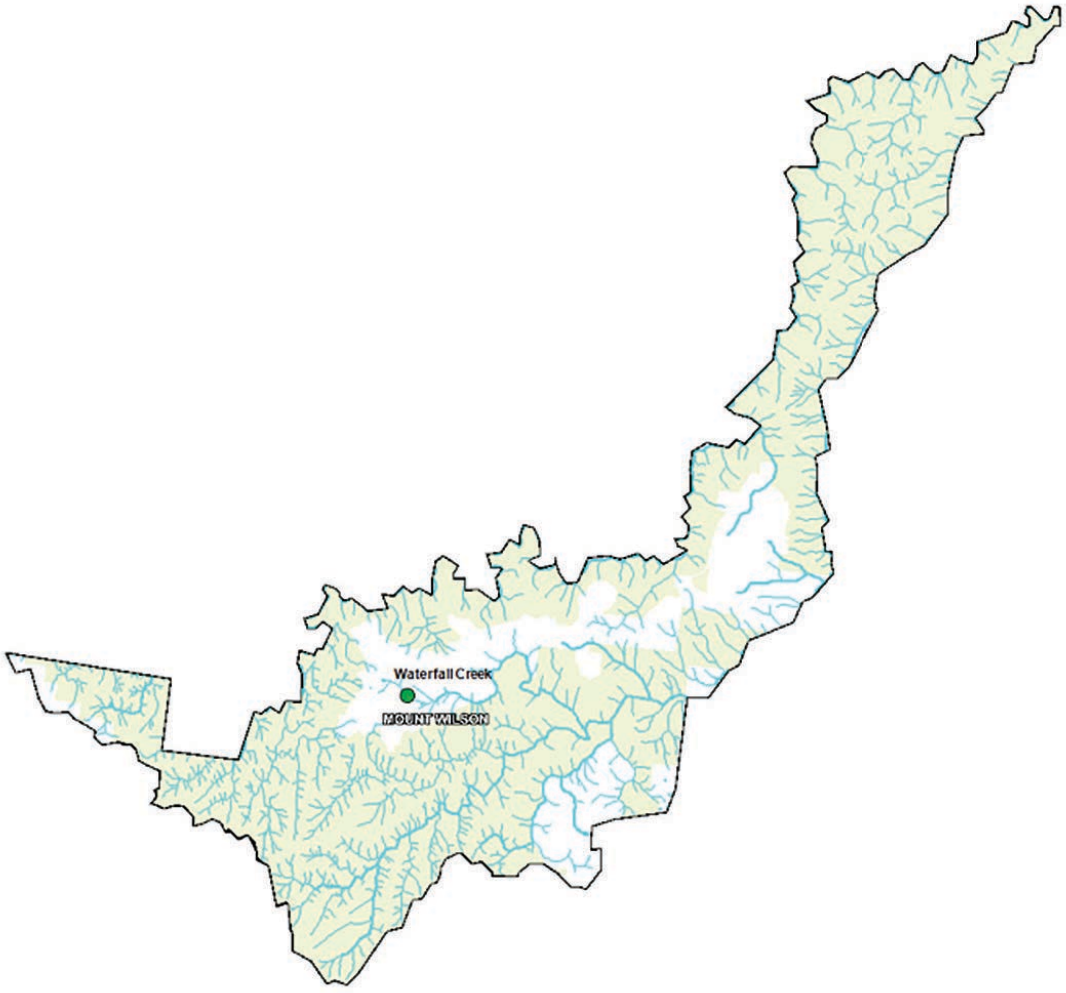
- Grose River tributary (Mt Vic)
- Hat Hill Creek
- Popes Glen Creek
- Govetts Leap Brook
- Yosemite Creek
- Katoomba Creek
- Govetts Creek
- Water Nymphs Dell
- Dantes Glen
- Hazelbrook Creek
- Woodford Creek
- Springwood Creek

Kedumba Cachment

- Wentworth Falls Lake
- Kedumba Creek
- Gordon Creek
- Valley of the Waters Creek
- Leura Falls Creek – Leura Cascades
- Leura Falls Creek – Commonwealth St
- Leura Falls Creek – Cumberland St
- Jamison Creek – Weeping Rock
- Jamison Creek – Shops
- Jamison Creek – Darwin Bridge

Nepean Catchment

- Glenbrook Lagoon
- Fitzgerald Creek
- Long Angle Creek
- Blue Gum Swamp Creek
- Frasers Creek
- Frasers Creek tributary
- Cripple Creek
- Lapstone Creek
- Knapsack Creek



Excellent Good Fair Poor Reference Site

Figure 4: Colo River catchment - waterway health ratings

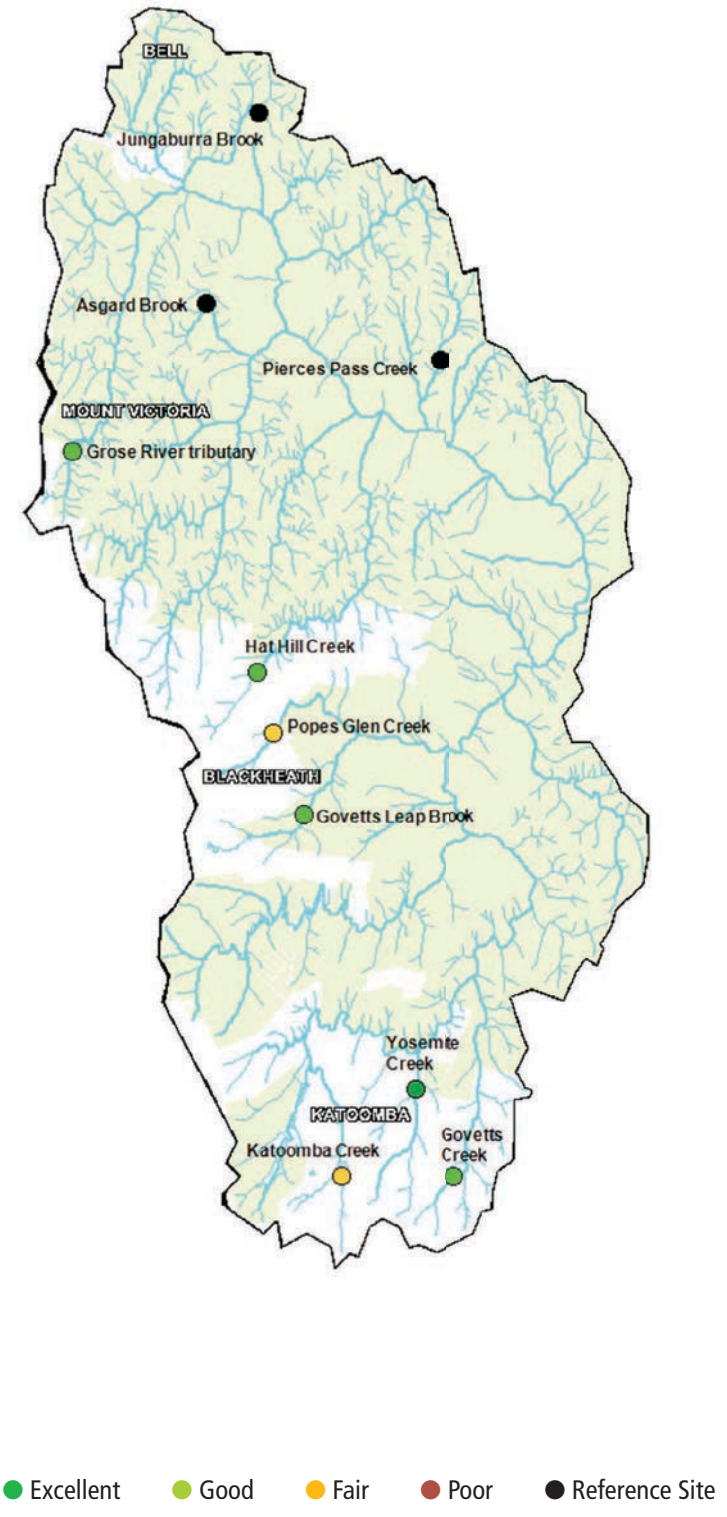


Figure 5: Upper Grose River catchment - waterway health ratings

Figure 6: Lower Grose River catchment - waterway health ratings

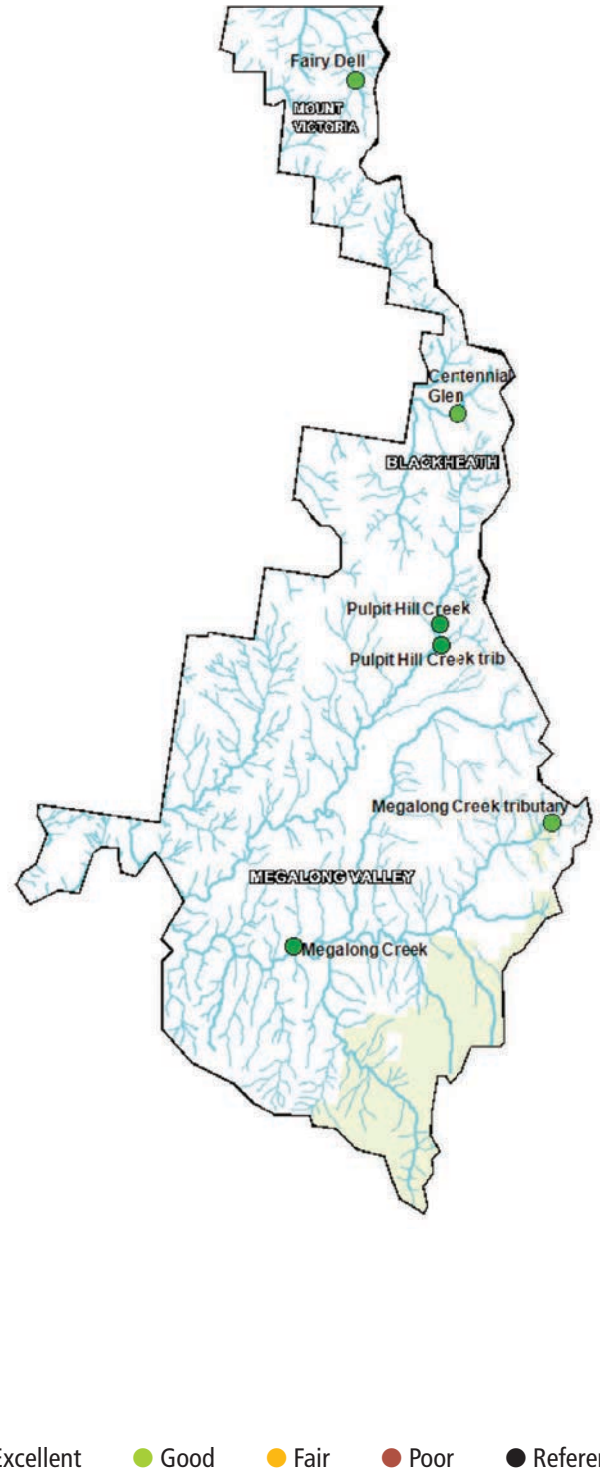


Figure 7: Coxs River catchment – waterway health ratings

Figure 8: Kedumba River catchment - waterway health ratings

Figure 9: Erskine Creek catchment - waterway health ratings

Figure 10: Glenbrook Creek catchment – waterway health ratings

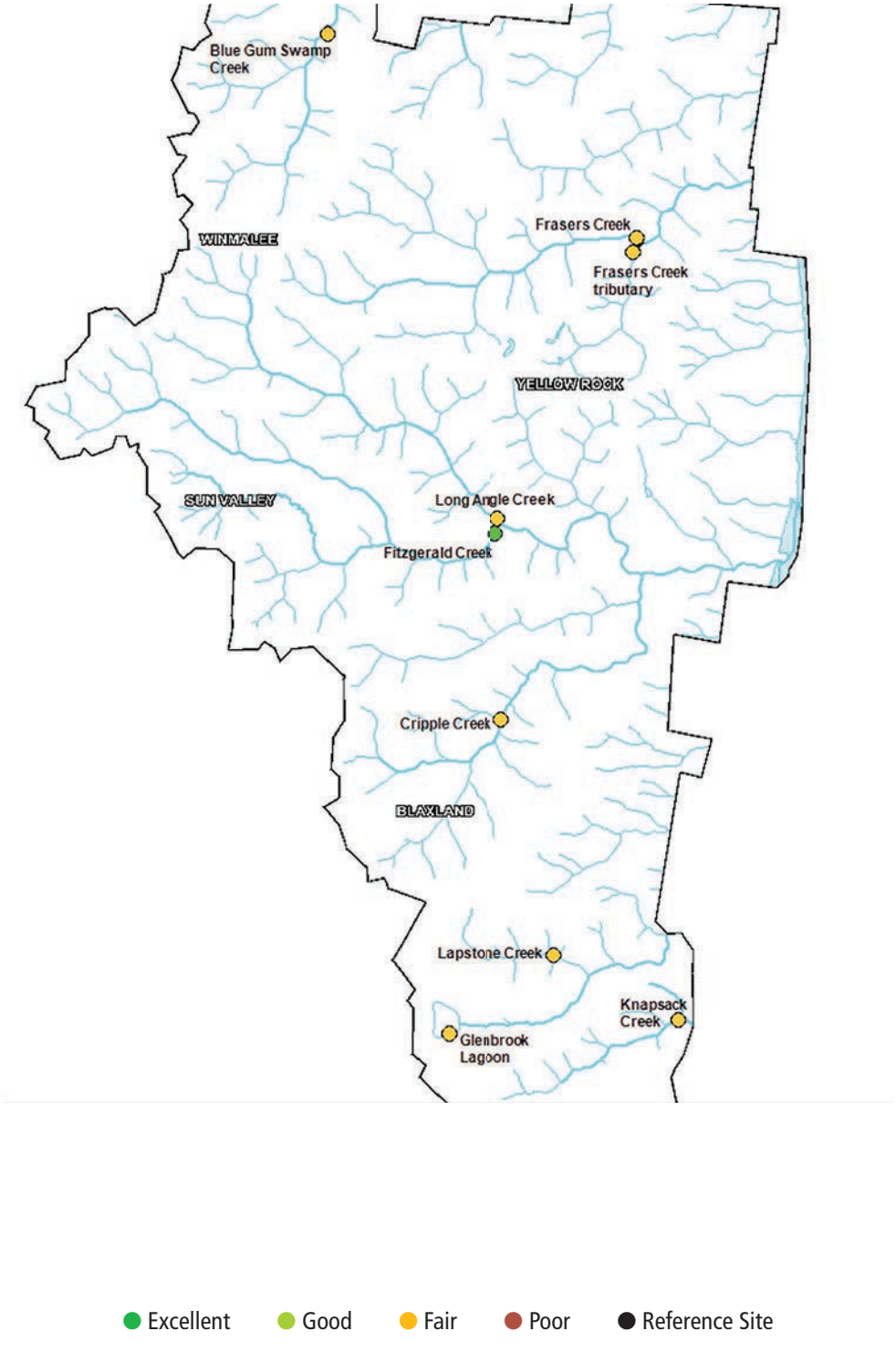


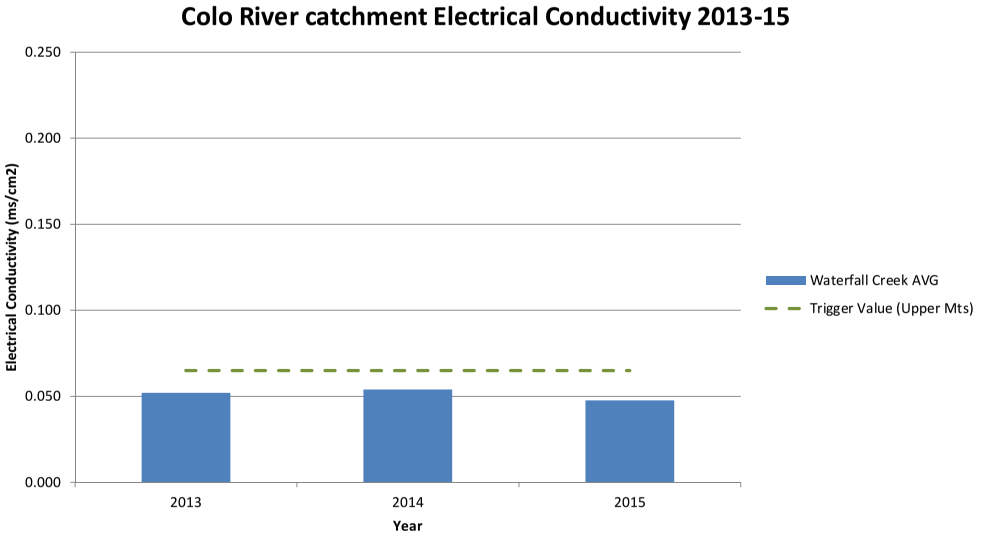
Figure 11: Nepean River catchment – waterway health ratings

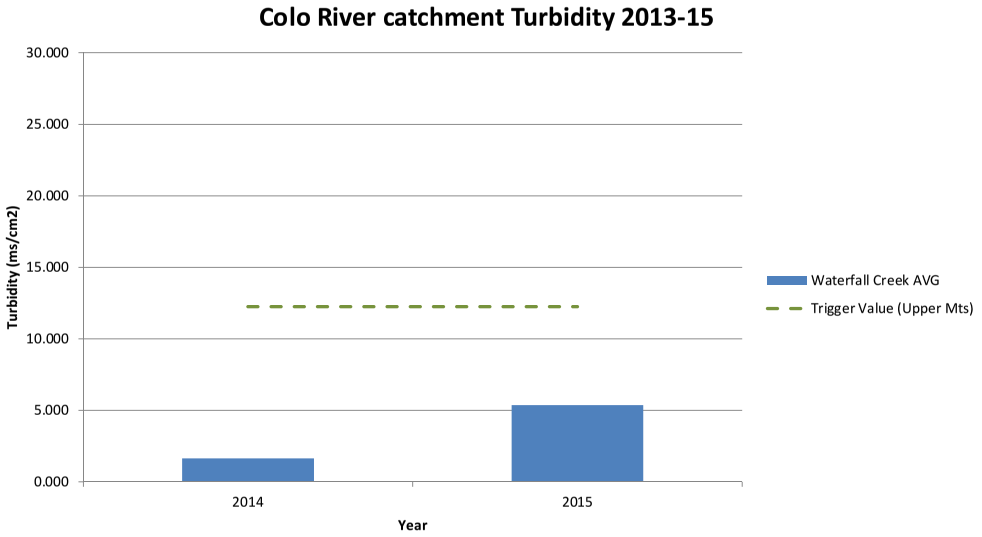
Govetts Leap Brook, Braeside walking trail, Blackheath

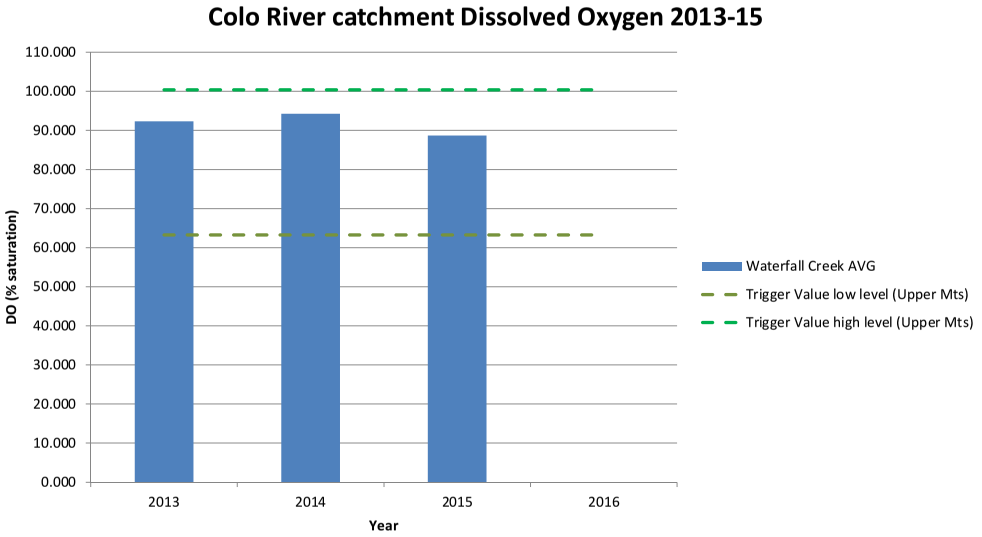
Water quality

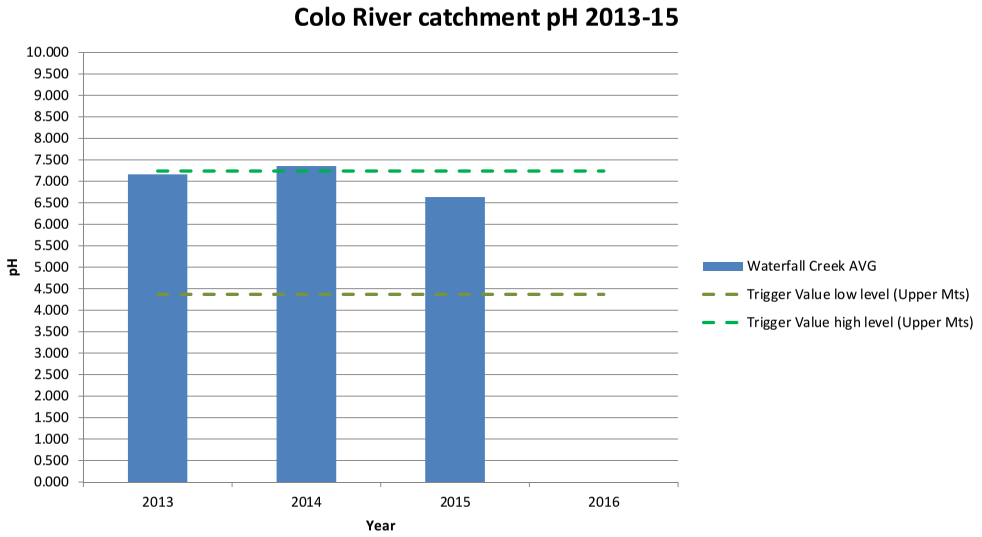
Figures 12 to 19 graph water quality results for 2013-15 alongside local trigger values (derived from 95th/5th percentile values recorded at reference sites during 2010-2015). Each year's result is the average of triplicate samples taken on a single date (for EC, pH, DO, turbidity), or a single sample (for alkalinity, nitrate-N and faecal coliforms). Gaps in graphs indicate an absence of data, not zero values.

Figure 12 (below): Colo River Catchment Water Quality 2013-15

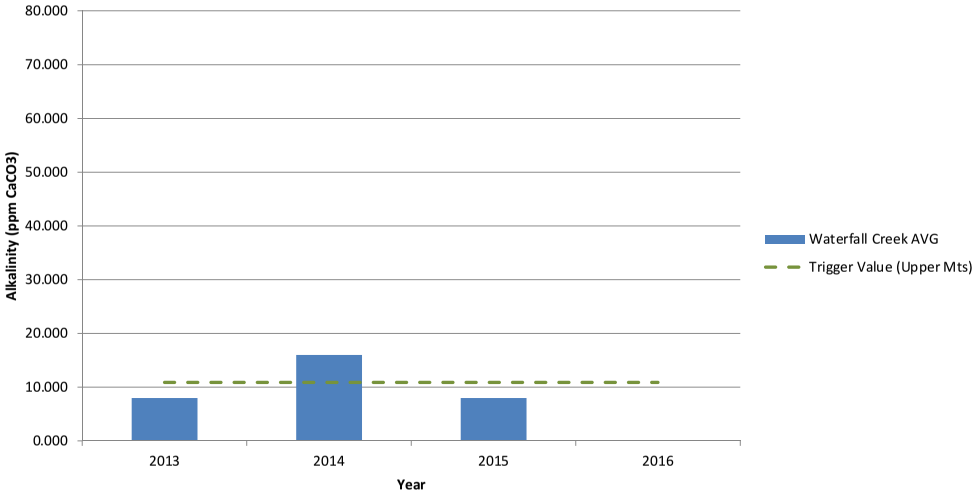




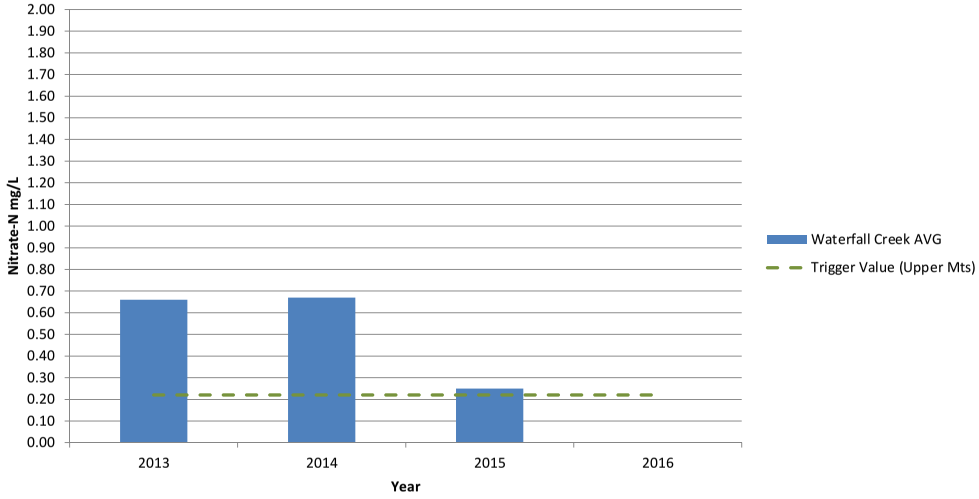




Colo River catchment Alkalinity 2013-15



Colo River catchment Nitrate-Nitrogen 2013-15



Colo River catchment Faecal Coliforms 2013-15

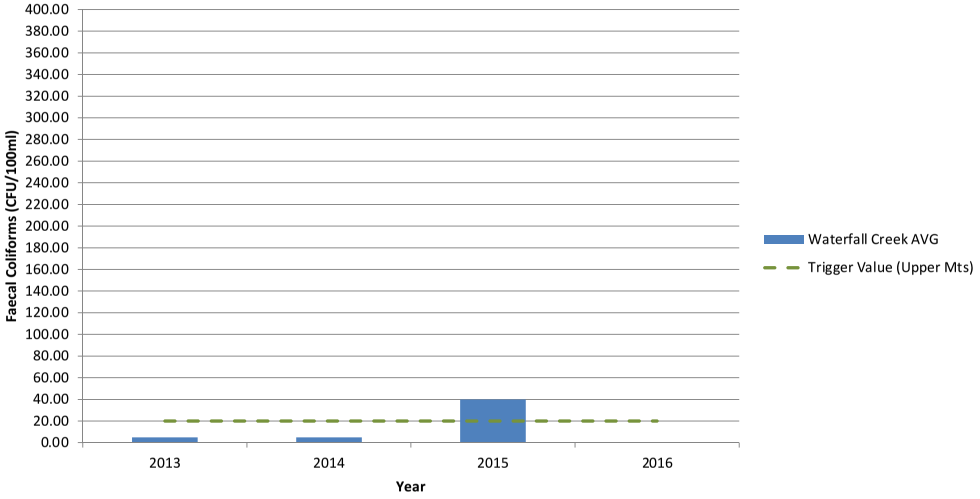
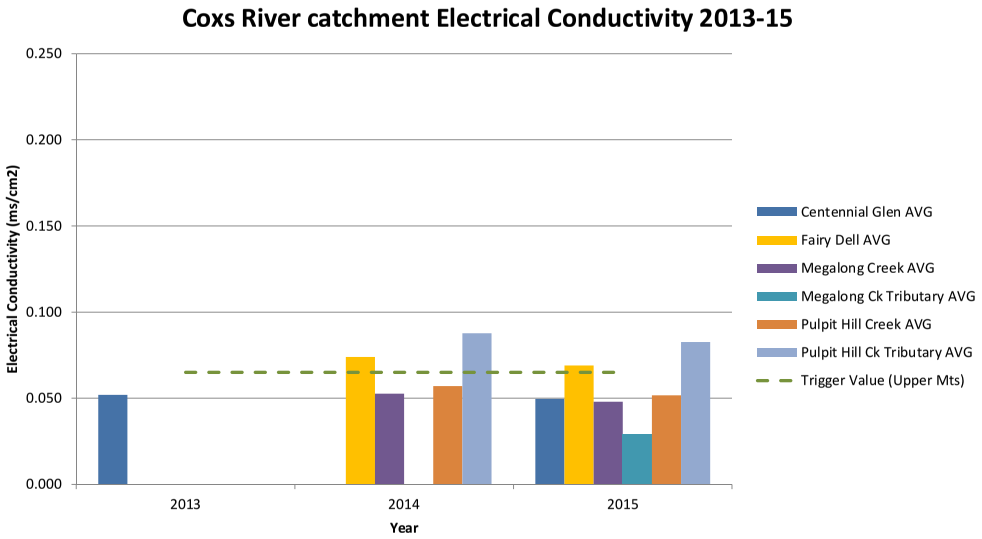
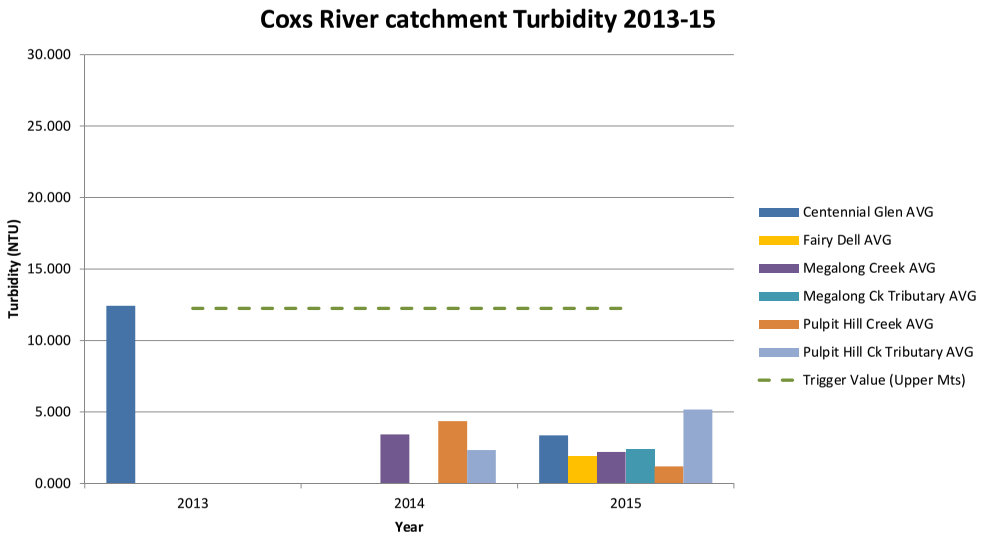
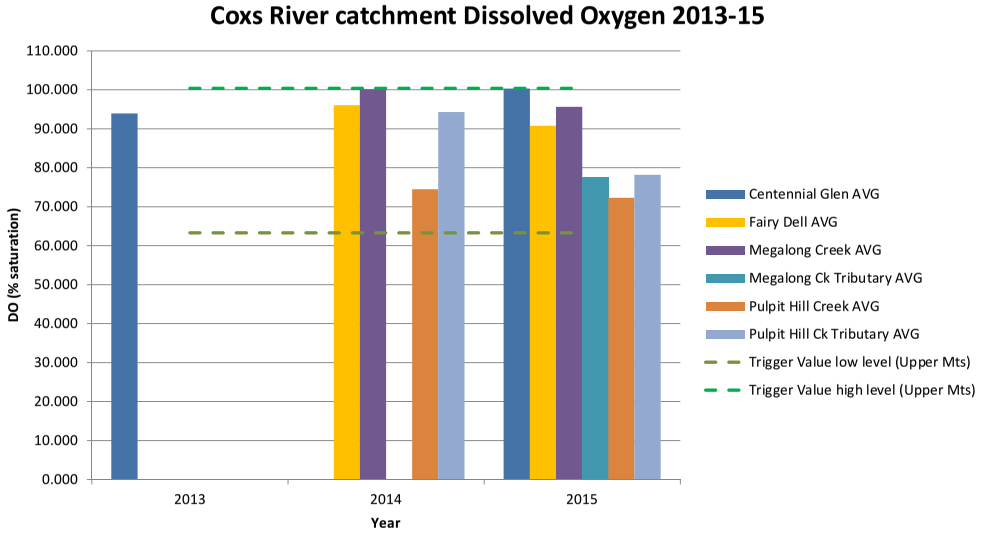
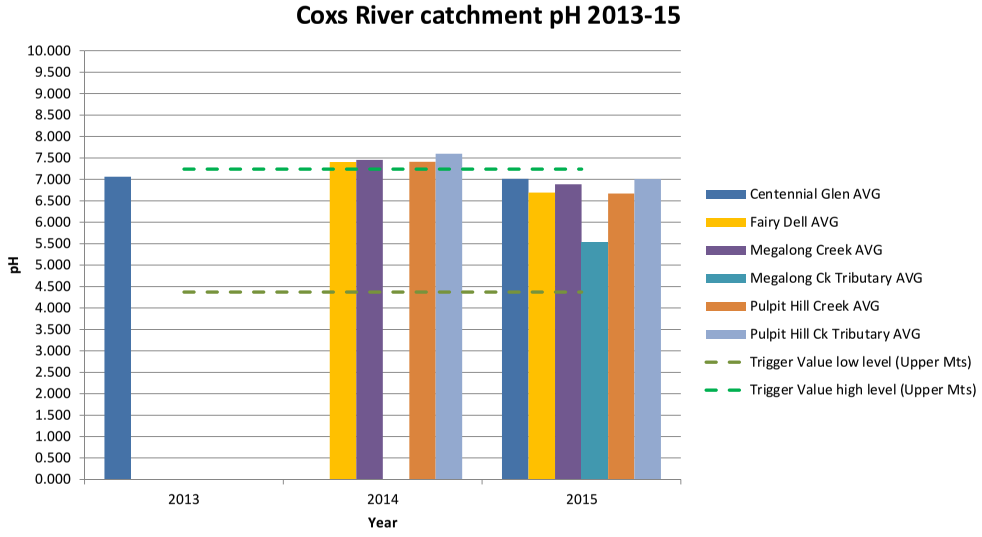


Figure 13 (below): Coxs River Catchment Water Quality 2013-15

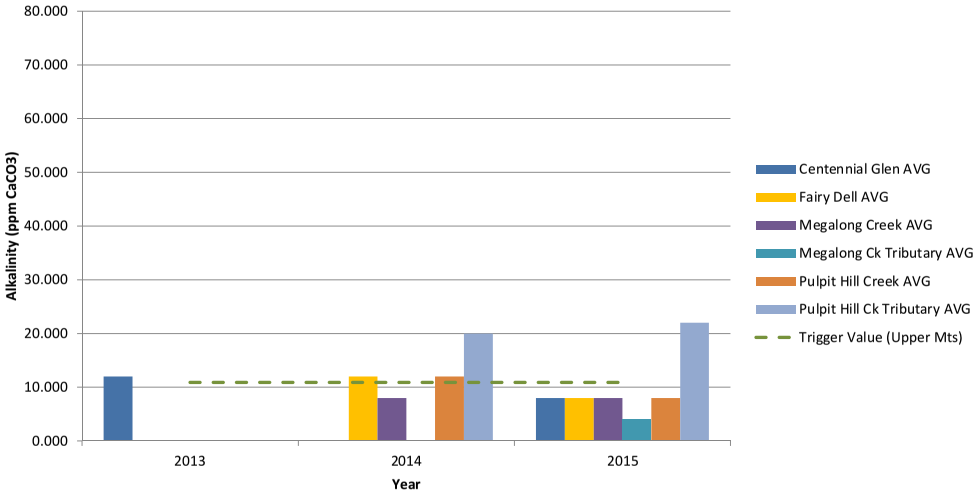




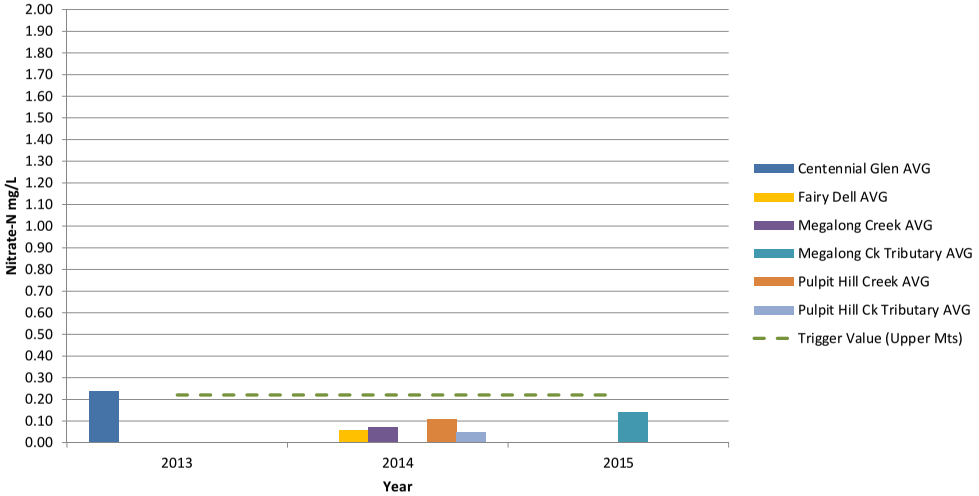




Coxs River catchment Alkalinity 2013-15



Coxs River catchment Nitrate-Nitrogen 2013-15



Coxs River catchment Faecal Coliforms 2013-15

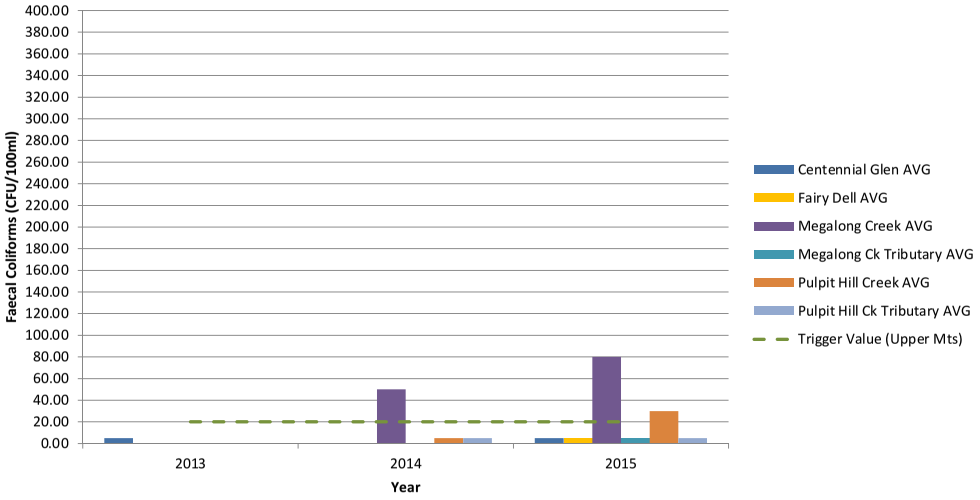
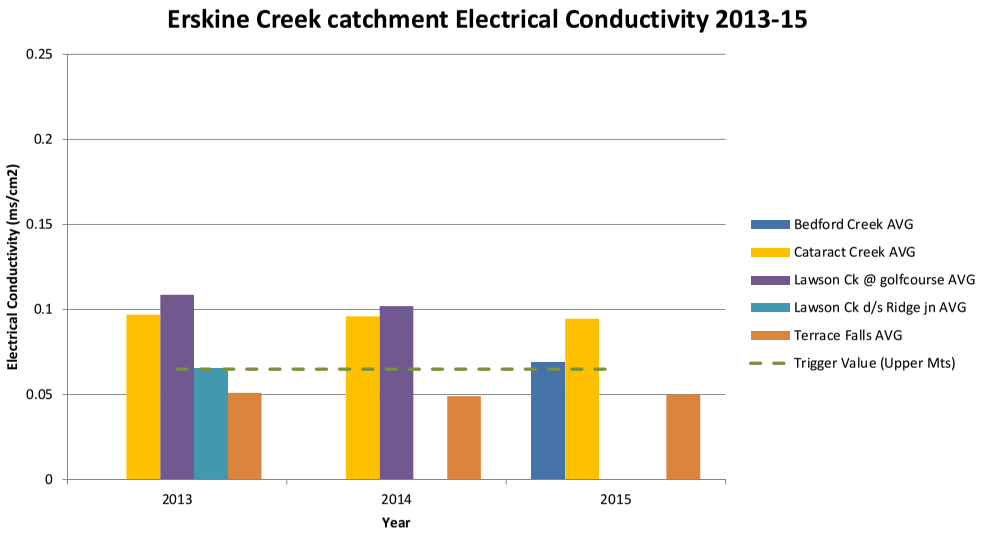
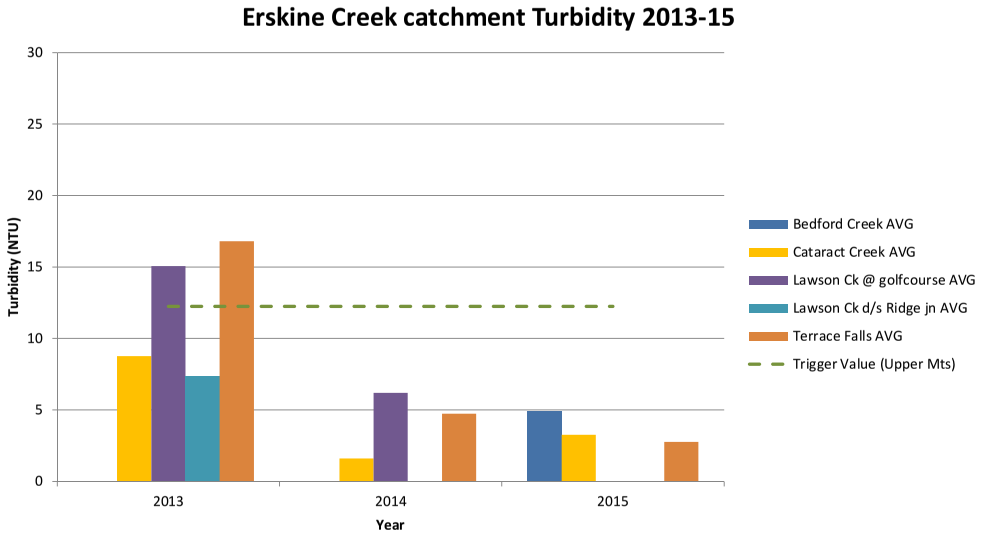
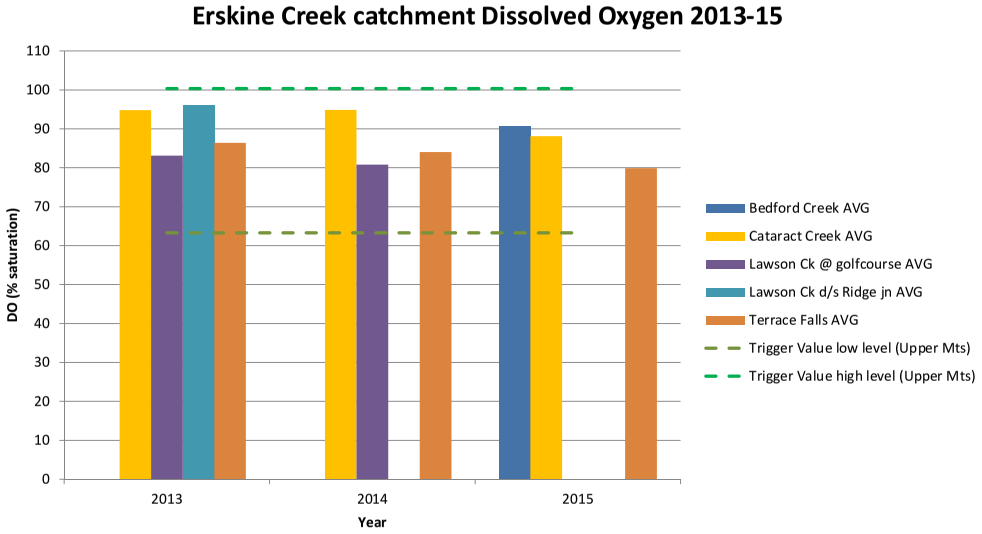
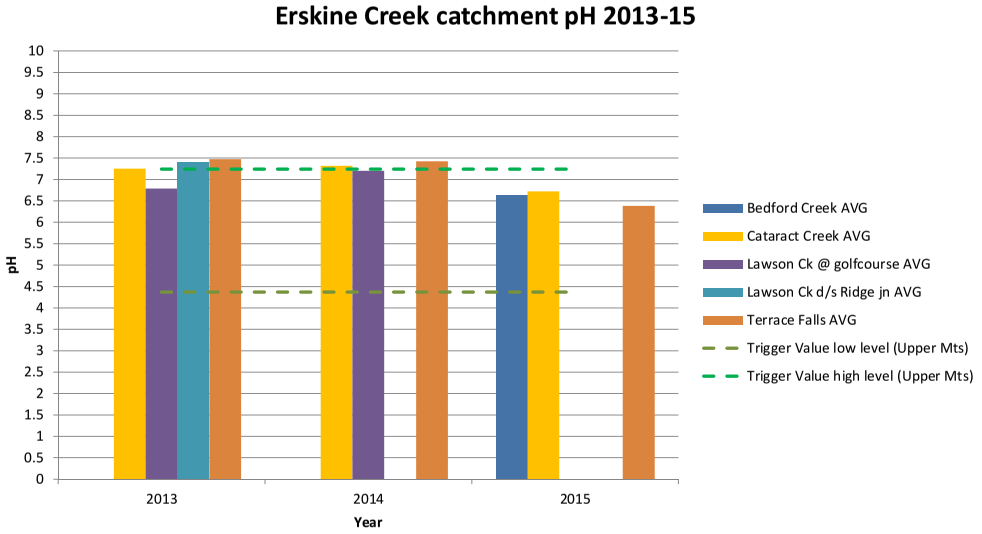


Figure 14 (below): Erskine Creek Catchment Water Quality 2013-15

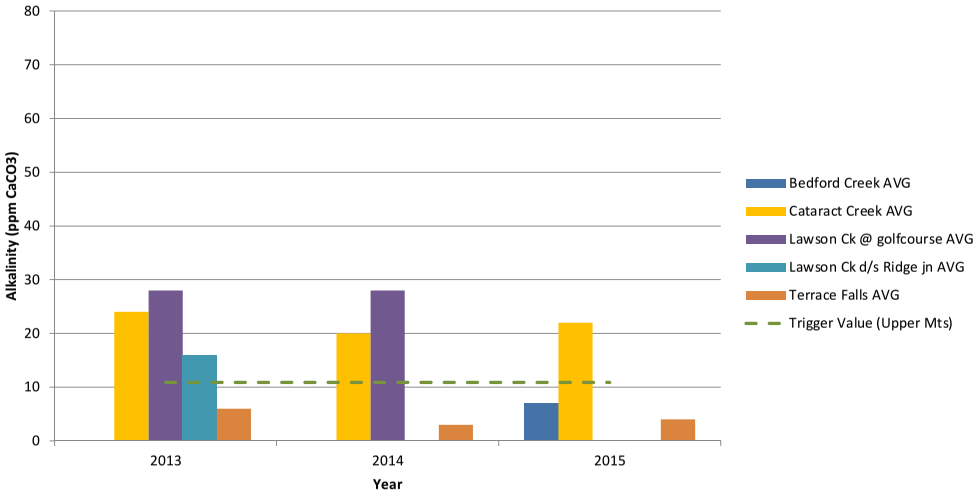




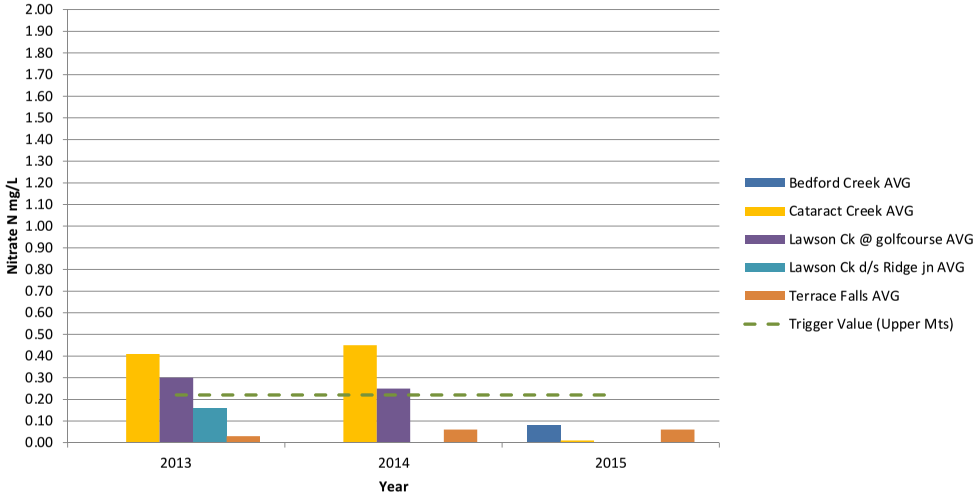




Erskine Creek catchment Alkalinity 2013-15



Erskine Creek catchment Nitrate-Nitrogen 2013-15



Erskine Creek catchment Faecal Coliforms 2013-15

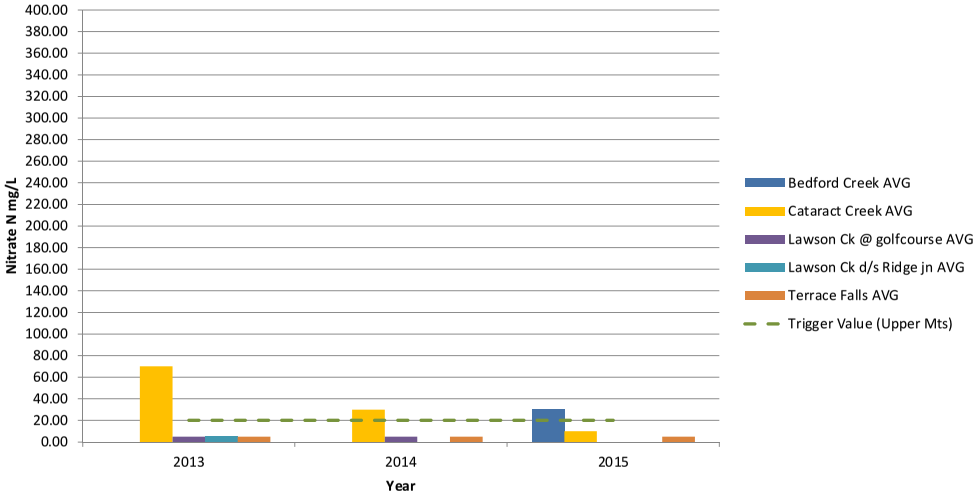
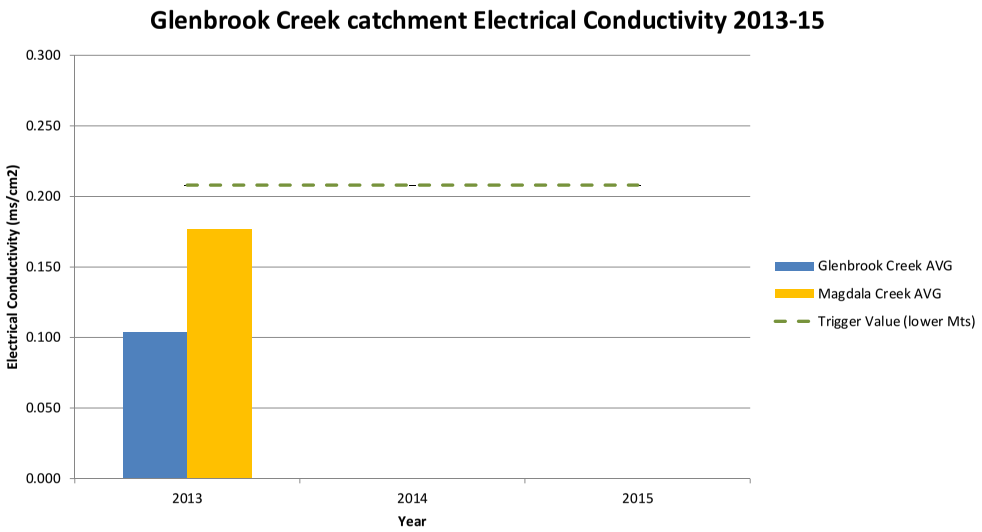
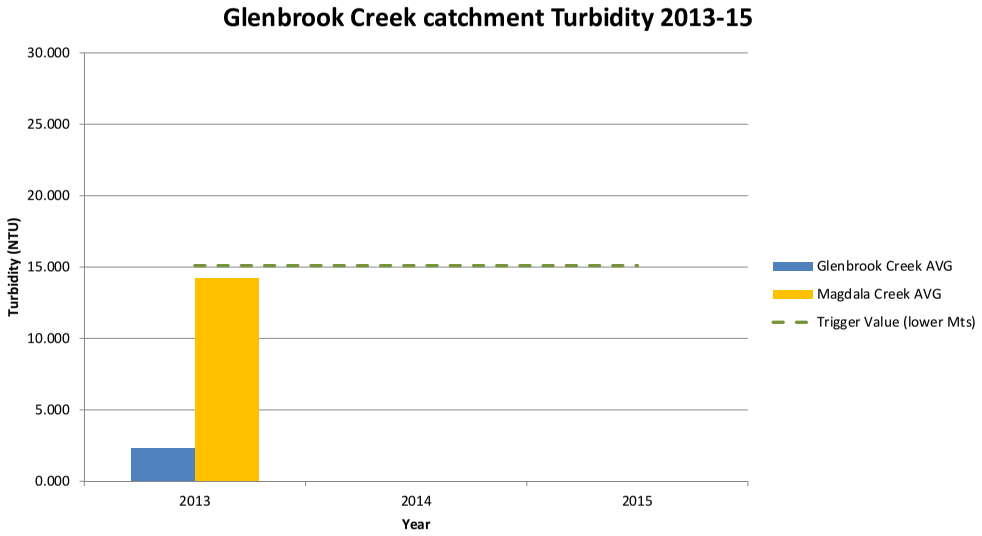
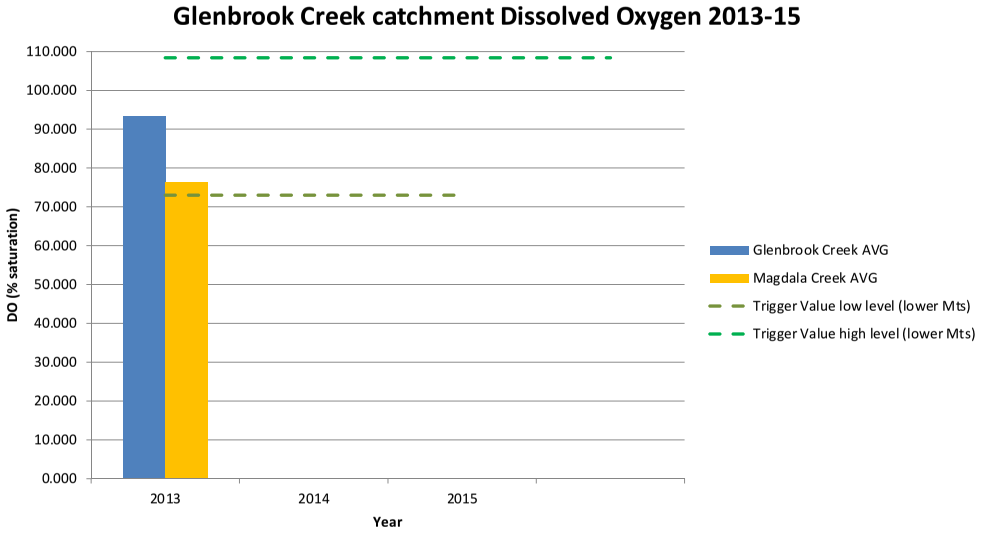
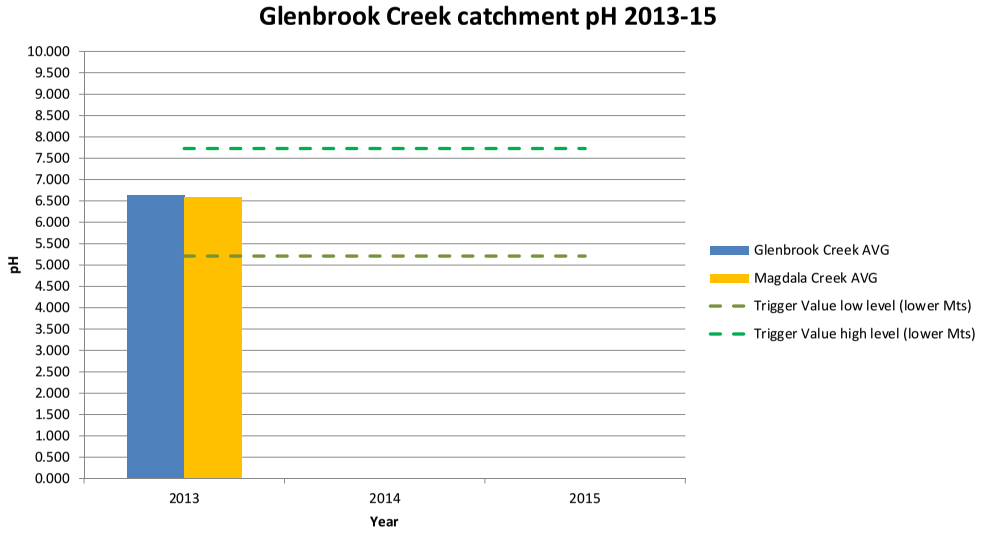


Figure 15 (below): Glenbrook Creek Catchment Water Quality 2013-15

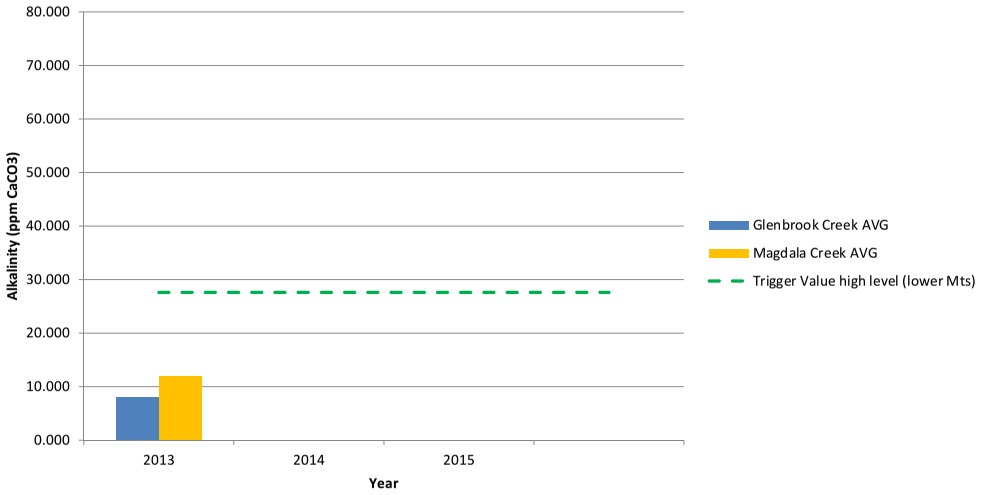




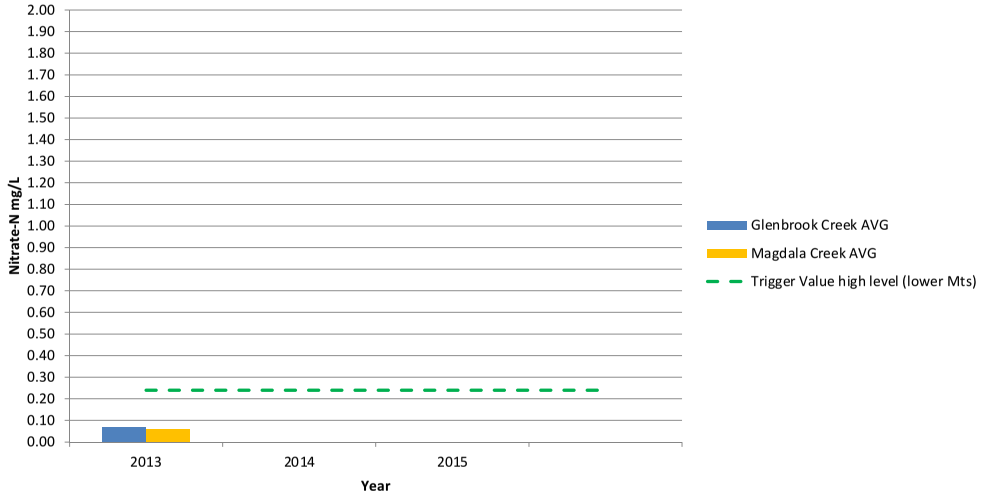




Glenbrook Creek catchment Alkalinity 2013-15



Glenbrook Creek catchment Nitrate-Nitrogen 2013-15



Glenbrook Creek catchment Faecal Coliforms 2013-15

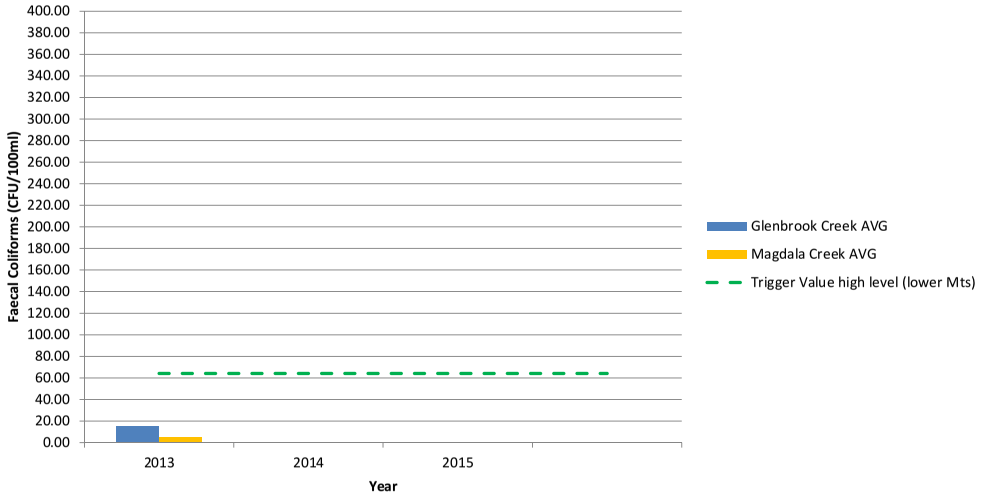
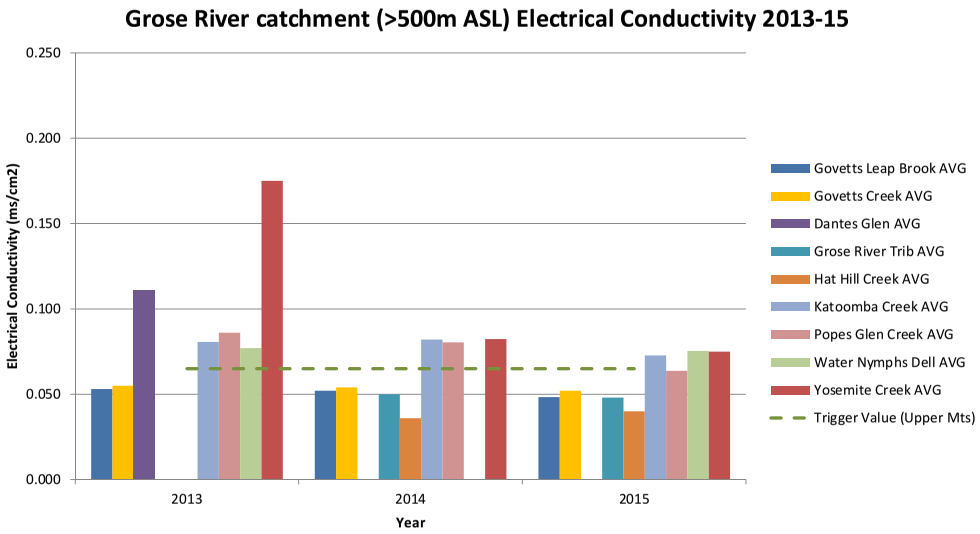
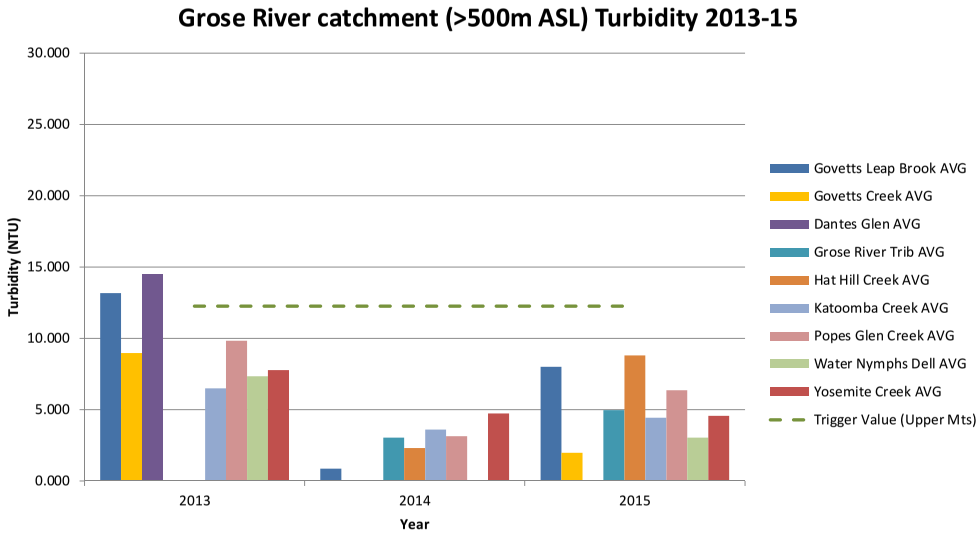
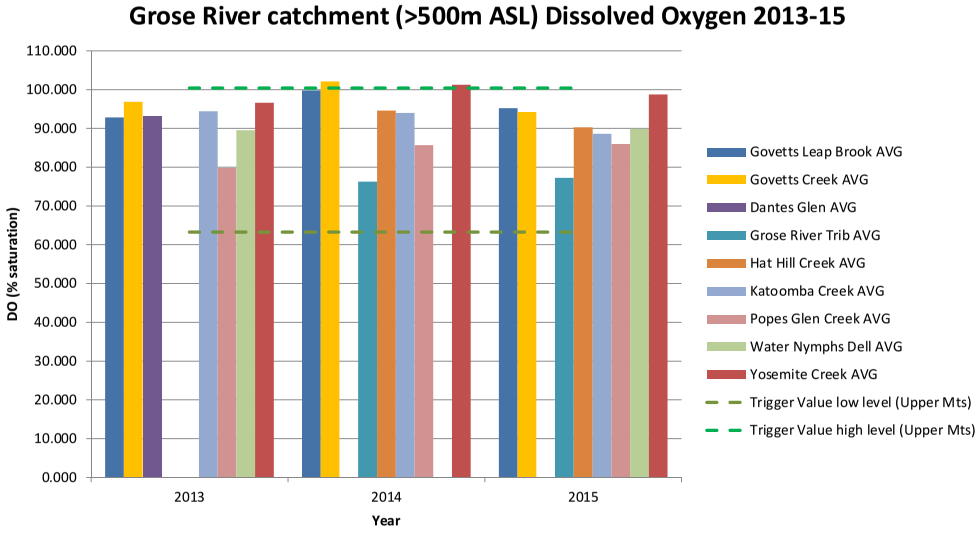
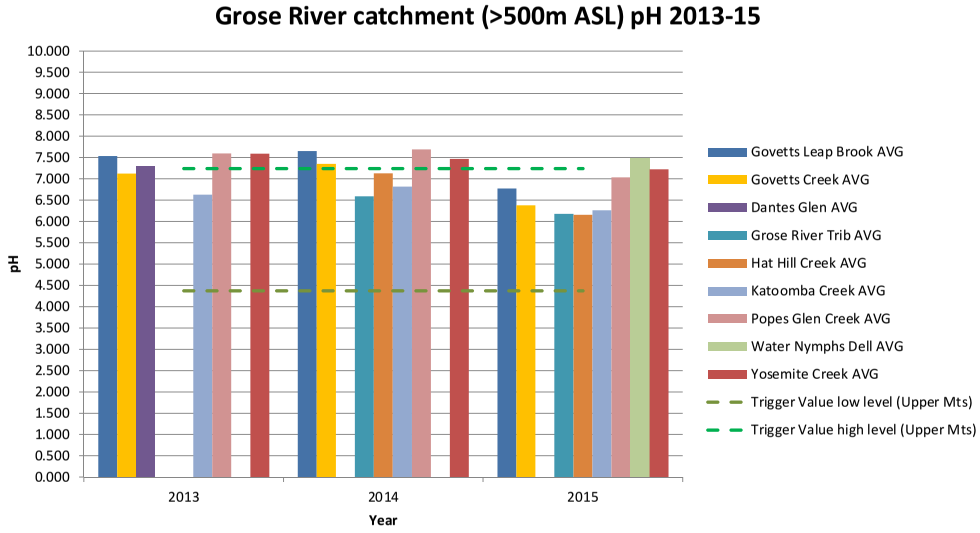


Figure 16 (below): Grose River Catchment (>500m ASL) Water Quality 2013-15

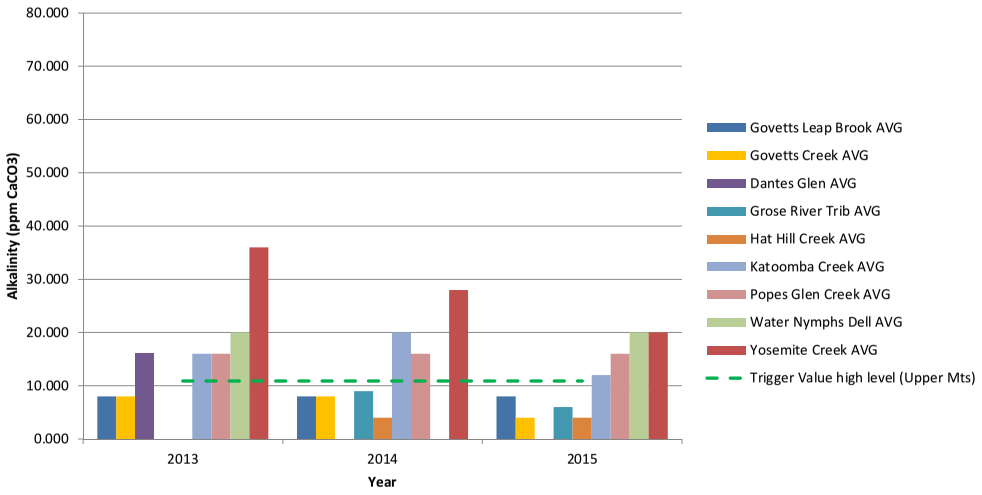




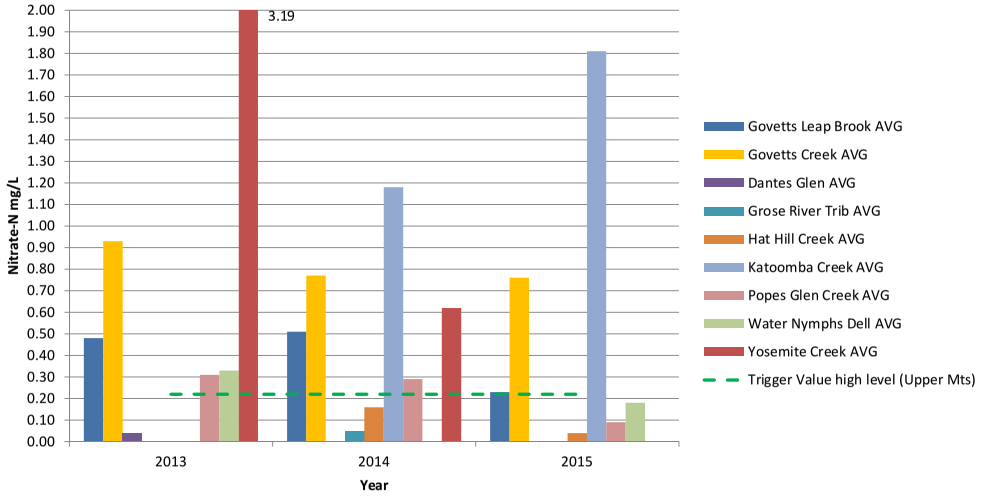




Grose River catchment (>500m ASL) Alkalinity 2013-15



Grose River catchment (>500m ASL) Nitrate-Nitrogen 2013-15



Grose River catchment (>500m ASL) Faecal Coliforms 2013-15

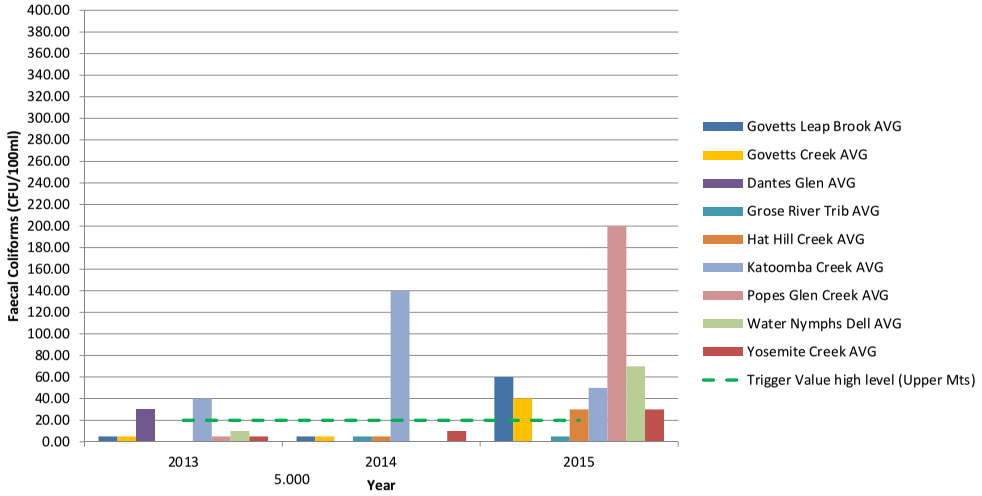
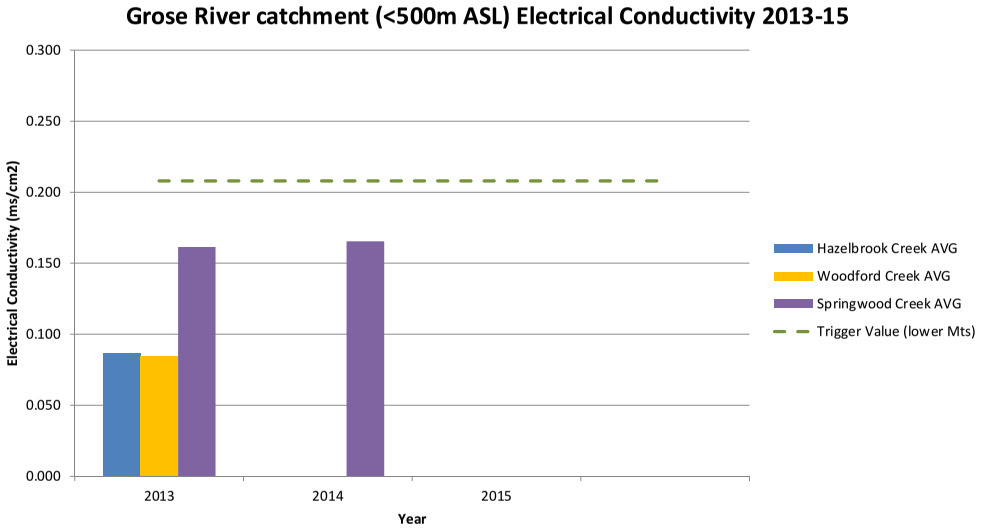
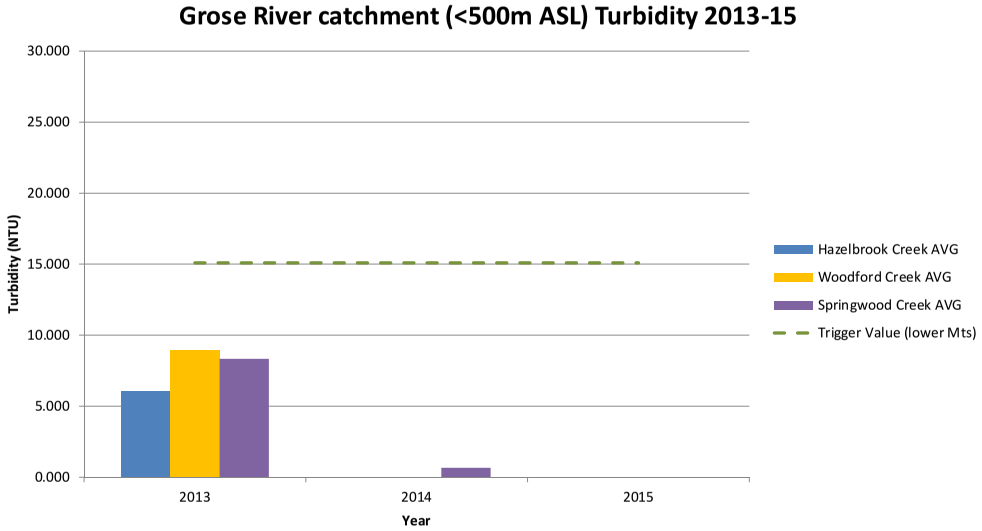
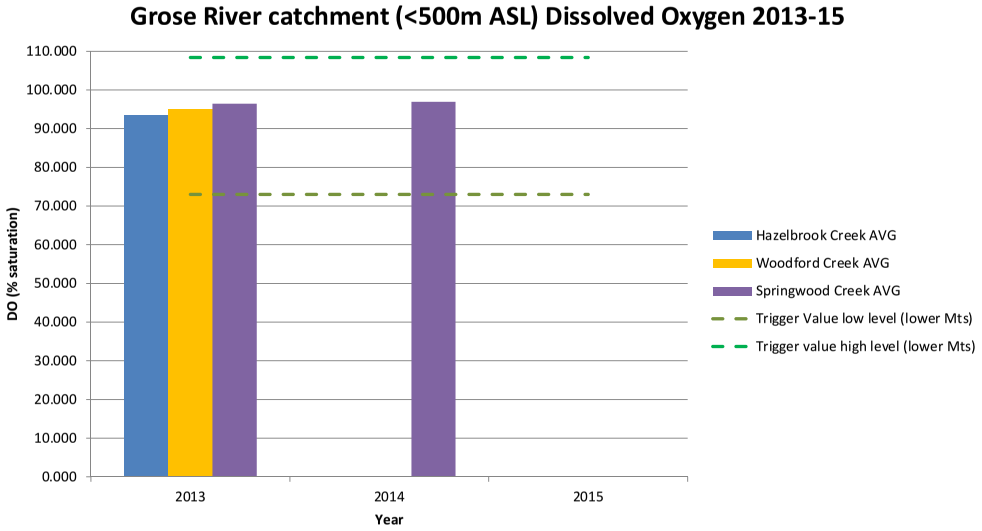
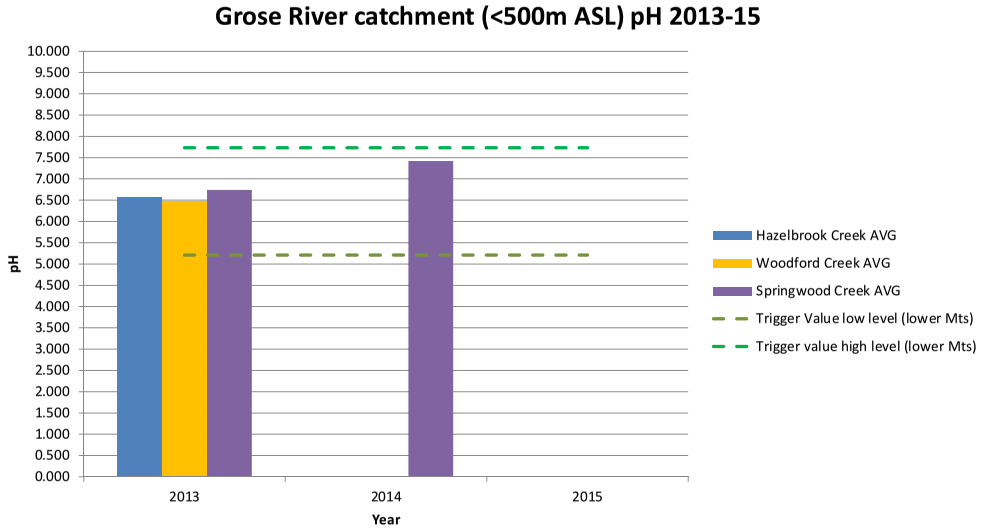


Figure 17 (below): Grose River Catchment (<500m ASL) Water Quality 2013-15

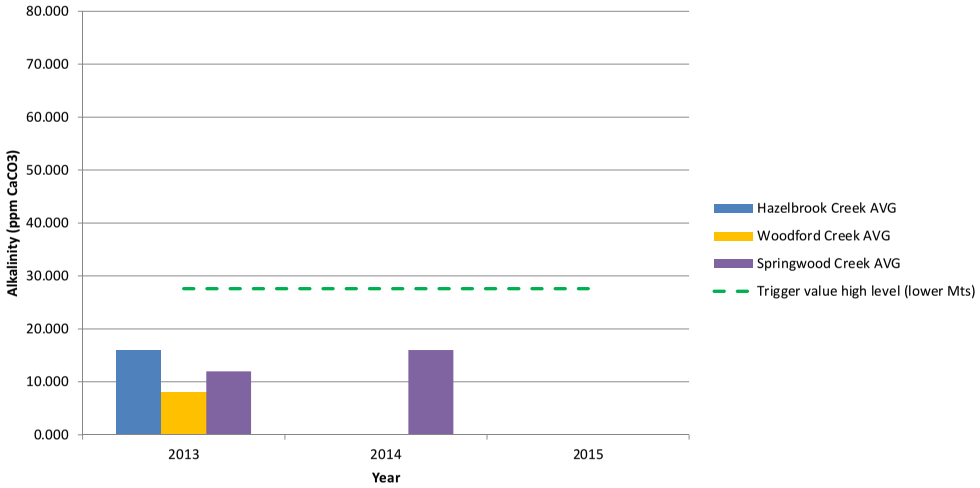




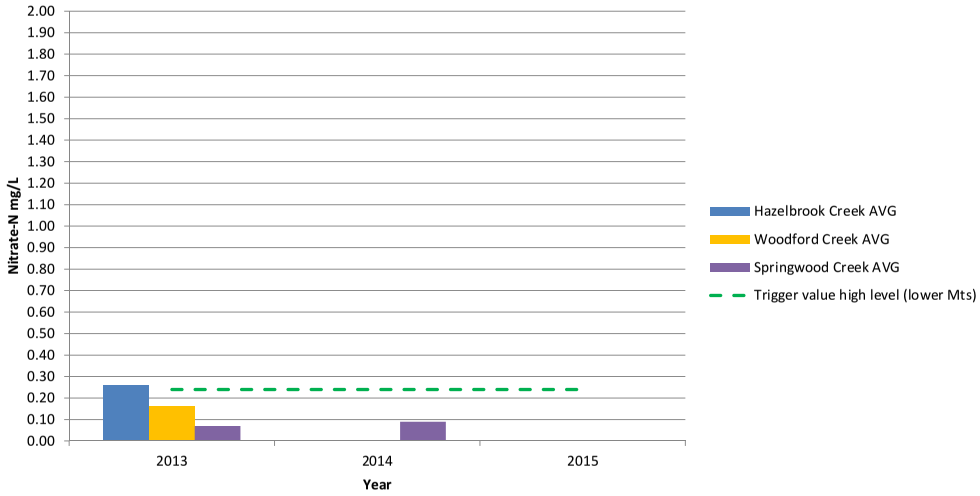




Grose River catchment (<500m ASL) Alkalinity 2013-15



Grose River catchment (<500m ASL) Nitrate-Nitrogen 2013-15



Grose River catchment (<500m ASL) Faecal Coliforms 2013-15

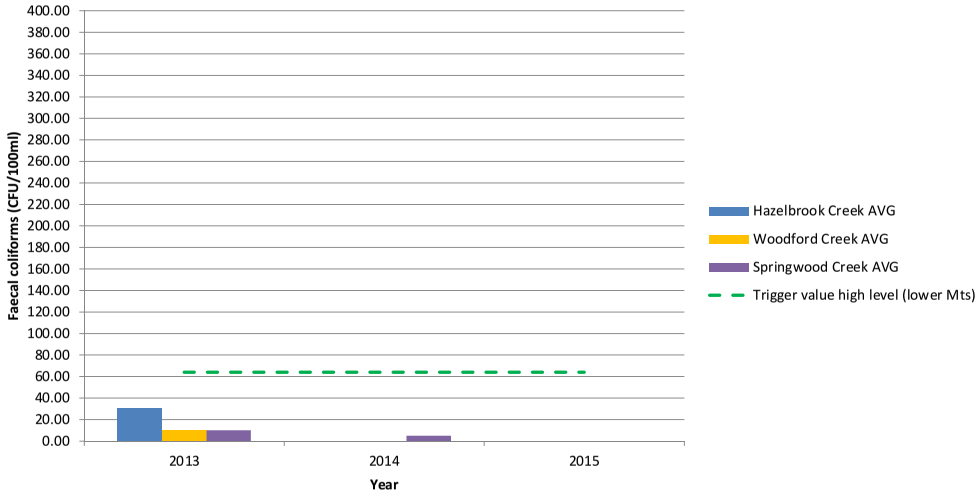
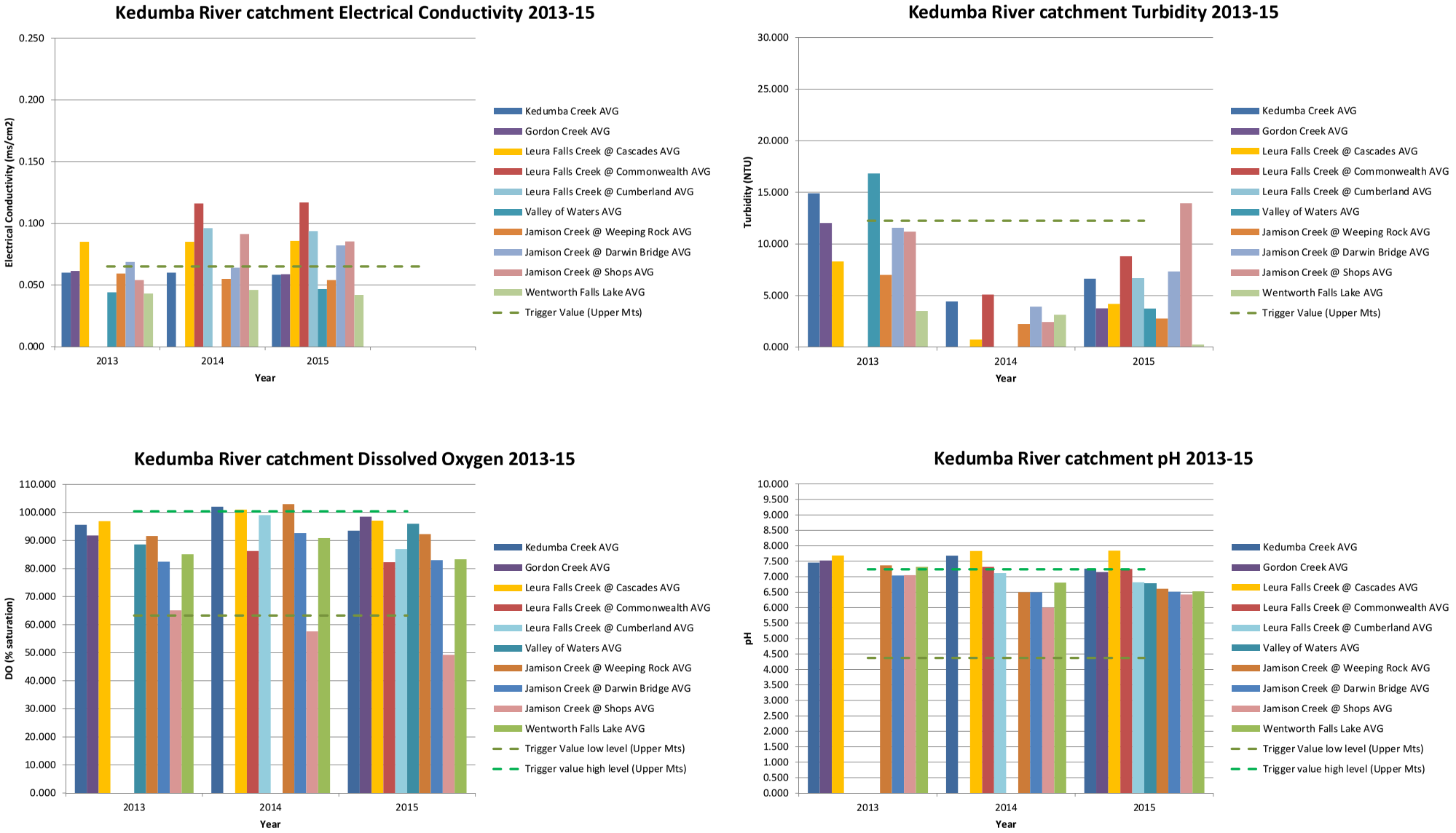
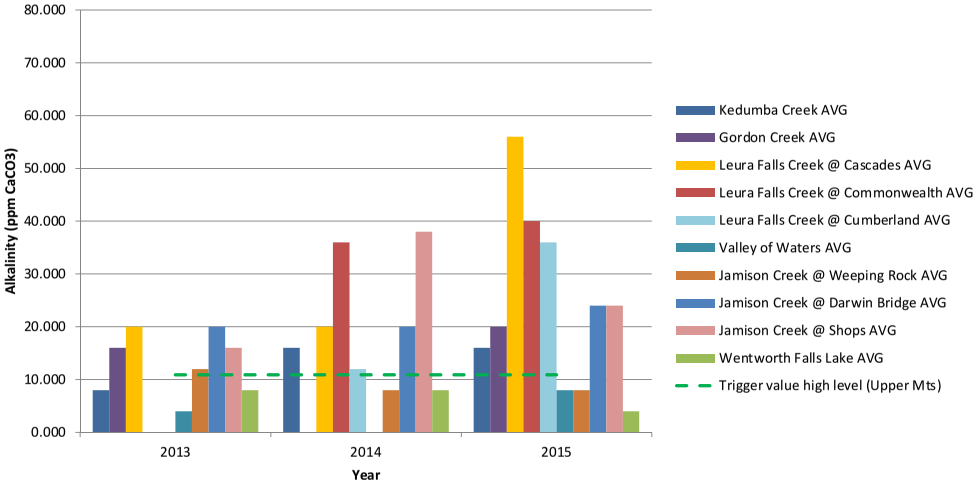


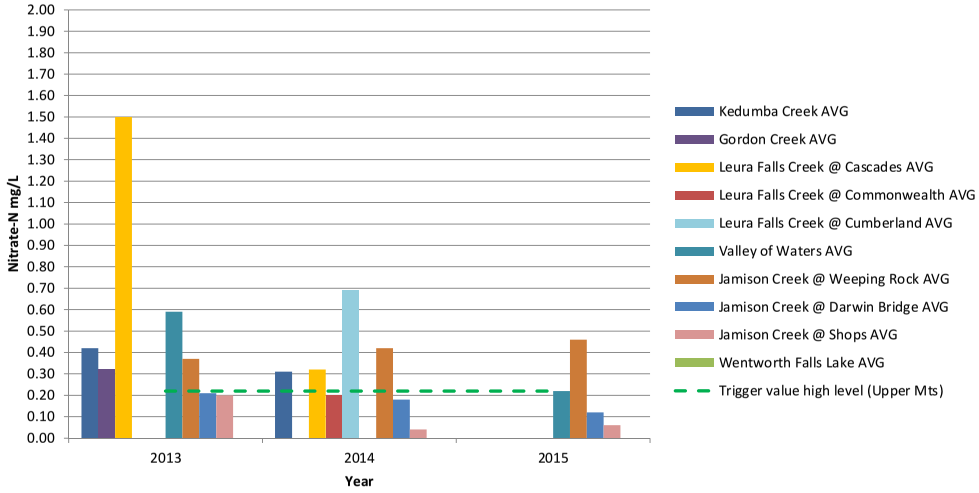
Figure 18 (below): Kedumba River Catchment Water Quality 2013-15



Kedumba River catchment Alkalinity 2013-15



Kedumba River catchment Nitrate-Nitrogen 2013-15



Kedumba River catchment Faecal Coliforms 2013-15

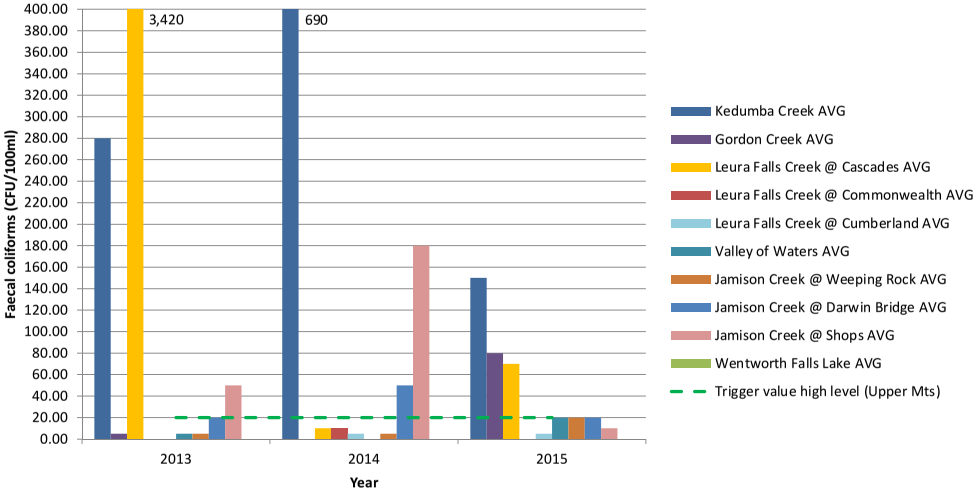
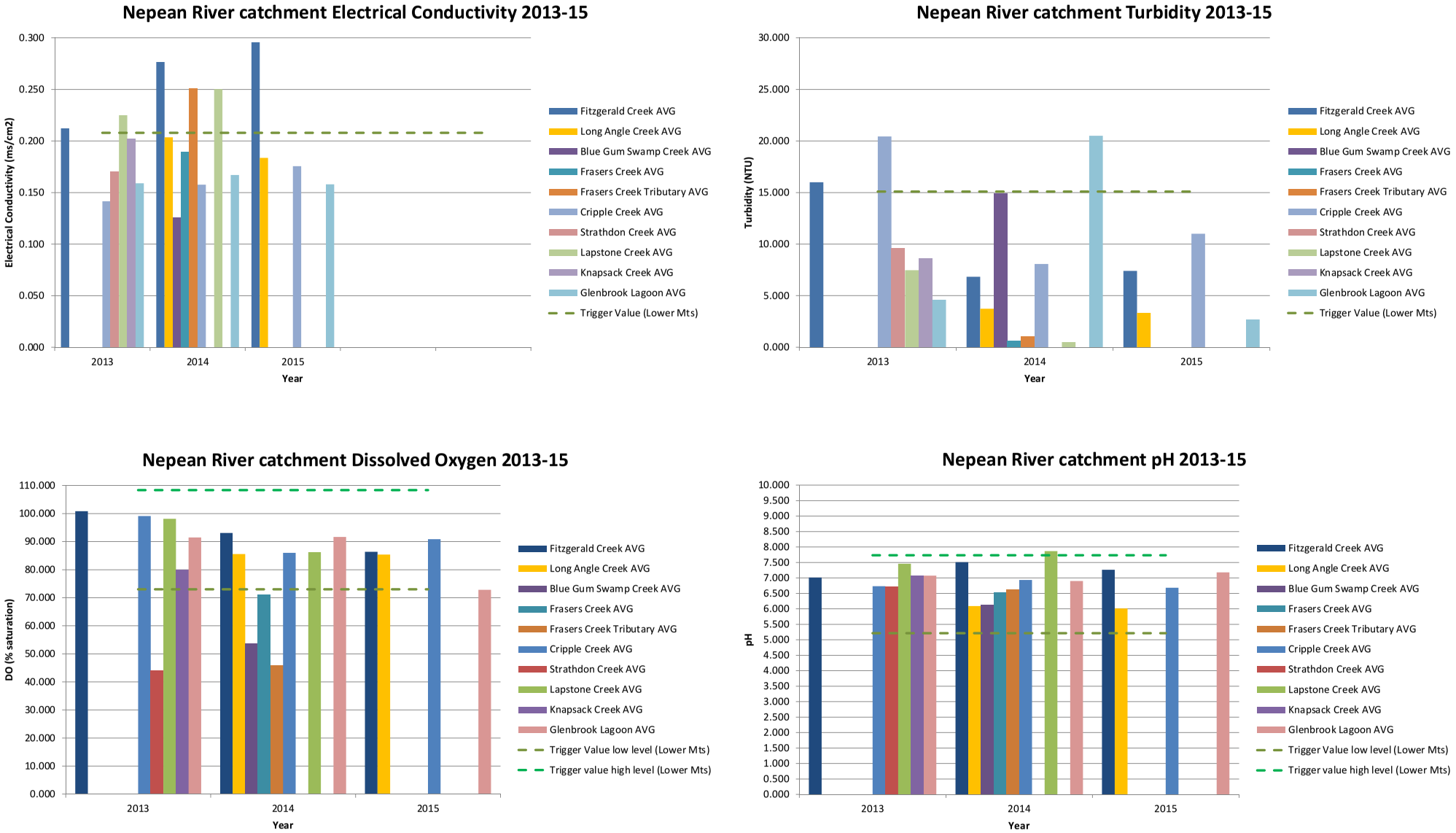
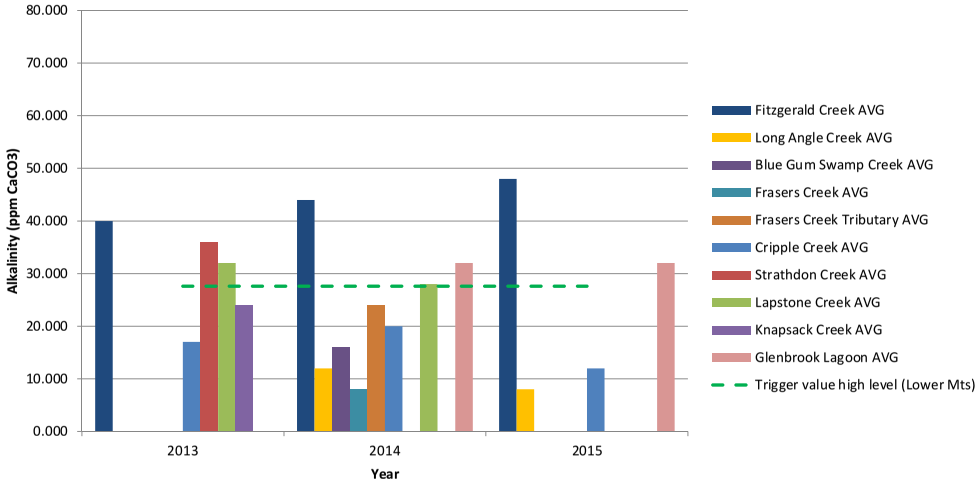


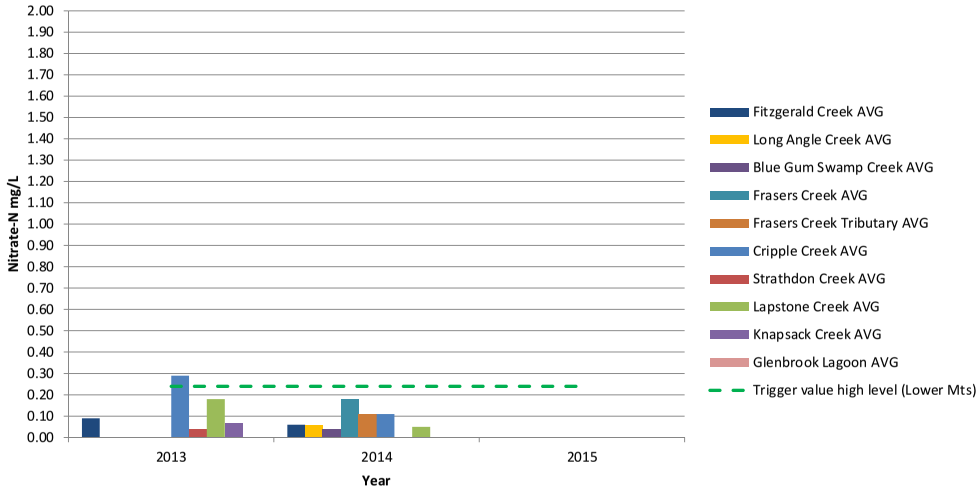
Figure 19 (below): Nepean River Catchment Water Quality 2013-15



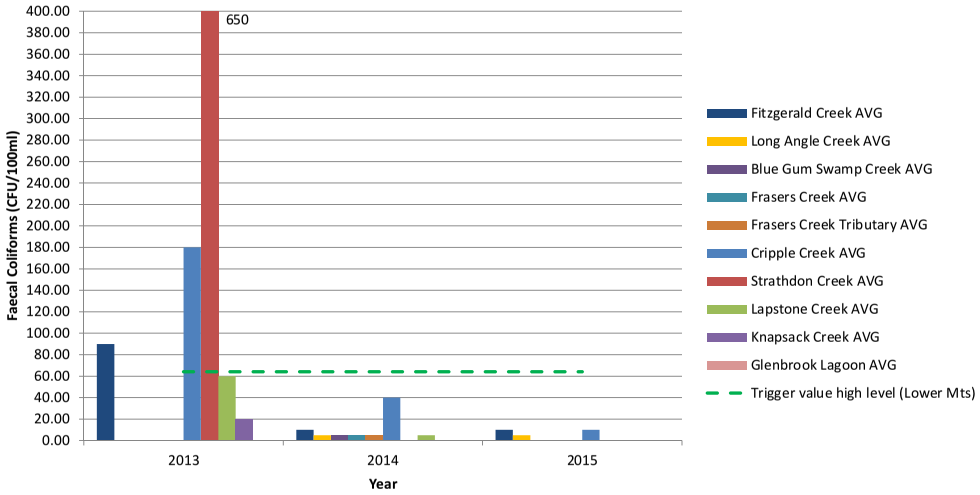
Nepean River catchment Alkalinity 2013-15



Nepean River catchment Nitrate-Nitrogen 2013-15



Nepean River catchment Faecal Coliforms 2013-15



Recreational Water Quality - enjoying our waterways safely

The waterway health ratings contained in this report represent the condition of the aquatic ecosystems and do not necessarily correlate with how water quality at each site may affect human health. For example, Megalong Creek at Old Ford Reserve, Megalong Valley was given an 'excellent' waterway health rating (based on its diverse and sensitive macroinvertebrate community), yet the same site is generally rated as having 'poor' recreational water quality due to raised enterococci levels from upstream grazing.

Megalong Creek is not alone: many Blue Mountains waterways are susceptible to faecal pollution (from sewer faults, stormwater pollution and inputs from agricultural animals) and bacterial water quality is not always suitable for swimming. Faecal pollution is more likely during and for up to three days following rain, however it is possible for contamination to occur at any time, even during dry weather.

Figure 20: Recreational water quality at Ingar Pool is generally good, as its entire catchment is protected bushland within the Blue Mountains National Park.

Common ailments associated with swimming in contaminated water are eye, ear, nose and throat infections, skin diseases and gastrointestinal disorders. Following these general rules will help minimise the risk of infection due to contact with contaminated water:

1. Avoid all contact with waterways during and for up to 3 days following rain;
2. If considering swimming during dry weather conditions:
   - Understand the catchment area for the waterway and the associated risks of water pollution (look at Google Maps/Earth, a topographic map or ask Council for advice);
   - Ensure the location is free from signs of pollution such as discoloured water, odour or 'urban' debris in the water (such as rubbish, exotic leaves etc);
   - Keep water out of ears, eyes, nose and mouth (i.e. keep head above water);
   - Avoid water contact with broken skin such as cuts, bites or grazes;
   - Remember that the very young, very old and those with compromised immunity are at greater risk of illness due to contact with poor quality water.

For more information on recreational water quality in the Blue Mountains, please refer to Council's 2016 Recreational Water Quality Report (BMCC, 2017).

Minnehaha Falls (Yosemite Creek), Katoomba

3 Trends & Case Studies

blue mountains City Council

Trends and Case Studies

In 2016 a range of additional data sources and analyses were collated, to examine trends and emerging issues over the preceding ten years (Gooderham, 2016; McCormack, 2016; Sharp et al, 2016; Ellis, 2016).

No distinct temporal trends were evident when examining the entire dataset (Gooderham, 2016), though altitude had a clear effect on macroinvertebrate assemblages, consistent with prior analyses (Wright, 2012). We selected a handful of subcatchments for more detailed analysis and examined results with reference to the specific incidents, patterns of disturbance and restoration programs that may have influenced the health of these waterways (Smith et al, 2016; St Lawrence et al, 2014; Day et al, 2014).

Improvement at Yosemite Creek

Yosemite Creek in North Katoomba represents a microcosm of the challenges faced by urban creeks, in a catchment with residential and industrial development, a major highway, a waste management facility, a Council depot, schools, sports fields and a reticulated sewerage system prone to periodic failure.

Recent aquatic monitoring results suggest that this whole-of-catchment approach is beginning to pay off, and that ecosystem recovery takes time.

In the early 2000s, Yosemite Creek was in relatively poor health. Decades of urban stormwater runoff had eroded upland swamps and channels at the creek's headwaters, causing sedimentation of downstream pools and loss of habitat for aquatic fauna. Water quality had been degraded by stormwater pollution, landfill leachate and sewerage system failures. Local residents lamented the loss of their favourite swimming hole, the 'bottomless pool' at the base of Minnehaha Falls, which had been transformed into a sandy beach through the accumulation of thousands of tonnes of sediment (Smith et al, 2016).

Over the ensuing 15-year period, Council implemented a catchment rehabilitation program that began with a community vision of restoring the pools along Yosemite Creek. Stormwater treatment systems were installed at key nodes throughout the catchment, sediment sources were addressed and extensive swamp and creekline restoration works were completed (BMCC, 2010). Catchment businesses and residents were engaged in programs to reduce stormwater pollution and make private properties more 'water sensitive', and groups of Bushcare volunteers made astounding progress treating key riparian weeds such as broom. The Katoomba Waste Management Facility was upgraded and eventually the landfill component was closed, capped and rehabilitated, halting the generation of contaminated leachate in the catchment.

Recent aquatic monitoring results suggest that this whole-of-catchment approach is beginning to pay off, and that ecosystem recovery takes time. Annual surveys show steady increases in the overall number of aquatic macroinvertebrate families and the number of mayfly, stonefly and caddisfly (EPT) families found at Yosemite Creek (see figure 21). Macroinvertebrate families increased from 12 taxa in 2008 to 22 taxa in 2015, while EPT taxa increased from 5 to 8 families over the same period. The site also improved from an AUSRIVAS Band B rating (below reference condition) in 2008 and 2009 to a consistent Band A rating (equivalent to reference condition) during 2012-2015 (Gooderham, 2016; Ellis, 2016; Smith et al, 2016).

With erosion and sediment source control in place throughout the catchment to minimise new inputs of sediment, flooding of the creek then allowed the Minnehaha Falls plunge pool to be scoured of sand and restored to its former depth (Smith et al, 2016).

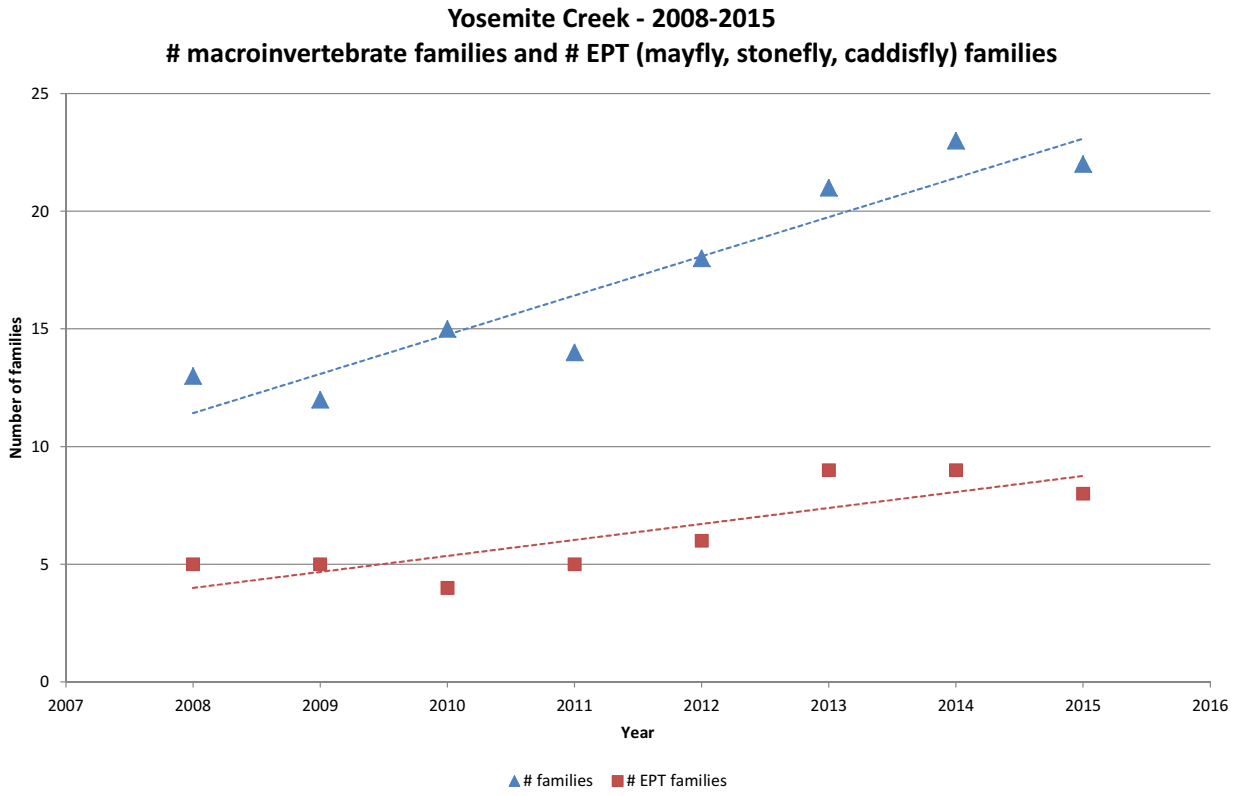


Figure 21: Yosemite Creek's aquatic biodiversity improved steadily from 2008-2015

Figure 22: (left to right) Minnehaha Falls in the 1960s; clogged with sediment in 2003; and with the plunge pool restored in 2016

Figure 23: Works were carried out in the Yosemite Creek catchment to treat stormwater and rehabilitate creeklines and swamps (photos 2004-2007)

Threats at Leura Falls Creek

Council monitors aquatic macroinvertebrates at three sites on Leura Falls Creek: Leura Cascades (site code 20BLA), Cumberland Walkway (site code 59BLA) and Commonwealth St (site code 58BLA). Figure 24 below plots Leura Falls Creek data alongside data from two undisturbed reference creeks (Asgard Brook, Mt Victoria and Ingar Creek, Hazelbrook) and shows how 'similar' the macroinvertebrate assemblage is for each sample (i.e. the closer sample points are to each other, the more similar their macroinvertebrate assemblages).

Trend lines on the non-metric multi-dimensional scaling (NMDS) in figure 24 suggest a move away from reference condition over time (to 2015) at all three Leura Falls Creek sites, which may indicate degradation as a result of urban influences.

A study conducted during October and November 2015 by WaterNSW and the Centre for Aquatic Pollution Identification and Management (Melbourne University) found a range of contaminants in the water and sediment of Leura Falls Creek, intensifying concerns about pollution from a variety of sources in the catchment. A total of 8 pesticides were detected, including two synthetic pyrethroid insecticides (bifenthrin and permethrin) found at levels known to cause toxicity to aquatic life. Other toxicants including hydrocarbons (PAHs and TPHs) and trace metals were also found at concentrations potentially toxic to aquatic life. Evidence of sewer leaks was also recorded, with high E. coli levels and human Bacteroides found in some samples (Sharp et al, 2016).

Freshwater crayfish surveys conducted at Leura Falls Creek in 2013 and 2016 suggested a significant decline in the population of Sydney Crayfish (Euastacus australasiensis) in the creek during this period, with reduced live numbers recorded compared to the 2013 survey and dead adult crayfish observed during the 2016 survey (McCormack, 2016).

Together, these studies point to an urgent need for further monitoring to isolate and address pollution sources, particularly the more toxic contaminants such as pesticides. Council intends to pursue these issues in 2017.

The Leura Falls Catchment Improvement Project (see page 51 for a summary of this project) constructed seven stormwater treatment systems within the catchment during 2015-16, to improve hydrology and water quality, with the ultimate goal of reversing the trend of degradation towards restoration of waterway health at Leura Falls Creek. Aquatic macroinvertebrate and water quality monitoring will continue into the future, to assess the effectiveness of catchment restoration and stormwater treatment measures on improving overall waterway health.

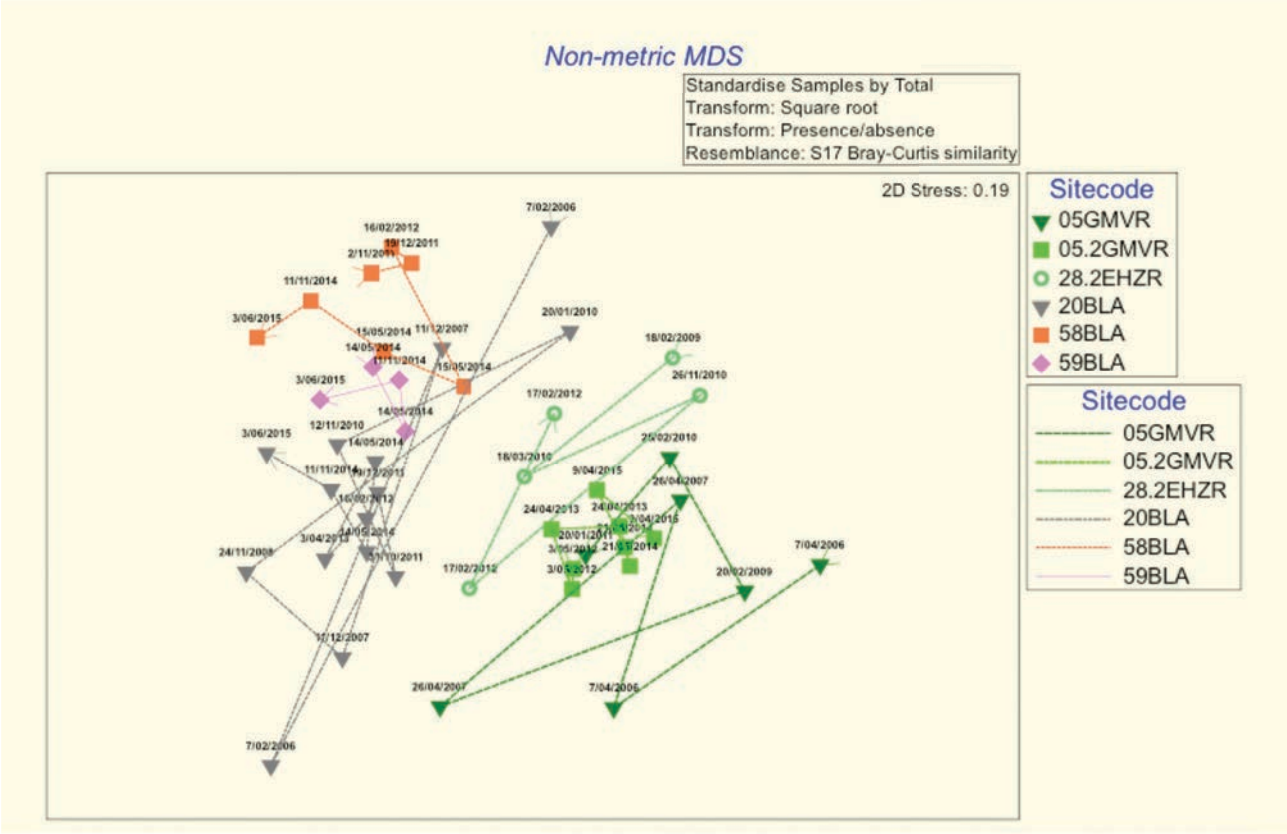


Figure 24: NMDS ordination of Leura Falls Creek macroinvertebrate data 2006-2015. Urban sites on Leura Falls Creek (20BLA – Leura Cascades, 58BLA – Commonwealth St and 59BLA – Cumberland Walkway) form a cluster separate from un-impacted reference sites on similar creeks (05GMVR/05.2GMVR - Asgard Brook, Mt Victoria and 28.2EHZR – Ingar Creek, Hazelbrook). Leura Falls Creek appears to be moving farther away from reference condition over time, suggesting degradation.

Recovery at Jamison Creek

In July 2012, over 1000 dead Giant Spiny Crayfish (Euastacus spinifer) were found in a two kilometre reach of Jamison Creek, Wentworth Falls. They were killed by a pesticide, Bifenthrin, which entered the creek via stormwater from a residential property located 300m from the creek (but directly connected by a conventional stormwater system of pits and pipes) (St Lawrence et al, 2014).

It wasn't just the crayfish affected; in fact the majority of macroinvertebrate families previously recorded at the creek (pre-incident average of 17 families including 5 sensitive mayfly, stonefly and caddisfly taxa) were absent from the July 2012 (post-incident) survey. In the months following the contamination, steady

improvements in aquatic macroinvertebrate diversity and abundance were observed, with results comparable to pre-incident samples achieved within two years.

Crayfish surveys undertaken in April 2013 revealed a rapid re-recruitment of E. spinifer into the stream. Surveys in May 2016 showed significant further recovery of the population, with an abundance of healthy animals collected and evidence of breeding observed (figure 25) (McCormack, 2016).

Recovery is thought to have been assisted by the presence of good-condition, pesticide-unaffected tributaries, allowing re-recruitment into the main trunk of Jamison Creek within a short timeframe. Inputs to the creek and its tributaries of high quality groundwater (via Temperate Highland Peat Swamps on Sandstone) are also believed to have offset ongoing urban impacts and supported the return of a 'healthy' assemblage of aquatic fauna.

Between 2016 and 2018, Council will construct stormwater treatment systems at more than fifteen sites in the Jamison Creek catchment, as part of a joint project with WaterNSW to protect the creek from urban impacts.

Figure 25: Two mature female Euastacus spinifer with sperm deposits at Jamison Creek (May 2016) – evidence of a breeding population.

Bushfire-affected subcatchments (2013 fires)

PRIMER analysis did not detect evidence of fire-related change in waterways with catchments affected by the 2013 bushfires in the lower mountains (Long Angle Creek, Fitzgerald Creek, Blue Gum Swamp Creek, Frasers Creek or Cripple Creek) or the upper mountains (Fairy Dell Creek or Grose River tributary, Mt Victoria). Many of these waterways exhibited a high degree of underlying variability between 2006 and 2015 (possibly due to ephemerality in the lower mountains creeks), which may have masked any bushfire effects if they did occur (Gooderham, 2016).

Stormwater treatment system (gross pollutant trap and raingarden) constructed to protect Leura Falls Creek

4 Protecting our Waterways

blue mountains City Council

Protecting our Waterways

Council delivers a series of programs that help protect and enhance the health of local waterways and catchments.

Council's Local Environment and Development Control Plans aim to ensure that development in our city incorporates the key principles of water sensitive urban design – protecting natural waterways, maintaining the natural hydrology of catchments, minimising demand on the reticulated water supply, promoting the harvesting and reuse of rainwater and stormwater and integrating water into the landscape to enhance ecological, visual, social, economic and cultural values (BMCC, 2015b).

In addition, Council delivers a series of programs that help protect and enhance the health of local waterways and catchments:

- The *Environmental Stormwater* program, constructing treatment systems to improve hydrology and remove pollutants from stormwater before it enters natural waterways;
- The *Creekline Restoration* program, repairing damaged creek banks and beds and preventing creekline erosion and sedimentation;
- Grant-funded *restoration programs* in priority catchments such as Leura Falls Creek, Jamison Creek and Glenbrook Lagoon;
- The *Blue Mountains Water Sensitive City Strategy* (in development) will include an Action Plan to identify and deliver priority projects such as:
  - installing rainwater/stormwater harvesting and reuse systems at Council facilities (helping ease the damage to waterways caused by urban runoff);
  - incorporating water sensitive technologies such as permeable surfaces, raingardens, swales etc into Council developments and scheduled upgrades/renewals of Council assets such as footpaths, roads, drainage systems and town centres;
- Grant-funded bushland restoration programs in *Endangered Ecological Communities* such as the Temperate Highland Peat Swamps on Sandstone of the mid to upper mountains; and the shale-based forests of the lower mountains;
- *Bush regeneration and noxious weed control* at reserves throughout the city;
- *Community Conservation* programs such as Bushcare, Landcare and Swampcare;
- Engagement and education programs such as the *Connect with Nature* program, to build community water literacy and capacity to protect waterways.

Council prioritorises subcatchments based on a combination of their values and the risks of degradation (with highest priority allocated to catchments with both high value and high risk, such as Leura Falls Creek and Jamison Creek).

Values may include:

- high aquatic biodiversity;
- downstream protected areas such as the World Heritage Area and drinking water supplies;
- presence of threatened species and ecological communities;
- high levels of community involvement e.g. Bushcare and catchment groups;
- high tourism significance;
- availability of catchment-specific funding – e.g. WaterNSW grants for stormwater treatment in drinking water catchments.

Risks may include:

- high levels of directly connected catchment imperviousness (and associated high risk of stormwater pollution and geomorphic degradation);
- landuses with heightened probability of toxic contamination, such as industrial areas or landfills;
- measured poor water quality;
- presence of significant aquatic weeds e.g. Salvinia and Cabomba.

Council manages a range of assets to help protect our waterways, including more than:

- **20 raingardens/stormwater biofiltration systems**
- **35 stormwater/rainwater harvesting and reuse systems on council facilities**
- **200 stormwater quality improvement devices such as gross pollutant traps.**

Action shot: Leura Falls Catchment Improvement Program

Leura Falls Creek rises in an urbanised sub-catchment, flows through Leura Cascades, into the Blue Mountains World Heritage Area and on to Sydney's drinking water supply at Lake Burragorang. Urban stormwater threatens the creek's unique values, with altered hydrology and pollution of particular concern.

With a grant from WaterNSW, Council and the local community are working together to restore creeklines and bushland throughout the Leura Falls catchment, and to implement stormwater treatment systems aimed at improving creek health.

Gross pollutant traps, raingardens and wetland cells were constructed at seven sites during 2015-16, targeting pollutants such as nutrients, pathogens, suspended solids, sediment and litter.

Preliminary water quality testing has found significant reductions in pollutants, with treatment systems achieving up to 93% reduction in faecal coliforms, up to 91% reduction in total nitrogen, up to 67% reduction in nitrate, up to 50% reduction in ammonia, dissolved phosphorus and total phosphorus, and up to 44% reduction in suspended solids. A comprehensive monitoring program is ongoing, to further assess the outcomes of the project.

The project engaged local residents and businesses in catchment tours, raingarden workshops and creek protection seminars. The on-ground works and educational initiatives complement the efforts of dedicated community volunteers in the Leura Falls Creek Catchment Working Group and the ten Bushcare and Landcare groups active in the Leura Falls catchment.

A similar project will be commenced in the Wentworth Falls Lake/Jamison Creek catchment in 2016-17, with stormwater treatment systems set to be constructed at over fifteen sites in this catchment by 2018.

Figure 26: Three of the six site-specific stormwater biofiltration treatment systems constructed to improve water quality in Leura Falls Creek, and (bottom right – by Ona Janzen) a workshop for catchment residents and Katoomba High School students on 'How to build a raingarden at home'.

Action Shot: Connecting Kids, Creeks and Catchments

Council's Connecting Kids, Creeks and Catchments program supports Council's on-ground creek restoration and stormwater mitigation works by addressing the root cause of waterway ill-health – human behaviour.

There is a wealth of research showing that children who connect with nature grow up to become more environmentally responsible adults. Each year, our Healthy Waterways Team works with around 12 schools and 600 students across the city, delivering hands-on, experiential learning with a focus on healthy waterways and the impacts of stormwater.

With the aim of engaging children and young people with their local creeks and bushland, we tailor every learning program to link strongly with both the curriculum and the needs of each school. Learning days

focus on the big concept questions: *Where does the water go? What's so special about our bush?* Activities include creek crawls, stormwater drain 'spotting', drain mapping, weed and vegetation studies, waterbugs and water quality testing, learning about stormwater impacts, looking at council's stormwater treatment systems and finding out what can be done at home to help protect our waterways.

Recent highlights include working with Glenbrook Public and Springwood High Schools to install stormwater management structures in the school grounds. Students were involved with the design and construction of sediment traps, sandstone rock ramps and biofiltration systems at the schools. They learnt about mapping and construction, took part in photo-monitoring, before and after water quality testing and on-going weeding, and showcased their project to other schools, parents and community. Council also ran creek and catchment activities with Warrimoo, Lapstone, Wentworth Falls, Katoomba and Blackheath Public Schools, Winmalee High School, Korowal School, Kindlehill School and Blue Mountains Grammar School.

Videos: **Bioblitz Wentworth Falls Lake** https://www.youtube.com/watch?v=Bu5m2YuaoV0
Catchment studies at Warrimoo PS https://www.youtube.com/watch?v=LgtW9VEHhz4

Figure 27 (left to right): Warrimoo Public School students study catchment maps and ask: Where does the water go?; Members of the SQID (Stormwater Quality Improvement Device) Squad for Leura Falls Creek Catchment; Using the lifelike Stormwater Action Model, students learn about the benefits of water sensitive urban design; Bioblitz: Macroinvertebrate studies at Wentworth Falls Lake

Water Sensitive Homes

Consider an undisturbed bushland catchment: rain falls and the vast majority (around 85%) of this water is evapo-transpired into the air by the forest. Around 15% of the rainfall soaks through soils and makes its way slowly to the creek via subsurface flows or groundwater. There is little or no surface runoff (Walsh, 2016b).

This creek is healthy, with good water quality, steady dry-weather baseflows, stable stream geomorphology and high aquatic biodiversity. The clear, deep pools make inviting swimming holes.

Now consider what happens when the bushland in this catchment is cleared and replaced with impervious surfaces: roofs, roads and concrete. Rain falls on the hard surfaces and flows to gutters and stormwater drains, picking up pollutants such as pesticides, sewage leaks, weed propagules and litter as it goes. Stormwater pipes carry the contaminated runoff and dump it directly into the creek. Runoff from all over the catchment hits the creek in a very short space of time and the greatly increased volume and velocity of the water erodes headwater swamps, creek beds and banks. Sediment is dumped where the stream flow slows, infilling the once-inviting swimming holes and creating nutrient-enriched sand slugs that will soon be colonised by weeds. Little or none of the rainfall soaks into the ground – there will be no slow, subsurface movement of water to the creek and it is likely that the flow will dry up during periods with no rain. This creek is now sick, with poor water quality, degraded stream geomorphology, weed infestation and impoverished aquatic biodiversity. Swimming in this creek may cause gastroenteritis and eye, ear or skin infections.

Fortunately, development does not need to be as damaging as this. Water Sensitive Urban Design (WSUD) aims to prevent urban runoff impacts, by mimicking the natural water cycle. New developments in the Blue Mountains are required to manage stormwater in accordance with the principles of WSUD (BMCC, 2015b). However, in many parts of the Local Government Area, urban development occurred during the era of conventional stormwater management, when the sole objective was to collect water from the urban environment and transfer it out of sight as quickly as possible.

In catchments such as these, managing stormwater at the source to protect waterways relies on retrofitting established properties with features such as rainwater tanks and raingardens.

Significant outcomes can be achieved relatively simply, by installing rainwater tanks to capture roof runoff during rain and then using this water regularly in the household toilet/s and washing machine and for watering gardens through a combination of passive irrigation and on-demand watering. Tank overflows can be diverted to infiltration raingardens, to help recharge groundwater and stream baseflows (Melbourne Water, 2013; Walsh, 2016).

The ideal outcome for stream health is to entirely prevent runoff from the property. When first exposed to this idea, many people are concerned that such an approach will starve the local stream of flows, however this is not the case (Walsh, 2016). Stormwater inputs to creeks are almost always degrading factors, as this pattern of hydrology is so different to the pre-development movement of water through a catchment, and the water itself is often contaminated by its passage through the urban environment (Walsh et al 2004; Tippler et al 2012; Davies et al 2012; St Lawrence et al 2014).

The challenge in a high rainfall area such as the Blue Mountains (annual average of 1400mm in Katoomba) is in fact to use enough of the water collected by tanks to prevent overflow and stormwater runoff.

Figure 28 below illustrates a scenario that could be implemented on an average Blue Mountains residential block of 714m^2, to achieve a water balance similar to that of the same block of land prior to development.

Figure 28 (below – adapted from Walsh, 2016b): An example of how retrofitting Water Sensitive technology such as rainwater tanks plumbed in to toilet and laundry, passive irrigation, and raingardens can restore the hydrological balance of a residential block in the Blue Mountains to near-natural conditions, protecting the creek downstream. The added benefit is that the 'water sensitive' house will have all its water needs for toilet flushing, laundry and garden watering met without drawing any of this from the Sydney Water drinking water supply. Each year the conventional house sends 240,000L of runoff straight to the creek through stormwater pipes – in a catchment such as Leura Falls Creek this equates to 312 million litres of polluted water hitting the creek each year, just from residential runoff alone (with road, industrial and commercial runoff additional to this).

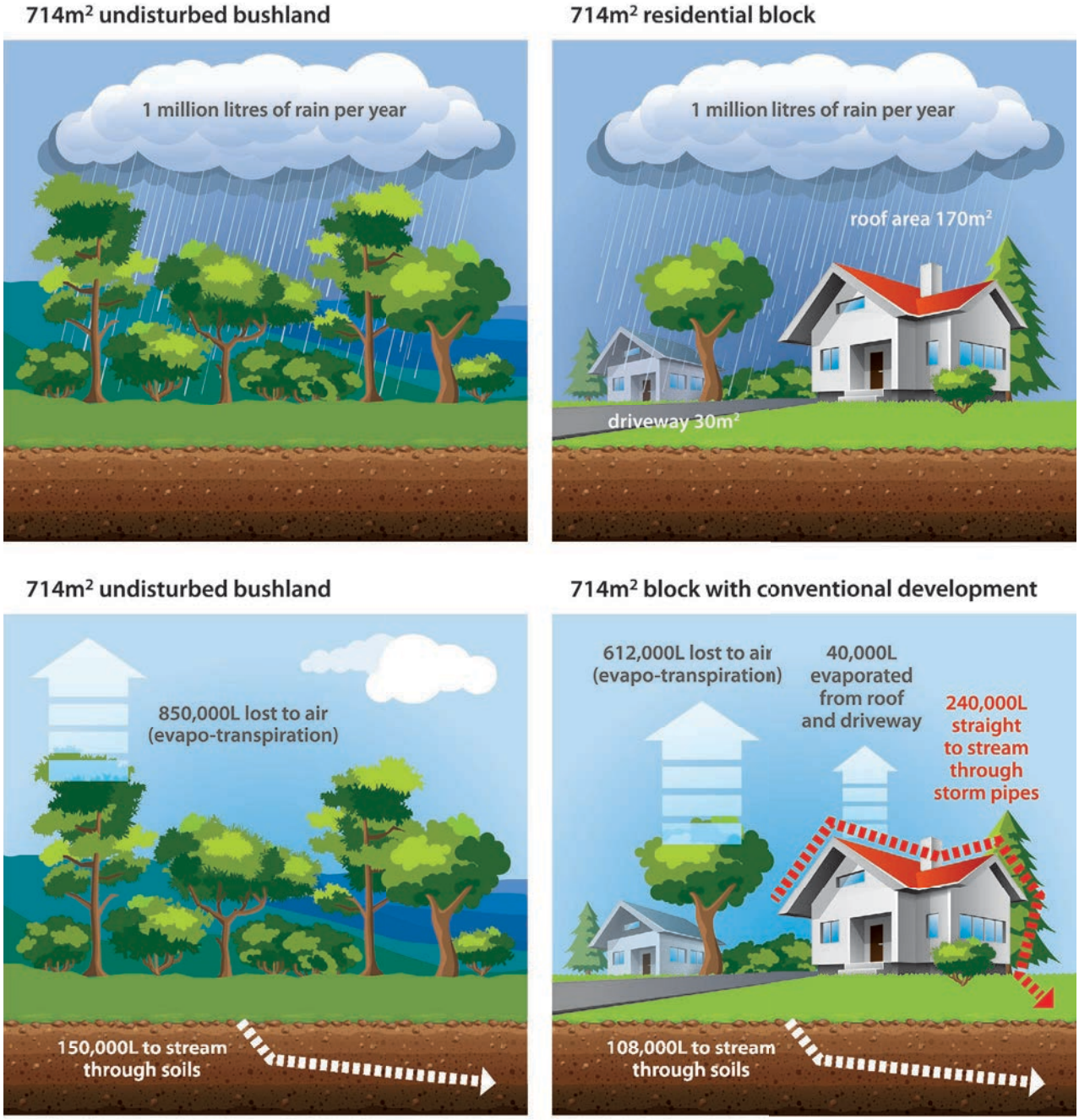

714m² undisturbed bushland
1 million litres of rain per year
714m² residential block
1 million litres of rain per year
roof area 170m²
driveway 30m²
714m² undisturbed bushland
850,000L lost to air
(evapo-transpiration)
150,000L to stream
through soils
714m² block with conventional development
612,000L lost to air
(evapo-transpiration)
40,000L
evaporated
from roof
and driveway
240,000L
straight
to stream
through
storm pipes
108,000L to stream
through soils
714m² block with water sensitive development
612,000L lost to air
(evapo-transpiration)
40,000L
evaporated
from roof
and driveway
240,000L kept out of stormwater
• 60,000L toilet and laundry
• 138,000L garden watering:
passive and on-demand
(some evaporates,
some infiltrates)
• 42,000L infiltration
via raingarden
>150,000L to stream
through soils and rain garden

Figure 29: Rainwater tanks capture roof runoff for use on the property (toilet, laundry and garden). This is one of the best ways to protect waterways from urban runoff, while reducing potable water consumption. The tank above overflows to the raingarden along the fence at the left of the photo (photo by Chris Walsh).

Figure 30: Home raingardens can filter and infiltrate stormwater, to reduce urban runoff problems (photo by Ona Janzen).

Community Conservation Programs

Another way for local residents to help protect Blue Mountains waterways is to get involved in one or more of council's community conservation programs, such as Bushcare, Swampcare, Landcare, Bush Backyards or Streamwatch (Streamwatch is run by the Australian Museum and supported by council).

For more information on community conservation programs, please visit **www.bmcc.nsw.gov.au/sustainableliving/environmentalinformation/bushcare** or call (02) **4780 5528**.

Figure 31: Over 500 Bushcare, Swampcare and Landcare volunteers help restore Blue Mountains bushland, swamps and creeklines; while Streamwatch volunteers regularly test water quality at their sites. Photos by Ona Janzen.

Bedford Creek, Woodford

5 Conclusion

Between 2013 and 2015, 52.5% of urban waterways monitored by Blue Mountains City Council were rated as being in good or excellent health. 40% were in fair health and 7.5% in poor health, with scores based on the diversity and sensitivity of aquatic macroinvertebrates recorded at each site. Impairment at degraded sites was generally due to stormwater runoff from urban areas.

Council is working to protect good condition waterways and improve the health of impaired waterways, by implementing the Local Environment and Development Control Plans, constructing stormwater treatment systems, rehabilitating creeklines, delivering catchment restoration projects and running community engagement and education programs. The forthcoming Blue Mountains Water Sensitive City Strategy will help the city manage our water resources more holistically.

Council's aquatic monitoring programs will continue to assess the condition of local waterways over time, guiding catchment and waterway management and keeping our community up-to-date with reliable, science-based information.

blue mountains City Council

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Glenbrook Lagoon

healthy waterways

For more information
www.bmcc.nsw.gov.au/waterways

Report pollution
NSW Environment Line **131 555**

Report sewage leaks
Sydney Water **13 20 90**

Dispose of chemicals safely
Household Chemical Cleanout:
www.bmcc.nsw.gov.au/cleanout

Become a volunteer
www.bushcarebluemountains.org.au

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