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Caloundra South
Water Quality Management Plan

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Caloundra South
Water Quality Management Plan

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1 INTRODUCTION

This Water Quality Management Plan (WQMP) addresses the management and monitoring of surface water and groundwater on and adjacent to the Caloundra South site in accordance with Condition 4 of the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) Final Approval Decision conditions and addresses the following:

a) Outlines baseline water quality data (Section 2);

b) Sets out water quality performance objectives and parameters (Section 3);

c) Sets monitoring and reporting periods (Section 4);

d) Sets out scientifically robust methods for sampling and data collection (Section 5);

e) Includes a risk assessment of any modelling, assumptions and predictions used (Section 6);

f) Identifies readily measurable performance indicators and goals and performance indicators at which point corrective actions will be taken (Section 7);

g) Identifies corrective actions, and/or mechanisms for developing corrective actions, and the parties responsible for implementing corrective actions (Section 8);

h) Includes a scientifically robust method for detecting relevant changes in water quality parameters in Bell's Creek and Pumicestone Passage (Section 7); and

i) Identifies adaptive management mechanisms to ensure current industry best practice is being implemented on the site (Section 9).

2 BASELINE WATER QUALITY DATA

Baseline water quality data have been collected in and around Caloundra South for many years by Stockland, Sunshine Coast Council and the Ecosystem Health Monitoring Program. These data are presented in detail in other reports, with a summary provided below.

2.1 Pumicestone Passage Water Quality

Pumicestone Passage has a large catchment containing a mix of mostly rural land uses, with large areas of intensive agricultural activities (horticulture) and plantation forestry (pine). Urban development is primarily located within the northernmost portions of the catchment where tidal flushing is highest, with the majority of the rural catchments discharging to the more poorly mixed zones in the central part of the estuary. The Caloundra South development will discharge into the northern part of Pumicestone Passage via Bells Creek and Lamerough Creek.

The Ecosystem Health Monitoring Program (EHMP), a multi-agency funded (lead by the Queensland Government) environmental monitoring program, has been collecting water quality data at monthly intervals at a number of sites within Pumicestone Passage for more than 10 years. The following summary of ambient water quality levels in Pumicestone Passage is drawn from an earlier interpretation of this highly valuable data set.

2.1.1 Water Quality Objectives

Water Quality Objectives for Pumicestone Passage are defined in Schedule 1 of the Environmental Protection (Water) Policy 2009. The set of generic objectives relevant to the region as a whole are contained in an extract of the Queensland Water Quality Guidelines for Basin 141 which covers the entire Passage and contributing waterways such as Coochin Creek and Bells Creek and are included for comparison purposes in Table 2-2.

This area lies within the defined region PLE1 in Plan WQ1413 (see Figure 2-1 which refers to the northern enclosed coastal estuarine section). This area and others in the Passage have been defined as having ‘High Ecological Value’ and relevant performance objectives for such waters are defined as ensuring that 20^{th}, 50^{th} and 80^{th} percentile water quality parameters are maintained. Relevant Water Quality Objectives using these percentiles have been derived for a specific site at the mouth of Bells Creek in Pumicestone Passage using the more than 10 years of EHMP data and are presented in Table 2-1.

These **site specific** objectives having been used for impact assessment purposes for the Caloundra South site as the more generic scheduled objectives (see Table 2-2) are intended to represent average water quality in this entire zone, and hence are not considered appropriate targets to use for one particular project (that is Caloundra South) which will affect one particular section of the entire PLE1 region (near to the mouth of Bells Creek).

Table 2-1 Site Specific WQOs Derived for EHMP Site 1311 (at the Mouth of Bells Creek)

Parameter	WQO			Units
	20%ile	50%ile	80%ile	
turbidity	5.4	8.8	11.5	NTU
chlorophyll a	1.4	2.6	4.0	µg/L
total nitrogen	220	260	330	µg/L
total phosphorus	14	18	24	µg/L
dissolved oxygen	88.4	94.8	102.0	% saturation
pH	7.9	8.1	8.2	

Table 2-2 Pumicestone Passage WQOs provided for Region PLE1 in Plan WQ1413

Parameter	WQO			Units
	20%ile	50%ile	80%ile	
turbidity	2	4	6	NTU
chlorophyll a	1.0	1.6	2.5	µg/L
total nitrogen	150	190	220	µg/L
total phosphorus	15	18	25	µg/L
dissolved oxygen	90	95	105	% saturation
pH	8.0	8.2	8.3	

2.1.2 Pumicestone Passage Zones

Pumicestone Passage can be considered as consisting of several ‘zones’ which are relevant to both the establishment of water quality objectives and the performance of water quality assessments. In Plan WQ1413 in Figure 2-1, the northern zone of the Passage can be considered as those areas covered by area PLE1 towards Caloundra. The middle estuary zone is defined as area PME1 from just north of Halls Creek to the southern area of Tripcony Bight and the southern part of the passage is all areas south of Tripcony Bight to the southern tip of Bribie Island. Subsequent sections of this report review ambient water quality behaviour with reference to these ‘zones’.

2.1.3 Salinity

- Pumicestone Passage effectively behaves as a ‘double ended’ estuary. Tidal flows and associated salinity levels propagate into the Passage from each end, producing lowest salinities approximately midway along the Passage in the general vicinity of the middle estuary zone near Tripcony Bight (see Figure 2-1).
- Salinities in the middle/poorest flushed zone of Pumicestone Passage range from those of effectively freshwater to fully marine concentrations.
- Lowest salinities are somewhat to the north of the middle zone of Pumicestone Passage, this being reflective of recognised net northerly flows in the Passage.

- There would appear to have been lower typical salinities and far greater variations in salinity levels in Pumicestone Passage in recent years than those observed beforehand, reflective of the breaking of significant drought conditions in the region over this time period.

2.1.4 Temperature

- Temperatures would appear to be largely consistent along the length of Pumicestone Passage, with a potentially slight (less than 1° C) elevation in mean temperature levels in the middle zone of the Passage; and
- Sites near Caloundra South exhibit almost identical temperature behaviour.

2.1.5 pH

- pH levels appear to show similar spatial and temporal trends to salinity, which could be expected.
- Of the more than 1030 samples analysed, only 4 were below neutral (pH 7). This indicates that there are no obvious manifestations of any particular influence of actual acid sulphate soil conditions in the catchment and acidic coastal heathlands are not dominant in the catchment.
- Like salinity, pH levels seem to have been lower (reflecting more near neutral stormwater run-off) and more varied in the last 2 to 3 years than beforehand.
- Pumicestone Passage near the Caloundra South site is naturally not compliant with (i.e. in the case of pH, less than) relevant water quality objectives.

2.1.6 Dissolved Oxygen

- The majority of DO levels are typically quite high within Pumicestone Passage, reflecting the high tidal velocities and relatively good tidal flushing, predominantly un-urbanised catchment and absence of major point source sewage discharges.
- There are occasional occurrences of low DO in the middle zone of the Passage. The lower DO levels typically coincide with lower salinity levels when catchment run-off (causing the lower salinities) will typically have lower dissolved oxygen concentrations and also convey oxygen demanding substances into the Passage, thereby reducing DO levels. DO levels in the waterways may also be affected sediment oxygen demand and water column algal respiration/photosynthesis activities.
- Like salinity, DO levels seem to have been lower (reflecting the aforementioned influence of catchment run-off) in the last 2 to 3 years than previously in the data record.
- Pumicestone Passage near the Caloundra South site is naturally compliant with (i.e. in the case of DO, greater than) relevant water quality objectives.

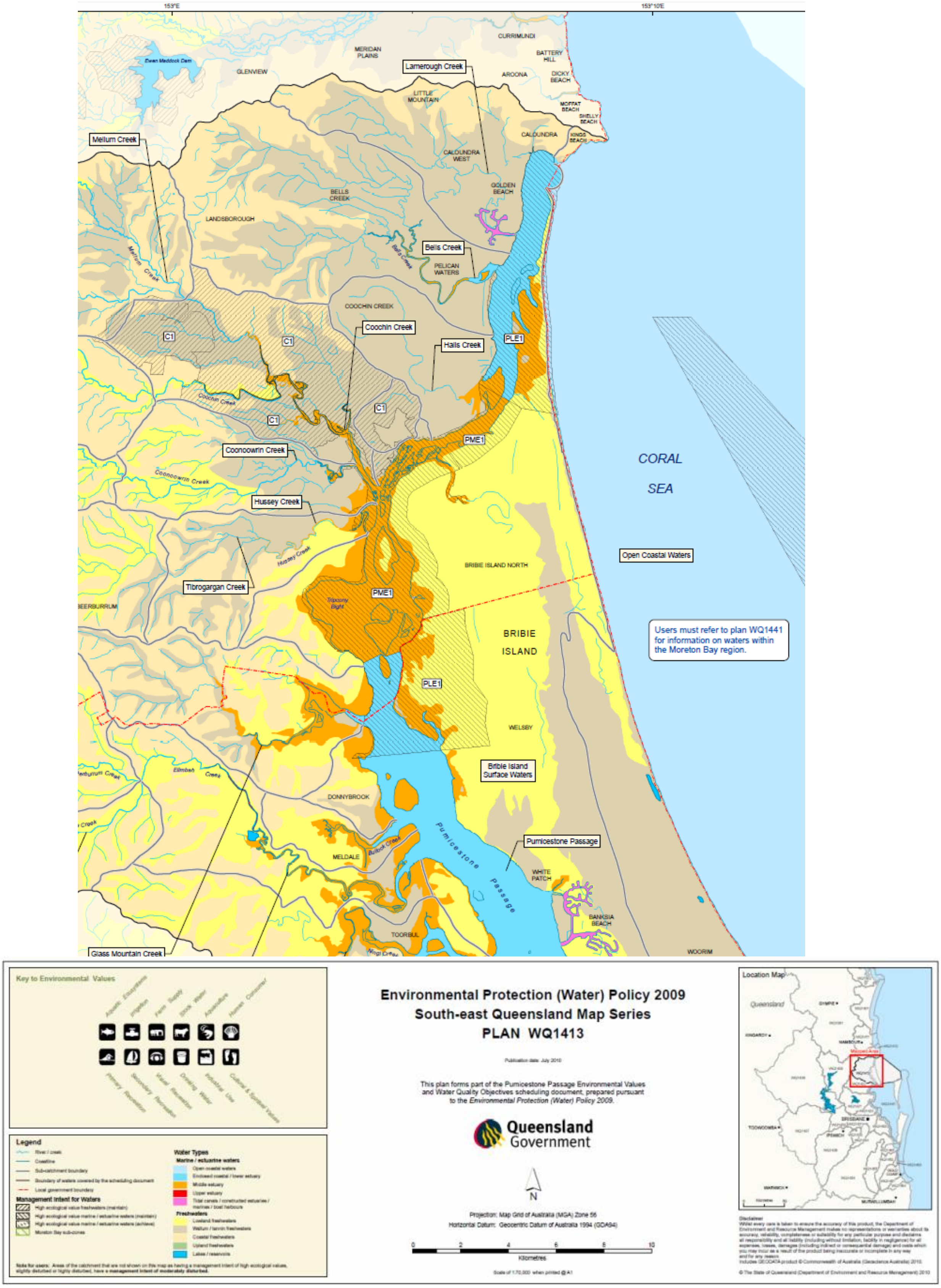

Figure 2-1 Plan WQ1413 (Extract to Highlight Relevant Area for Caloundra South)

2.1.7 Turbidity

- Turbidity levels peak in the central to northern zones of Pumicestone Passage, reflecting the combination of maximum catchment influences, longest residence times and lowest salinities (salinity tends to flocculate fine sediments, thereby reducing turbidity, hence the lower salinities in this section will see a reduced level of such flocculation occurring). The highest median turbidities are observed just to the south of the Caloundra South landholding.
- There would not appear to be any major change in turbidity levels over the last (wetter) 2-3 years, which may indicate that turbidities are predominantly generated by processes within the Passage (e.g. fine sediment resuspension due to tide, wind and wave action, algal growth, etc) other than being strongly influenced by catchment runoff. Alternatively, it may indicate settling of catchment derived sediments in the areas upstream of the EHMP monitoring points – neither hypothesis can be confirmed at this time.
- The sections of Pumicestone Passage adjacent to and extending north and south of the Caloundra South landholding are naturally not compliant with (i.e. in the case of turbidity, greater than) relevant water quality objectives.

2.1.8 Total Nitrogen

- TN levels are elevated in the central reaches of Pumicestone Passage, with the relevant zone of elevated levels being somewhat larger than that evidenced by the previous water quality parameters.
- There would appear to be a correlation between elevated TN levels and reduced salinities, indicating a link between catchment run-off and estuarine nutrient concentrations. Similarly, there would appear to be a trend to higher average and extreme TN levels in the Passage in the (wetter) recent years.
- Much of the central and northern sections of Pumicestone Passage are already exhibiting total nitrogen levels which are naturally not compliant with (i.e. in the case of TN, greater than) relevant water quality objectives.

2.1.9 Total Phosphorus

- TP levels appear to be surprisingly consistent throughout the length of Pumicestone Passage. There are elevated peak levels in the central portions of the Passage, typically associated with run-off and reduced salinities.
- There would not appear to be any major signal or change in TP levels within the Passage due to the greater rainfall/run-off which occurred over recent years.
- The sections of Pumicestone Passage, adjacent to and extending north and south of, the Caloundra South landholding are largely compliant with relevant water quality objectives.

2.1.10 Chlorophyll a

- Chlorophyll *a* levels appear to emulate previous water quality trends in Pumicestone Passage, these being elevated concentrations in the central and northern regions.
- There would not appear to be any major signal or change in chlorophyll *a* levels within the Passage due to the greater rainfall/run-off which occurred over recent years.

- The sections of Pumicestone Passage adjacent to and extending north and south of the Caloundra South landholding are currently exhibiting chlorophyll a levels which are naturally compliant with (i.e. in the case of chlorophyll *a*, less than) relevant water quality objectives.

2.1.11 Summary of Key Pumicestone Passage Water Quality Findings

Table 2-3 Existing WQO Compliance in Pumicestone Passage near Bells Creek

Parameter	Currently Compliant
turbidity	×
chlorophyll a	√
total nitrogen	×
total phosphorus	√
dissolved oxygen	√
pH	×

- Water quality in the northern sections of Pumicestone Passage is generally of a high quality. The area has significant environmental values which require water quality protection.
- The northern sections of Pumicestone Passage, which receive runoff from the Caloundra South site and adjacent catchment areas, are well flushed, as evidenced by the relatively high salinity levels in this region.
- pH levels are typically near neutral, indicating no significant ASS runoff or other such influences from the catchment.
- Dissolved oxygen levels are typically quite high, with the possible exception of when heavy rainfall conditions trigger significant catchment runoff.
- Nutrient levels are typically quite low, with the exception of when heavy rainfall conditions trigger significant catchment runoff. Nitrogen levels typically currently exceed relevant overall regional water quality objectives while phosphorus levels are compliant, indicating that the catchment is contributing very low levels of phosphorus.
- Turbidity/suspended sediment levels typically currently exceed relevant overall regional water quality objectives, reflecting the influence of rural land disturbance to the south of the Caloundra South site.
- Pumicestone Passage adjacent to the Caloundra South site currently exhibits chlorophyll a levels that are complaint with relevant water quality objectives.

2.2 Bells Creek Water Quality

2.2.1 Background

The Bells Creek catchment area is currently occupied by active and dormant (fallow) plantation forestry, with some casual grazing in places and several pockets of conservation zones. Urban development is currently confined to the mouth of the creek only. The western part of the catchment is intersected by the 6 lane Bruce Highway which travels through both the Bells Creek North and South catchments.

The following summary of ambient water quality is provided based on a limited data set collected in this waterway by both Sunshine Coast Council and Stockland. This data set encompasses a period in total of a little over 3 years, not the more than 10 years available in Pumicestone Passage via the EHMP. Also, certain key water quality parameters were not analysed by Council for various reasons, which somewhat limits the value of their data. We do note however that EHMP monitoring has now started in Bells Creek (at the instigation of Stockland) and will be the benchmark against which future water quality assessments are conducted.

2.2.2 Water Quality Objectives

Relevant State water quality objectives for Bells Creek are set out in Table 2-4 below.

Table 2-4 Water Quality Objectives for Bells Creek

Parameter	WQO	Units
turbidity	<8	NTU
chlorophyll a	<4	μg/L
total nitrogen	<300	μg/L
total phosphorus	<25	μg/L
dissolved oxygen	85-105	% saturation
pH	7-8.4	

2.2.3 Salinity

- Bells Creek exhibits similar salinity levels in its lower reaches to those seen in proximate sections of Pumicestone Passage. With movement upstream along Bells Creek, salinity levels typically reduce and salinity variations markedly increase. Salinity levels at the junction of Bells Creek North and South vary from completely fresh to in some cases hypersaline.
- Salinities in Bells Creek can fluctuate rapidly, varying from almost oceanic levels to fresh in periods of less than a month, with salinity recovery taking somewhat longer, of the order of 3 to 4 months.
- There are no salinity recommendations by way of water quality guidelines within the EPP (Water).
- Salinity levels in the January '07 to January '09 period were consistently higher than those following January '09, reflecting the breaking of significant drought conditions in the region around this time.

2.2.4 Temperature

- Temperatures are largely consistent along the length of Bells Creek.
- Temperatures in Bells Creek appear to be similar to those in Pumicestone Passage, typically varying from a minimum of around 15 deg C in winter to a maximum of around 30 deg C in summer.
- There are no specific temperature recommendations by way of water quality guidelines within the EPP (Water).

2.2.5 pH

- Median pH levels downstream of the junction of Bells Creek North and South are above 7, with those more upstream sites showing regular pH levels lower than 7, in some cases dropping to levels between 5 and 6 due to existing/pre-development related runoff from upstream pine plantation areas and former melaleuca wetlands.

- pH levels for waters passing on to the site from upstream catchments are typically near neutral.
- The absence of extremely low pH levels (i.e. less than 5) indicates that there are no significant amounts of acid sulphate bearing soils present on the site as indicated in the PER, i.e. soils across the site have generally low concentrations of natural acidity across the site, and a very low potential for additional acidity to be generated from oxidation of the in-situ soils as a result of excavation or filling.
- Like salinity, pH levels were higher (reflecting less inflows of near neutral catchment stormwater run-off) prior to January '09 than after, reflecting the breaking of significant drought conditions in the region around this time.
- In regard to compliance with water quality objectives (WQO's), relevant state guidelines recommend median pH levels of 8.0 to 8.3 for the lower reaches of Bells Creek and pH levels of 7.0 to 8.4 for all other sites. Comparing these WQO's with available data, the waterway is effectively compliant.

2.2.6 DO

- Median DO levels for the downstream sites are typically modest to high (above 80% saturation) with progressive reductions with passage upstream, with upper sites exhibiting median levels below 60% (and occasionally significantly lower in the order of 20% saturation).
- DO levels in sites upstream of the Caloundra South landholding are typically between 60 and 80% saturation.
- The low DO levels in the upper parts of Bells Creek will reflect the influence of lower tidal velocities (and hence less re-aeration) and longer residence times of waters in these reaches.
- Unlike salinity, DO levels seem to have increased after January '09, this trend will reflect the increased catchment flows and lower residence times in the upper estuary in this period of time.
- In regard to compliance with WQO's, relevant state guidelines recommend median DO levels of 90-105% for the lower reaches of Bells Creek and DO levels of 85-105% saturation for all other sites. Comparing these WQO's with available data, the following comments can be made:
  - For the lower reaches of Bells Creek, available data indicates compliance with guideline levels; and
  - There is considerable non-compliance with all guideline levels for the mid to upper reaches of the Creek, especially under dry weather conditions.
- Interestingly, the above does not reflect the non-compliance of proximate reaches of Pumicestone Passage with relevant DO guidelines, presumably as guidelines for the Passage are stricter due to their relating to 'High Ecological Value' waterways, whereas Bells Creek is designated as being 'Slightly to Moderately Disturbed'.

2.2.7 Turbidity

- Turbidity levels throughout the tidally influenced sections of Bells Creek are relatively consistent, with much higher turbidities typically being seen at the most upstream (freshwater) sites where the Bruce Highway crosses Bells Creek North and South.
- In regard to compliance with WQO's, relevant state guidelines recommend median turbidity levels of <6 NTU for the lower reaches of Bells Creek and median turbidity levels of <8 NTU for upstream sites. Comparing these WQO's with available data indicates compliance with the guideline level.
- Similarly to dissolved oxygen, it is interesting to note that the above does not reflect the non-compliance of proximate reaches of Pumicestone Passage with relevant turbidity guidelines, presumably for a similar reason as previously postulated.

2.2.8 Total Nitrogen

- Total Nitrogen in Bells Creek shows a consistent trend of increasing levels from the junction with Pumicestone Passage with distance upstream to the tidal limit. As could be expected, levels in the lower reaches of Bells Creek are directly comparable to those in Pumicestone Passage, while those near the tidal limit more closely resemble the quality of water washing from the upstream catchment.
- In regard to compliance with WQO's, relevant state guidelines recommend median total nitrogen levels of <0.22 mg/L in the lower reaches of Bells Creek and median total nitrogen levels of <0.3 mg/L for all upstream sites. Comparing these WQO's with available data, the following comments can be made:
    - For the lower reaches of Bells Creek, available data indicates marginal compliance or slight exceedances of the guideline values; and
    - For the upper reaches of Bells Creek, available data show the mid-levels of the creek as being mostly compliant, whilst the upstream levels are non-compliant.
- It is worth noting that the exceedance of the Total Nitrogen guideline level in Bells Creek reflects the previously described exceedance of guideline levels in Pumicestone Passage.

2.2.9 Total Phosphorus

- Total phosphorus in Bells Creek shows a consistent trend of almost uniformly low TP levels along the entire creek. There is no significant longitudinal gradient in TP as was observed for TN, presumably due to the recognised low levels of TP in site surface water and groundwater discharges from the site.
- In regard to compliance with WQO's, relevant state guidelines recommend median total phosphorus levels of <25 µg/L throughout Bells Creek (that is for the entire estuary). Comparing this guideline level with available data, it is apparent that Bells Creek is essentially compliant with the relevant water quality objective. This finding reflects the low levels of phosphorus currently washing off the site and the existing compliance of proximate sections of Pumicestone Passage with relevant water quality guidelines.

2.2.10 Chlorophyll a

- The available data set shows median levels in the lower reaches of the creek which are slightly higher than those in proximate sections of Pumicestone Passage. This indicates that there is some additional primary productivity occurring within Bells Creek to that which is already taking place within the waters of Pumicestone Passage which tidally influence Bells Creek.

- There would appear to be a very slight trend of increasing chlorophyll *a* levels with passage upstream along Bells Creek.
- Chlorophyll *a* levels for waters passing onto the site from upstream catchments are quite high.
- In regard to compliance with WQO's, relevant state guidelines recommend median chlorophyll a levels of <2.5 µg/L in the lower reaches of Bells Creek and levels of <4.0 µg/L for all upstream sites. Comparing these WQO's with the available data set, it is apparent that there is non-compliance with the relevant WQO at all percentile levels.
- It is worth noting that the non-compliance of waters in Bells Creek with chlorophyll *a* guideline levels reflects the previously described non-conformance of proximate sections of Pumicestone Passage with appropriate guideline levels in this area.

2.2.11 Summary of Key Bells Creek Water Quality Findings

Table 2-5 Existing WQO Compliance in Bells Creek

Parameter	Currently Compliant
turbidity	√
chlorophyll a	×
total nitrogen	√
total phosphorus	√
dissolved oxygen	×
pH	√

- Water quality in the Bells Creek is generally of a high quality.
- The waterway receives significant catchment runoff as evidenced by the regular and significant variations in salinity levels.
- pH levels vary from those expected of marine waters (>7.5) under dry conditions to near neutral when there is significant freshwater inflow, indicating no significant ASS runoff or other such influences from the catchment.
- Dissolved oxygen levels reduce with passage along the creek, reflecting the lower tidal flows and low reaeration rates.
- Nutrient levels are typically quite low, with the exception of when heavy rainfall conditions trigger significant catchment runoff. Nitrogen and phosphorus levels are typically complaint with water quality objectives, indicating that the catchment is contributing very low levels of nutrients.
- Turbidity levels typically comply with relevant water quality objectives, reflecting the small influence of existing land use within the site on Bells Creek.

- Bells Creek currently exhibits chlorophyll a levels greater than relevant water quality objectives, indicating that even though the nutrient levels are compliant that primary productivity is occurring within the creek itself.

2.3 Groundwater Quality

Over the last decade or so there have been major changes in groundwater levels on the site due to various land uses practices that have been enacted on the site as well as major climatic patterns due to El Nino induced processes. These changes haven seen groundwater levels vary by in some cases over a metre due to changes from a vegetated site under moderate rainfall conditions (moderate groundwater conditions) to a cleared site under low rainfall conditions (low groundwater conditions) and now its current state of a cleared site under high rainfall conditions (high groundwater conditions).

Throughout the above period of change in groundwater levels on the site, a considerable body of groundwater chemistry data have been collected from a range of locations. Based on these data, the following groundwater quality summaries can be presented.

By way of an overall summary comment, the site has no significant groundwater quality issues.

2.3.1 Physicochemical Data

Shallow groundwater has an electrical conductivity range of 92 to 3,266 μS/cm with a median value of 236 μS/cm and a mean value of 502 μS/cm, meaning that the groundwater is effectively freshwater at nearly all times and shows little indication of saline intrusion. Shallow groundwater sampled across the site has relatively low to moderate salinity only. Shallow groundwater samples have a pH range of 3.82 to 6.86 with a median of 5.07 and mean of 5.15.

2.3.2 Nutrient Data

Available data indicates slightly elevated concentrations of nitrogenous compounds in the shallow groundwater. The total nitrogen data has a mean of 0.59 mg/L as N and a median of 0.52 mg/L as N. Similarly, total Kjeldahl nitrogen data has a mean of 0.56 mg/L and median of 0.465 mg/L. Ammonia has a mean of 0.14 mg/L and a median of 0.019 mg/L. Nitrate data has a mean of 0.18 mg/L and a median value of 0.015 mg/L.

Total phosphorus data has a mean of 0.184 mg/L as P and a median of 0.054 mg/L as P. Reactive phosphorus data has a mean of 0.006 mg/L and a median of 0.002 mg/L.

2.3.3 Metals Data

The site in its entirety has low levels of metals present in groundwater as summarised below.

- The peak recorded dissolved iron level was 9.36 mg/L with mean and median values of less than 2.33 and 0.33 mg/L respectively;
- The peak recorded aluminium level was 2.04 mg/L with mean and median values of less than 0.2 and 0.02 mg/L respectively;
- No arsenic concentrations were recorded above the detection limit of 0.001 mg/L;

- The peak recorded cadmium level was 0.0012 mg/L with mean and median values less than 0.0003 and 0.0002 mg/L respectively;
- The peak recorded chromium level was 0.0004 mg/L with the other bores all recording values less than the detection limit of <0.001 mg/L;
- The peak recorded copper level was 0.007 mg/L with mean and median values less than 0.0038 and 0.004 mg/L respectively;
- No mercury values were recorded above a detection limit of 0.0001 mg/L;
- The peak recorded nickel level was 0.021 mg/L with mean and median values less than 0.0067 and 0.006 mg/L respectively;
- The peak recorded lead level was 0.08 mg/L with mean and median values less than 0.014 and 0.0015 mg/L respectively;
- The peak recorded manganese level was 0.159 mg/L with mean and median values of 0.08 and 0.089 mg/L respectively; and
- The peak recorded zinc level was 0.159 mg/L with mean and median values of 0.038 and 0.034 mg/L respectively.

2.3.4 Organic Carbon and Iron

Data shows a range of dissolved iron levels with a mean concentration of 2.33 mg/L and a median concentration of 0.33 mg/L. At one site only a detectable dissolved organic carbon concentration of 12 mg/L was recorded. These results indicate that the presence of organically complexed iron in the groundwater at that site is unlikely.

2.3.5 Summary of Key Groundwater Quality Findings

- Groundwater levels on the site are heavily influenced by site vegetation cover and prevailing climatic conditions.
- All site groundwater is effectively fresh with little indication of saline intrusion.
- Groundwater nutrient levels are slightly elevated.
- The site in its entirety has low levels of metals and organic carbon present in groundwater

2.4 Summary

- Water quality in Pumicestone Passage adjacent to the site is largely controlled by rural catchment sources to the south of the Caloundra South landholding. There is minimal existing compliance with desired water quality objectives and a high standard of management of water quality on the site will be required to ensure that WQO compliance levels do not worsen.
- Water quality levels in Bells Creek are largely compliant with water quality objectives and some impacts due to development of the Caloundra South could be accepted.
- There are no existing groundwater quality issues at the Caloundra South site. Surveillance of groundwater quality pre-construction, during construction and post-construction will be required.

3 WATER QUALITY PERFORMANCE OBJECTIVES AND PARAMETERS

3.1 Surface Water

From a surface water quality and quantity perspective, key objectives that the development of the Caloundra South site will be required to satisfy are as follows:

- The Queensland Department of Environment and Heritage Protection (DEHP) has defined adjacent sections of Pumicestone Passage as having High Ecological Value (HEV) status in the Environmental Protection (Water) Policy (EPP Water) –2009. The commensurate Water Quality Objective (WQO) which accompanies this designation is of the nature of ‘no change’, but more specifically is quantified as:

  “maintain existing water quality (20_{th}, 50_{th} and 80_{th} percentiles)”.

- DEHP has also stipulated WQOs for Bells Creek for particular parameters as defined in Schedule 1 of the Environmental Protection (Water) Policy 2009. These have been identified in the previous sections under the relevant parameter and form the basis of the water quality performance criteria for many of the environmental management measures across the Caloundra South site.

- The Federal Department of Sustainability, Environment, Water, Population and Communities (SEWPaC), with others, has defined large sections of Pumicestone Passage and associated waterways as having Ramsar wetland status. The associated significance criteria which accompany this designation are as follows:

  a) Areas of the wetland being destroyed or substantially modified;

  b) A substantial and measurable change in the hydrological regime of the wetland (e.g. volume, timing, duration and frequency of surface and groundwater flows);

  c) The habitat or lifecycle of native species being seriously affected;

  d) A substantial and measurable change in the water quality of the wetland (e.g. salinity, pollutants, nutrients and water temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health; and

  e) An invasive species that is harmful to the ecological character of the wetland becoming established, or an existing invasive species spreading.

3.2 Groundwater

Groundwater on the site is subject to seasonal variability and historic changes due to land use changes on the site (i.e. from pine plantation to grazing). It should also be noted that up-gradient of the site there are a variety of existing and future land uses which may contribute to groundwater quality, as follows:

- Landfill site
- Existing and future residential and industrial development.

The fundamental groundwater quality performance objective is for site development to have no adverse impacts on groundwater quality or levels outside the development footprint as such changes could affect Matters of National Environmental Significance (MNES) and Matters of State Environmental Significance (MSES) (hereafter collectively referred to as Protected Matters).

4 MONITORING AND REPORTING PERIODS

4.1 Surface Water Quality Monitoring

Surface water quality monitoring will provide both certainty that earlier impact assessment predictions are being achieved or complied with and also relevant information with which to refine or optimise design elements of the project to ensure such compliance occurs. Also, in the unlikely event that impact assessment predictions are not being complied with, these monitoring data will be invaluable in regard to guiding and assessing relevant corrective actions. To achieve these objectives, monitoring will need to be both ambient or condition based (e.g. monthly background water quality surveys) and also targeted towards specific water related elements of the site (e.g. efficacy monitoring of a particular water sensitive urban design device).

Given the above, the following surface water quality monitoring actions are proposed. These actions are expanded upon in Section 5 below.

Table 4-1 Surface Water Quality Monitoring Recommendations

Monitoring Activity	Monitoring	
	Commencement	Cessation
Ambient	A minimum of six months[1] prior to construction commencement within a particular catchment	A minimum of 12 months after all development work has been completed within the respective catchment
Event Based	A minimum of six months[2] prior to construction commencement	12 months after all development work has been completed within the respective catchment
EHMP (water quality)	Two monitoring sites have already been established and data collection has been occurring since mid 2012	3 years after all development work has been completed on the site
Real Time Turbidity	A minimum of six months[1] prior to construction commencement	12 months after all development work has been completed within the respective catchment
Load Based	Commenced within one year of construction commencing elsewhere on the site	10 representative storms from each of two years are required to be monitored
Treatment Device	Upon the effective completion of the earlier stages of the Northern Residential and Northern Employment Precincts	After data have been collected from 10 representative storms (that is storms with greater than 20mm of rainfall)
Construction Stage	During the construction phase of development works	At the completion and stabilisation of 'active' works in any locality.

[1] There will be a need to ensure that this six month period encompasses a suitable range of wet and dry weather conditions, with special emphasis on wet conditions when any potential impacts from the site will be most noticeable. Sufficient wet weather data would constitute several storm events of greater then 20mm magnitude being sampled prior to construction commencing, with ongoing data collection to extend the available record as time passes.

[2] Ambient data collection should also encompass wet and dry periods

Development works in the above table refers to site establishment activities such as ground preparatory works, drainage works, bulk earthworks, vegetation clearing and grubbing, but does not include construction of residential housing or commercial premises.

4.2 Groundwater Quality Monitoring

Groundwater quality monitoring will provide certainty that previous impact predictions are being achieved or complied with. Also, in the unlikely event that this is not the case, these monitoring data will be invaluable in regard to guiding and assessing relevant corrective actions.

The following groundwater quality monitoring actions are proposed.

Table 4-2 Groundwater Quality Monitoring Recommendations

Monitoring Activity	Monitoring	
	Commencement	Cessation
Groundwater	Sampling of baseline condition should occur within the six months period prior to construction works. Once construction has commenced: • All bores within the catchment where active construction works have commenced will be sampled on a biannual basis, up to and for 12 months after active development works are completed in respective catchments; • Construction bores within catchments where there are construction activities occurring and which are in close proximity (i.e. within 500m) to areas of active development works will be sampled on a monthly basis. • All 'Sentinel' and 'Control' bores within catchments where active construction works are occurring will be monitored on a monthly basis.	12 months after active construction works are completed in respective catchments

4.3 Reporting and Review

An Annual Environmental Report (AER) will be prepared and published on the project website within three (3) months of every twelve (12) month anniversary of the commencement of works on the site until 12 months after cessation of activities on the site to present the various aspects of the implementation of the Caloundra South project including water quality monitoring activities outlined in this Plan.

This report will summarise compliance with the conditions of approval and the implementation of any management plans, reports, strategies and methods over the previous twelve (12) month period as required under the conditions of approval. Within five (5) days of publication, a copy of the report will be forwarded to the relevant federal government minister responsible for the approval.

Non-compliance with any of the conditions of the approval must be reported to the relevant federal government minister responsible for the approval within two (2) business days of becoming aware of the non-compliance. Triggers for water quality related corrective actions to prevent non-compliance are outlined in the sections below.

The monitoring of triggers for further investigation, implementation of corrective actions and reporting will be overseen by the superintendent for the site. This activity will continue throughout construction phases (during bulk earthworks and other preparation activities) and during operational phases until indicated under the different monitoring programmes of this plan.

Within three (3) months of every three (3) year anniversary of the commencement of works for the first nine (9) years from commencement of works and then within three (3) months of every five (5) year anniversary thereafter until cessation of activities on the site, an independent audit of compliance will be undertaken to evaluate accordance with the conditions of approval and all associated management plans, reports, strategies and methods. The audit report will be submitted to the relevant federal government minister responsible for the approval within three (3) months of the date of completion of the audit and will identify any remedial actions that have been taken in response to the audit in addition to any proposed changes to management plans, reports, strategies or methods.

5 METHODS FOR SAMPLING AND DATA COLLECTION

5.1 Surface Water Quality and Hydrology Monitoring

5.1.1 Scope of Monitoring Proposed

The primary surface water quality issues to consider for monitoring include:

- Construction works discharges;
- Wastewater discharges;
- Treatment measure performance; and
- Disturbed/exposed acid sulphate soils.

In terms of monitoring parameters, the following primary parameters need to be considered in developing the monitoring program:

- pH
- Salinity;
- Turbidity and Total Suspended Solids;
- Nutrients (Nitrogen and Phosphorus);
- Heavy metals and metalloids; and
- Hydrocarbons and their derivatives.

These parameters have been reviewed and will be assessed with the exception of the following which have been effectively discounted as needing measurement as described:

- In regard to heavy metals and metalloids (with the exception of aluminium and iron – which may be related to potential acid sulphate soils on site), based on data collected in South East Queensland, including sites on the Sunshine Coast, there should be minimal sources of such materials from this predominantly urban residential site other than in road runoff. As all road runoff will be extensively treated using advanced Water Sensitive Urban Design (WSUD) techniques (which are highly effective at removing particulate bound metals), monitoring for these constituents is not considered necessary.
- In regard to hydrocarbons, the same comment as per heavy metals is made.
- As there are no wastewater discharges from the site to Bells Creek or Pumicestone Passage, monitoring for same is also not required. Any impacts of accidental spills will be detected by the ambient nutrient monitoring.

Noting these exceptions, the proposed surface water quality monitoring plan consists of the following components:

- Freshwater Ambient Monitoring;
- Event Based Monitoring;
- Estuarine EHMP Monitoring;

- Real Time Turbidity Monitoring;
- Load Based Monitoring;
- Treatment Device Monitoring; and
- Construction Stage Monitoring.

Figure 5-1 presents the locations at which surface water monitoring activities will take place. The monitoring activities which will occur at each of these locations are described below and summarised in their entirety in Table 5-1.

5.1.2 Freshwater Ambient Monitoring

Monthly ambient water quality surveys will be conducted at eight locations within the site, three each respectively on Bells Creek North and Bells Creek South and two on Lamerough Creek. Sites will commence being monitored in the respective waterways a minimum of six months ahead of any development works occurring within local catchments (encompassing wet and dry conditions as discussed previously) and will continue for a minimum of 12 months after all development work has been completed within the respective catchments, or sooner if deemed appropriate by the relevant nominated assessing authority.

The following water quality parameters will be measured by these surveys via a combination of in situ measurements using a pre-calibrated water quality instrument and water sampling and subsequent laboratory analyses:

- pH;
- Conductivity;
- Temperature;
- Turbidity;
- Dissolved oxygen
- Total Suspended Solids;
- Total nitrogen, Organic N, Ammonia N and NOx;
- Total phosphorus and filterable reactive phosphorus;
- Chlorophyll ‘a’;
- Iron; and
- Aluminium.

5.1.3 Event Based Monitoring

Event based water quality samplers will be installed at appropriate locations on Bells Creek North and South at the upper and lower boundaries of the Caloundra South site. Monitoring in the respective waterways will commence a minimum of six months ahead of any development works occurring within local catchments (encompassing wet and dry conditions as discussed previously) and will continue for a minimum of 12 months after all development work has been completed within the respective catchments, or sooner if deemed appropriate by the relevant nominated assessing authority. Additional monitoring stations will be deployed midway along Bells Creek North and South six (6) months before substantial urban land development works are to commence in the areas upstream of these locations.

These samplers will be triggered by flows in either of the creeks, and will collect composited, flow proportional samples from significant run-off events. These samples will be analysed for the following parameters:

- Flow
- Total Suspended Solids;
- Total Nitrogen;
- Total Phosphorus; and

5.1.4 Estuarine EHMP Monitoring

Two Ecosystem Health Monitoring Program (EHMP) sites have been located within Bells Creek downstream of the development (see Figure 5-1). These sites are being tested on a monthly basis by Queensland Department of Environment and Heritage Protection (DEHP) staff as a component of regular monthly surveys of Pumicestone Passage. The full suite of regular EHMP analyses will be conducted at each of these sites.

At the time of preparation of this report, these sites had been established and monitoring has been under way since mid-2012. The data are being included in current EHMP reporting regimes.

5.1.5 Real Time Turbidity Monitoring

Coincident and concurrent with the event based samplers on Bells Creek North and South it is proposed to establish real time turbidity monitoring stations, with additional instruments also being located at the following locations (that is up to five stations in total):

- The upstream confluences of the site with Bells Creek North and South; and
- The downstream extent of the development footprint within the Lamerough Creek Catchment.

Turbidity monitoring in the respective waterways will commence a minimum of six (6) months ahead of any development works occurring within local catchments (encompassing wet and dry conditions as discussed previously) and will continue for a minimum of twelve (12) months after all development work has been completed within the respective catchments, or sooner if deemed appropriate by the relevant nominated assessing authority. These stations will collect and transmit water level and turbidity data in real-time mode for stream flows passing their respective locations. Relevant alarm systems will be installed on the site such that should predefined triggers or increases in turbidity levels occur, appropriate site personnel will be notified via text message and email such that rectification actions to address the causes of the turbidity exceedance can be immediately undertaken.

5.1.6 Load Based Monitoring

Load based monitoring will be conducted on catchments <u>within the site</u> to better understand the quality of water washing from the site. Two sites will be established within the ultimate development footprint from which data will be collected for a two (2) year period (commencing within one year of construction starting elsewhere on the site) to thoroughly quantify the baseline quality of run-off from the site.

Indicative locations for these sites are shown in Figure 5-2. These site locations may be refined somewhat depending on subsequent local suitability investigations.

At each of these sites, an event-based stormwater sampler will be installed and stormwater flow and quality data collected from at least twenty (20) representative storms over a two (2) year period. Samples collected by the stormwater samplers will be composited and the event mean concentration for each storm event derived.

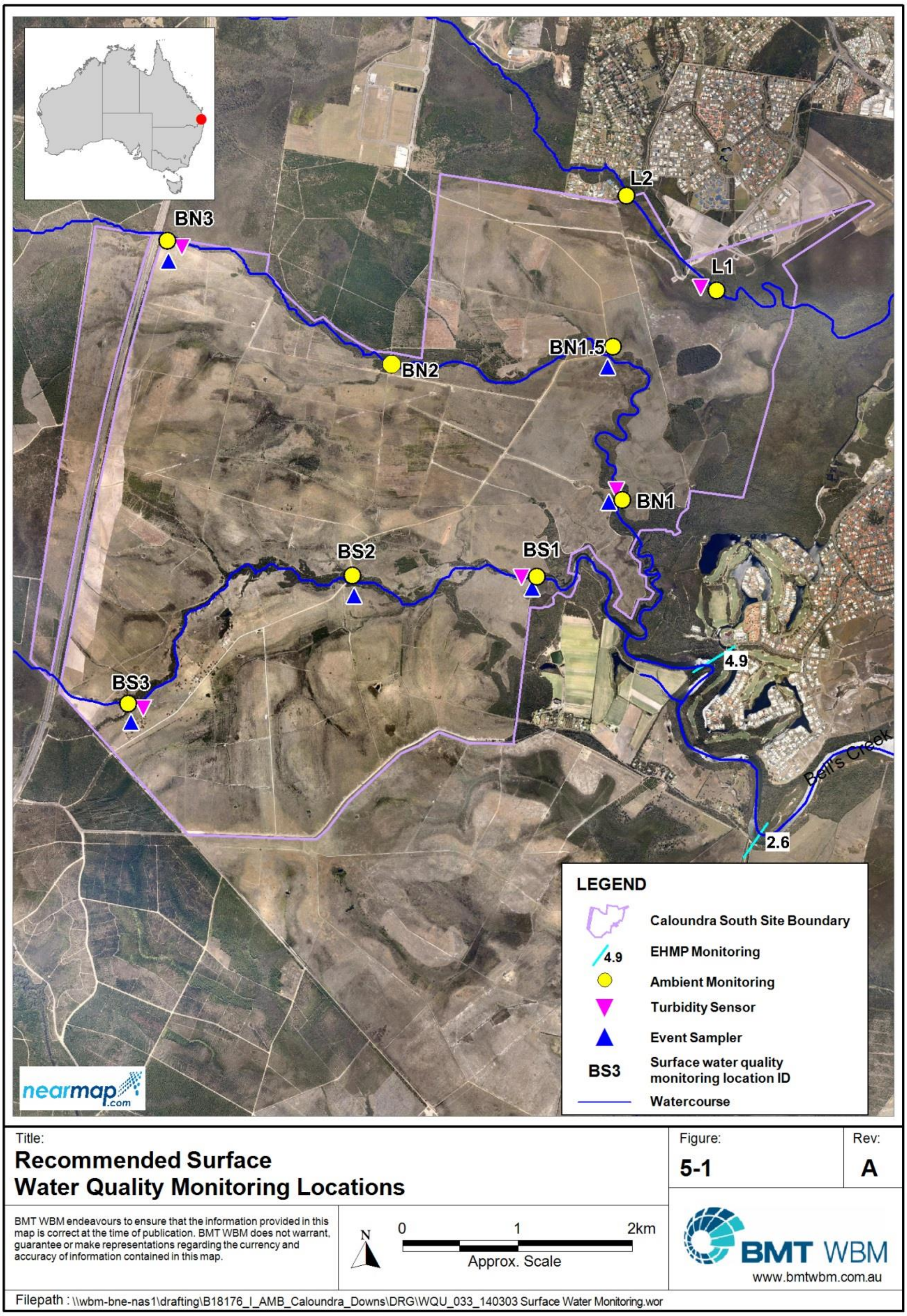

Figure 5-1 Recommended Surface Water Quality Monitoring Locations

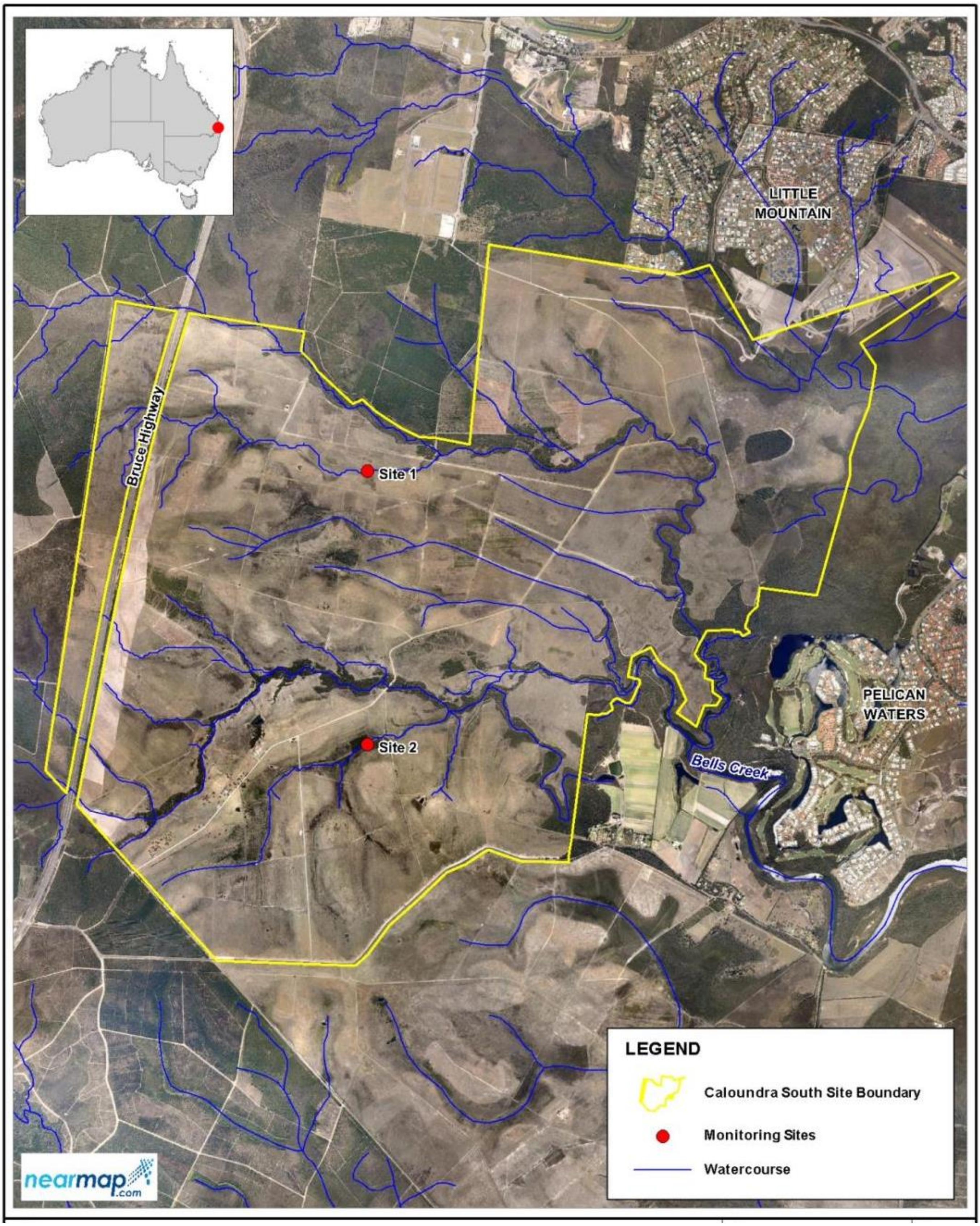

Figure 5-2 Indicative Load Based Water Quality Monitoring Locations

5.1.7 Treatment Device Monitoring

Load based monitoring of treatment devices will be conducted to confirm the efficacy of these devices and to allow the refinement of device designs as the development proceeds. As the development layout is not completely finalised, and as such monitoring cannot take place until development works are largely complete and the treatment devices are established, it is premature for this WQMP to specify exactly how and where such treatment device monitoring will take place.

Upon the effective completion of some of the earlier parts of the Northern Residential and Northern Employment precincts, especially those areas draining towards Bells Creek North, further assessment will be undertaken as to where and how such treatment device monitoring can take place.

Treatment device monitoring will occur for one representative established bioretention system and one representative established wetland system. For each of these systems, event-based stormwater samplers will be installed upstream and downstream of the device and stormwater flow and quality data collected from ten (10) representative storms. Samples collected by the stormwater samplers will be composited and the event mean concentration for each upstream and downstream sampling site derived such that load reductions can be calculated.

5.1.8 Construction Stage Monitoring

Construction stage monitoring will be included in the details of precinct scale Construction Environmental Management Plans (CEMP's). The following monitoring regime will be integrated into each Precinct-based CEMP:

- Regular (daily and after major rain events) site inspections of all erosion and sediment control measures.
- Regular (daily and after major rain events) inspections of areas surrounding construction site to detect and manage any occurrence of sediment deposition off-site.
- Rainfall will be recorded at 9am each working day from an installed rain gauge.
- All construction activities will be monitored daily for compliance with erosion and sediment control measures.

Within sediment basins within each precinct, turbidity and pH will be measured daily. Monitoring measures related to receiving water quality (e.g. outside of the sedimentation basins) are described in Sections 5.1.2, 5.1.3, 5.1.4 and 5.1.5 above.

Specific within site construction stage monitoring will cease at the completion and stabilisation of 'active' works in any precinct, which refers to those works associated with land forming and bulk excavation and filling works, not the house construction phase which will follow, as the majority of erosion and sediment controls will be the responsibility of each construction contractor responsible for lot scale works.

5.1.9 Summary of Surface Water Quality and Hydrology Monitoring

Table 5-1 Surface Water Quality Monitoring Summary

Monitoring Category	Nature of works	Commencement	Cessation
Freshwater Ambient	• Monthly ambient water quality surveys at eight locations within the site, three each respectively on Bells Creek North and Bells Creek South and two on Lamerough Creek • The following water quality parameters to be measured via a combination of in situ measurements using a pre-calibrated water quality instrument and water sampling and subsequent laboratory analyses: o pH; o Conductivity; o Temperature; o Turbidity; o Dissolved oxygen o Total Suspended Solids; o Total nitrogen, Organic N, Ammonia N and NOx; o Total phosphorus and filterable reactive phosphorus; o Chlorophyll 'a'; o Iron; and o Aluminium.	6 months[3] before development starts in upstream catchments	A minimum of 12 months after all development work has been completed within the respective catchment
Event Based	• Event based water quality samplers will be installed on Bells Creek North and South at the upper and lower boundaries of the Caloundra South site. • Additional event based water quality samplers will be deployed midway along Bells Creek North and South before substantial urban land development works are to commence in the areas upstream of these locations. • These samplers will be triggered by flows in either of the creeks, and will collect composited, flow proportional samples from significant run-off events. These samples will be analysed for the following parameters: o Flow o Total Suspended Solids; o Total Nitrogen; o Total Phosphorus; and o	6 months[3] before development starts in upstream catchments	12 months after all development work has been completed within the respective catchment
Estuarine EHMP	Two Ecosystem Health Monitoring Program (EHMP) sites within Bells Creek downstream of the development	Immediately	3 years after all development work has been completed on the site
Real Time Turbidity	• Establish real time turbidity monitoring stations at the following locations (five stations in total): o Bells Creek North and South at the lower boundary of the Caloundra South site o Bells Creek North and South at the upper boundary of the Caloundra South site; and o The downstream extent of the development footprint within the Lamerough Creek Catchment	6 months[3] before development starts in upstream catchments	12 months after all development work has been completed within the respective catchment
Load Based	• Two sites will be established within the ultimate development footprint and data collected for a two (2) year period to quantify the quality of run-off from the site, commencing within one year of construction starting elsewhere on the site. • At each site, an event-based stormwater sampler will be installed and stormwater flow and quality data collected from at least 20 representative storms over a two year period. Samples collected will be composited and event mean concentrations for each storm event derived.	As soon as practical	10 representative storms from each of two years are required to be monitored
Treatment Device	• Monitoring will occur for one representative established bioretention system and one representative established wetland system. • Event-based stormwater samplers will be installed upstream and downstream of these devices and stormwater flow and quality data collected from 10 representative storms. • Samples collected will be composited and the event mean concentration for each upstream and downstream sampling site derived such that load reductions can be calculated.	Upon the effective completion of some of the earlier parts of the Northern Residential and Northern Employment precincts	After data have been collected from 10 representative storms
Construction Stage	• Regular (daily and after major rain events) site inspections of all erosion and sediment control measures. • Regular (daily and after major rain events) inspections of areas surrounding construction site to detect and manage any occurrence of sediment deposition off-site. • Rainfall will be recorded at 9am each working day from an installed rain gauge. • All construction activities will be monitored daily for compliance with erosion and sediment control measures. • Turbidity, pH, Electrical Conductivity (EC) and Dissolved Oxygen (DO) will be measured daily within sediment basins within each precinct,	With the commencement of construction works in any precinct	At the completion and stabilisation of 'active' works in any locality.

[3] As described earlier, weather patterns during this period need to be taken into consideration when the collected data are interpreted

5.2 Groundwater

5.2.1 Monitoring Bore Network

A network of groundwater monitoring bores is located across the site, as illustrated in Figure 5-3. The monitoring bore network is comprised of:

- Sentinel bores – located in close proximity to designated conservation areas (creek corridors and frog conservation zones) and to be maintained until the monitoring program is complete in the respective catchment. These bores will be the major sources of reliable and defensible surveillance data to enable the assessment of any potential impacts to Matters of National Environmental Significance (MNES) and Matters of State Environmental Significance (MSES) (hereafter collectively referred to as Protected Matters) and/or downstream receiving environments. Triggers for further investigation and corrective actions will be developed from data collected at these Sentinel bores.
- Construction bores - located within the development footprint. These bores will be used to identify potential groundwater issues within the active areas of construction, and to guide 'cause and effect' assessments and associated corrective actions (if required) should changes be detected in the data being collected at the Sentinel bores. These bores will be decommissioned when proximate development land reforming (cut and/or fill) works occurs.
- Control bores - located at the up-gradient boundary of the development footprint to monitor for any potential offsite influences on groundwater level and quality and to serve as a reference or control for changes in groundwater levels and quality in the (down-gradient) Sentinel bore network. These bores will be maintained until the monitoring program is complete in the respective catchment.

The locations of some of the bores in Figure 5-3 (i.e. those labelled as relocated or proposed) are indicative at this stage; their exact locations will depend on site access and site suitability to be determined at the time of installation.

The following factors were considered in the development of the monitoring bore network to ensure it is adequate to detect potential construction related groundwater impacts on Protected Matters:

- The locations of Sentinel bores within close proximity to designated conservation areas (creek corridors and frog conservation zones) to either directly represent areas of Protected Matters or to represent areas draining to locations where Protected Matters are important considerations. These bores will not be disturbed by construction activities and will remain in place until the monitoring program is complete in the respective catchment.
- The use of Control bores at the up-gradient boundary of the site to detect offsite influences and natural fluctuations in groundwater quality and levels.
- Intensive monitoring at Sentinel and Control bores to ensure sufficient baseline data is collected (to set bore-specific trigger values) such that any potential impacts will be able to be readily identified during and after construction works in a catchment.
- Groundwater flow direction was used to locate (up-gradient) Control and (down-gradient) Sentinel bores to enable the observation of any potential changes in water levels or quality as groundwater flows across the site.

- The number and location of bores is considered sufficient to represent groundwater levels and quality in conservation areas, and to capture up-gradient and down-gradient groundwater level and quality processes.
- The monitoring bore network focuses on groundwater quality in the shallow alluvial aquifer as it is assumed that any construction-related groundwater impacts will be reflected in the shallow aquifer.

5.2.2 Scope of Proposed Monitoring

A stratified program of monitoring is proposed, depending upon whether works are occurring in particular catchments, as follows:

- Pre-construction baseline monitoring will be carried out prior to commencement of construction works in a catchment. All bores will be monitored on a monthly basis at least 12 months prior to construction until a sufficient baseline bore-specific data set is available (i.e. at least 10 data points over at a least a 12 month period). Should construction occur prior to the completion of pre-construction monitoring (e.g. new bores), site-specific baseline data (i.e. baseline data from across the entire site) will be assigned to the bore.
- For bores where a sufficient baseline bore-specific data set is unable to be collected (e.g. new bores), site-specific baseline data will be assigned to the bore (refer to Section 7.3).
- All bores within catchments with active construction works occurring will be sampled on a biannual basis where practicable (depending on construction activities occurring), up to and for 12 months after active construction works are completed in their respective catchments.
- ‘Construction’ bores within catchments where there are construction activities occurring and which are in close proximity (i.e. within approximately 500m) to areas of active construction works will be sampled on a **monthly** basis. These bores will be decommissioned when proximate development land reforming (cut and/or fill) works occurs.
- All ‘Sentinel’ and ‘Control’ bores within catchments where active construction works are occurring will be monitored on a **monthly** basis.

‘Active construction works’ refers to site establishment activities such as ground preparatory works, drainage works, bulk earthworks, vegetation clearing and grubbing, but does not include construction of residential housing or commercial premises.

5.2.3 Pre-construction Baseline

Prior to construction commencing in a catchment, at least ten (10) rounds of data will be collected over at least a 12 month period at all bores within the catchment where practicable. This will involve sampling and analysis of the following:

Field Parameters:

- Water level;
- pH;
- Electrical conductivity;
- Temperature; and

- Dissolved oxygen.

Analytical Parameters:

- Major Anions (Alkalinity);
- Major Cations;
- Total nitrogen, Organic N, Ammonia N and NOx;
- Total phosphorus and filterable reactive phosphorus;
- Soluble sulfate (Cl^-:SO_4^{2-}) ratio;
- Nutrients (e.g. Nitrate and nitrite);
- Dissolved metals; and
- PAHs including BTEXN, TPH, TRH.

Information gathered as part of this pre-construction monitoring program will update the baseline data sets that have been collected on the site over many years.

5.2.4 Construction Phase Biannual Monitoring

Biannual monitoring (once every six months) will be undertaken at all bores within catchments with active construction works occurring. This will involve sampling and analysis of the following:

Field Parameters:

- Water level;
- pH;
- Electrical conductivity;
- Temperature; and
- Dissolved oxygen.

Analytical Parameters:

- Major Anions (Alkalinity);
- Major Cations;
- Total nitrogen, Organic N, Ammonia N and NOx;
- Total phosphorus and filterable reactive phosphorus;
- Soluble sulfate (Cl^-:SO_4^{2-}) ratio;
- Nutrients (e.g. Nitrate and nitrite);
- Dissolved metals; and
- PAHs including BTEXN, TPH, TRH.

5.2.5 Construction Phase Monthly Monitoring

During active construction works within each catchment, monthly monitoring will be conducted at all 'Construction' bores within 500m of active construction works, and monthly monitoring will be conducted at all 'Sentinel' and 'Control' bores. This will involve sampling and analysis of the following:

Water level;

- pH;
- Electrical Conductivity;
- Total nitrogen, Organic N, Ammonia N and NOx;
- Total phosphorus and filterable reactive phosphorus;
- Dissolved Iron; and
- Dissolved Aluminium.

Water quality testing for the full suite of parameters, including heavy metals (cadmium, chromium, copper, nickel, lead, and zinc), will be conducted in association with the aforementioned biannual surveys.

5.2.6 Summary of Groundwater Quality and Hydrology Monitoring

Table 5-2 Groundwater Quality Monitoring Summary

Monitoring Category	Nature of Works	Commencement	Cessation
Pre-construction Baseline	• Within at least 12 months of commencing active construction works in a catchment, all bores within the catchment proposed for active construction works will be monitored on a monthly basis until a sufficient bore-specific data set is available (at least ten rounds of data collected over at least a 12 month period prior to construction). • Field Parameters: o Water level; o pH; o Electrical conductivity; o Temperature; and o Dissolved oxygen. • Analytical Parameters: o Major Anions (Alkalinity); o Major Cations; o Total nitrogen, Organic N, Ammonia N and NOx; o Total phosphorus and filterable reactive phosphorus; o Soluble sulfate (Cl-:SO42-) ratio; o Dissolved metals; and • PAHs including BTEXN, TPH, TRH.	• At least 12 months prior to commencing construction in a catchment, where practicable. • Should construction occur prior to the completion of pre-construction monitoring (e.g. new bores), site-specific baseline data (i.e. baseline data from across the entire site) will be assigned to the bore.	• Commencement of active construction works in a catchment
Biannual Monitoring	• Biannual monitoring (once every six months) will be undertaken at all bores within catchments with active construction works occurring. • Field Parameters: o Water level; o pH; o Electrical conductivity; o Temperature; and o Dissolved oxygen. • Analytical Parameters: o Major Anions (Alkalinity); o Major Cations; o Total nitrogen, Organic N, Ammonia N and NOx; o Total phosphorus and filterable reactive phosphorus; o Soluble sulfate (Cl-:SO42-) ratio; o Dissolved metals; and o PAHs including BTEXN, TPH, TRH.	• Once active construction works commence in a catchment, all bores within the catchment will be sampled on a biannual basis.	• 12 months after active construction works are completed in respective catchments
Construction Phase Monthly Monitoring	• Monthly will be conducted at all ‘Construction’ bores within 500m of active construction works. • Monthly monitoring will be conducted at all ‘Sentinel’ and ‘Control’ bores. • Monitoring will be conducted for the following parameters: o Water level; o pH; o Electrical Conductivity; o Total nitrogen, Organic N, Ammonia N and NOx; o Total phosphorus and filterable reactive phosphorus; o Dissolved Iron; and o Dissolved Aluminium.	• ‘Construction’ bores within catchments where there are construction activities occurring and which are in close proximity (i.e. within approximately 500m) to areas of active construction works will be sampled on a **monthly** basis. • All ‘Sentinel’ and ‘Control’ bores within catchments where active construction works are occurring will be monitored on a **monthly** basis.	• 12 months after active construction works are completed in respective catchments

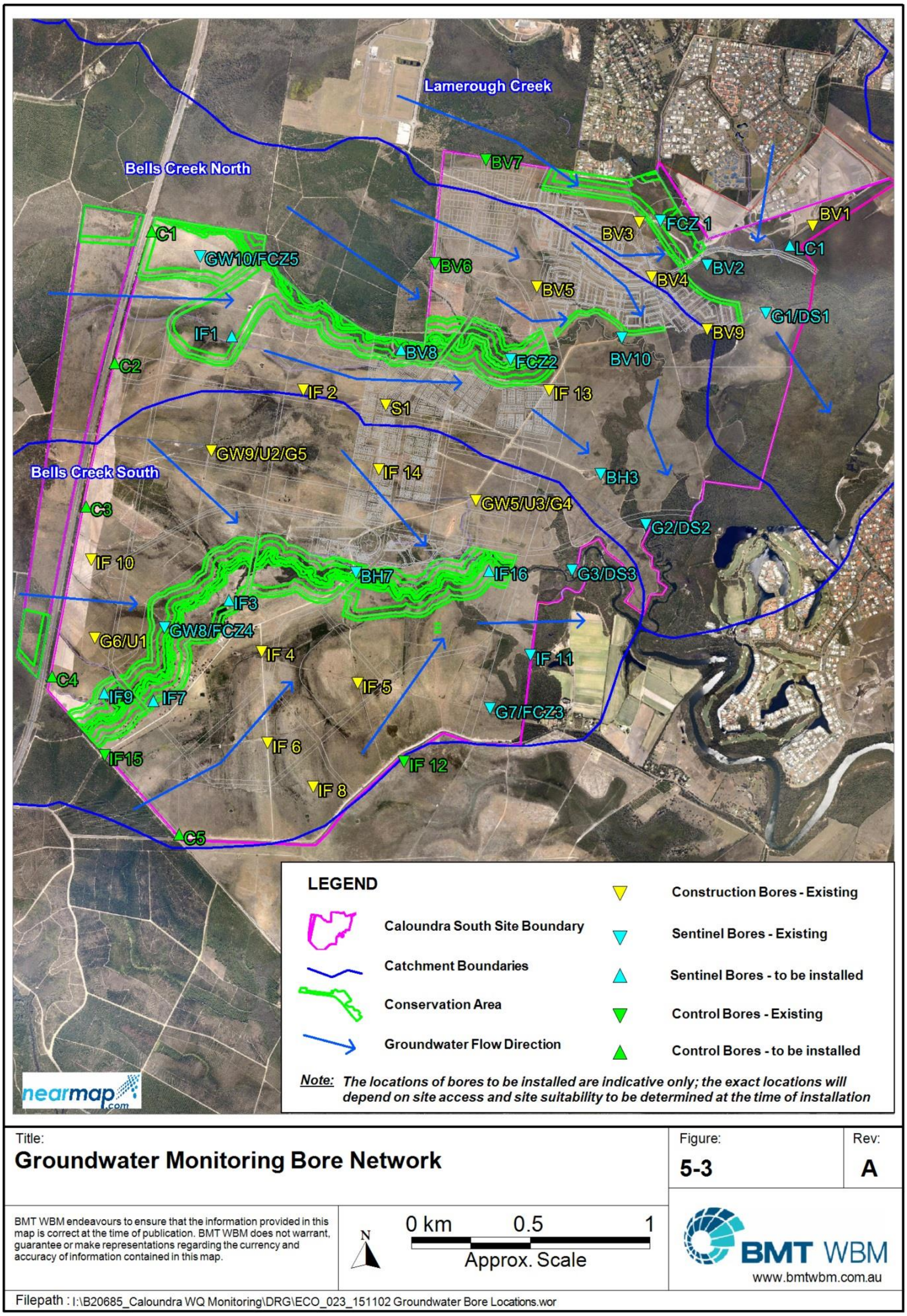

Figure 5-3 Groundwater Monitoring Locations

6 RISK ASSESSMENT OF MODELLING, ASSUMPTIONS AND PREDICTIONS USED

6.1 Background

All modelling undertaken utilising predictive modelling tools is highly dependent on the quality of the input data, the calibration and validation processes performed and the assumptions made in conducting the modelling. The aim when developing models is to develop purposeful, credible models from data and prior knowledge, in consort with end-users.

With respect to Caloundra South, several tranches of modelling were undertaken to investigate the development impacts and potential mitigation measures. These included:

- Catchment modelling of the site and subcatchments upstream, within and downstream of the development;
- Receiving water quality modelling to examine impacts on Bells Creek and Pumicestone Passage;
- Precinct scale stormwater quality modelling; and
- Precinct and development scale water balance modelling.

It is not appropriate in this section to outline all the details and assumptions of each modelling package, however a basic risk assessment has been performed for these modelling tasks as set out below. Complete details of the models used, their parameterisation and assumptions are contained within the relevant reports prepared for the PER and PER supplement, with the following summaries being provided herein:

- Catchment modelling;
- Receiving water quality modelling;
- Stormwater quality modelling; and
- Water balance modelling.

6.2 Risk Assessment

This risk assessment was undertaken in general accordance with the risk management standard AS/NZS ISO 31000:2009, which includes the following steps:

- Identify the risks;
- Analyse the risks;
- Evaluate the risks; and
- Mitigate or treat the risks.

Whilst the risks associated with predictive modelling do not necessarily fit well into a 'typical' risk assessment process, where possible the elements defined above have been used to conduct this assessment.

6.2.1 Identify the Risks

As with any modelling effort, the risks in utilising predictions based on the modelling are dictated by several factors. These risk factors include:

- The purposes for modelling are clearly stated and understood;
- The suitability of the models chosen to represent the processes and characteristics of the problem being modelled;
- Uncertainties within the forcing data used are understood and quantified where possible;
- Use of forcing data considers the specifics of the location being modelled (both temporally and spatially);
- Model parameters chosen are locally relevant and suitable for the chosen models;
- Model operators have sufficient skill to use the predictive tools chosen and understand the implications of model outputs and uncertainties;
- Quantified calibration and verification is undertaken where necessary and applicable; and
- Model outputs are compared to other techniques.

Each of the above represents a risk to the reliability and robustness of the model predictions and any decisions that may have been supported by modelling outputs.

6.2.2 Analyse the Risks

Each of the identified risk factors are analysed below.

a) *The purposes for modelling are clearly stated and understood* – In the case of the Caloundra South, the primary purpose of each model was to quantify the likely impacts from development of the site on specific environmental objectives, and to provide forcing data for "downstream" models such as catchment and receiving water models. Secondary objectives were identified such as minimising the extent of impact, optimising treatment measure performance and sizing and minimising overall demands on water resources. In each case, these purposes were clearly identified at the commencement of each modelling task.

b) *The suitability of the models chosen to represent the processes and characteristics of the problem being modelled* – Each of the model frameworks chosen were those that represented the latest model developments (such as MUSIC, Source, Urban Developer etc all developed through Australian based research), or those which had previously been applied to the region.

c) *Uncertainties within the forcing data used are understood and quantified where possible* – A large range of forcing data was used for each of the modelling frameworks applied to Caloundra South. In all cases, the best available locally specific data was chosen, however the uncertainty in some of that forcing data was not always explicit (e.g. rainfall data). As with any monitoring data, there is likely to be some degree of uncertainty in the results, for example water quality monitoring data from laboratory analysis has explicit uncertainties calculated and these vary with the magnitude of the result, such that numbers closer to detection limits of the analyses have higher uncertainties than those with higher analysis results.

d) *Use of forcing data considers the specifics of the location being modelled (both temporally and spatially)* – Any forcing data used for Caloundra South modelling was that which was the most locally specific for the site. In some cases there may be variability across the site for some spatial characteristics (e.g. rainfall), in which case more forcing data was obtained to mitigate such issues.

e) *Model parameters chosen are locally relevant and suitable for the chosen models* – Model parameters used in the Caloundra South modelling were selected based on industry guidance (e.g. SEQ MUSIC Modelling Guidelines), or from applications of the same models in similar regions.

f) *Model operators have sufficient skill to use the predictive tools chosen and understand the implications of model outputs and uncertainties* – If modellers do not have sufficient experience in the use of models, it is highly likely that significant errors could be made without recognition that this has occurred. In the case of Caloundra South, all modelling tasks were undertaken and/or supervised by highly experienced professional modellers with specific experience in applying the model frameworks to similar sites and in the same region.

g) *Quantified calibration and verification is undertaken where necessary and applicable*. – Calibration and verification of model outputs are essential where definitive representation of existing conditions are required. Where this was completed for the Caloundra South site's existing conditions, the catchment and receiving water quality models utilised significant local observed data to undertake calibration and verification for each framework and these works were outlined in various modelling reports.

h) *Model outputs are compared to other techniques* - Where possible, model outputs should be compared to other modelling outputs or appropriate quantification techniques. In the case of the work undertaken for Caloundra South, outputs from smaller scale models were compared to the larger regional models. For example, outputs from MUSIC stormwater models were compared to the catchment models and other techniques for estimating flows and pollutant export.

6.2.3 Evaluate the Risks

The identified risks were evaluated utilising risk tables included in Appendix A. The method for evaluating risks involved assessing the 'likelihood' of an environmental impact occurring with the 'consequence' of an environmental impact occurring. This likelihood and consequence ratings are based on the analysis of risks as discussed above.

6.2.4 Mitigating the Risks

Of all the risks described above, the only one that was identified as a moderate risk was if the uncertainties within the forcing data used were understood and quantified where possible. In terms of Caloundra South, a large range of forcing data was used for the modelling frameworks applied. In each case, the forcing data used was that which was considered "best practice" or industry standard. As such, the outputs of the models are likely to be consistent with any other models developed for similar sites across Australia and represent best modelling practice. This was recognised as such in the reviews of the modelling works undertaken.

Table 6-1 Risk Evaluation

Risk Factor	Description of Impact	Likelihood of Impact	Consequence of Impact	Risk Rating
The purposes for modelling are clearly stated and understood;	If the purpose of a model is not understood, then incorrect modelling predictions may be derived or may not be appropriate to the site	Very unlikely (1)	Minor (2)	Low (3)
The suitability of the models chosen to represent the processes and characteristics of the problem being modelled;	Models which do not portray the processes or characteristics are not likely to account for the dynamics of changes across the site or on receiving environments	Very unlikely (1)	Minor (2)	Low (3)
Uncertainties within the forcing data used are understood and quantified where possible;	If the uncertainties are too large, the model outputs may not be able to discretise any potential changes in impacts as a result of the modelled scenarios	Moderate (3)	Minor (2)	Moderate (5)
Use of forcing data considers the specifics of the location being modelled (both temporally and spatially);	Where forcing data is not locally specific, it may result in model outputs that do not account for spatial or temporal variability of the local environment	Unlikely (2)	Minor (2)	Low (4)
Model parameters are chosen are locally relevant and suitable for the chosen models;	If inappropriate parameters are chose the model outputs are not likely to represent the site and give misleading outputs	Unlikely (2)	Minor (2)	Low (4)
Model operators have sufficient skill to use the predictive tools chosen and understand the implications of model outputs and uncertainties;	Inexperienced modellers will not have a full understanding of the implications of data, parameters and assumptions used and can result in outputs that do not adequately account for impacts or site conditions	Very unlikely (1)	Moderate (3)	Low (4)
Quantified calibration and verification is undertaken where necessary and applicable; and	Uncalibrated and unverified models are usually worse than no model at all	Unlikely (2)	Minor (2)	Low (4)
Model outputs are compared to other techniques	Without some cross verification of techniques, the decision maker has no concept of the robustness and reliability of the model prediction	Unlikely (2)	Minor (2)	Low (4)

7 PERFORMANCE INDICATORS AND GOALS

7.1 Water Quality – Construction Stage

Impacts to downstream water quality are avoided or otherwise minimised in accordance with the achievement of the following water quality performance criteria for site sedimentation basins:

- pH 6.5 to 8.5.
- During periods of flow in Bells Creek North or South and for any such flow events up to and including the design rainfall event as specified below, discharge turbidity offsite (as measured by the downstream automated turbidity monitor) to be no greater than 10% above background with background being the quality of water entering the site *via* the culverts where Bells Creek North and South pass under the Bruce Highway.
- Nutrients (nitrogen and phosphorus) to be managed through normal erosion and sediment control practices.
- The following monitoring regime will be integrated into each Precinct-based CEMP:
    - Regular (daily and after major rain events) site inspections of all erosion and sediment control measures;
    - Regular (daily and after major rain events) inspections of areas surrounding construction site to detect and manage any occurrence of sediment deposition off-site;
    - Rainfall will be recorded at 9am each working day from an installed rain gauge;
    - All construction activities will be monitored daily for compliance with erosion and sediment control measures; and
    - Within sediment basins, turbidity, pH, Electrical Conductivity (EC) and Dissolved Oxygen (DO) will be measured daily.

Corrective actions may be required each time there is either a significant (i.e. greater than 25%) exceedance of the above stated performance standards for discharges from site sediment basis or if there are similar triggers of the automatic turbidity monitoring infrastructure. If lesser exceedances are observed (e.g. between 15 and 25%) then initial surveillance assessments will be triggered that may identify areas that could be better managed, thereby reducing off site export of sediments.

Design Rainfall Event

Sediment basins onsite have been designed to manage stormwater flows up to the following design rainfall events:

- For traditional sediment basins, the design rainfall event is 77 mm over a 5 day period.
- For high efficiency sediment (HES) basins, rainfall intensity and inflow duration govern the time available for suspended sediment to settle in the basin. The design rainfall event for these basins is 0.5 times the peak 1 year ARI discharge.

7.2 Water Quality – Operational Stage

7.2.1 Receiving Water Quality

Earlier PER and supplementary PER works proposed a performance indicator approach, which encompassed reviewing the relationship between three-month average water quality levels at relevant ‘control’ and ‘impact’ sites within Pumicestone Passage to define when investigation and corrective action works would be triggered. Subsequent to this earlier recommendation, available EHMP data have been interrogated to assess the likely efficacy of this approach and it would appear that natural variability in ambient water quality levels may preclude such an approach. As such, an alternative and more robust way in which the efficacy of site water quality management intervention can be measured and directed is proposed, still using EHMP data. This approach is summarised below.

7.2.1.1 Pumicestone Passage

- The existing water quality behaviour of Pumicestone Passage is to be quantified using historical EHMP data. These data should relate the behaviour of two control sites (EHMP sites 1309 and 1310) to one impact site (EHMP site 1311). The locations of these sites are shown in Figure 7-1. The relationship between the control and impact sites should use three month running averages of EHMP water quality data as a key performance metric.
- For key water quality parameters, appropriate in situ relationships between water quality levels at the control and impact sites will be developed using EHMP data. Figure 7-2 to Figure 7-10 illustrate such relationships that have been derived using existing data for a range of water quality parameters. These data show the following:
  - A ‘line of best fit’ describing the relationship between the water quality at the control and impact sites – which, as shown in most cases indicates a very good level of fit between the two datasets.
  - ‘Investigation’ and a ‘corrective action’ lines, defined respectively as being located 1.5 and 3 standard deviations outside the ‘line of best fit’. These lines effectively encompass the majority of **natural** variability in water quality levels in Pumicestone Passage. Further investigation may involve investigation of other land uses in the area which may potentially contribute to water quality changes in Bells Creek estuary and Pumicestone Passage.
  - Any data recorded at the impact site during the construction and/or operational stages of the project that is located between the two ‘investigation’ lines will not require any action as these data are indicating water quality levels in Pumicestone Passage that is effectively comparable to pre-development conditions.
  - Should data recorded at the impact site during the construction and/or operational stages of the project fall between the ‘investigation’ and ‘corrective action’ lines (see for example Figure 7-2), then site-specific investigations as outlined in separate Environmental Management Plan (EMP) documentation for this project will be triggered to define whether development works are affecting receiving water quality and, if necessary, corrective action may be commenced.
  - Should data recorded at the impact site during the construction and/or operational stages of the project fall outside the ‘corrective action’ lines, then more detailed assessments and site-specific actions will be triggered.

- Regular (2 yearly) reviews of the relationships illustrated in Figure 7-2 to Figure 7-10 should be conducted to capture any potential overall long-term changes in water quality within Pumicestone Passage which may result from works being conducted elsewhere in the catchment.

7.2.2 Receiving Water Quality in Bells Creek

A similar approach should be taken to triggers for water quality management in Bells Creek, with in this case the relationship between the two Stockland funded EHMP sites in Bells Creek (impact sites) and the behaviour of two control sites in Pumicestone Passage (again EHMP sites 1309 and 1310) being used. This will require the collection of 6 months more background data in Bells Creek as the available data set in Bells Creek (see Figure 7-11) is still somewhat scarce for these assessments to have any real statistical strength.

Regular (2 yearly) reviews of these relationships should also be conducted to capture any potential overall long-term changes in water quality within Pumicestone Passage which may result from works elsewhere in the catchment.

7.2.3 Site Pollutant Export Loads

A load based monitoring program will be conducted on the site to further define both existing pollutant loads washing from the site and to assist in determining how these loads may change with development of the site. Given that there is likely to be significant variability between and within event monitoring sites as noted in previous stormwater monitoring studies (BCC 2005), monitoring data will be compared with the predicted loads from previous modelling of the site and where differences greater than 2 standard deviations of the mean annual loads are identified, further site investigations and comparison with other monitoring activities will be undertaken to determine whether these are due to variability or indicative of changes in load runoff from the site. This load base monitoring will also be informed by the load based monitoring of treatment devices.

Figure 7-1 EHMP Data Collection Locations

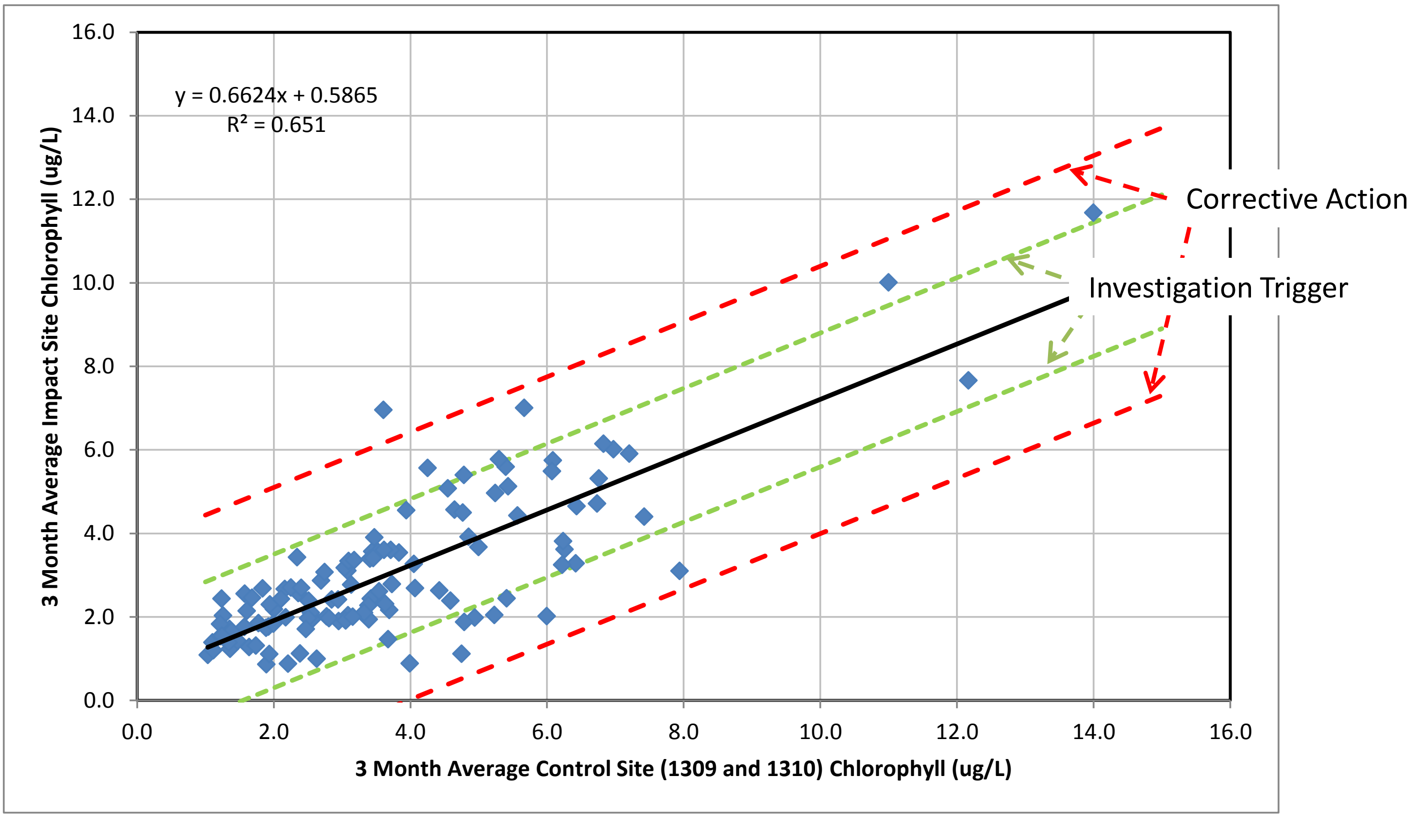

Figure 7-2 EHMP Data Assessment – Pumicestone Passage – Chlorophyll a

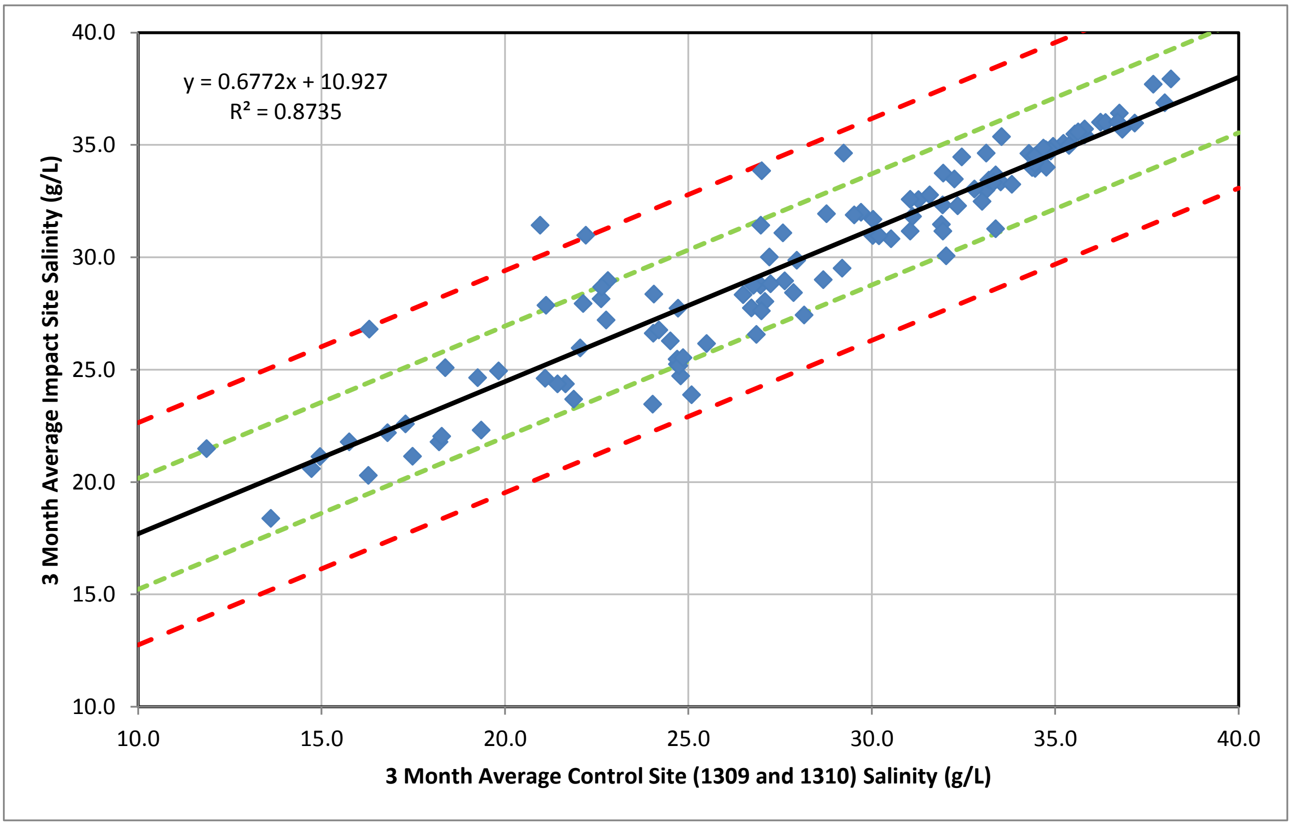

Figure 7-3 EHMP Data Assessment – Pumicestone Passage – Salinity

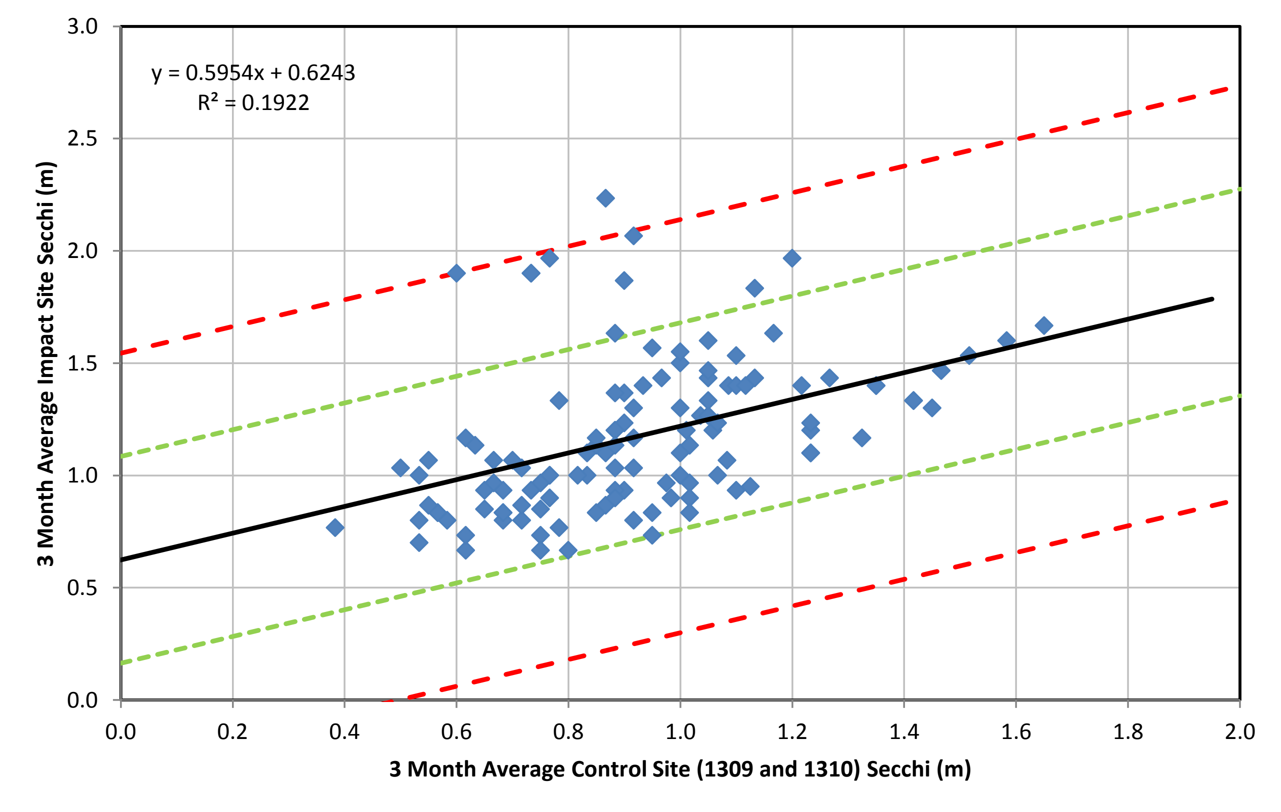

Figure 7-4 EHMP Data Assessment – Pumicestone Passage – Secchi

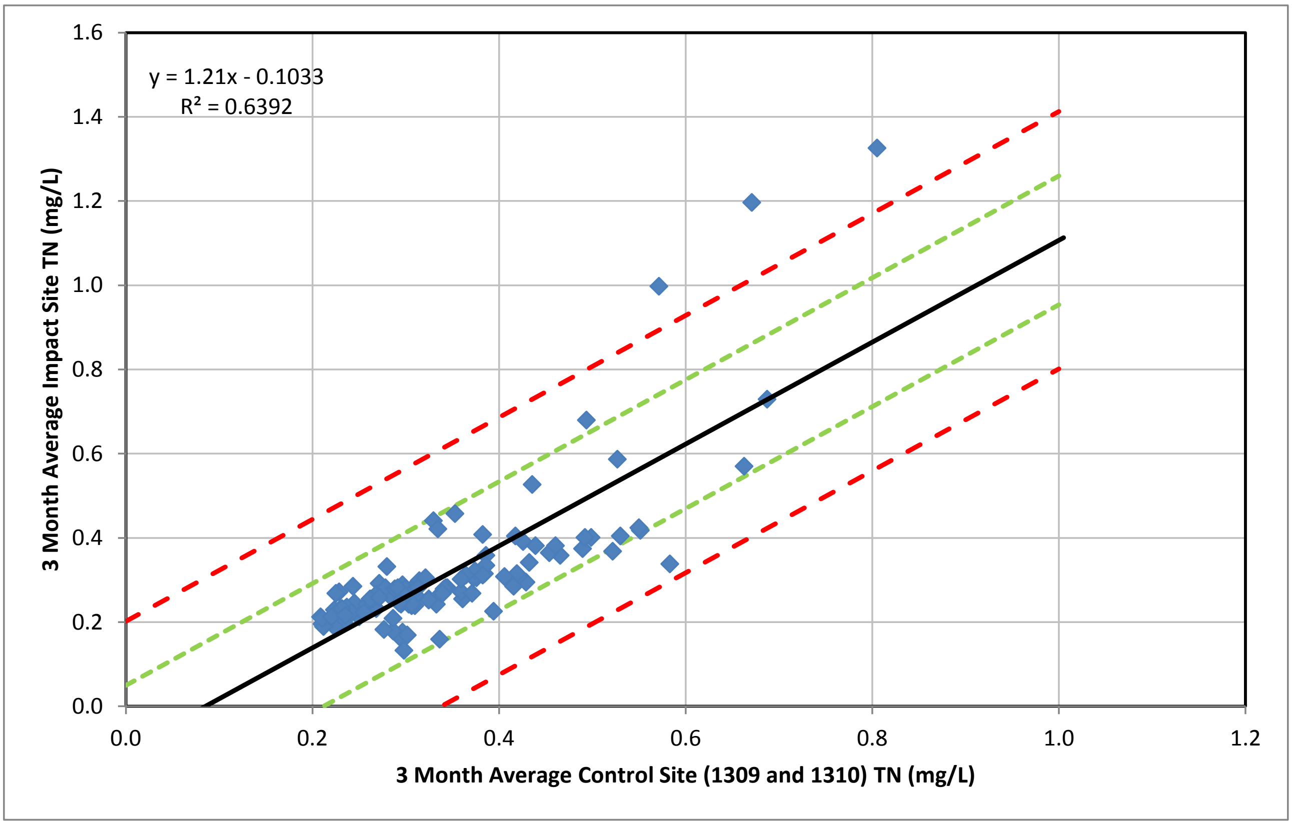

Figure 7-5 EHMP Data Assessment – Pumicestone Passage – Total N

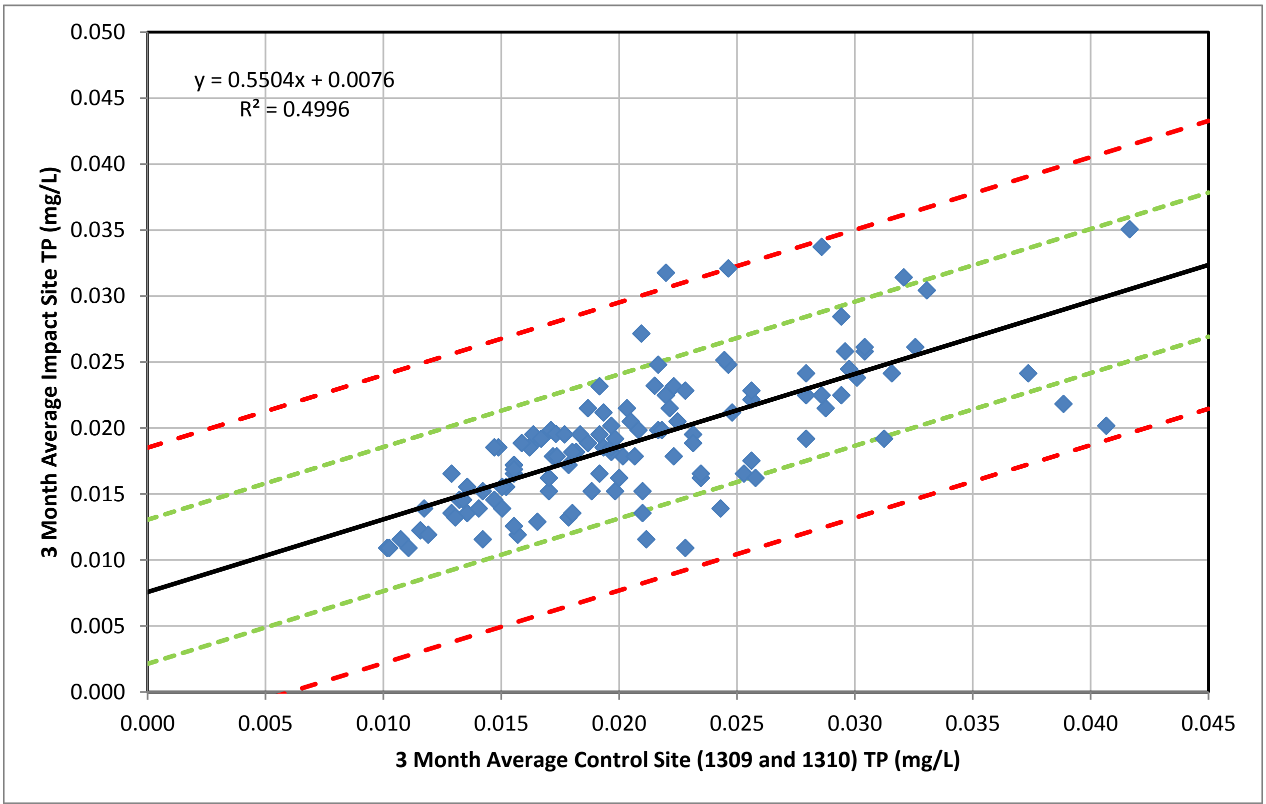

Figure 7-6 EHMP Data Assessment – Pumicestone Passage – Total P

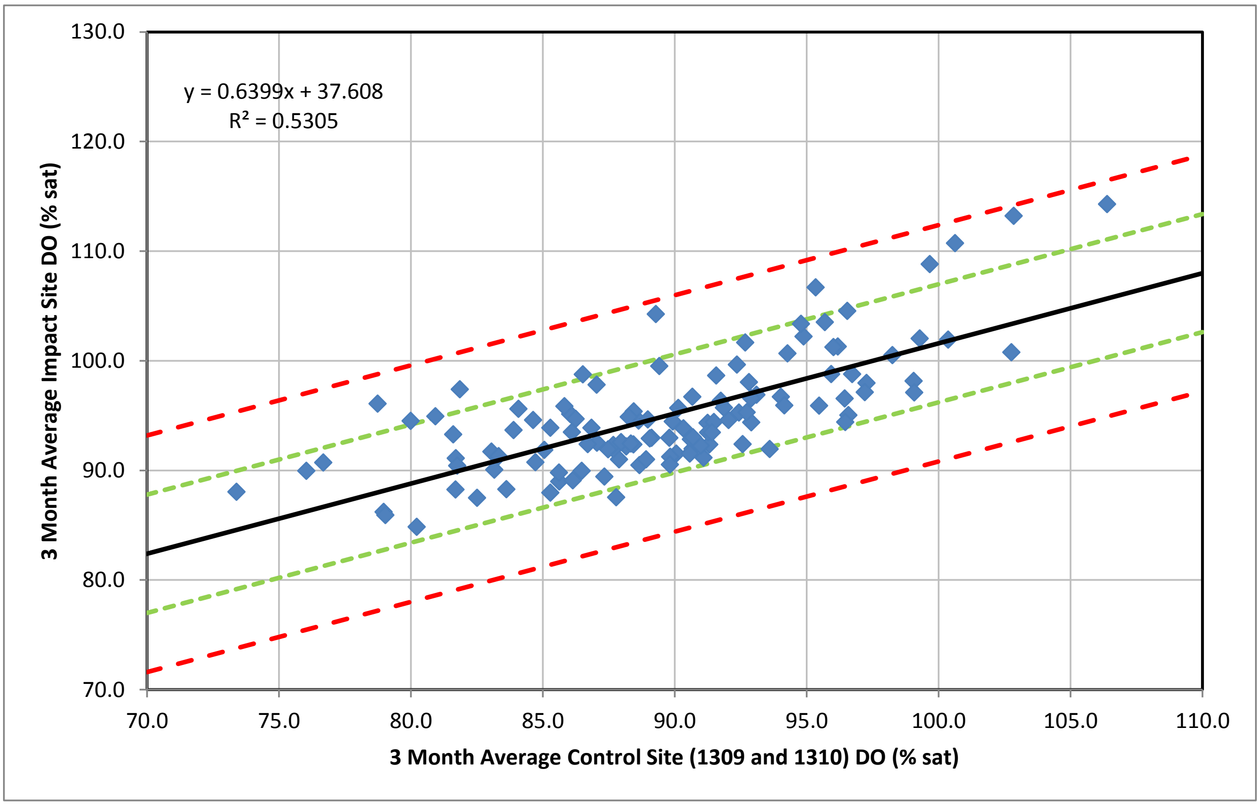

Figure 7-7 EHMP Data Assessment – Pumicestone Passage – DO

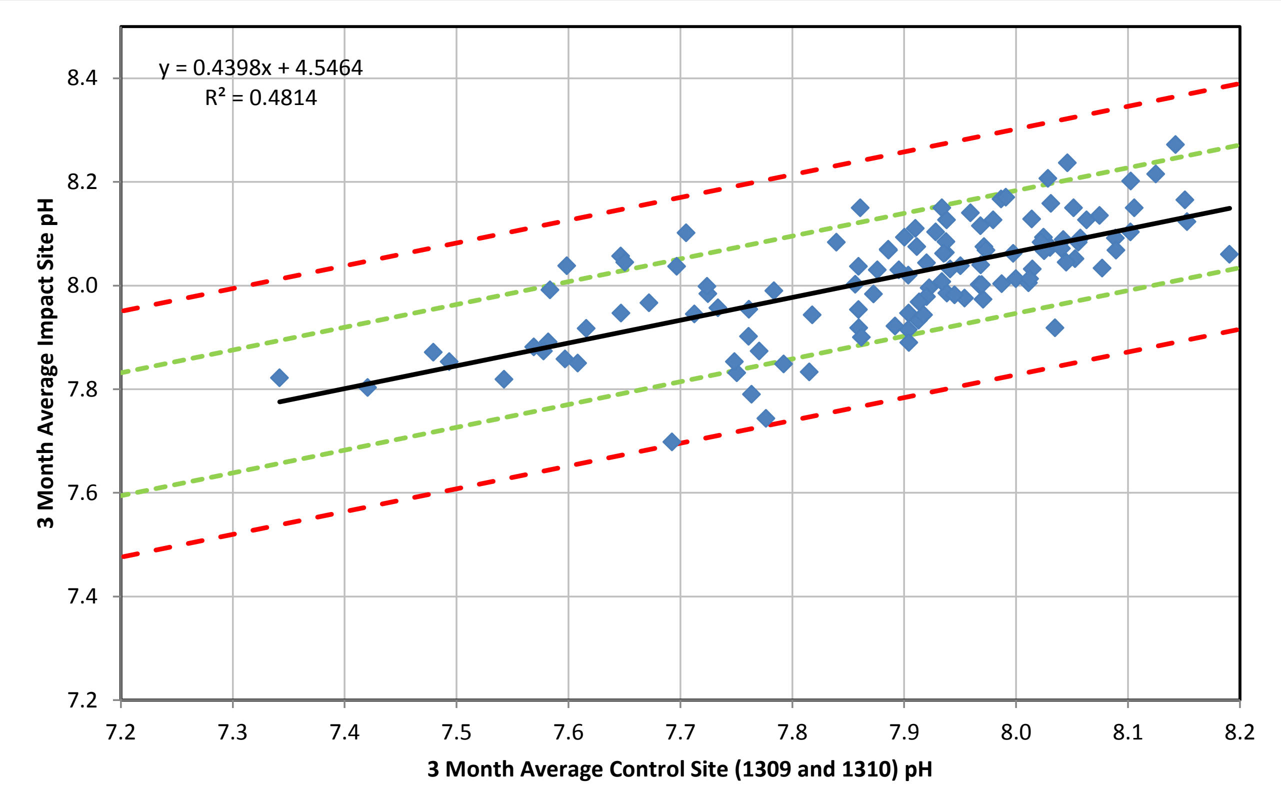

Figure 7-8 EHMP Data Assessment – Pumicestone Passage – pH

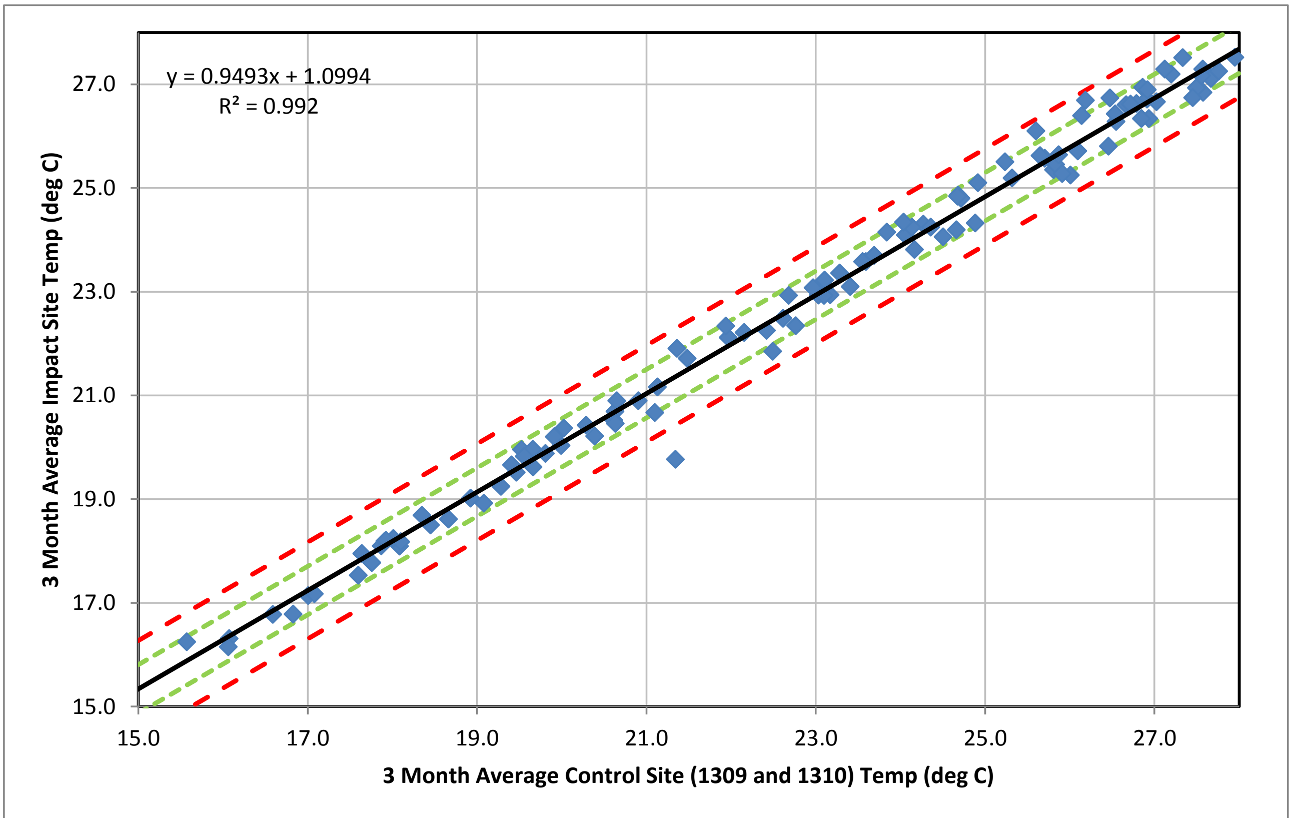

Figure 7-9 EHMP Data Assessment – Pumicestone Passage – Temperature

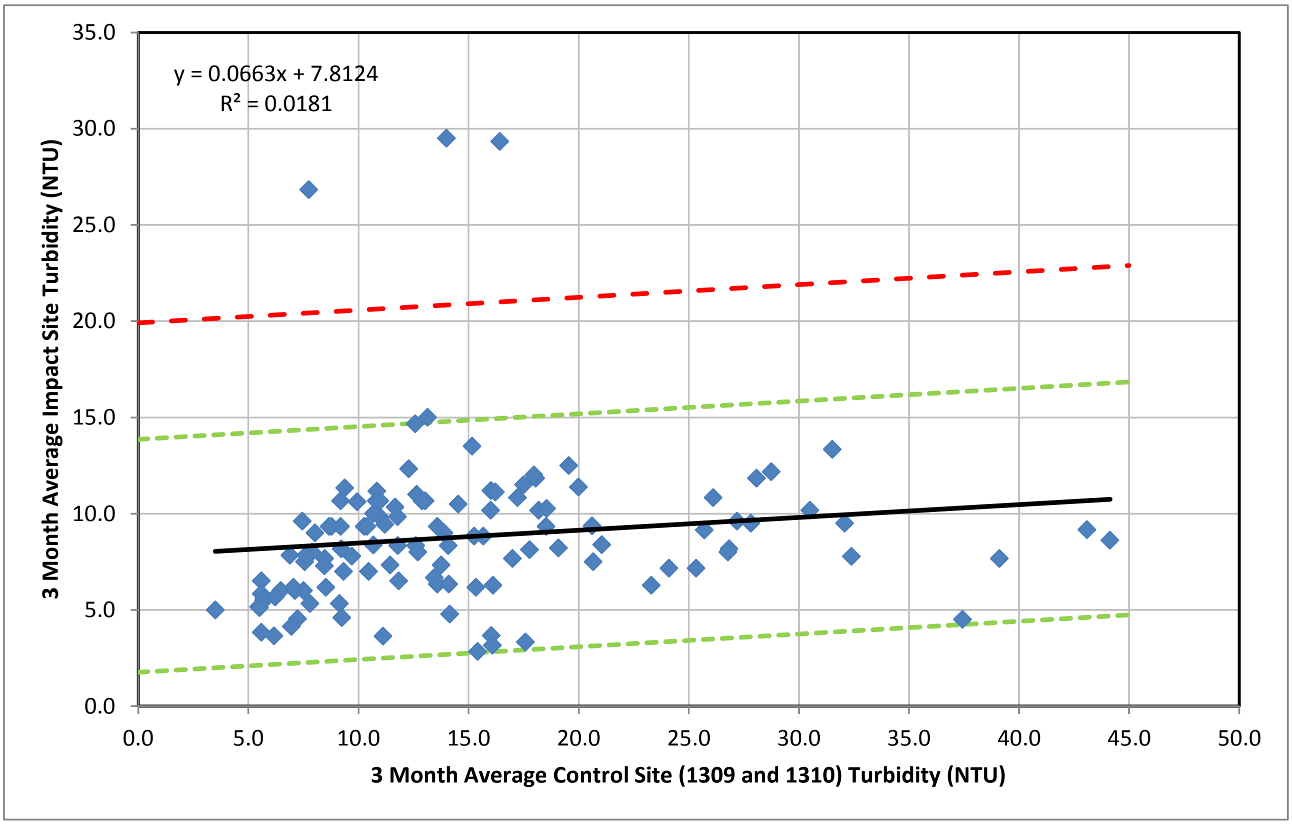

Figure 7-10 EHMP Data Assessment – Pumicestone Passage – Turbidity

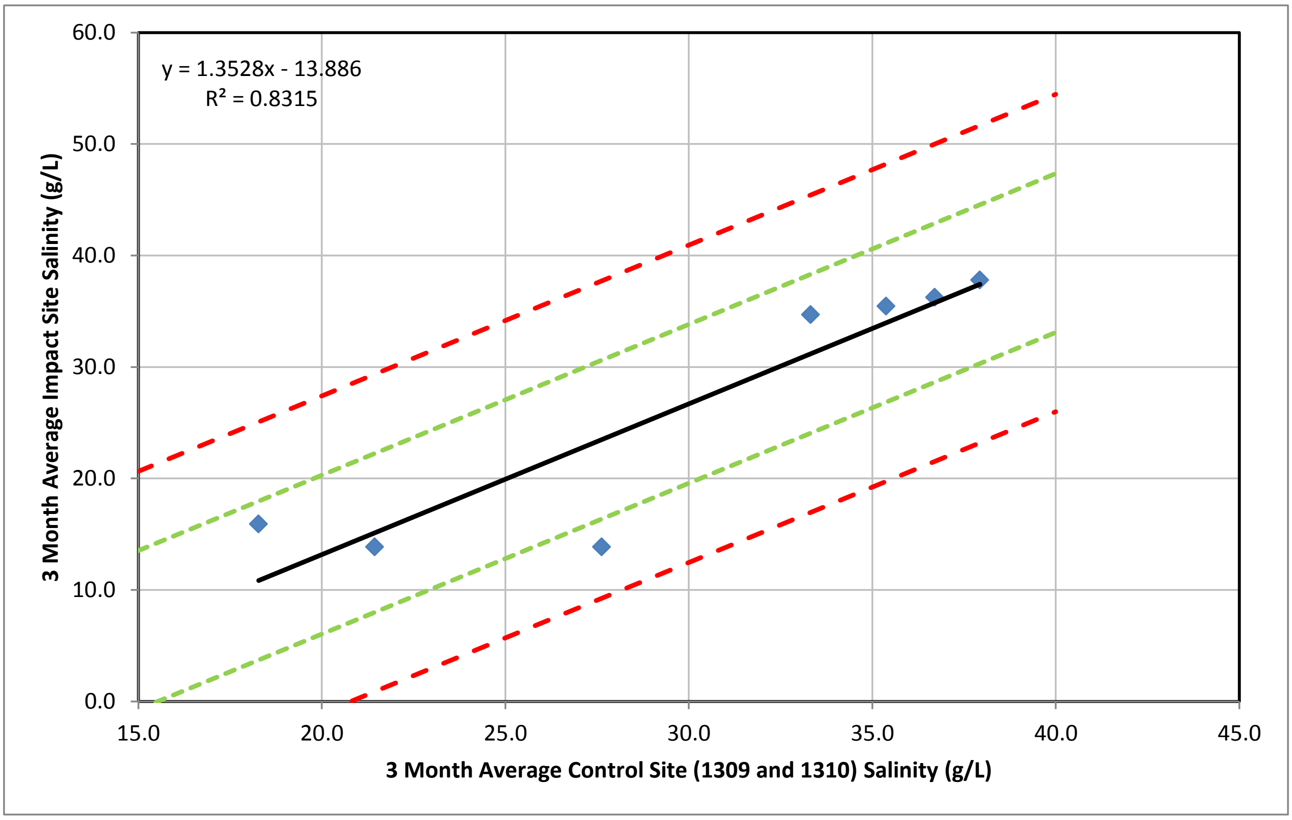

Figure 7-11 EHMP Data Assessment – Bells Creek – Salinity

7.3 Groundwater

7.3.1 Performance Indicators

Measurable performance indicators for groundwater, which focus on the protection of Protected Matters, include the following:

- Construction activities do not result in changes to groundwater levels or groundwater quality in Wallum Sedge Frog (WSF) breeding areas that are outside the acceptable limits as specified in the Wallum Sedge Frog Management Plan (WSFMP) (i.e. pH 3 to 5 and electrical conductivity 8 to 77 µs/cm).
- Construction activities do not result in poor quality groundwater seepage into surface water bodies (indicated by three month rolling median being maintained within 20^{th} and 80^{th} percentile values of baseline surface water quality).

The following sections describe the process for assessing these performance indicators.

7.3.2 Groundwater Quality

7.3.2.1 Trigger Values

Trigger values are to be developed for all bores, including 'Construction', 'Sentinel' and 'Control' bores. Exceedance of trigger values at 'Sentinel' bores will trigger further investigation. Trigger values at 'construction' bores will be used to identify potential impacting activities within the active areas of construction, and to guide corrective action if required, while trigger values at 'Control' bores will be used to monitor for offsite influences on groundwater quality and to serve as a reference for changes in groundwater quality in Sentinel bores.

Groundwater quality trigger values should be established based on a minimum of ten (10) data points over at least a 12 month period to capture seasonality. As the available baseline data for some existing groundwater bores is less than this requirement, **bore-specific** trigger values cannot be developed for all monitoring bores. Therefore, **site-specific** groundwater quality trigger values have been developed for use for those bores with limited baseline data.

These site-specific trigger values were developed by grouping data from approximately 40 historical monitoring bores across the site. This method provides a large number of data points across a number of years and therefore provides a statistically sound approach for assessing potential construction related groundwater impacts for bores with limited baseline data.

Site-specific trigger values have been developed by calculating the 80^{th} percentile (and/or 20^{th} percentile for parameters where issues arise from low levels). Exceedance of these trigger values at Sentinel bores would trigger further investigation.

The site-specific groundwater quality triggers are presented in Table 7-1. These site-specific triggers will be applied to bores with limited baseline data. It is important to note that for bores with sufficient baseline data (i.e. more than ten data points over at least 12 months), bore-specific trigger values using the methodology described above will be developed and used in preference to site-specific triggers.

Importantly, within 12 months of the date of this report, with the monitoring as per Section 5.2, the majority of Sentinel bores and all Control bores will have sufficient baseline data to enable robust bore-specific trigger values to be developed. As such, the adoption of site-specific triggers will only be a temporary manifestation at these locations. For some Sentinel bores located down-gradient of areas of current or imminent construction, there may be an opportunity for the site-specific triggers to gradually be replaced by bore-specific triggers using data from continued monitoring if groundwater quality is demonstrated to be unaffected by construction works further up in the catchment.

Table 7-1 Site-Specific Groundwater Quality Triggers

Parameter	Units	Investigation Trigger ($20^{th}/80^{th}$ percentile)
EC	mS/cm	1.1
pH – upper (80th percentile)	pH units	6.37
pH – lower (20th percentile)	pH units	5.00
Fluoride	mg/L	0.28
Chloride	mg/L	374
Sulfate	mg/L	150
Total alkalinity	mg/L	23
Calcium	mg/L	43
Magnesium	mg/L	62
Sodium	mg/L	277
Potassium	mg/L	8
Ammonia	mg/L	0.12
Nitrite	mg/L	0.01
Nitrate	mg/L	1.87
NOx	mg/L	1.88
TKN	mg/L	1.20
Total Nitrogen	mg/L	1.26
Reactive Phosphorus	mg/L	0.013
Total Phosphorus	mg/L	0.46
Aluminium (dissolved)	mg/L	0.28
Cadmium (dissolved)	mg/L	0.001
Chromium (dissolved)	mg/L	0.001
Copper (dissolved)	mg/L	0.005
Lead (dissolved)	mg/L	0.003
Manganese (dissolved)	mg/L	0.414
Nickel (dissolved)	mg/L	0.006
Zinc (dissolved)	mg/L	0.15
Iron (dissolved)	mg/L	11.2
Mercury (dissolved)	mg/L	0.0001
Arsenic (dissolved)	mg/L	0.001
BTEX	µg/L	LOR
TPH/TRH	µg/L	LOR
PAHs	µg/L	LOR

LOR = Laboratory Limit of Reporting

7.3.2.2 Assessment of Groundwater Quality during Construction

Construction phase groundwater quality data will be analysed to determine the median from the most recent three (3) consecutive routine monitoring samples. This 'rolling median' will be used to compare with site-specific or bore-specific trigger values as appropriate.

Note that assessment of groundwater quality data against trigger values will only be undertaken for bores within catchments with active construction works (up to 12 months after active construction works are completed).

The following methodology is proposed to assess groundwater quality in catchments with active construction works:

- For bores with less than ten (10) baseline data points (captured over at least 12 months), construction phase groundwater monitoring data will be compared with **site-specific** groundwater quality trigger values.
- For bores with more than ten (10) baseline data points (captured over at least 12 months), construction phase groundwater monitoring data will be compared with **bore-specific** trigger values.
- If the construction phase monitoring data for Sentinel bores exceeds the 80^{th} percentile trigger value (or 20^{th} percentile for parameters with a lower limit), this will trigger an initial investigation into whether Protected Matters and/or receiving environments are being impacted.
- Impacts to Protected Matters and/or receiving environments are to be assessed as follows:
  a) Assess whether the three month rolling median of surface water quality data (only for parameters exceeded in groundwater) at the downstream boundary of site (e.g. BN1) is outside the $20^{th}/80^{th}$ percentile range of baseline data. If so, review the surface water quality data record at the upstream boundary of the site (e.g. BN3) to determine if parameters of concern are naturally elevated. If upstream surface water quality is within $20^{th}/80^{th}$ percentile of baseline data at this location, construction related impacts may be occurring at downstream receiving environments.
  b) Assess whether pH and electrical conductivity (EC) levels in site frog ponds are within acceptable limits.
  c) Assess whether trigger values at up-gradient Control bores are also being exceeded – indicating potential offsite influences on groundwater quality.
- If the monitoring data comparison indicates that Protected Matters or the receiving environment may be being impacted, this will trigger potential corrective action as per Section 8.2.3 of the WQMP.
- Construction phase monitoring data for construction bores will be compared to trigger values (either site-specific or bore-specific) to identify potential areas of concern, or point sources, within the construction areas. This will assist with targeting of locally specific corrective actions if required.

To illustrate the above points, a construction phase groundwater quality monitoring decision tree is presented in Figure 7-12.

Note: In the 12 month monitoring period after active construction works are completed in respective catchments, the above process of assessment against trigger values will continue. While corrective actions will not be able to be implemented, the purpose of this is to confirm that there are no lingering impacts to groundwater.

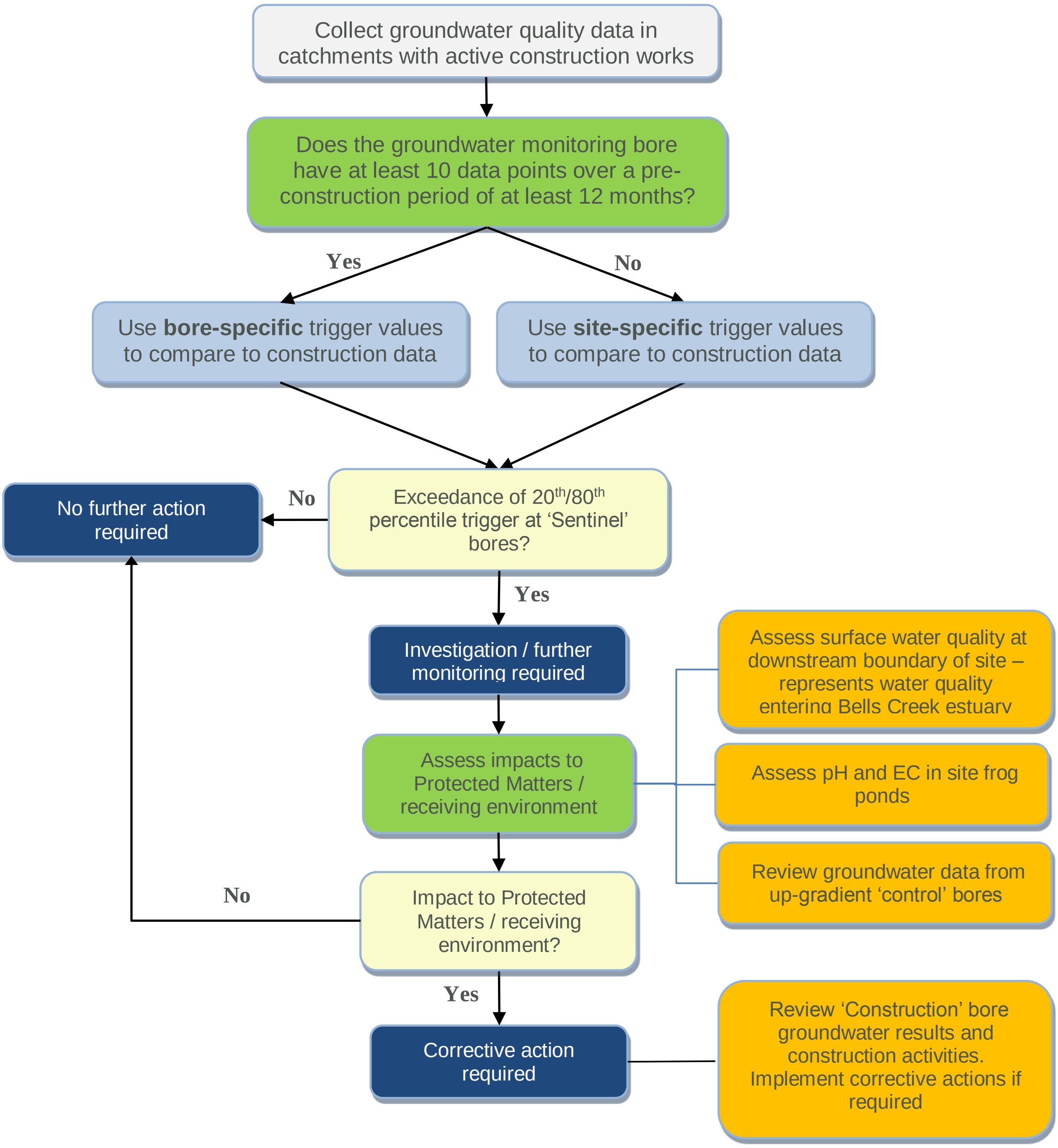

Figure 7-12 Construction Phase Groundwater Quality Monitoring Decision Tree

7.3.3 Groundwater Level

7.3.3.1 Trigger Values

For groundwater level, site-specific trigger values cannot be developed as groundwater level is unique to each monitoring bore. Therefore, for bores with limited or no baseline groundwater level data, a trend analysis is proposed to be used to assess whether construction activities are affecting groundwater levels. This trend analysis involves plotting time series groundwater level data to provide an indication of whether groundwater levels are trending up or down.

In addition to the time series groundwater level data, a cumulative rainfall departure curve (CRD) should be plotted on the same graph. This CRD represents above or below average rainfall for each month (cumulative departures from the arithmetic mean). A rising slope on the curve equates to a period of above average rainfall, while a falling slope equates to a period of lower than average rainfall.

These CRD curves are useful to correlate groundwater level fluctuations with precipitation events on the Caloundra South site. Groundwater levels within bores unaffected by construction activities typically correlate with fluctuations of the CRD, especially when direct recharge from rainfall is the dominant recharge process. Correlation of groundwater level fluctuations with the CRD provides an indication of whether groundwater level declines or rises are a result of climatic conditions, or are influenced by construction activities.

For bores with sufficient baseline groundwater level data, bore-specific trigger values will be calculated and used to identify potential impacts to groundwater level during construction.

7.3.3.2 Assessment of Groundwater Levels during Construction

Note that assessment of groundwater level data against trigger values will only be undertaken for bores within catchments with active construction works (up to 12 months after active construction works are completed). .

The following methodology is proposed to assess groundwater levels in catchments with active construction works:

- For bores with more than ten (10) baseline data points (captured over at least 12 months), construction phase groundwater monitoring data will be compared with bore-specific groundwater level trigger values.
- For bores with less than ten (10) baseline data points (captured over at least 12 months), construction phase groundwater monitoring data will be plotted as time series with CRD curve to assess trends in data compared to rainfall.
- If the construction phase monitoring data for <u>Sentinel bores</u> exceeds the 80th percentile trigger value (upper limit) or 20th percentile (lower limit), or if the trend in the previous three (3) months of data does not correlate with the trend in the CRD curve, this will trigger an initial investigation into whether Protected Matters are being impacted.
- Impacts to Protected Matters are to be assessed as follows:
  a) Assess whether water levels in frog ponds are within acceptable limits.
  b) Assess whether trigger values at up-gradient <u>Control bores</u> are exceeded - indicating natural fluctuations in groundwater levels.
- If Protected Matters are being impacted, this may trigger corrective action as per Section 8.2.3 of the WQMP.
- Construction phase monitoring data for <u>construction bores</u> will be compared with trigger values (either site-specific or bore-specific) to identify potential areas of concern within construction areas. This will assist with targeting of corrective actions.

To illustrate the above points, a construction phase groundwater level monitoring decision tree is presented in Figure 7-13.

<u>Note</u>: In the 12 month monitoring period after active construction works are completed in respective catchments, the above process of assessment against trigger values will continue. While corrective actions will not be able to be implemented, the purpose of this is to confirm that there are no lingering impacts to groundwater.

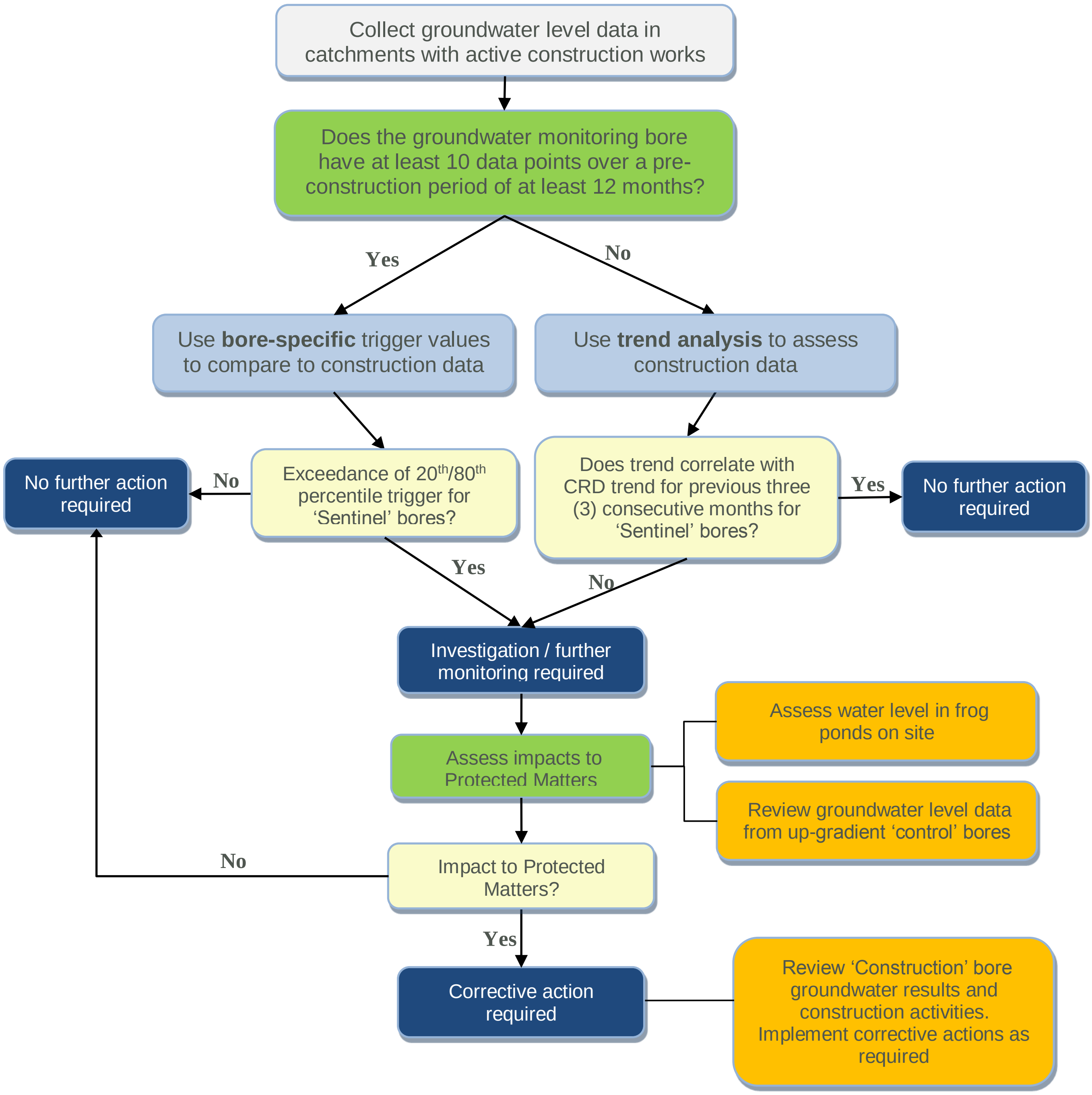

Figure 7-13 Construction Phase Groundwater Level Monitoring Decision Tree

8 CORRECTIVE ACTIONS

8.1 Water Quality - Construction Stage

Specific corrective actions will be developed as part of the Precinct-based CEMPs. Generally, where performance criteria are not being met, the following measures will be implemented:

- Contractor to amend erosion and sediment control measures as required in consultation with the Superintendent to address deficiencies through regular monitoring and inspections and in consultation with relevant regulatory agencies.
- Erosion and sediment control devices will be cleaned, repaired or replaced whenever inspections show signs of noncompliance or ineffective capability/capacity.
- Works will cease and/or other corrective actions taken (e.g. not allowing release of water from sedimentation basins) where erosion and sediment control devices are found not to be in accordance with the management and mitigation actions outlined in this plan or otherwise the performance requirements outlined above.
- Areas of exposed soils and extensive scour or erosion will be rehabilitated as soon as practicable after detection.

8.2 Water Quality - Operational Stage

8.2.1 Pumicestone Passage and Bells Creek

Generally, the water quality of the operational stage of the development will be highly dependent upon the performance of specific treatment measures within the development, notwithstanding contributing land uses upstream and downstream of the development Given that these are to be independently evaluated through a specific monitoring program, corrective actions will therefore need to be focussed on the treatment measures, but also consider overall implementation of the various management measures across the development.

Corrective actions related to operational phase water quality include the following:

- Review of existing data sets to examine trends and spatial context of any failures of WQOs;
- Identification of the source of the outliers (chronic or acute failure);
- Where sources are identified, investigate implementation of water quality management measures in these locations to ensure that they are established appropriately and functioning as designed. Specific rectification measures will be identified as part of the design process for each treatment measure;
- Investigation into potential spills/contamination event; and
- Examination of the load based monitoring and automated turbidity monitoring to determine if any trends are consistent with the changes in ambient water quality occurring in the operational phase.

8.2.2 Site Pollutant Export Loads

No corrective actions nominated

8.2.3 Groundwater

Corrective actions following a detection of an exceedance of a groundwater trigger levels as established above may include the following:

- The review of site construction management practices;
- Localised temporary filling or excavation works to adjust land elevations if required;
- Review of current and planned filling and excavation works.
- Changes to proposed re-vegetation and ecological enhancement strategies;
- Review of site surface water management devices (WSUD) and stormwater harvesting practices;
- Detection and remediation of spills or other contaminant releases (if groundwater quality is detected as being affected); or
- Review and amendment of acid sulphate soil management practices in the context of unusually low groundwater pH or the presence of dissolved metals at downstream monitoring locations.

9 ADAPTIVE MANAGEMENT MECHANISMS

Adaptive management of the implementation of treatment measures across the Caloundra South site is planned through the adoption of the various monitoring programs, especially those focussed on treatment measure performance. Initial stages of the development will occur in the Lamerough Creek catchment and it is intended that the implementation of the construction and operational treatment systems will be "trialled" in these catchments and modified through design and implementation such that when the development staging moves into the Bells Creek catchments, the performance and implementation of the treatment measures will have been optimised.

Furthermore, the ongoing review of monitoring outputs will provide sufficient data with which to undertake regular reviews of progress of the management actions and make appropriate changes where necessary. At this stage in the development process, these are not yet explicit; however an adaptive management framework underlies the monitoring program development and corrective actions identified.

In regard to adaptive management on the site, we note as follows:

- Stockland and their nominated contractors undertaking development works on the site will be the parties ultimately responsible and accountable for ensuring that actions associated with adaptive management take place.
- Stockland will appoint a suitable external consultant to implement, coordinate and oversight all environmental monitoring works. This consultant will be **independent** of the development contractor and will ensure appropriate accountability of monitoring as a trigger for corrective actions.
- Regular reports will be provided to relevant regulatory authorities and to the wider community as required by all Development Approvals in regard to
  a) The overall nature and results of monitoring works;:
  b) Any trends in the results obtained by these works;
  c) What, if any, corrective action triggers have been initiated as a result of the monitoring, and finally; and
  d) How effective these measures have been.
- Should actions be required, Stockland and their nominated development contractors will be responsible for the implementation and refinement of same to ensure that appropriate environmental protection goals associated with the project are achieved.

APPENDIX A: RISK ASSESSMENT TABLES

Score		TABLE OF CONSEQUENCE Environment
5	**Very High/ Catastrophic**	Catastrophe, irreversible damage to sensitive environment. Likely prosecution.
4	**High/ Major**	Disaster, high levels of media attention, prolonged but reversible damage to environment.
3	**Moderate**	Substantial environmental nuisance but full recovery expected.
2	**Low/ Minor**	Minor detrimental effect to environment.
1	**Very Low/ Insignificant**	Low environmental impact

TABLE OF LIKELIHOOD		
Score		**Likelihood**
5	**Almost certain**	The event is expected to occur in most circumstances. Likely to occur frequently.
4	**Likely/ probable**	The event will probably occur in most circumstances.
3	**Moderate/ occasional**	The event should occur at some time. Likely to occur sometime.
2	**Remote/ unlikely**	The event could occur at some time. Unlikely but possible.
1	**Rare/ very unlikely**	The event may occur only in exceptional circumstances. Assumed it may not be experienced.

Risk= Consequence +Likelihood						
		Risk Rating				
Consequence	**5**	6	7	8	9	10
	4	5	6	7	8	9
	3	4	5	6	7	8
	2	3	4	5	6	7
	1	2	3	4	5	6
		1	**2**	**3**	**4**	**5**
		Likelihood				

Risk Rating	Definitions
8-10	Intolerable
7	High
6	Significant Risk
5	Moderate Risk
2-4	Low Risk

APPENDIX B: CATCHMENT MODELLING DETAILS

Model Background

Source Catchments was used to define the catchment derived flows of water and associated loads of diffuse pollutants entering Pumicestone Passage. This modelling framework is developed and promoted by the eWater CRC, a federally funded Cooperative Research Centre combining Australia's pre-eminent research organisations, State Government water regulators and industry practitioners. The model's 'pedigree' stretches back some 10 years, being based on the original Environmental Management Support System (or EMSS) developed in the early part of this decade for the SEQ Healthy Waterways Partnership (HWP) to define diffuse loads to Moreton Bay and other South East Queensland (SEQ) waterways.

Model Data Sets and Model Configuration

The ***Source Catchments*** model developed for and applied by this project has been built upon many years of previous investigation in the Pumicestone Passage catchment and further afield in SEQ by BMT WBM staff and other local researchers. Of key significance in this regard are many of the data sets used to build the model itself. These data sets are introduced and described below.

Topography

Topography (land form, elevation, etc) is a key driver of how water washes from the Pumicestone Passage catchment. BMT WBM has been working for many years on developing the best possible Digital Elevation Model (DEM) of the SEQ region in our role as a key service provider to the HWP. This DEM has seen us obtain, review and combine many disparate date sources for the region.

Land Use

Land use is also an important data requirement of a ***Source Catchments*** model as it is a driver of diffuse loads predictions. In the case of the model developed for this project, we were able to access the most recent (2006) regional land use mapping data for the Pumicestone Passage catchment from DERM. The DERM data were then classified by functional units for the purpose of catchment modelling for efficiency as similar land use designations will have similar hydrologic and pollutant export characteristics. A summary of the total areas per functional unit is provided in the table below.

2006 Functional Unit Areas

Functional Unit	Area (ha)	% of Total Catchment
Broadacre Agriculture	903	1.32%
Dense Urban	431	0.63%
Grazing	5,225	7.66%
Green Space	48,259	70.72%
Intensive Agriculture	5,955	8.73%
Rural Residential	1,872	2.74%
Urban	2,658	3.89%
Water	2,941	4.31%
Total	**68,244**	

Rainfall

Rainfall data are also fundamental to the development and running of a ***Source Catchments*** model. In the case of this study, we have had access to (and adopted for use) daily synoptic rainfall data sets across the entire catchment of Pumicestone Passage as provided via the DERM SILO database. These data encompassed the period from 1980 to 2009.

Evapotranspiration

Evapotranspiration data are also crucial to accurately simulating the water balance/hydrology of a catchment. In the case of our modelling of the Pumicestone Passage catchment, we were able to apply long term potential evapotranspiration (PET) data sets produced by the Bureau of Meteorology.

Soils

Soil data for the Pumicestone Passage catchment are available and could have been expected to be required for this model study. However, in the case of the development of the Pumicestone Passage ***Source Catchments*** model, such data were not directly required as the influences of soils on rainfall-runoff processes were implicitly included via the model hydrologic calibration. Similarly, the influence of soils on the pollutant concentration of stormwater runoff was also implicitly included via the model pollutant washoff/generation model formulation and calibration.

Model Configuration

The various data sets described above were collated, reviewed and quality assured before being used for an initial 'build' of a prototype ***Source Catchments*** model. This model was tested for suitability and several modifications made to enhance its functionality.

Model Calibration and Validation

The Pumicestone Passage ***Source Catchments*** model was constructed using relevant model coefficients which were calibrated/validated by other substantial studies conducted in the SEQ region over recent years, and in particular over the last 12 months by BMT WBM. These studies focussed primarily on calibration of the hydrologic (i.e. rainfall-runoff) and water quality (i.e. pollutant export) elements of the model. A summary of the works conducted in this regard and examples of relevant investigation results within (and adjacent to) the catchment of Pumicestone Passage is provided below.

Hydrologic Calibration

In association with regional modelling work being conducted by BMT WBM, a major hydrologic recalibration exercise of the rainfall-runoff elements of ***Source Catchments*** has recently been undertaken. This exercise involved comprehensive model parameter optimisation assessments using highly sophisticated multiple scenario simulation software. Essentially, this resulted in many thousands of model scenarios (automatically generated using various model parameter sets generated using random seeding techniques) for models forced using the rainfall and evaporation data identified above until the optimal calibration result was obtained with reference to gauged daily stream flow records. These records, collected by DERM, extended over many years, thereby encompassing wet, dry and average rainfall conditions. We provide the following summary of salient assessment results.

For the comprehensive SEQ model and this study, the hydrologic run-off model used to simulate catchment flows was SimHyd which is a conceptual rainfall-runoff model within ***Source Catchments*** that simulates daily runoff, including baseflow, using daily precipitation and PET data.

Some manual adjustment was performed to the SimHyd coefficients for the catchments encompassing the Caloundra South project area in order to simulate correct runoff volumes associated with those catchments. Typical rainfall-runoff coefficients (ratio of total runoff to total rainfall) from the Caloundra South event based water quality monitoring program conducted by BMT WBM on behalf of Stockland were approximately 0.4, which are relatively high and are possibly due to elevated groundwater levels. As such, the hydrologic parameters of the Caloundra South catchments were modified to reflect the site conditions. Because most of the area within the Caloundra South site is classified as green space, the modifications to hydrologic parameters were made to green space for the Caloundra South sites. These SimHyd parameters are presented in the table below.

Caloundra South SimHyd Parameters

SimHyd Parameter	Value
Baseflow Coefficient	0.1
Impervious Threshold	1.0
Infiltration Coefficient	65
Infiltration Shape	1.50
Interflow Coefficient	0.75
Pervious Fraction	0.992
Rainfall Interception Storage Capacity	0.6
Recharge Coefficient	5.0
Soil Moisture Storage Capacity	120

Pollutant Export Calibration

Again in association with regional modelling investigations being conducted by BMT WBM, in this case on behalf of the eWater CRC, a major review has been completed of event based pollutant load monitoring data collected in recent years in SEQ. This event monitoring data collection program has been specifically targeted at obtaining highly relevant water quality data during significant runoff events from a range of land uses and catchments across the region, and has extended now over a two-year period. In total, some 73 storm events have been sampled, providing one of the most comprehensive, synoptic multi-land use data collection studies in Australia. Key participants in this data collection study, which was championed and coordinated by the HWP and DERM personnel, included DERM, SEQ Water, Local Governments and community based organisations in the region.

The ultimate product of this investigation, which (like the hydrologic calibration) is a regionally specific and relevant set of pollutant export coefficients for SEQ. The following summary is provided of the results of this investigation as they related to the catchment of Pumicestone Passage. The pollutant load values in ***Source Catchments*** are modelled as event mean concentrations (EMC) and dry weather concentrations (DWC) which characterise concentrations for storm events and inter-event, or ambient, conditions respectively.

The values used for EMCs in this study constitute the optimised values estimated from the eWater CRC study. Those values are provided in the table below. Urban values were applied to urban, dense urban and rural residential functional units because the eWater CRC study did not include analysis of dense urban and rural residential functional units, and this was deemed an appropriate surrogate for these functional units.

Also included in the table below are dry weather concentrations (DWC) which are consistent with values adopted previously for the area. In some instances, due to collating data sources together, some DWCs were greater than EMCs. In those instances, EMC values were assigned to the DWC. Pollutant export loads for chlorophyll *a* and salinity were set to 0.

General EMC/DWC values

Functional Unit	EMC (mg/L)			DWC (mg/L)		
	TSS	TN	TP	TSS	TN	TP
Broadacre Agriculture	281	2.300	0.318	5	0.50	0.015
Grazing	265	2.612	0.259	5	0.83	0.050
Green Space	22	0.725	0.018	3	0.50	0.015
Intensive Agriculture	1032	2.555	0.480	10	0.50	0.015
Urban*	817	0.826	0.953	7	0.83	0.050

* Applied to Urban, Dense Urban, and Rural Residential

Also of direct relevance to these investigations are the findings of a two (2) year baseline data collection monitoring program conducted on the Caloundra South site by BMT WBM on behalf of Stockland. The results of this program have also been used to inform the modelling work conducted using ***Source Catchments***. The monitoring program provided both EMC and DWC values used in the catchment modelling for the catchments that correspond to the Caloundra South site. Those EMC/DWC values are specified in the table below. Because the majority of the Caloundra South site within the catchment model is classified as green space, the EMC/DWC values will only be applied to the green space. The remainder of the DWC values were taken from and are reported in the table below.

Caloundra South Monitoring Program EMC/DWCs for Green Space

Subcatchment	EMC (mg/L)			DWC (mg/L)		
	TSS	TN	TP	TSS	TN	TP
SC #3 (Site 1)	29.3	1.25	0.08	15.0	1.10	0.07
SC #5 (Site 2)	11.4	0.80	0.03	8.0	0.80	0.03
SC #6 (Site 3)	9.5	1.04	0.04	8.0	0.92	0.03
SC #4 (sites 2 and 3)	11.0	0.85	0.03	8.0	0.85	0.03

<u>Model Application</u>

The ***Source Catchments*** model as described above has been used to quantify the large scale/whole of catchment flows and loads of pollutants entering Pumicestone Passage. These loads will be crucial in driving and influencing water quality levels in Pumicestone Passage. The model was executed as existing conditions then modified to reflect the effects of the Caloundra South development under a range of scenarios, including a cumulative impact assessment using future land use data.

APPENDIX C: RECEIVING WATER QUALITY MODELLING DETAILS

Model Background

The Receiving Water Quality Model (***RWQM***) Version 2 (***V2***) model has been developed, calibrated, validated and applied on numerous occasions by BMT WBM on behalf of the HWP and other key SEQ stakeholders, including an assessment of water quality within Pumicestone Passage (WBM 2005). It is a two-dimensional, depth averaged model which is based on heritage code from the Resource Management Associates (RMA) finite element model, originally developed by Professor Ian King. In development of ***RWQM V2***, significant enhancements to the water quality algorithms were undertaken by scientists at the HWP and what was then the Queensland EPA. The model has a strong track record and pedigree of application in the region.

In this application, BMT WBM has excised from larger scale (regional) modelling the relevant sections of models which encompass Pumicestone Passage. Of interest, this particular portion of the model was developed and initially calibrated by BMT WBM for the HWP in 2005 as a stand-alone model before being incorporated, with some refinements, into a regional model. In this study, the Pumicestone Passage model was re-excised from the full 2005 model, and temporal and spatial boundary conditions extended to cover periods since 2005. It was then recalibrated and subsequently used for impact assessments of various potential development scenarios in the Caloundra South landholding. These works are detailed below.

It is noted that the excised model of Pumicestone Passage was adopted in this study due to constraints placed on the study by model run times. In particular, it was found that, even with the fastest computers available, executing the full RWQM2 domain over multiannual periods was not tractable (given the number of scenarios and calibration runs), and as such the excised model was adopted.

Model Data Sets and Model Configuration

Bathymetry

Pumicestone Passage is a relatively shallow, estuarine body of water with extensive mangrove areas which wet and dry each tidal cycle. BMT WBM is constantly updating a Digital Elevation Model (DEM) of all marine and estuarine waterways in SEQ as new data comes to hand as this DEM is regularly used in many of our modelling activities. For the Pumicestone Passage modelling conducted for Stockland, we have configured the ***RWQM V2*** model with the most recent bathymetry.

Boundary Conditions

The Pumicestone Passage ***RWQM V2*** model is forced by boundary conditions in Deception Bay to the south and offshore from Caloundra to the north. Relevant tidal boundaries for these locations have been extracted from regional modelling studies and also validated against Queensland Department of Transport (DOT) tide tables. Specifically, the full ***RWQM V2*** model was interrogated at the boundary locations of the excised and updated Pumicestone Passage model to provide tidal water level conditions for the excised model. These original model tidal conditions were used to generate tidal cycles over a 13-month lunar year which consists of approximately 383 days. This lunar year was replicated and appended in sequence through 2010 to obtain tidal conditions for each calendar year from 2006 to 2010.

Catchment Inflows

Results from the ***Source Catchments*** model of the Pumicestone Passage catchment described earlier in this report were extracted and used to define catchment inflows to the model due to catchment runoff and associated diffuse source pollutant loads.

Meteorological Forcing

Relevant meteorological (e.g. wind speed and direction) and other salient atmospheric (e.g. solar radiation) forcing data are required for ***RWQM V2*** execution. These data were obtained from BOM Meso-LAPS modelling simulation results available to BMT WBM from other studies we are currently conducting in SEQ. Meso-LAPS is a fine scale version of the BOM Limited Area Prediction System (LAPS) software.

Initial Conditions

Initial conditions, specifically related to start-up of the water quality model, were established by initialising the model with constant average EHMP values across the model and executing the model for a warm up period of three months prior to the model starting period (i.e. commencement of results interrogation).

Model Calibration and Validation

Hydraulic Calibration and Validation

The excised model has previously been calibrated to Acoustic Doppler Current Profiler (ADCP) data collected over a tidal cycle at several locations along Pumicestone Passage. This exercise was not repeated here as the model used in this study was the same as that original model in all hydrodynamic respects. Notwithstanding this, some comparisons of tidal water elevation along Pumicestone Passage were undertaken to ensure model consistency.

Water Quality Calibration and Validation

The model was calibrated to a period of significant 'wet' conditions (this period being 1/7/2007 to 30/6/2008) and validated to a period of predominantly 'dry' conditions (this period being 1/7/2006 to 30/6/2007). This approach was adopted as it lends considerable support to the coupled catchment-receiving water quality model system in its ability to reliably simulate a suitable range of seasonal and climatic conditions within Pumicestone Passage.

Calibration entailed comparison of model predictions with monthly EHMP data, with commensurate adjustments to relevant water quality model process coefficients until suitable model results were obtained. Key literature was used to inform any model coefficient modifications. For the validation assessments, these model process coefficients were kept constant and only boundary/inflow conditions were changed to suit the different temporal setting.

Discussion

As much as was practical in establishing this model calibration, water quality parameters set in the previous study were maintained with only minor adjustment for a few constituents. The following items with respect to this calibration are noted:

- The original model calibration was over a dry period (i.e. the year 2000 – the same year as used in the original (then) Queensland EPA calibration), so this study represents the first attempt to apply the excised Pumicestone Passage model over a wet period. This is justification for the required parameter adjustments undertaken here (in addition to that required due to the more extensive EHMP data available and the modified influence of the upgraded catchment model used here compared to that used earlier).
- The calibration and validation results show the model is accurately capturing the effects of catchment inflows, tidal flushing and subsequent salt recovery within Pumicestone Passage. This is a direct validation of the advection-dispersion characteristics of the model, of which the correct representation is essential in an assessments-style analysis such as the current study. In some locations especially in northern reaches of the estuary, modelled salinities appear to be lower than the target EHMP data, however, this is expected because the ***RWQM V2*** does not simulate evaporation, which may be creating higher salinities during the summer periods in shallower waters.
- Turbidity timeseries predict results associated with storm events that are not necessarily captured in the EHMP data – such rainfall related increases are a direct consequent of the ***Source Catchments*** predictions. The general behaviour of turbidity, however, is adequately captured by the model.
- The model accurately predicts the seasonality and summer period growth of algae within Pumicestone Passage. In some areas there are slight under-predictions of chlorophyll *a* concentrations during the dry season, however the model demonstrates the seasonal pattern and magnitude of algae growth appropriately. This result is deemed satisfactory.
- Pumicestone Passage is characterised by a shallow northern channel and deeper southern channel. The calibration results show that the model captures the influence of these north/south entrances well in that the estuary is highly influenced by catchment inflows in the mid to northern reaches and more influenced by the ocean boundary in the southern channel.
- Finally, the calibration and validation of the excised model is deemed satisfactory for the purposes of this study. In general, satisfactory agreement between the recorded EHMP data and the model results was achieved both for the calibration (wet) and the validation (dry) periods, to an extent appropriate for the purposes of this study.

<u>Model Application</u>

Model Study Period

In order to capture the effects of both wet and dry conditions for an assessment analysis, the model was executed for a period of approximately 4 years, beginning on 1/7/2006 and ending on 31/5/2010. This results in almost 4 years of continuously modelled flows, pollutant loads and water quality within the estuary.

Modelled Constituents

Based on associated performance objectives, the relevant water quality constituents considered for impact analysis were:

- Total nitrogen;
- Total phosphorus;
- Total suspended solids;
- Chlorophyll *a*; and
- Salinity.

Dissolved oxygen, although simulated and included as a secondary constituent in the validation process, has not been included in this impact analysis. It is possible to do so in future.

Modelled Conditions

Various modelled scenarios include an existing condition (or basecase) scenario that establishes the conditions against which subsequent scenarios are compared were assessed using the model.

APPENDIX D: STORMWATER QUALITY MODELLING DETAILS

Model Background

MUSIC has been used in this study to define how various levels of stormwater quality management intervention, specifically via the application of water sensitive urban design (WSUD) techniques, can affect the flows and loads of stormwater borne pollutants from the Caloundra South site, following development. The ***MUSIC*** modelling investigations were informed by ***Urban Developer*** modelling (see Appendix E) and were subsequently used to inform how loads from the ***Source Catchments*** modelling of the urban portions of the Caloundra South site needed to be modified in order to reproduce the influence of WSUD interventions.

Modelling Methodology

Preamble

A representative 270 ha portion of the site was selected to assess stormwater management issues. This portion of the development area is referred to as ‘Area MP1’.

Area MP1 will primarily include a mix of residential lots, industrial areas, a school, retirement village and parkland – within an area of 270 ha.

Software

The *MUSIC* software (Version 4) of the eWater CRC has been used in these assessments.

Source Nodes

Within *MUSIC*, the user is required to specify source nodes. The source nodes represent the pollutant generating areas of the site.

Rainfall-runoff and pollutant export characteristics for the existing (pre developed) site were developed based on the data collected by BMT WBM’s previously described baseline monitoring program at the Caloundra South site.

Rainfall-runoff and pollutant export characteristics as given by Water by Design’s (2010) “MUSIC Modelling Guidelines” were applied for the ‘developed’ land usage scenarios. The Water by Design (2010) *MUSIC* properties for the ‘industrial’ land usage classification were used to describe the industrial areas, whilst the properties for the ‘residential’ classification were used for all other areas within the site.

For the developed land use scenario, the site was discretised into lot, road reserve and parkland – with the lot areas further discretised into roof areas (draining to a rainwater tank and/ or directly to drainage) and ‘ground level’ (i.e., ‘non-roof’) areas (in accordance with Water by Design (2010)).

For the purposes of this study, the site was not separated into individual sub-catchments.

Meteorological Data

Modelling was performed for a period of ten years (from 1st January 1997 to 31st December 2006), using recorded pluvio data from the Caloundra Water Treatment Plant (Station 40496) and monthly areal Potential Evapotranspiration.

Modelled Conditions

Various modelled scenarios include an existing condition (or basecase) scenario that establishes the conditions against which subsequent scenarios are compared were assessed using the model.

APPENDIX E: WATER BALANCE MODELLING DETAILS

Model Background

Urban Developer is a modelling tool developed by the eWater CRC. Its primary focus is on enabling rigorous and robust analyses of Integrated Water Cycle Management (IWCM) processes, specifically focussing on assessments of how advanced water sustainability initiatives such as rainwater tanks, greywater reuse, third pipe systems and demand management can influence urban water processes.

The primary reasons ***Urban Developer*** was applied in relation to Caloundra South are as follows:

- To understand how IWCM processes can deliver desired SCRC water cycle performance objectives.
- To understand how rainwater capture and reuse initiatives will operate based on the local climatic regime and most importantly to enable this understanding to then be used in forcing the associated ***MUSIC*** urban stormwater quantity/quality modelling (i.e. rainwater capture and reuse will significantly reduce the quantity of urban stormwater, this will then enable WSUD infrastructure on the site to perform much more efficiently).

Model Data Sets and Model Configuration

Lot Layout

The primary focus of ***Urban Developer*** in this project has been to understand how IWCM actions will affect water cycle management at the lot scale. The model has the capability to simulate IWCM processes also at up to the suburb scale, however in this case such functionality has not been required. As such, we have focussed on IWCM simulations of a 'typical' lot, with such a lot having the following relevant characteristics:

- Lot area 400 $m^{2;}$
- Roof area 200 $m^{2;}$
- 3 residents; and
- Varying IWCM configurations.

Water Consumption

With Caloundra South being a greenfield site, there are no available water consumption data with which to test/calibrate ***Urban Developer***. As such, the approach we have taken has been as follows:

- Develop a base model configured around 'pre-millennium drought' water consumption behaviour. That is, typical water consumptions pre drought were of the order of 300 L/c/day and the intent is for the model to reproduce this rate.
- Develop a 'post drought' demand model which simulates demand management and outdoor water use behavioural changes following the 'millennium drought'.
- Undertake a range of IWCM simulations to enable identification of how water usage/discharge patterns are likely to change. The obvious intention here is to see compliance with the desired SCRC objectives of 80% reductions in potable water supply and wastewater discharge.

Rainfall

All modelling assessments have been conducted using a 10-year duration (1978-1986), 6-minute time step, rainfall series derived for the site. Relevant statistics describing this rainfall series are provided in the table below.

Rainfall Statistics – *Urban Developer* Modelling

Parameter	Value
Average Annual Rainfall	1327 mm
Maximum Annual Rainfall	2090 mm
Minimum Annual Rainfall	969 mm

Potential Evaporation

Relevant average monthly evaporation data were sourced and used to inform/force the model.

Temperature

Relevant daily temperature data were sourced and used to inform/force the model.

<u>Model Calibration and Validation</u>

It was not possible to rigorously calibrate and validate the model as Caloundra South is a greenfield site and no locally specific water usage data were available. Rather, the following approach was adopted:

- The model was 'calibrated' by being set up, using the data described above, to reproduce 'pre-millennium drought' water use conditions. This calibration essentially relates to the model demand nodes, as those other elements of the model are essentially parameterised, and require no real calibration. The following relevant South-East Queensland, pre-drought, water use statistics were adopted:
  - Typical internal water uses in South East Queensland were of the order of 150-200 L/c/day;
  - Typical external water uses in South East Queensland were of the order of 40% of total use; and
  - Hence, total usage of water was of the order of 260-310 L/c/day.

  Urban Developer was run with default internal water uses, with no demand management modifications in place and with external water uses turned off. The resultant average internal water usage/mains demand was subsequently predicted to be 169 L/c/day, which compares favourably with the aforementioned 150-200 L/c/day range, especially as these values will reflect the additional effect of system losses, leakage, etc, whereas the ***Urban Developer*** predictions are at the lot scale and do not include such additional flows.

Urban Developer was subsequently run with relevant external water uses such that the total water consumption was equivalent to the 260-310 L/c/day range cited above, with an actual modelled value of 294 L/c/day being achieved.

- Model 'validation' was undertaken by attempting to reproduce the post-millenium drought water use paradigm, where internal water appliances are more efficient and patterns of external water demands have significantly changed (reduced). Specifically, the changes made to the ***Urban Developer*** demand model were to improve internal water use by changing key appliances as follows, together with halving external water demands.
  - Shower: 'standard' to 'A' rating;
  - Washing machine: 'top loader' to 'front loader'; and
  - Toilet: single flush to dual flush (11/6 litre).

  By making these changes, the ***Urban Developer*** model simulated per capita water demands of 188 L/c/day, which is acceptably close to the desired Queensland Water Commission (QWC) "no restriction" water use target of 200 L/c/day, especially given the small lot size of the modelled allotment. Of this 188 L/c/day, on average 67% was used internally and 33% externally.

Model Application

The Caloundra South ***Urban Developer*** model was subsequently applied to simulate various IWCM cases, of progressively greater complexity and water saving/reuse potential.

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