SouthmetroConnect

Baseline water and sediment quality

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Appendix I

Baseline water and sediment quality

South Metro Connect

Main Roads Western Australia

13 May

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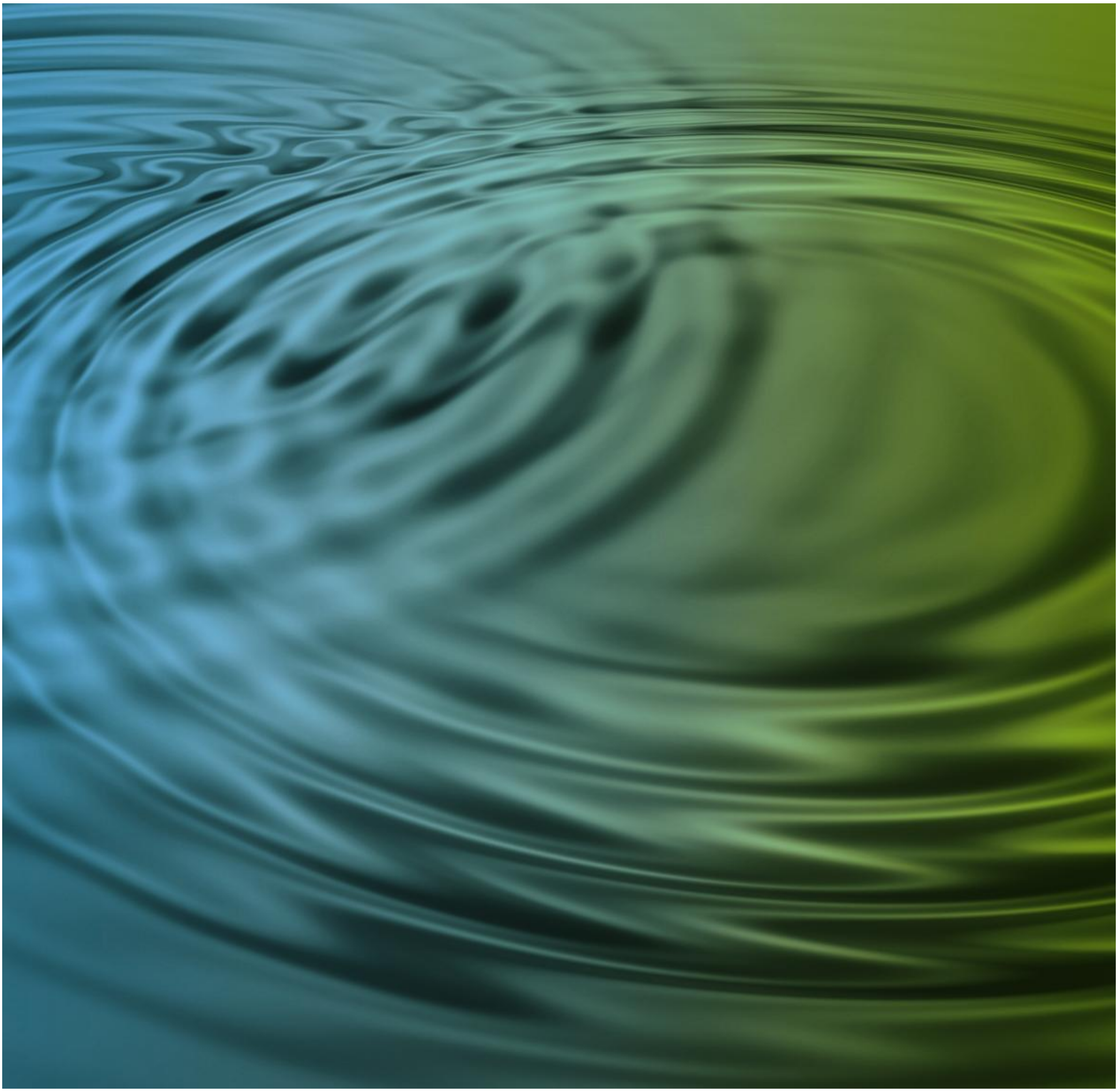
Roe Highway Extension Baseline Water and Sediment Quality



Roe Highway Extension Baseline Water and Sediment Quality

Prepared for

Main Roads Western Australia

Prepared by

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Reviewed by Troy Collie

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Acronyms

AA	Advanced Analytical Pty Ltd
AHD	Australian Height Datum
ANZECC/ARMCANZ	Australian and New Zealand Environmental and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand
ATSDR	Agency for Toxic Substances and Disease Registry
BOD	Biological Oxygen Demand
BoM	Bureau of Meteorology
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CCW	Conservation Category Wetland
DEC	Western Australian Department of Environment and Conservation
DEWHA	Department of the Environment, Water, Heritage and the Arts
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved Oxygen
DoW	Department of Water
EC	Electrical Conductivity
EIL	Ecological Investigation Level
EPA	Western Australian Environmental Protection Authority
ISQG	Interim Sediment Quality Guideline
Lakes EPP	Environmental Protection (Swan Coastal Plain Lakes) Policy 1992
LCS	Laboratory Control Samples
LOR	Limit of Reporting
MRWA	Main Roads Western Australia
NATA	National Association of Testing Authorities
NOx	Nitrogen oxide (Nitrite and Nitrate)
PAH	Polycyclic Aromatic Hydrocarbons
REW	Resource Enhancement Wetland
RPD	Relative Percent Difference
TDS	Total Dissolved Salts
TN	Total Nitrogen
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbon
TP	Total Phosphorus
TSS	Total Suspended Solids
UFI	Unique Feature Identifier
USEPA	United States Environmental Protection Agency
YSI	Yellow Springs Instrument

Executive Summary

The wetlands in the project area belong to the Eastern Chain of Beeliar Wetlands within the Swan Coastal Plain. The values and qualities of wetlands are protected by a variety of Commonwealth and State legislation and policies. The geomorphology and stratigraphy studies have identified differences in the sedimentary fill underlying the wetlands, which influences water movement, infiltration and water quality. This report provides water and sediment quality information collected from Bibra Lake, North Lake and surrounding sumplands situated in the Beeliar Regional Park.

The purpose of this report is to provide background information on the water and sediment quality of the wetlands as part of a required environmental investigation for the proposed construction of the Roe Highway Extension. The proposed extension is aligned between Bibra Lake and North Lake, increasing the impervious surface area, which may result in increased stormwater runoff. Runoff may increase pollutants in the wetland catchment. The baseline information collected from this study has been used to provide information on the existing condition of the wetlands, the types of contaminants that occur in the proposed road alignment and how best to manage any future contaminants potentially entering the system.

Water and sediment samples were collected and analysed for general constituents, nutrients, elements, hydrocarbons, organics and biological components. The areas sampled for water and sediment quality include:

- Stormwater outlets within the wetland surface catchments;
- North and Bibra Lakes, Roe Swamp and Horse Paddock Swamp for water (when present) and sediment; and
- Groundwater quality from bores in the area.

Sampling was conducted over the period November 2009 to September 2010. Each of the sampling components was carried out using recognised methodology and analysis. Unfortunately, winter 2010 was very dry (the driest on record) and most of the wetlands had little or no water in them by September. This reduced the number of stormwater sampling events and limited groundwater recharge.

The results from the study are presented in four sections:

- Bibra Lake water and sediment quality;
- North Lake water and sediment quality;
- Roe Swamp, Lower Swamp, Horse Paddock Swamp and surrounding sumplands sediment quality; and
- Groundwater quality in the catchment.

Bibra Lake Water and Sediment Quality

Surface water levels in Bibra Lake fluctuate seasonally, with some parts of the lake drying out in summer and refilling in winter. During summer, the northern and southern parts of Bibra Lake dry out, leaving a water pocket on the western side of the lake. The water quality appeared to be in better condition during winter (August 2010) and spring months (November 2009) than the summer months (February 2010). During February 2010, elevated pH levels, dissolved salt (measured as electrical conductivity) and dissolved oxygen concentrations were recorded in the water column. These conditions, supported by elevated chlorophyll *a* concentrations, indicated that an algal bloom was present.

The study found aluminium, arsenic, chromium, copper, lead, zinc and total petroleum hydrocarbon (TPH) in elevated concentrations in the water column, predominantly at the western side of Bibra Lake. Stormwater drains at the western side of the lake discharge runoff containing elevated elements and comparatively higher TPH concentrations than the other drains. These drains are likely to be the source of poor water quality in this area. The presences of elements and TPH in the stormwater runoff is typical in urban drains, primarily due to the influence of vehicle traffic in this area. Urban and agricultural activities (fertiliser and pesticide application) may also contribute to the pollutants, such as zinc, in the stormwater runoff.

Bibra Lake water column nutrient concentrations were elevated above guideline levels and were highest during summer months (February 2010). Stormwater runoff is one of the nutrient sources for the lake, along with groundwater and sediment recycling. Nutrients stored in the lake sediment are released to the water column by the wetting and drying cycle of the lake and the aerobic and anaerobic processes in the sediment and water column.

Sediments in the Bibra Lake area were found to be high in naturally-occurring aluminium and iron. Lead was the only element detected at concentrations exceeding guideline levels (this was from sediment at one site on the north-eastern side of the lake). Elements in the sediment may originate from runoff and settle into the lake bed, releasing back into the water column under certain conditions (e.g. acidic water condition).

North Lake Water and Sediment Quality

North Lake undergoes an annual wet and dry cycle. Water levels in North Lake were very low throughout the monitoring period with the lake drying out in February 2010. The lake water pH was neutral to slightly alkaline in November 2009 and slightly acidic in August 2010. This fluctuation in pH levels was also recorded in the dissolved salt and dissolved oxygen concentrations, which were higher in August 2010. Elevated concentrations of iron were recorded during the monitoring of the North Lake water column in August 2010. The acidic water conditions may have resulted in the iron bound in the sediment being released into the water column. North Lake water quality deteriorates seasonally and may be attributed to the acidic water conditions.

Similar to Bibra Lake, North Lake receives inputs of pollutants from stormwater runoff. The presence of lead and traces of TPH in the water column is associated with vehicle traffic. In addition, galvanised gutters and downpipes from adjacent residential areas may be a source of zinc into the lake. The lake sediments accumulate elements, hydrocarbons, nutrients and other contaminants. These pollutants are released into the water column under acidic water conditions where they may impact aquatic biota in the lake.

Roe Swamp, Lower Swamp, Horse Paddock Swamp and Surrounding Sumplands Sediment Quality

These areas of the wetlands were dry throughout the monitoring period and only sediment samples were collected. The sediment had high concentrations of copper, lead and nickel, and detectable levels of polycyclic aromatic hydrocarbons (PAH) and TPH at Roe Swamp and Horse Paddock Swamp. These sites are adjacent to the road and may receive pollutants from road runoff. Traces of dichlorodiphenyldichloroethylene(DDE) and trans-chlordane, both organochlorine pesticides, were found in the sediment. Australia discontinued the use of DDE in 1987 and trans-chlordane in 1997. However, since they are persistent in the environment for many years, traces found in the sediment indicate historical usage in the catchment.

Groundwater Quality

For the purpose of describing the hydrological feature of the groundwater, the study area is divided into three zones: the “delivery zone” to the east, which corresponds to the Bassendean Sand; the “wetland functional zone” in the centre, which corresponds to the belt containing the chain of wetlands; and the “impoundment zone” to the west, which corresponds to the material underlying the Spearwood Dunes. The general groundwater flow is from east (Jandakot Mound) to the west (coastal area).

As the groundwater flows from the delivery zone to the impoundment zone, the dissolved salt concentration gradually increases. The source waters that enter the wetlands area are generally low in salt content. As the groundwater flows through the soil layers, it also transports minerals contained in the soil. This pattern was also observed in the groundwater pH levels. In the water source or delivery zone, pH varied from slightly acidic to close to neutral. In the wetland zone, pH was approximately 7, but varied over time. At the impoundment zone, groundwater pH was slightly alkaline.

Aluminium is present in an elevated concentration in the groundwater, which is probably due to natural occurrence in the sediment in the area. Lead in the groundwater was mainly detected at sites close to the road, associated with road runoff. Arsenic was present in low concentrations in the groundwater and may be due to adsorption by hydrous iron oxide. Stormwater runoff from the urban catchment that leaches into the groundwater is likely to be the source of other pollutants such as chromium, zinc and TPH. Traces of pirimiphos-methyl was detected at one of the groundwater sites.

Groundwater provides Bibra Lake and North Lake with nutrients. Nitrogen, in the form of nitrate, is readily transported to the lakes via groundwater inflow. Phosphorus, in contrast, is adsorbed to the sediment and is less mobile in the groundwater. However, due to the limited adsorption capacity of Bassendean Sand, phosphorus is released to the water column under low oxygen and high pH conditions. High nutrient levels in the groundwater may be due to septic tank leakage, landfill leachates, industrial waste discharges or fertiliser and pesticide use.

A concurrent investigation indicates acid sulphate soil is present in the sediments located within the study area. Acid sulphate soil may affect the groundwater constituents within localised parts of Bibra Lake and North Lake by making so elements more soluble and potentially more toxic to aquatic life.

Conclusion

The project area and surrounds have been modified from a landscape dominated by agriculture, vegetated surfaces and other undeveloped areas in the mid-1970s to the mainly residential developments prevalent today. As a result of past and current land use practices, the wetlands and surrounding vegetated areas are not pristine. Dissolved elements, hydrocarbons and nutrients were recorded in the groundwater, stormwater, surface water and sediment within the project area at concentrations indicative of anthropogenic effects. Algal blooms were recorded in the lakes during the monitoring period and previous studies have frequently reported blooms dominating large areas of North and Bibra Lakes.

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1.0 Introduction

In August 2009, Main Roads Western Australia (MRWA) and AECOM formed the South Metro Connect alliance. The team was created for the development phase of the Roe Highway Extension project. Its primary objective is to work collaboratively with specialist consultants, stakeholders and regulatory authorities to develop an environmentally, socially and economically acceptable project design, in order to obtain relevant statutory approvals.

The highway was designed to connect Fremantle Port with the major industrial areas, as well as major transport corridors. Since the early planning and inclusion of Roe Highway into the Metropolitan Region Scheme, seven sections of the highway have been completed, culminating in 2006 with connection to the Kwinana Freeway north of Berrigan Drive. The State Government has committed to completing a further section of the highway between Kwinana Freeway in Jandakot and Stock Road in Coolbellup.

The project area is situated within the City of Cockburn and is aligned to run east-west between North Lake and Bibra Lake. The State Government recognises the environmental value in the vicinity of the proposed project and the project will strive for the highest environmental outcome.

The extension of Roe Highway will increase the impervious surface within the project footprint; the additional network of roads and footpaths may increase the flow of stormwater runoff (Department of Water (DoW) 2007). Pollutants such as elements, nutrients, and petroleum hydrocarbons are usually deposited on impervious road surfaces (Brabec *et al.* 2000). Stormwater includes rainwater and anything collected by the water on these surfaces. The water then flows into pipes and drains carrying all the collected contaminants into the receiving water (DoW 2007). Increases in impervious surface area and rainfall therefore increase stormwater volume and velocities, and may result in increased pollutants entering a catchment. In order to asses and manage the impact of this increase, it is necessary to have baseline information about the receiving water prior to any development.

This report presents and discusses: baseline lake and wetland surface water results from three water sampling events (November 2009, February 2010 and August 2010); lake and wetland stormwater sampling undertaken between April and August 2010; lake and wetland sediment sampling undertaken in April and May 2010; and lake and wetland groundwater sampling results taken from May 2010 to September 2010.

1.1 Requirement of the Environmental Scoping Document

The project Environmental Scoping Document indicated the necessity for the study and investigation of water quality, and proposed the following:

- Collection of baseline data to determine the current water quality of the wetlands, as well as the acceptable limits of change that may arise from the construction and operation of the proposed project;
- Provision of a baseline against which to assess construction effectiveness;
- Establishment of existing oxygen conditions in nearby surface waters, as part of the baseline;
- Provision of a baseline for checking the effectiveness of infrastructure design solutions and operating conditions; and
- Assessment of performance and compliance.

Surface water quality sampling was undertaken in November 2009, February 2010 and August 2010. Stormwater quality sampling was undertaken on seven occasions during the rainy season from April 2010 to August 2010. Sediment quality sampling was undertaken in April 2010 and May 2010. Groundwater bores were sampled monthly from May 2010 to September 2010. Water and sediment samples were analysed for general constituents, nutrients, elements, hydrocarbons, organics and biological components. Depths at which surface water samples were collected were determined by profiling the water column. Areas sampled include:

- Stormwater outlets;
- North and Bibra Lakes, Roe Swamp and Horse Paddock Swamp containing ponded surface waters;
- Lake and wetland bed sediments for pollutant content; and
- Groundwater quality in bores.

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2.0 Existing Environment

2.1 Background

The Swan Coastal Plain climate is dominated by a hot, dry summer with a mild, wet winter. The majority of rain occurs between April and October. All other months are generally hot and dry resulting in high evaporative losses from wetlands (Burkett 2005). The long-term annual average rainfall from 1876 to 2000 for Perth is approximately 870 mm and the pan evaporation is approximately 1800 mm; however, since 1976, there has been a reduction in annual average rainfall to 790 mm (Burkett 2005).

The surface and ground water resources are an integral component of the Beeliar wetland system. The Beeliar Lakes are located in the superficial aquifer on the Swan Coastal Plain, where the Bassendean Sands meet the Tamala Limestone. Bassendean Sands have a low clay fraction and poor bacterial adsorption properties, while Tamala Limestone is very porous. Groundwater is likely to be one of the dominant water sources for the lakes. Burkett (2005) reported that phosphorus and nitrates have contaminated the groundwater of the superficial aquifers, as a result of nutrient loadings from septic tanks, intense horticultural activities and industrial waste in the catchment.

The quality and levels of standing water in lakes and wetlands are influenced by interactions between ground and surface waters. The nature and extent of those interaction are described by Syrinx/VCSRG (2010). Water levels within Bibra and North Lakes and associated wetlands are generally an expression of groundwater from the Jandakot Mound (the smaller of the two main shallow unconfined groundwater resources near Perth) and other localised surface inflows. The maximum elevation of the Mound is located approximately 6 km east-south-east of Bibra Lake. The wetlands occur where the ground level is lower than the level of the groundwater (Syrinx/VCSRG 2010).

Surface water within the wetland system is also a result of rainfall runoff via natural overland flow paths. These surface waters are affected by processes of evaporation, evapo-transpiration and recharge to groundwater. Purpose-built stormwater treatment devices do not appear to be present for outlets draining to Bibra Lake. For inflows to North Lake, stormwater appears to be treated only by mesh screening to trap larger debris. Discussions with the DoW, MRWA and the Department of Environment and Conservation (DEC) have identified that none of these organisations monitor the stormwater quality within the project area. When it is generated within the study area, stormwater discharges directly into the lakes and wetlands.

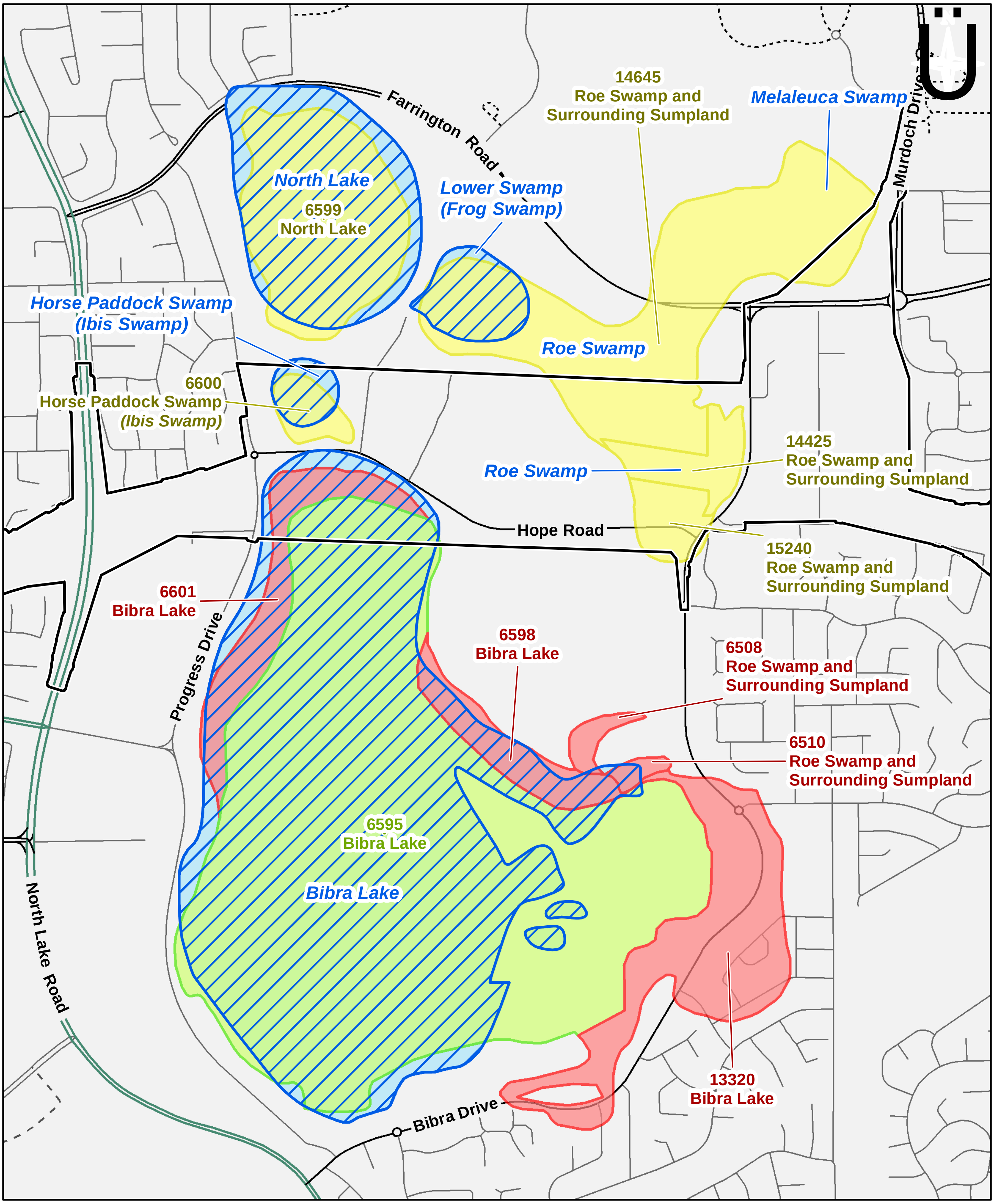
2.2 Bibra Lake

Bibra Lake is one of the largest lakes in the Beeliar chain and consists of open water, resulting from an expression of groundwater on the western side of the Jandakot Mound. The Geomorphic Wetlands Dataset identifies Bibra Lake (Unique Feature Identifiers (UFIs) 6595 and 6522) as a Resource Enhancement Wetland (REW) sumpland (Figure 1), whereas UFIs 6601, 6598 and 13320 are evaluated as Multiple Use sumplands (wetlands which are only seasonally inundated). The REW (UFI 6595) and Multiple Use wetlands (6601, 6598 and parts of UFI 6510) are protected under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* (Lakes EPP) (DEC 2009). There are an additional three unnamed sumpland wetlands (UFIs 6508, 6510 and 6509) adjoining Bibra Lake, which are evaluated as REW and Multiple Use.

Wetlands evaluated as REW are those which may have been partially modified, but still support substantial ecological attributes and functions. These are priority wetlands with the ultimate objective of management, restoration and protection towards improving their conservation category. Multiple Use wetlands are those with few important ecological attributes and functions remaining (Water and Rivers Commission 2001).

Bibra Lake has relatively impermeable lake deposits, with sandy shores restricted to a small area to the west. As a consequence, groundwater inflow and outflow is restricted when the water level drops (Environmental Protection Authority (EPA) and Water Authority of Western Australia 1990). Bibra Lake is part of Bush Forever Site 244.

Elevated nutrient levels within Bibra Lake, caused at least in part by seepage from an old disposal site and feeding of birds, have caused algae to form. Land clearing is likely to have contributed to increased surface runoff and infiltration into groundwater destined for the North and Bibra Lakes (Jim Davies and Associates 1994).



CCW & EPP Wetlands

Figure 1

0 100 200 300 400

Metres

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Legend

- Conservation Category Wetland
- Resource Enhancement Wetland
- Multiple Use
- EPP Lake
- Project Area

AECOM

The City of Cockburn has conducted seasonal surface water sampling and analysis of Bibra Lake since 1995. The summary of results from 1995 to 2009 is as follows:

- Phosphorus is limited, as shown by a high nitrogen to phosphorus ratio at the height of algal productivity in late summer;
- Concentrations of organic phosphate are highest in autumn and summer and lowest in winter and spring. This indicates that the phosphorus is assimilated by phytoplankton during the warm summer months. Chlorophyll levels peak during the same period;
- Ammonia concentrations are highest in autumn and winter, but are lower than concentrations considered to be toxic to aquatic organisms;
- Lake waters tend to be slightly alkaline due to groundwater inflows and bicarbonate shift caused by algal carbon fixation, which drives pH levels towards alkaline;
- The highest organic and total nitrogen levels are evident in autumn and winter, and lowest in summer;
- Dissolved salt concentration varies throughout the year, as a result of fresh inflows from runoff and shallow groundwater ingress during winter; and
- Concentrations of solutes increase through summer and autumn, which may be due to the hot and dry conditions and associated evaporation and transpiration.

Figure 2 summarises the seasonal variance and relationships between nitrogen and phosphorus levels, and resultant algal/plant growth shown by the phytoplankton plant pigment, chlorophyll *a*. There is generally a positive relationship between increasing nitrogen and chlorophyll *a* concentrations and an inverse relationship between phosphorus and chlorophyll *a*. Nitrogen-fixing phytoplankton may predominant in late summer, resulting in a positive correlation between total nitrogen and plant biomass.

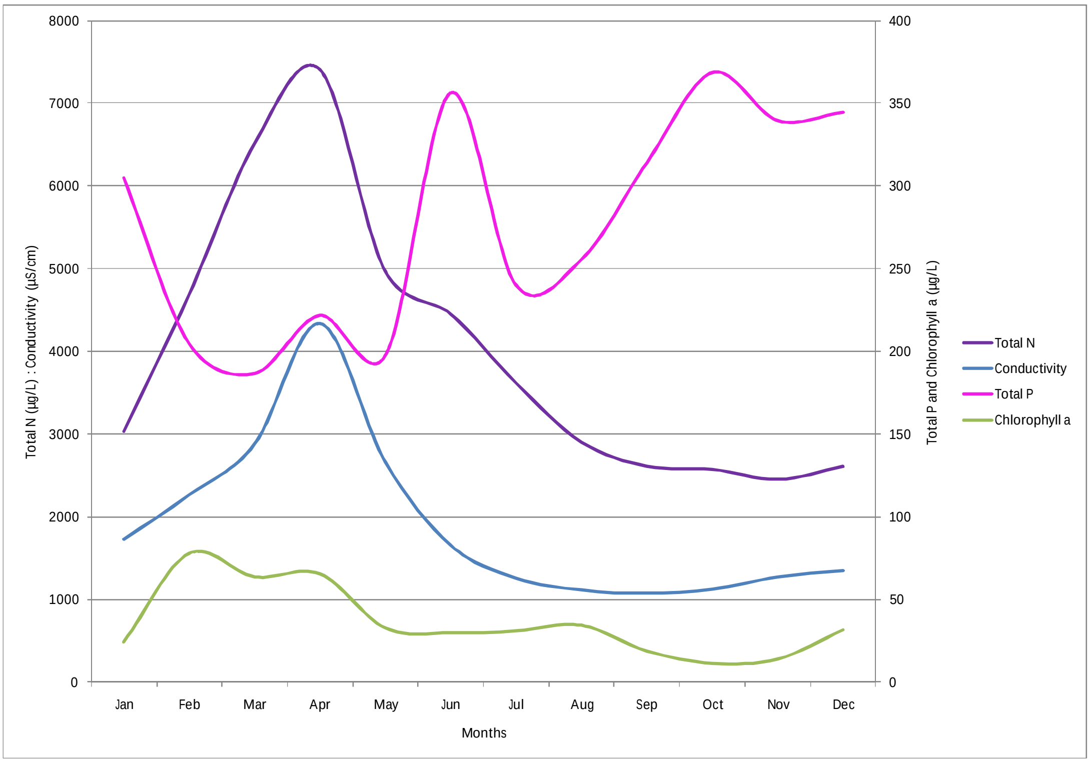

Figure 2 **Mean monthly trend in nitrogen (Total N), phosphorus (Total P), chlorophyll *a* and TDS (measured as electrical conductivity) in Bibra Lake (derived from City of Cockburn data) 1995-2009**

Assays of carbon (C), nitrogen (N) and phosphorus (P) content of algae from the wetlands showed that elements occur in the atomic ratio of approximately 100C:16N:1P (Townley *et al.* 1993). This ratio can help determine the limiting nutrient for algal growth. Phosphorus limitation may occur if the nitrogen:phosphorus ratio exceeds 17.

During late summer/early autumn (March – April), the concentration of nitrogen is the highest due to nitrogen fixation at the height of phytoplankton productivity. At the same time, phosphorus is consumed by phytoplankton, giving a nitrogen:phosphorus ratio of approximately 30:1 (Figure 2). This indicates that the phosphorus is assimilated in phytoplankton during the warm summer months when the lengthy photoperiod is most suitable for plant growth. This condition is reversed in winter months when there is less phytoplankton activity. During winter months, less phosphorus is consumed by phytoplankton and less nitrogen is fixed from the atmosphere. This creates a nitrogen:phosphorus ratio of approximately 10:1, a situation in which nitrogen limitation may occur.

Electrical conductivity (EC) is highly variable throughout the year. EC variations are likely due to freshwater inflows from runoff and shallow groundwater during winter, evident during spring months (average 1200 µs/cm), and due to the concentrating evaporative effects of summer time heat during autumn months (average 3000 µs/cm).

2.3 North Lake

The Geomorphic Wetlands Dataset identifies North Lake (UFI 6599, Figure 1) as a Conservation Category Wetland (CCW) (DEC 2009). This is the highest priority for wetlands as they support a high level of ecological attributes and functions.

North Lake is a groundwater expression of the western Jandakot Mound, where groundwater flow enters the lake through the sandy eastern shore (EPA and Water Authority of Western Australia 1990). This CCW is protected under the Lakes EPP and North Lake is part of the Bush Forever Site 244.

Historical data indicates that runoff from the surrounding urban catchments, including Murdoch Drain, entered North Lake. A previous study estimated that of the phosphorus and nitrogen in North Lake, Murdoch Drain provided 73% and 60%, respectively, while 20% and 26%, respectively, reportedly entered the lake from groundwater on the eastern side (Bayley 1989). Bayley (1989) determined that the nutrients in the groundwater entering the eastern edge probably originated from Murdoch Drain. The highest concentrations of nutrients in Murdoch Drain were shown to be associated with short periods of high drain flow following storms. This means that much of the nutrient load was delivered during short periods of high flow. Murdoch Drain was disconnected in the mid-1990s to decrease nutrient flows from Murdoch University to North Lake (Philip Jennings pers. comm. 2009).

Bayley (1989) reported that bores upstream of North Lake showed groundwater as a significant source of nutrients, delivering twice as much phosphorus over 12 months as Kardinya Drain and slightly more than half as much nitrogen. Sediment samples taken in January 1988 from “the layer of ooze” in the deeper parts of the lake returned high phosphorus concentrations that were mostly in the organic form. Data collected during the study indicated that approximately 92% of the annual phosphorus load is retained within the lake (Bayley 1989).

Direct precipitation on the surface of the lake is reported to be the largest contributor of water to the lake, closely followed by the groundwater and, in the past, surface flows from Murdoch Drain (Bayley 1989). Furthermore, Bayley (1989) indicated that groundwater exports considerably more nitrogen from the lake than it imports and that evaporation was the largest flux of water from the lake. Davis *et al.* (1988) assessed water quality data from 1970 to 1986 and concluded that the levels of ammonium and nitrate were very high in Bibra Lake and North Lake in comparison with Thomsons Lake and the chlorophyll *a* levels were higher in the two permanent lakes than in Thomsons Lake.

2.4 Roe Swamp, Lower Swamp, Melaleuca Swamp and Surrounding Sumplands

Roe Swamp, Lower Swamp, Melaleuca Swamp, and surrounding sumplands (herein referred to as Roe Swamp) (UFIs 15240, 14425 and 14645, Figure 1) are seasonally inundated wetlands, located to the east of North Lake. An artificial drain, known locally as Lower Swamp, links the three wetland areas. Although the three wetlands are linked together and form one system, it is also possible that they function separately and contain different environmental values. There is minimal available literature that describes these sumplands in detail.

Despite surrounding urban development, Roe Swamp has remained relatively unaltered in terms of its hydrological regime and vegetation cover (EPA 2003). During recent inspections by AECOM (August 2009), it was observed that these sumplands are infested by various weed species, particularly the Arum Lily. Roe Swamp is composed of two channel-ways with deeper water pockets draining into North Lake (LeProvost, Semeniuk & Chalmer 1984).The majority of Roe Swamp (with the exception of the eastern section) is located within Bush Forever Site 244. The wetland vegetation is described as being equivalent to the Bassendean Complex in terms of the number of large Melaleucas present. The western portion of Roe Swamp (UFI 14645) is protected under the Lakes EPP.

2.5 Horse Paddock Swamp

The Geomorphic Wetlands Dataset identifies Horse Paddock Swamp (UFI 6600, Figure 1) as a CCW, which is located between North and Bibra Lakes. This wetland is also protected under the Lakes EPP. Although it has been colonised by terrestrial vegetation, such as thistle and grasses, its gently sloping shores and surrounds have been cleared with scattered trees remaining (EPA 2003). Horse Paddock Swamp is located within Bush Forever Site 244, which describes the wetland vegetation as being equivalent to the Herdsman Complex.

2.6 Hydrologic Condition of Lake System

Based on existing topographic features and information from local residents, AECOM understands that surface water flows through an artificial drain (Murdoch Drain or Lower Swamp) in a north-westerly direction (Figure 3). This drain flows into North Lake. Lower Swamp transports surface water from Roe Swamp to the sumpland south-east of North Lake (Lower Swamp) and then to North Lake itself. This surface drain follows the natural contours of the land surface, but as the land surface rises slightly between the two basins, under natural conditions water would probably have flowed intermittently into North Lake during the period of maximum inundation for both basins. The frequency, rate and volume of surface water flow would have been low under natural conditions as the surface land gradient is very low. The branch of Lower Swamp drain oriented north-east into Melaleuca Swamp does not follow a natural surface gradient. The topographic heights in the wet areas surrounding Roe Swamp and in Melaleuca Swamp are similar, as may be expected because they are parts of the same wetland basin.

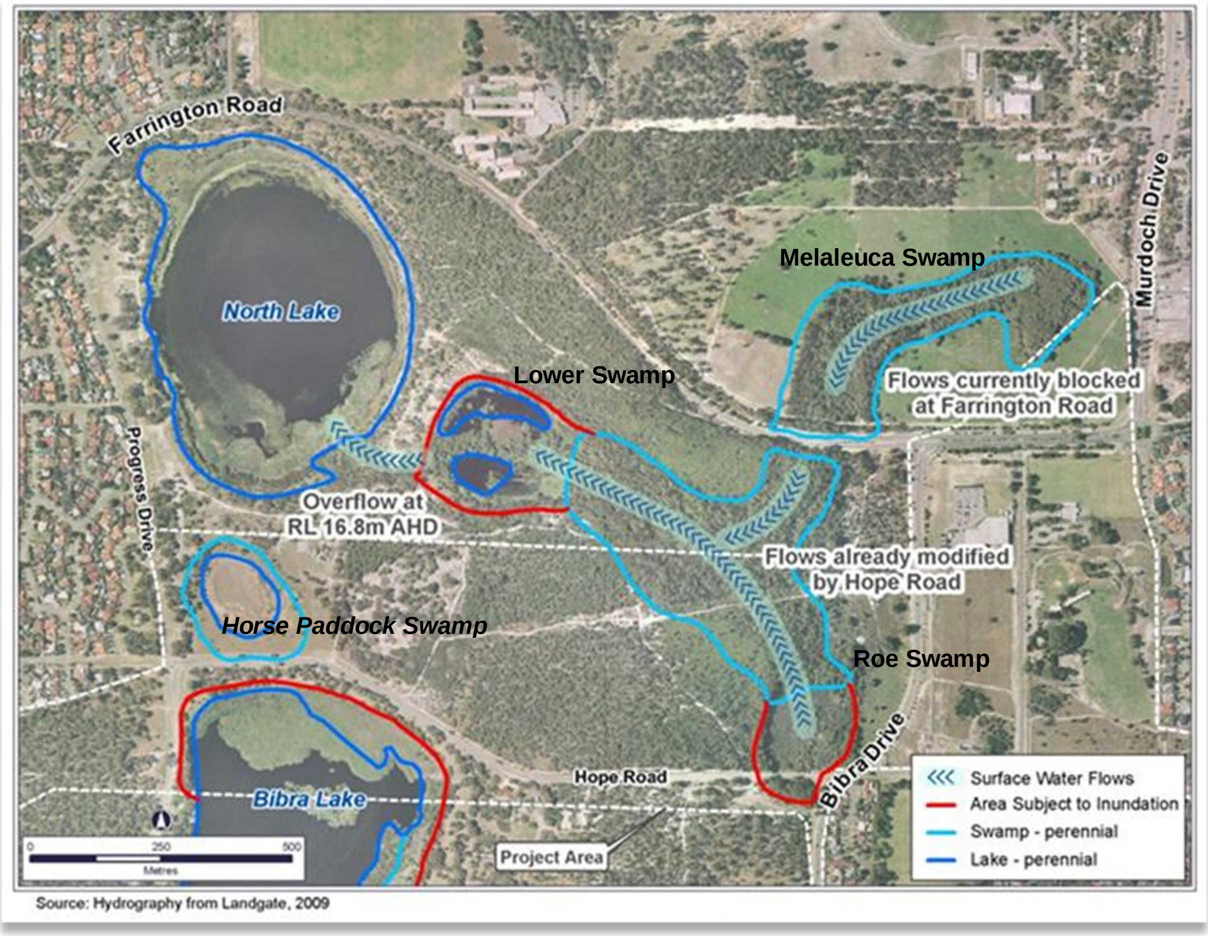

Figure 3 Surface water flows

The construction of Hope and Farrington Roads modified the natural flow paths associated with the connections between Roe Swamp, Horse Paddock Swamp, North Lake and Bibra Lake. Based on site inspections and City of Cockburn information, there do not appear to be any culvert crossings under Hope Road to allow water to flow (south to north) through these low lying areas. Information received from the City of Cockburn suggests that there are surface water contributions to the project area from the existing drainage networks, either by direct discharge or by overflow from constructed basins. Drainage network catchments contributing to the wetland system are described as follows:

- Pipe outlets discharge from Bibra Drive to the south and east of Bibra Lake, with catchments from road and residential areas between Bibra Drive and the Railway Reserve
- Pipe outlets discharge from Progress Drive to the west of North Lake and Bibra Lake, encompassing catchments from road and residential areas as well as undeveloped areas between Progress Drive and North Lake Road; and
- Pipe outlets discharge from Farrington Road to the north and east of North Lake between Murdoch Drive/Allendale Entrance and from North Lake Road to both North Lake and the swamps to the east of North Lake, including Roe Swamp and Murdoch Swamp.

Inflow waters can convey physical and chemical stressors that directly affect aquatic ecosystems. These can be distinguished as one of two types: those that are directly toxic to biota; and those that, while not directly toxic, can result in adverse changes to the ecosystem (e.g. to its biological diversity or its value to humans). Excessive amounts of direct-effect stressors cause problems, but some of these elements and compounds are essential at low concentrations for the effective functioning of biota. These include nutrients such as phosphorus and nitrogen, and heavy elements such as copper and zinc (ANZECC/ARMCANZ 2000).

Stormwater and groundwater discharging into the lake and wetland environments is already likely to contain contaminants including:

1. Persistent contaminants (including elements such as heavy metals and pesticides residues)
2. ‘Recyclable’ pollutants (such as plant nutrients including carbon, nitrogen and phosphorus); and
3. Other naturally-occurring constituents, albeit changed from background conditions (such as acidity, minerals, organic material and microbes).

Commercial and residential infrastructures within the greater catchment are dominant potential sources of persistent (long – lasting) contaminants which may enter the lakes and wetland system by surface or below ground flow pathways. For instance, vehicle traffic on roads in the catchment may generate some of these types of contaminants including elements (e.g. zinc, lead, and other elements) and hydrocarbons, including petroleum products (DoW 2007).

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3.0 Methodology

3.1 Sampling Locations

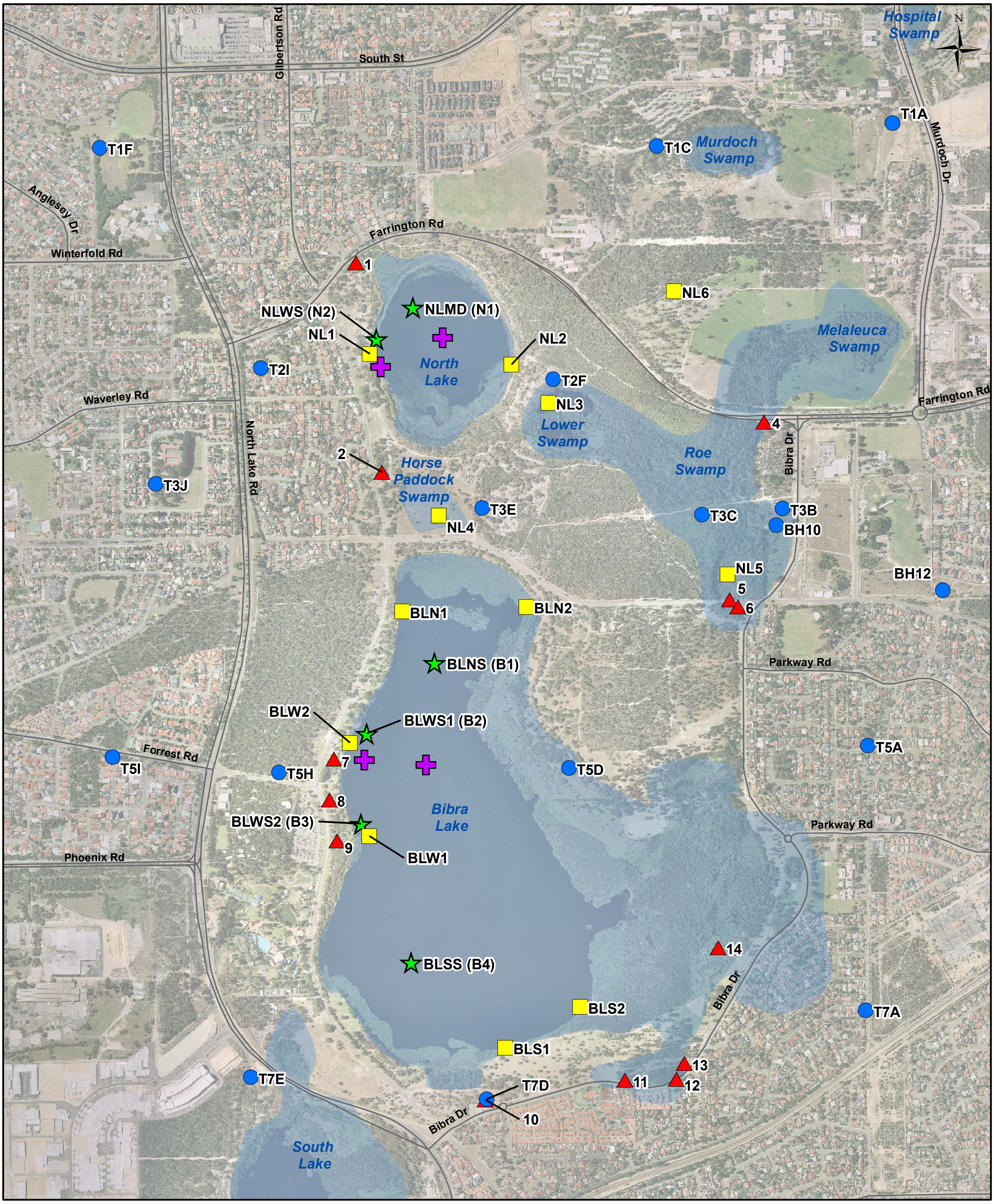
Surface water samples and water column profiles were taken at four sites in Bibra Lake and at two sites in North Lake (shown in Figure 4) to capture the most representative samples. Both lakes have deeper bathymetry on their western sides. Sites at northern (BLNS) and southern (BLSS) parts of Bibra Lake were chosen to assess whether there is any difference in water quality between locations within the lake. For the same reason, sites at the western (NLWS) and middle (NLMD) parts of North Lake were chosen. For both Bibra Lake and North Lake, algae samples were collected from western edge and middle of the lake.

Stormwater samples were taken at 13 outfalls surrounding Bibra Lake and North Lake, with water flows from some drains directly discharging into the lakes. Not all drains were sampled on every sampling event, due to lack of running water in the drains (i.e. insufficient rainfall).

Sediment samples were taken from a total of 12 sites, consisting of six sites at the perimeter of Bibra Lake, two sites at the perimeter of North Lake and one site each at Lower Swamp, Horse Paddock Swamp, the western edge of Roe Swamp and the wetlands near Murdoch University.

Groundwater samples were taken at 16 sites from piezometers (groundwater sampling wells) with a diameter of 25 mm and two sites with a piezometer diameter of 50 mm.

Sampling coordinates and location details are provided in Appendix A and illustrated in Figure 4.



Groundwater, Stormwater, Surface Water and Sediment Sampling Sites around Bibra Lake and North Lake

Figure 4

0 100 200 300 400 500 600

Meters

1:18,000 (A4)

Groundwater

Stormwater

Surface Water

Sediment

Algae Sampling

Wetlands

AECOM

Date Modified: 1/12/2010

Author: CBB \\auper1fp002\Geo\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\All_Sampling_Sites.mxd

3.2 Sampling Approach

Samples were collected by AECOM personnel from the sites described in Section 3.1. Upon collection, all samples were transported in ice-packed, insulated containers to an analytical laboratory for analysis.

3.2.1 Surface Water

Surface water sampling was undertaken in accordance with *AS/NZS 5667.4:1998, Water quality – Sampling, Part 4: Guidance on sampling from lakes, natural and man-made*.

Given the shallow depth of the lakes (<1 m), the water was assumed to be well mixed, so two replicate samples were taken from the middle of the water column at each surface water sampling location during sampling events. This was considered sufficient to represent the water body characteristics at each selected sampling location. Water samples were collected directly into sample containers, which were triple rinsed (excluding sample bottles with preservatives) with water from the sampling location before any samples were collected. Samples were kept chilled and were delivered to the laboratory for analysis within the laboratory's stipulated holding time.

Algae samples were collected from two locations in the lakes (shown in Figure 4) using a sampling bailer. One sampling point was located in the middle of the lake; the other was located at the edge of the lake to capture floating algae close to the shore.

Water quality profiles were obtained by lowering Yellow Springs Instrument (YSI) (in the November 2009 and February 2010 sampling events) or In-Situ TROLL 9000 (in the August 2010 sampling event) water quality profilers through the water column at each site. Water physiochemical parameters such as pH, turbidity, dissolved oxygen (DO), temperature and EC were recorded by instruments and the data were downloaded at the end of sampling.

3.2.2 Stormwater

Decontaminated plastic pails were used to collect samples directly from outfalls where running stormwater was identified. The plastic pails were triple rinsed with the outfall water before samples were collected. Water was then decanted directly into sample bottles provided by the laboratory. Field conditions were noted in a field report and included information such as weather, rain frequency, amount of water running from the outfall and whether drains were flowing or not.

3.2.3 Sediment

Sediment samples were taken using a stainless steel hand spade. Samples were separated based on depth intervals. Upper horizon surface samples were collected from the upper 5 cm of sediment and the lower horizon samples from 10–20 cm depth.

3.2.4 Groundwater

Groundwater sampling was undertaken in accordance with *AS/NZS 5667.11:1998, Water quality – Sampling, Part 11: Guidance on sampling of groundwaters.*

The groundwater bores were drilled and installed by VCSRG Pty Ltd; for more details refer to *Baseline Report on Stratigraphy and Hydrology in the Bibra and North Lake Area* (VCSRG 2010). As the project area is in a sensitive CCW area (refer to Section 2.3); a small and unobtrusive 25 mm diameter piezometer (PVC tube) was installed in each bore. Water samples were also taken from two 50 mm piezometers, which were installed by South Metro Connect for groundwater quality baseline monitoring.

The groundwater level at each monitoring site was recorded using an Aqua Dipper Pro water level measurement instrument. The bore water volume was calculated based on the groundwater level and three bore volumes were purged prior to sampling. Purged water was collected in a pail and disposed of away from the bore site. During the purging process, physical water parameters (pH, DO, conductivity, temperature, and redox potential) were measured using Aqua Read Flow Cell water quality testing equipment. The readings were taken at regular intervals and recorded. Water samples were taken from the bore once the readings stabilised (i.e. the difference between successive readings was within 10%).

Due to the size of the piezometers (25 mm diameter), a conventional 12 volt pump was unable to be used to purge the water from the bores. Instead, a Waterra peristaltic pump utilised to collect water from bores with a depth of less than 15 m and a Waterra foot valve pump was used to collect samples from deeper bores. For both collection methods, site-specific tubing was used to avoid cross-contamination between sites. Water samples were discharged into sample bottles directly from the tubing.

The two 50 mm diameter piezometers (BH10 and BH12) were also sampled using the same method and equipment. The sampling set up with the peristaltic pump and the flow cell for both 25 mm and 50 mm piezometers are shown in Figure 5 and Figure 6, respectively.

Figure 5 Sampling set up of the 25 mm piezometer

Figure 6 Sampling set up of the 50 mm piezometer

3.2.5 Decontamination

Re-useable equipment was washed and rinsed using a 2% solution of Decon 90 and finally rinsed with laboratory-supplied de-ionised water. Decontamination occurred before the first use of new supplies (e.g. plastic containers) and after each sample was collected. This was to minimise the potential for cross-contamination between sites.

3.2.6 Quality Control

Sampling methodology included the decontamination process to minimise the potential for cross-contamination and unrepresentative samples. During every sampling event, new, clean sample containers were sourced from the laboratory prior to sampling. Each batch of samples included one duplicate for every 10 samples submitted to the laboratory. The purpose of these duplicates was to allow the laboratory to perform internal quality assurance and the results were included in the laboratory report. Quality control methodology for each surface water, stormwater, groundwater and sediment sampling are detailed in the following sections.

3.2.7 Surface Water Sampling

Laboratory control samples were taken as a part of surface water quality control methodology. The term laboratory control sample (LCS) refers to a certified reference material, or a known interference-free matrix spiked with target analytes. This parameter is a measure of the precision and accuracy of an analytical method, independent of the sample matrix. The detection limits used in the evaluation are a dynamic measure based on a statistical evaluation of the processed laboratory control samples.

Laboratory control samples were within the appropriate control limits. Refer to Appendix C for laboratory reports documenting laboratory control sample results.

3.2.7.1 Stormwater Sampling

Two types of samples were taken during each of the stormwater sampling events:

- Field replicate samples: two samples obtained from the same site at the same time using exactly the same method; and
- Field duplicate samples: one sample was split into two subsamples and submitted as separate samples.

Replicate samples were collected directly from the running drains into two separate plastic pails and then decanted directly into sample bottles provided by the laboratory. Duplicate samples were collected by collecting the water into one plastic pail and then decanted into two sets of sample bottles.

Replicate and duplicate samples should agree within an relative percent difference (RPD) of 30–50 percent (AS 4482.1:2005). RPD is determined by:

RPD= (P-D)/((P+D)/2) x 100, where P = primary sample and D = duplicate/replicate sample.

Where a target analyte in the water sample was below the laboratory limit of reporting (LOR), a value of half the LOR was used to calculate the RPD.

The results of the replicate and duplicate samples are summarised as follows:

- The RPD for replicate samples were generally less than 50 percent for all parameters tested throughout the sampling rounds. However, RPD exceeded 50 percent intermittently throughout the sampling rounds for several parameters, such as chromium, copper, phosphorus, total petroleum hydrocarbon (TPH) C_{10}-C_{14}, TPH C_{15}-C_{28}, TPH C_{29}–C_{36}, total suspended solids, total nitrogen, total kjeldahl nitrogen and NOx. This may represent the natural variability in the running drains water and the snapshot nature of the sampling program; and
- The RPD for duplicate samples were also generally less than 50 percent for all parameters tested throughout the sampling round. Arsenic, copper, zinc, TPH C_{10}-C_{14}, TPH C_{15}-C_{28}, total suspended solids, total nitrogen, total kjeldahl nitrogen and NOx were parameters with RPD exceeding 50 percent intermittently throughout the sampling rounds. This may indicate small changes in concentration at very low level resulting in a large percentage change to the RPD.

Refer to Appendix C for the summary of stormwater sampling quality control results.

3.2.7.2 Groundwater Sampling

As groundwater samples were collected directly into the sampling bottles from the pump, only replicate samples were collected for groundwater. The RPD were determined with the same equation given in Section 3.2.7.1.

The RPD in the replicate samples were generally less than 50 percent throughout the sampling rounds, except for total phosphorus, total kjeldahl nitrogen, aluminium, chromium, manganese, lead, zinc, silicon and TPH C_{15}-C_{28}. This RPD exceedence occurred intermittently throughout the sampling rounds, which may indicate the snapshot nature of the sampling. The elevated RPD could also be associated with low concentration of both primary and replicate samples, where a small change could exaggerate the actual difference between the two samples.

Rinsate blanks were also collected and analysed for elements throughout the groundwater sampling rounds; commercially available deionised water was used to rinse the equipment. All rinsate analyses detected marginal levels of substances (copper, iron, nickel, silicon and zinc), which may be attributed to laboratory error as the values are close to the detection limits for the substances. Refer to Appendix C for the quality control results summary.

3.2.7.3 Sediment Sampling

RPD was calculated for each primary and duplicate pairing of sediment samples. RPDs generally provide an indication of the reproducibility of the sampling and analysis procedure. High RPDs (>50 percent) in soil may imply that the soil was not homogenous and/or the laboratory procedures were not reproducible.

Samples NL4 had an RPD in excess of 50 percent and a result greater than 10 times the LOR for some of the analytes, perhaps due to sample heterogeneity.

One rinse blank sample was collected and analysed at the completion of the soil sampling on 28 May 2010. Commercially-available deionised water was used to rinse the equipment and the rinsate sample was analysed for elements. The sample analysis detected marginal levels of substances. Aluminium and iron were detected in higher concentration compared to other elements, which may be due to traces left on the hand spade. It should be noted that aluminium and iron were abundant in the study area.

Overall the data indicates that sampling and analysis procedures were satisfactory, resulting in reproducible results. Refer to Appendix C for the quality control results summary.

3.3 Guidelines Application

The study area is surrounded by urban/residential land use, which is a highly modified ecosystem with high risk of contamination and low environmental value. Nevertheless, the stormwater and groundwater eventually discharge into wetlands (Bibra Lake and North Lake) possessing a high environmental value. In this report, a variety of methods have been used determine whether the concentrations recorded are not usually found in a similar pristine ecosystems and are therefore likely to have an impact on the wetlands.

3.3.1 Surface Water and Stormwater

The contaminant results of surface water and stormwater were assessed against the ANZECC/ARMCANZ (2000) 95 percent species protection freshwater guideline values for slightly to moderately disturbed ecosystems. These guidelines use the term “trigger levels” of concentrations of key water quality constituents to define conditions where the receiving waterbody may be exposed to a high risk of biological degradation of the aquatic ecosystem. Although these guidelines are set for receiving bodies not stormwater discharge points, they have still been used for stormwater in this report to indicate where elevated concentrations are recorded.

Where applicable, nutrient results and physical conditions were compared to default guideline values applicable to south–west Australia for wetlands (ANZECC/ARMCANZ 2000). Chromium was not speciated into chromium (III) and chromium (VI) by the laboratory, so a more conservative guideline for chromium (VI) was used; this may overestimate the toxicity (DoW 2007). Organochlorine pesticides, organophosphate pesticides and herbicide guidelines were adopted from EPA (1993) guideline values for pesticides in Australian water in addition to the DEC (2010) guideline values.

TPH is defined as the measureable amount of petroleum-based hydrocarbons in an environmental media (Agency for Toxic Substances and Disease Registry (ATSDR) 1999). TPH is a measured, gross quantity without identifying its constituent and represents a mixture. Thus, TPH itself is not a direct indicator of risk to human health or environment. For this reason, there are no guideline values applicable for TPH concentration in water.

3.3.2 Groundwater

There are no groundwater – specific guidelines for aquatic ecosystem health available. The 80th percentile of the DoW groundwater quality data from bores in the immediate vicinity of Bibra Lake/North Lake and up hydraulic gradient (Jandakot Mound) have been utilised as a benchmark for the groundwater quality of the study area.

3.3.3 Sediment

The concentrations of contaminants in sediment were compared against the low guideline values of interim sediment quality guidelines (ISQG-Low) (ANZECC/ARMCANZ 2000).

For organics (i.e. polycyclic aromatic hydrocarbons (PAH)), concentrations were normalised to 1 percent total organic carbon (TOC) before comparison with guidelines. Normalisation to 1 percent TOC is for the TOC range 0.2–10 percent, which equates to the PAH concentrations divided by the TOC value. For TOC outside of this range, division by the end TOC value is applied i.e. for TOC less than 0.2 percent, the concentration is divided by 0.2 and for TOC higher than 10 percent, division by 10 is applied (Department of Environment, Water, Heritage and the Arts (DEWHA) 2009).

Due to the high organic content of the sediment and the tendency of some elements to bind to organic content of the sediment, elements concentrations were also normalised to 1 percent TOC to provide an estimate of the concentration that is not bound to the sediment (i.e. to estimate the bio-availability).

Although there are no guideline values available for TPH in sediment, ecological investigation levels (EIL) are available for TPH in soil and are adopted as guideline values in this report. EIL indicate the threshold levels of phytotoxicity and uptake of contaminants that may result in impairment of plant growth, reproduction or unacceptable residue levels (DEC 2010a). Furthermore, EIL are intended to provide preliminary risk assessment to determine whether concentrations of substances in soil potentially pose a risk to the environment or relevant environmental value (DEC 2010a).

3.4 Sampling Frequency

3.4.1 Surface Water

Three sampling events were conducted:

- 19 and 20 November 2009 (spring)
- 4 February 2010 (summer); and
- 26 August 2010 (winter).

Sampling was undertaken only at two sites in Bibra Lake in February 2010, Bibra North-West and Bibra West, due to the seasonal variation in water level. No water samples were collected from North Lake due to the absence of water at the sampling sites.

Low rainfall and high evaporative losses caused the wetlands to dry out and therefore they could not be sampled during the majority of the sampling events. For this reason, the third round of surface water sample collection and analysis was conducted on 26 August 2010, when water levels in both Bibra and North Lakes were sufficient to conduct sampling. The water samples were taken from all four sites at Bibra Lake and only one site at North Lake (North Lake West) due to insufficient water in the middle of the lake. During this sampling round, groundwater sampling was also conducted (23-24 August 2010) to allow comparison between surface and groundwater.

3.4.2 Stormwater

Stormwater sampling can only be measured during or immediately after a significant rainfall event. Predicting storm events over the project area is a crucial part of stormwater sample collection. Ideally, samples should be collected at the beginning of a storm event in order to identify the potential contaminants that have collected in the catchment (for example, on the roads in an urban setting) during dry periods.

Extended forecasts from the Bureau of Meteorology (BoM) website and other weather sources were monitored before a sampling event was conducted. Stormwater sampling was instigated during large rain events (i.e. at least 10 mm rainfall). The rainfall at Jandakot weather station (the closest weather station to the study area) was closely monitored along with the Perth Radar (BoM 2010), in order to forecast large rain events.

The year in which the study was undertaken was a low rainfall year. Total rainfall between July 2009 and July 2010 was approximately 732 mm, of which about 347 mm fell between March 2010 and July 2010 (BoM 2010). Due to the relatively low rainfall and irregular downpours experienced within the sampling period, not all the stormwater drains were found to be flowing during major rainfall events and, therefore, not all sites could be sampled. Seven adequate stormwater sampling events occurred during the 2010 wet season (April to September). Stormwater sampling events are summarised in Table 1.

Table 1 Stormwater sampling events and rainfall

	Sampling Round 1	Sampling Round 2	Sampling Round 3	Sampling Round 4	Sampling Round 5**	Sampling Round 5	Sampling Round 6	Sampling Round 7
Date	14/04/2010	21/05/2010	22/05/2010	27/05/2010	14/06/2010	15/06/2010	8/07/2010	12/08/2010
***Preceding 24 hours Rainfall(mm)**	28.8	0	28.9	23.4	11.2	20.2	0	25.2
***Following 24 hours Rainfall(mm)**	10.4	29.8	16.4	11	20.2	4.6	32	14.2

Notes:
*Precipitation (rainfall) in the last 24 hours to 9 am (Source: Jandakot airport weather observation, BoM 2010). Note that rainfall occurring after 9 am on the sampling day is recorded on the next day rainfall data.
**During sampling round 5 (14/06/2010), due to minimal rainfall, stormwater samples were only taken from Site 7. None of the other drains were flowing when the sampling occurred.

3.4.3 Groundwater

The 25 mm piezometer groundwater wells were sampled between the 20th and 24th days of each month, from June 2010 to September 2010. BH10 and BH12 were sampled on 5 February 2010 and 23 August 2010. During the August 2010 sampling, surface water sampling was also conducted to allow for comparison between surface and groundwater.

3.4.4 Sediment

In order to obtain information on baseline chemistry of natural variability in sediment quality, sediment sampling was conducted on:

- 8 April 2010 at Bibra Lake
- 28 May 2010 at North Lake; and
- 24 August 2010 at Horse Paddock Swamp and Roe Swamp.

3.5 Test Parameters

The parameters considered most likely to be affected by stormwater runoff from construction and operation of roads were selected for testing. Nearby landfill leachate and agricultural contamination also have the potential to contribute pollutants to the lakes (Hirschberg 1991). Therefore, parameters that indicated these potential impacts were also tested. These included nutrients, total and dissolved elements, organic compounds and hydrocarbons. Pesticides and herbicides were also tested to indentify contamination associated with residential land uses. Parameters measured, LOR and laboratory methodologies are listed in Appendix B.

Due to the direct, generally untreated surface runoff that discharges into the lakes and wetlands within the project area, sampling sites and parameters were selected to characterise the existing physical and biological water quality of the system, as well as to identify the changes likely to arise as a result of the development and operation of the proposed road infrastructure. Safety and site access were also taken into consideration when selecting sampling sites.

All organophosphate pesticides will degrade into water-soluble products that are non–toxic, hence the toxicity is short term in contrast to organochlorine pesticides (International Programme on Chemical Safety (IPCS) n.d.). At neutral pH, the half-life of organophosphate pesticides varies from a few hours to several weeks. In slightly acidic soil (pH 4 to 5), these half-lives are extended (IPCS n.d.). However, the constituent of soils itself may catalyse the degradation. Therefore, in sediment, this particular type of pesticides was only tested in surface samples with an assumption that there was recent input of organophosphate pesticides into the sediment.

All water and sediment samples were sent for analysis to Advanced Analytical Pty Ltd, a National Association of Testing Authorities (NATA) accredited laboratory.

Algae identification was conducted in surface water samples to understand the dominant and subdominant algae taxa to genus or species level. Algae identification was undertaken by Dalcon Environmental Pty Ltd, an environmental consultant providing services in marine and freshwater ecology and water quality.

Physicochemical profiling of the water column of the lakes was conducted in the field using a YSI or In-situ TROLL 9000 water quality profiler as detailed in Section 3.2.1 (Figure 7).

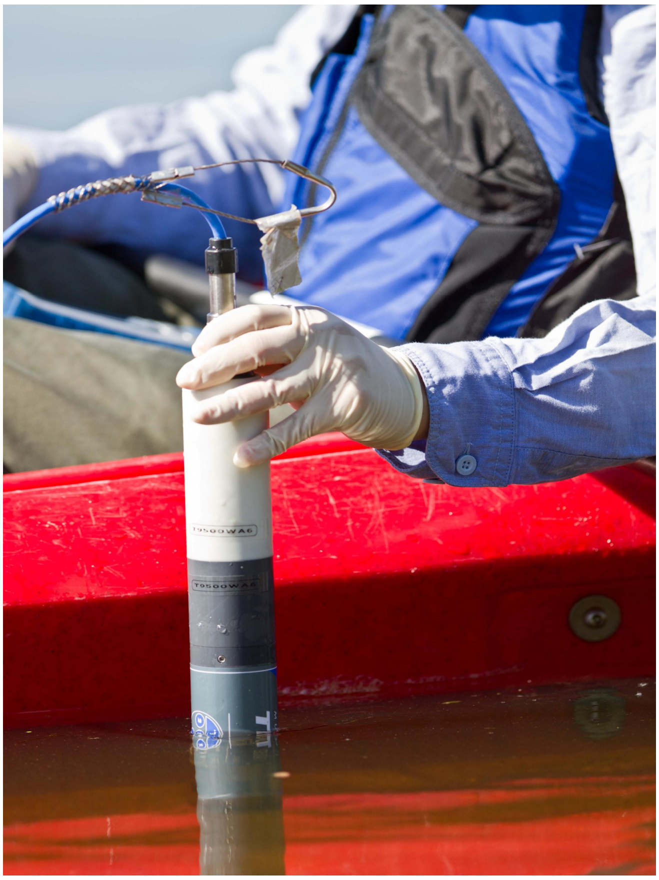


Figure 7 Water profile reading using In-Situ TROLL 9000, including for oxygen conditions

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4.0 Results

The quality of surface water, stormwater and sediment for the monitoring period November 2009 to August 2010 is presented in the following sections for Bibra Lake; North Lake; and Roe Swamp, Lower Swamp, Horse Paddock Swamp and Surrounding Sumplands (Section 4.3).

It should be noted that due to seasonal fluctuations in the wetlands and the drains, not all sites were sampled during the monitoring period.

4.1 Bibra Lake

4.1.1 Surface Water

No samples were collected from Bibra North and Bibra South in the February 2010 sampling event, due to decreased water levels.

4.1.1.1 Chemical Parameters

4.1.1.1.1 Elements – Total

A summary of the total elements results is presented in Table 2.

Aluminium, chromium, copper, iron, lead and zinc concentrations were found to be higher than the guideline level during the sampling period.

During November 2009, aluminium and zinc concentrations exceeded the guideline value at all sites, with maximum values of 390 µg/L and 35 µg/L, respectively. Chromium, copper and lead concentrations were also higher than the guideline value at all sites except Bibra North.

Arsenic and iron were analysed during the February 2010 and August 2010 sampling surveys. Arsenic concentrations did not exceed the guideline value. Iron exceeded the guideline value in February 2010 with a maximum concentration of 370 µg/L.

During the August 2010 sampling event, iron and zinc exceeded the guideline value with maximum mean concentrations of 1600 µg/L and 14 µg/L, respectively. Aluminium also exceeded the guideline value at Bibra North and Bibra West sites with mean concentrations of 57 µg/L and 58 µg/L, respectively.

In contrast to the November 2009 and February 2010 results, the August 2010 sampling results did not report detectable chromium or copper concentrations in the water column. Additionally, mean concentrations of lead were lower in August 2010 than in November 2009 and February 2010.

4.1.1.1.2 Elements – Dissolved

A summary of the dissolved elements results is presented in Table 3.

Total elements concentrations should be higher than dissolved (acid soluble) elements concentrations (Laboratory method reference: USEPA 200.8 – ICPMS (total elements); USEPA 200.7 – ICP-OES (dissolved elements). However, due to the nature of the sampling (snapshot samples) concentrations of dissolved elements greater than the total elements may be detected. In this case, it is assumed that all (100 percent) of the total elements are available in their dissolved form.

The dissolved elements concentrations measured were similar to the total elements concentrations. For most elements measured, 81 percent to 100 percent of the total element concentrations, were available in the dissolved form. An exception was potassium, where only 45 percent, was available in the dissolved form.

Dissolved aluminium, iron and zinc were higher than the guideline values with a maximum concentrations of 69 µg/L, 1600 µg/L and 14 µg/L, respectively.

Cadmium LOR was the same as the guideline value (<0.2 µg/L) and all cadmium concentrations measured were below LOR in all samples.

Table 2 Total elements mean concentrations (± standard error, n=2) of Bibra Lake surface water quality

Analytes	Units	LOR	Guideline Level	November 2009				February 2010		August 2010			
				Bibra North (BLNS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra North (BLNS)	Bibra North West (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)
Aluminium - Total	µg/L	<5	55	170±5	260±5	390±45	380±0	240±0	250±5	57±0.5	48±1.5	58±4.5	47±0.5
Arsenic - Total	µg/L	<1	24 as As (III) or 13 as As (V)	-	-	-	-	11±0.5	11±0	5±0.05	4.6±0.05	4.5±0.15	4.8±0.05
Cadmium - Total	µg/L	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium - Total	µg/L	<1	1 as Cr (VI)-	<1	1.3±0.05	1.8±0.15	1.6±0	1.2±0	1.3±0.05	<1	<1	<1	<1
Copper - Total	µg/L	<1	1.4	1.1±0.05	1.6±0.3	4.2±0.3	1.4±0.1	1.4±0.15	1.8±0.1	<1	<1	<1	<1
Iron - Total	µg/L	<50	300*	-	-	-	-	360±0	370±5	1200±0	1300±0	1600±200	1300±0
Nickel - Total	µg/L	<1	11	1±0	1.1±0	1.6±0.05	1.3±0	2.5±0	2.7±0.05	1.4±0	1.3±0.05	1.4±0.05	1.2±0
Lead - Total	µg/L	<1	3.4	3.1±0	3.9±0.15	5.2±0.25	4.3±0	4.3±0.05	4.4±0.05	1.6±0	1.6±0	1.6±0.05	1.7±0.1
Selenium - Total	µg/L	<1	5*	<1	<1	<1	<1	1	<1	<1	<1	<1	<1
Zinc - Total	µg/L	<5	8	8.8±0.9	9±2	35±0.5	8.4±0.4	18±2	29±0	14±0.5	14±2	9.5±0.55	8.7±1.35
Magnesium - Total	mg/L	<0.1	-	-	-	-	-	170±10	160±0	18±0	19±0	17.5±0.5	19±0
Potassium - Total	mg/L	<0.1	-	-	-	-	-	68±1	68±1.5	40±0	42±1	38±2	42±0
Silicon - Total	mg/L	<0.01	-	-	-	-	-	-	-	0.6±0	0.64±0	1.4±0.05	0.7±0.09
Barium - Total	µg/L	<1	-	-	-	-	-	-	-	80±0.5	81±0	81±6.5	83±0
Manganese - Total	µg/L	<1	1900	-	-	-	-	-	-	23±0.5	21±0	15±3	20±1
Strontium - Total	µg/L	<5	-	-	-	-	-	-	-	400±5	410±0	390±10	410±0

Notes:
Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.
*DEC 2010 Assessment levels for Soil, Sediment and Water.
Concentrations exceeding guideline values are highlighted in yellow.
"-" indicates that the particular test was not conducted (a function of sampling plan and standing surface water availability)

Table 3 Dissolved elements mean concentrations (± standard error, n=2) and percent (%) of total elemental concentration for Bibra Lake surface water quality during August 2010

Analytes	Units	LOR	Guideline Level	Bibra North (BLNS)		Bibra North West (BLWS1)		Bibra West (BLWS2)		Bibra South (BLSS)	
				Concentration	% of total*	Concentration	% of total*	Concentration	% of total*	Concentration	% of total*
Aluminium - Dissolved	µg/L	<5	55	66±1	100%	54±6	100%	69±9.5	100%	60±2.5	100%
Arsenic - Dissolved	µg/L	<1	24 as As (III) or 13 as As (V)	4.8±0.05	96%	4.5±0.05	98%	4±0.1	89%	4.4±0.05	92%
Cadmium - Dissolved	µg/L	<0.2	0.2	<0.2	n/a	<0.2	n/a	<0.2	n/a	<0.2	n/a
Chromium - Dissolved	µg/L	<1	1 as Cr (VI)-	<1	100%	<1	n/a	<1	n/a	<1	n/a
Copper - Dissolved	µg/L	<1	1.4	<1	100%	<1	n/a	<1	n/a	<1	n/a
Iron - Dissolved	µg/L	<50	300**	1100±0	92%	1200±0	92%	1600±150	100%	1200±50	92%
Nickel - Dissolved	µg/L	<1	11	1.4±0.05	100%	1.4±0.05	100%	1.4±0.05	100%	1.4±0.05	100%
Lead - Dissolved	µg/L	<1	3.4	1.4±0	88%	1.5±0	94%	1.3±0	81%	1.4±0	82%
Selenium - Dissolved	µg/L	<1	5*	<1	n/a	<1	n/a	<1	n/a	<1	n/a
Zinc - Dissolved	µg/L	<5	8	12±0.5	86%	14±1.5	100%	13±0.5	100%	12±0.5	100%
Magnesium - Dissolved	mg/L	<0.1	-	40±0	100%	42±1	100%	38±2	100%	42±0	100%
Potassium - Dissolved	mg/L	<0.1	-	18±0.5	45%	19±0	45%	17±0.5	45%	19±0	45%
Silicon - Dissolved	mg/L	<0.01	-	0.5±0.02	83%	0.7±0.005	100%	1.1±0.13	79%	0.7±0.01	100%
Barium - Dissolved	µg/L	<1	-	79±0	99%	82±0.5	100%	80±4	99%	82±0.5	99%
Manganese - Dissolved	µg/L	<1	1900	22±0	96%	21±0.5	100%	10±1	67%	19±0.5	95%
Strontium - Dissolved	µg/L	<5	-	390±0	98%	410±0	100%	390±0	100%	410±0	100%

Notes:
Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.
**DEC 2010 Assessment levels for Soil, Sediment and Water.
Concentrations exceeding guideline values are highlighted in yellow.
* Percent of total: indicates the dissolved elements percentage of the total elements. In cases where dissolved elements are in higher concentrations than the total elements, 100% of total is assumed.
n/a: not applicable.

4.1.1.1.3 Nutrients

A summary of the results for Bibra Lake nutrient sampling is presented in Table 4.

Total phosphorus (TP) mean concentrations were higher than the guideline value throughout the monitoring period. TP concentrations were similar during November 2009 and February 2010, with maximum concentrations of 0.87 mg/L and 0.74 mg/L, respectively. In August 2009, the maximum TP concentration recorded was 0.39 mg/L.

Total nitrogen (TN) was higher than the guideline value throughout the monitoring period with a maximum concentration of 12.5 mg/L in February 2010. During November 2009 and August 2010, TN concentrations were 3.3 mg/L and 2.7 mg/L, respectively.

TN:TP ratios during November 2009 and August 2010 were less than 16:1. In February 2010, the ratio was 17:1 in surface water samples collected from the Bibra North-West and Bibra West sites, indicating that phosphorus limitation could be occurring on this occasion.

Orthophosphate concentrations were higher than the guideline value throughout the monitoring periods. Concentrations were highest during November 2009, with a maximum concentration of 0.4 mg/L, and lowest in February 2010, with a maximum concentration of 0.04 mg/L.

Concentrations of nitrogen oxide (NOx, the sum of NO_3 and NO_2) in the samples collected during November 2009 and August 2010 sampling events exceeded the guideline value at all but one sampling site in Bibra Lake (Bibra West). The highest mean concentration was 0.23 mg/L, which was recorded in August 2010. NOx was not detected above LOR in surface water samples in February 2010.

Chlorophyll *a* concentrations remained below the guideline value in surface water samples from November 2009 and August 2010. An increase in chlorophyll *a* concentrations was observed in the February 2010 sampling event, with a maximum mean concentration of 140 µg/L measured at the Bibra West site.

4.1.1.1.4 Total Suspended Solids, Biological Oxygen Demand and Electrical Conductivity

A summary of the results for Bibra Lake total suspended solids (TSS), biological oxygen demand (BOD) and EC is shown in Table 5.

In November 2009, TSS mean concentrations were higher at the Bibra West (48 mg/L) and Bibra South (44 mg/L) sites than at the other two sites. In February 2010, TSS mean concentrations at the Bibra North-West and Bibra West sites increased from their November 2009 concentrations to 61 mg/L and 69 mg/L, respectively. Comparatively low TSS values were recorded in the August 2010 samples, with a maximum value obtained of 5 mg/L.

BOD concentrations were found to be comparatively low in August 2010 (<2–3 mg/L) and November 2009 (4.5-8 mg/L) samples, and high in February 2010 samples, with mean concentrations ranging between 27 to 28 mg/L.

EC was the highest during February 2010 with a maximum value of 6700 µS/cm. November 2009 and August 2010 EC values averaged 1300 µS/cm and 1800 µS/cm, respectively.

Table 4 Nutrients mean concentrations (± standard error, n=2) of Bibra Lake surface water quality

Analytes	Units	LOR	Guideline Level	November 2009				February 2010		August 2010			
				Bibra North (BLNS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra North (BLNS)	Bibra North west (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)
Chlorophyll *a*	µg/L	<0.02	30#	13±2	21±3.5	29±0.5	25±0.5	110±10	140±15	3.6±0.2	3.9±0.5	3.1±0.2	7.2±0.9
Total Phosphorus (TP)	mg/L	<0.04	0.06#	0.53±0	0.77±0.01	0.8±0.04	0.87±0.01	0.74±0.01	0.73±0.02	0.39±0.02	0.32±0.01	0.27±0.01	0.33±0.02
Orthophosphate	mg/L	<0.1	0.03#	0.2±0	0.4±0	0.3±0	0.4±0	0.04±0	0.04±0	0.21±0.01	0.14±0.01	0.1±0.02	0.16±0.01
NO_x as N	mg/L	<0.01	0.1#	0.15±0.01	0.19±0.01	0.18±0	0.14±0	<0.01	<0.01	0.13±0	0.21±0.01	0.03±0.005	0.23±0.01
Total Kjeldahl Nitrogen	mg/L	<0.1	-	2.15±0.15	2.4±0.1	3.1±0.1	2.7±0.4	12.5±0.5	12.5±0.5	2.5±0.05	2.8±0.2	2.5±0.25	2.9±0.5
Total Nitrogen (TN)	mg/L	<0.1	1.5#	2.3±0.2	2.6±0.1	3.3±0.1	2.8±0.4	12.5±0.5	12.5±0.5	2.4±0.05	2.6±0.2	2.5±0.25	2.7±0.5
TN :TP Ratio	-	-	-	4:1	3:1	4:1	3:1	17:1	17:1	6:1	8:1	9:1	8:1

Notes:

ANZECC/ARMCANZ (2000) Guideline values for Wetlands in South-West Australia.

Concentrations exceeding guideline values are highlighted in yellow.

Table 5 TSS, BOD and EC mean concentrations (± standard error, n=2) of Bibra Lake surface water quality

Analytes	Units	LOR	November 2009				February 2010		August 2010			
			Bibra North (BLNS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra North (BLNS)	Bibra North west (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)
Total Suspended Solids	mg/L	<2	12±1.5	27±10.5	48±0	44±0.5	61±4	69±3.5	2±0	2.5±0.5	3±0	5±0
Biological Oxygen Demand	mg/L	<2	4.5±0.5	4.5±0.5	8±2	6±0	28±0	27±1.5	<2	<2	<2	3±3
*Electrical Conductivity	µS/cm		1300±0(n=58)	-	1300±0 (n=28)	1300±0 (n=18)	6000±23 (n=45)	6700±74 (n=22)	-	1800±11 (n=10)	1800±3 (n=9)	-

Notes:
*Average electrical conductivity value through the water column, (n) indicates the number of readings taken by the water profiler instrument.
"-" indicates that the particular test was not conducted (a function of standing surface water availability)

4.1.1.1.5 Total Petroleum Hydrocarbon

TPH concentrations measured during the monitoring period are detailed in Table 6. There were no guidelines levels for TPH concentrations in water as it is not naturally present in water.

TPH C_6-C_9 fractions were not detected during the monitoring periods. TPH C_{10}-C_{14} fractions were only recorded in samples taken at Bibra North-West (86 µg/L) and Bibra West (77 µg/L) in February 2010. TPH C_{15}-C_{28} fractions were detected at all sites sampled in November 2009, February 2010 and August 2010, with the highest mean concentrations occurring in February 2010. TPH C_{29}-C_{36} fraction mean concentrations were detected above LOR in November 2009 and February 2010. Similar to TPH C_{15}-C_{28}, TPH C_{29}-C_{36} concentrations were highest in February 2010, with a maximum mean concentration of 500 µg/L measured at the Bibra West site.

4.1.1.1.6 Persistent Organic Contaminants

Benzene, toluene, ethyl benzene and xylenes (BTEX) were all below detection limits. No PAH were detected above LOR in any of the samples taken throughout the sampling events.

Organochlorine and organophosphate pesticides, semi-volatile compounds (phthalates) and ultra-trace residues were analysed in water samples collected during February 2010 and August 2010. None were detected in the surface water sampled from Bibra Lake. A summary of the analytical results is included in Appendix D.

Table 6 TPH mean concentrations (± standard error, n=2) of Bibra Lake surface water quality

Analytes	Units	LOR	November 2009				February 2010		August 2010			
			Bibra North (BLNS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra North (BLNS)	Bibra North-West (BLWS1)	Bibra West (BLWS2)	Bibra South (BLSS)
TPH C_6-C_9	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
TPH C_{10}-C_{14}	µg/L	<50	<50	<50	<50	<50	86±1.5	77±14	<50	<50	<50	<50
TPH C_{15}-C_{28}	µg/L	<100	250±10	230±0	280±35	250±15	1100±215	1000±180	190±5	190±5	180±5	190±0
TPH C_{29}-C_{36}	µg/L	<100	150±5	140±5	170±25	140±10	440±45	500±65	<100	<100	<100	<100

4.1.1.1.7 Surface Water Stratification

Water profiles of Bibra Lake were obtained by lowering a multi-parameter sensor through the water column. The water level of Bibra Lake was very shallow: less than 1 m depth in November 2009 and less than 0.5 m in February 2010. Water levels in August 2010 varied between 0.3 m and 0.8 m, depending on the site in the lake. It is noted that the sensor length was 0.55 m, therefore water profile readings from very shallow water columns were not recorded. Water quality profiles are illustrated in Figure 8 and Figure 9 and described in the following sections.

4.1.1.1.8 pH

During the November 2009 sampling event, pH values did not vary significantly throughout the water column or between sampling sites. Variations were observed between sites, with values ranging from pH 8.1.7 to pH 8.40; the highest pH reading was obtained at the Bibra South site. The readings exceeded the ANZECC/ARMCANZ (2000) upper limit for pH (8.0) for freshwater lakes at all locations (Figure 8a).

February 2010 pH values were generally higher than during the November 2009 event, ranging from pH 8.28 to pH 8.75. Values showed greater variability throughout the water column (particularly at Bibra North-West) compared to November 2009, with pH values being lower towards the bottom of the lake.

During the August 2010 sampling event, readings generally varied between pH 8.27 and pH 8.43.

4.1.1.1.9 Turbidity

The November 2009 sampling event recorded varied turbidity readings between sites, with higher readings obtained at Bibra West and Bibra South than at Bibra North. Turbidity readings appeared to be higher at the bottom than the surface of the lake, ranging from 8.1 NTU (at the surface at Bibra North) to 38 NTU (at the bottom at Bibra West) (Figure 8b).

During the February 2010 sampling event, turbidity readings were similar at both sites sampled and were higher on the surface than at the bottom of the lake. At the lake surface, turbidity readings ranged between 37 NTU and 40 NTU, while below surface turbidity levels were between 2.6 NTU and 9 NTU. This may indicate the presence of abundant algae on the lake's surface.

Turbidity readings were lower during the August 2010 sampling event than during the November 2009 and February 2010 events and did not vary greatly throughout the water column. The readings ranged between approximately 5 NTU and 6 NTU.

4.1.1.1.10 Dissolved Oxygen

During the November 2009 sampling event, DO readings did not vary greatly between sites, with the highest and lowest readings measured at the Bibra West (8 mg/L) and Bibra South (7.2 mg/L) sites, respectively. Minor variation was observed in DO readings at the Bibra North site; however, in general, no stratification was observed and DO levels did not fall below the guideline value of 5 mg/L (ANZECC/ARMCANZ 2000) (Figure 9a).

Dissolved oxygen readings at Bibra North-West in February 2010 showed a steady decrease in DO with depth. DO readings at the Bibra West site increased with depth during the same sampling event. In general, DO levels were higher than the guideline value (5 mg/L), except at the Bibra North-West site below approximately 0.9 m depth. Above approximately 0.6 m in depth, February 2010 DO readings were generally higher than those found during November 2009 and August 2010.

In August 2010, DO readings were generally lower than in February 2010, but higher than in November 2009. The readings were relatively similar between sites, ranging from 10.5 mg/L to 11.5 mg/L with no major variations detected throughout the water column. DO level was higher than the guideline value of 5 mg/L at all sites in August 2010.

4.1.1.1.11 Temperature

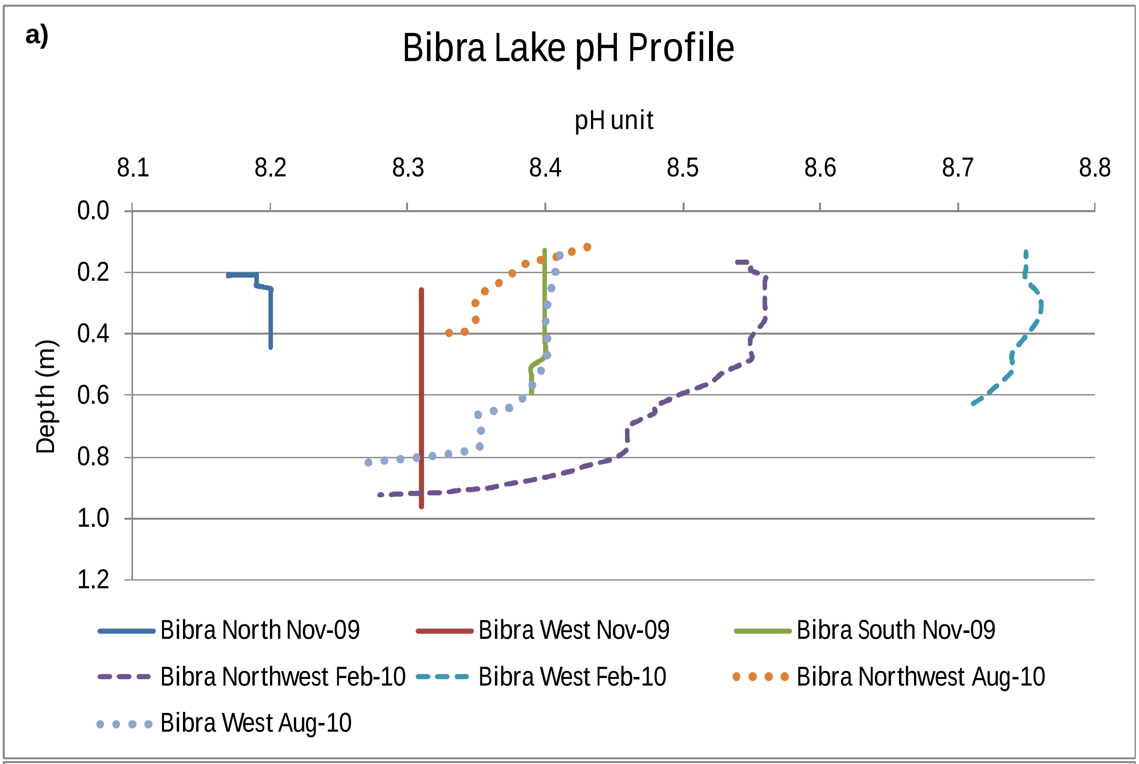
During November 2009, some variation in temperature readings were recorded between sites (ranging between 18.7°C and 21.5°C), which most likely reflects the time of day when the readings were taken. In general, temperature readings were consistent throughout the water column. There was no evidence of significant stratification (Figure 9b).

In February 2010, temperature readings at the deeper Bibra North-West site were similar throughout the water column, ranging between 20.5°C and 21°C. At the Bibra West site, the temperature was higher (27.3°C at the surface) and decreased with depth.

Water temperature readings during August 2010 were lower than during November 2009 and February 2010, ranging from 15.4°C to 16.4°C. Temperature readings were similar throughout the water column, indicating no significant stratification.

4.1.1.1.12 Dissolved Salts

Dissolved salts were measured as EC, which was observed to be relatively constant throughout the water column during the monitoring period (Figure 10), with the exception of February 2010. EC values in November 2009 and August 2010 were similar in concentration (approximately 1300 µS/cm and 1800 µS/cm, respectively), compared to February 2010, when values were considerably higher (averaging between 6000 and 6700 µS/cm) and varied throughout the water column.



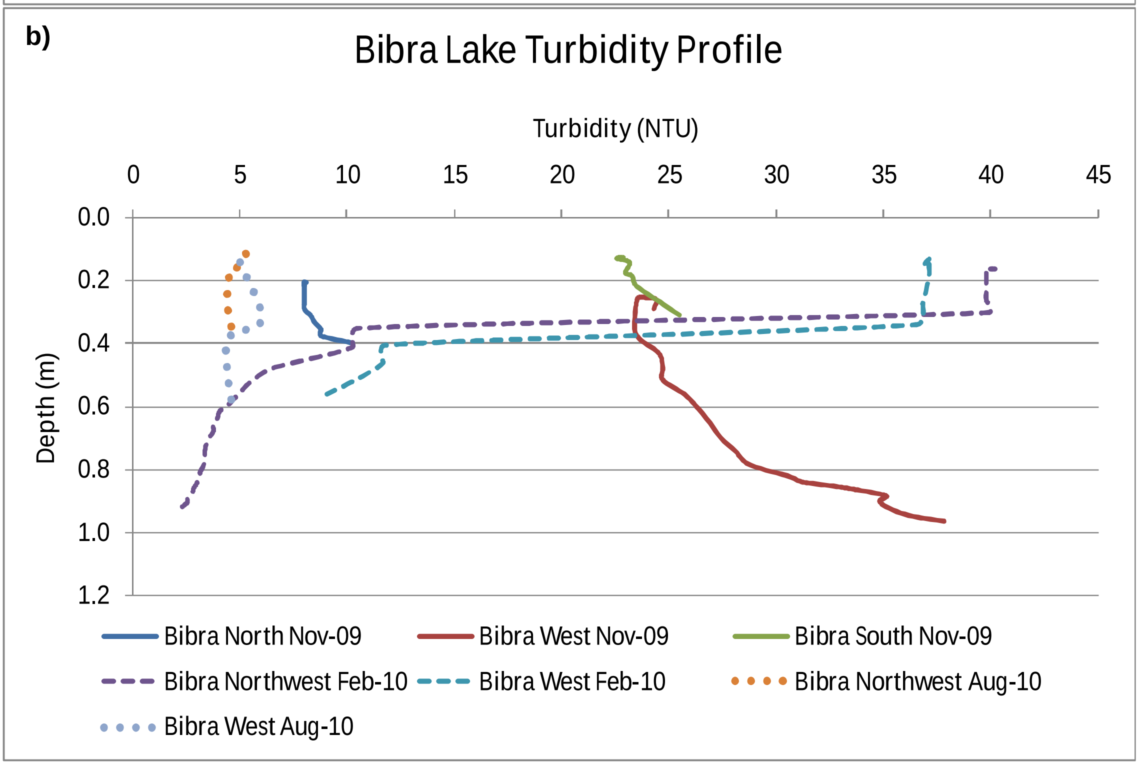


Figure 8 **Bibra Lake water profiles: a) pH profile, b) turbidity profile**

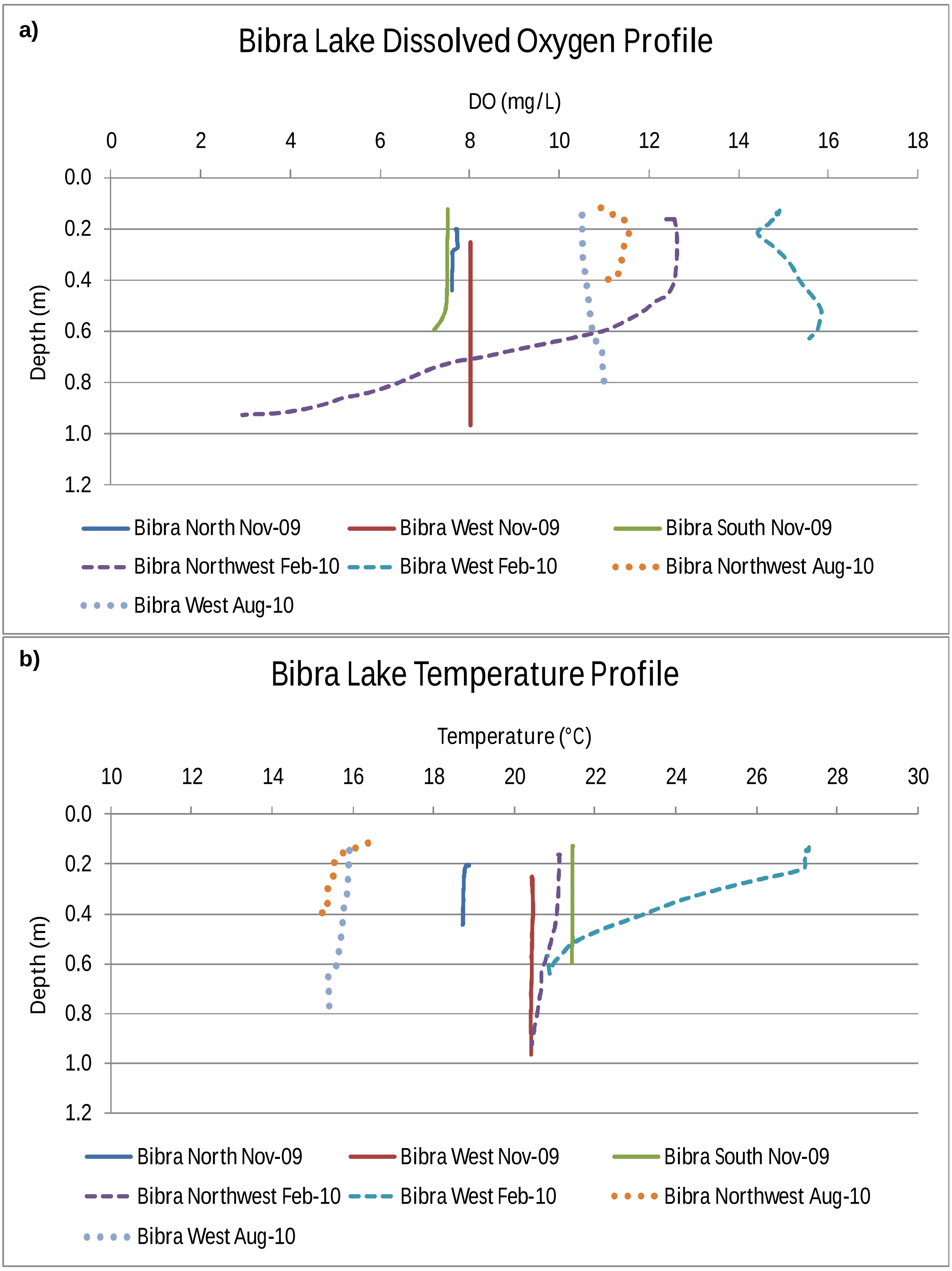


Figure 9 Bibra Lake water profiles: a) DO profile, b) temperature profile

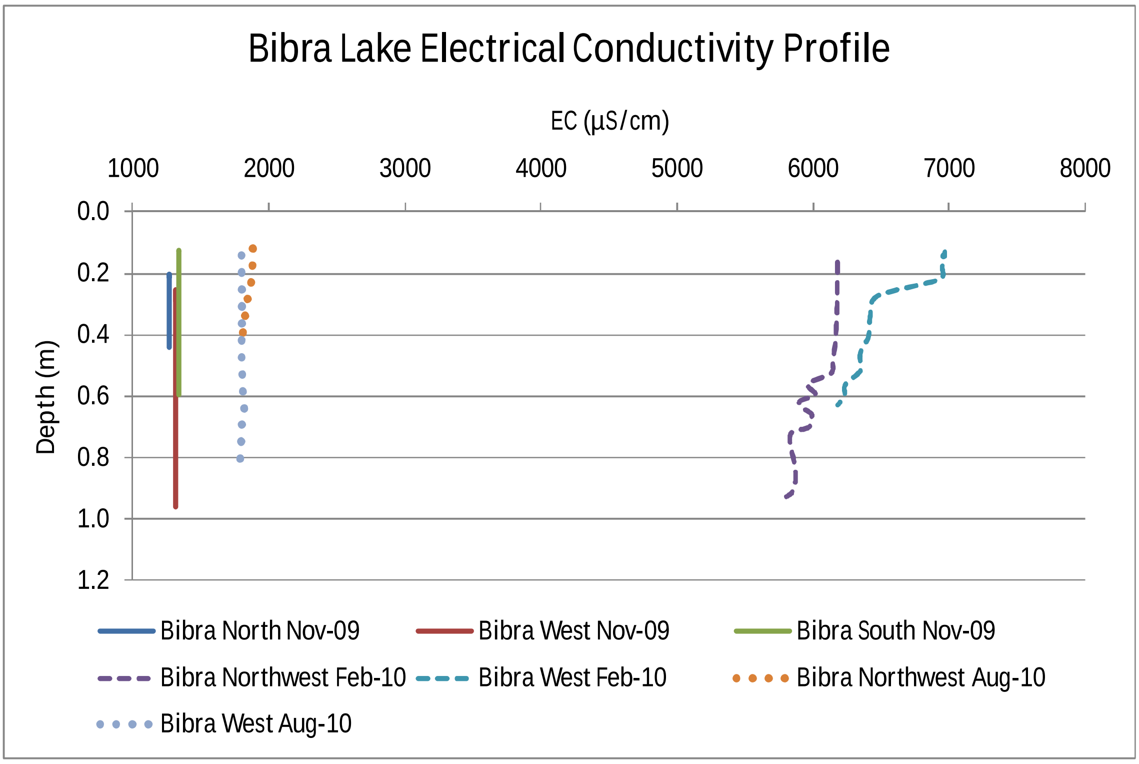


Figure 10 Bibra Lake water electrical conductivity profile

4.1.1.2 Phytoplankton Community Composition

4.1.1.2.1 November 2009

There were several potential taste- and odour-causing algal species identified at the boundary and middle of Bibra Lake in November 2009. However, there were no potentially toxic species detected in the lake. *Mougeotia* spp. dominated the Bibra Lake algal assemblage. *Zygnemopsis* spp. was also noted as an abundant species at the lake's boundary (western side of Bibra Lake) but not in the middle of the lake. A summary of algae identified during sampling is presented in Table 7.

Table 7 Bibra Lake November 2009 algae genera/species

Genera	Lake Boundary	Middle of the Lake
Bacillariophyceae (Diatoms)		
Amphora spp.	Present	-
Diadesmis confervaceae	Present	-
Fragilaria spp.	Present	Present
Navicula spp.	Present	Present
Nitzshia spp.	Present	-
Synedra spp.	Present	Present
Chlorophyceae (Green algae)		
Ankistrodesmus spp.	Present	Present
Chlamydomonas spp.	-	Present
Desmidium spp.	-	Present
Elakatothrix spp.	-	Present
Microspora sp. 001	-	Present
Mougeotia spp.	Dominant	Dominant
Oedogonium spp.	Present	Present
Oocystis spp.	Present	Present
Scenedesmus spp.	Present	-
Spirogyra spp.	Present	-
Zygnemopsis spp.	Abundant	-
Cryptophyceae		
Chroomonas spp.	Present	Present
Cryptomonas spp.	Present	Present
Cyanobacteria (Blue Green Algae)		
Aphanocapsa sp. 001	Present	-
Aphanocapsa sp. 002	Present	-
Planktolyngbya contorta (s)	Present	-
Planktolyngbya subtilis	Present	Present
Pseudanabaena sp. 001	Present	-
Synechocystis spp.	-	Present
Euglenophyceae (Euglenoids)		
Euglena spp.	-	Present
Prasinophyceae		
Prasinophyte spp.	-	Present

Notes:
Potential taste- and odour-causing species are highlighted in yellow.
"-" indicates that the particular algae was not found in the samples.

4.1.1.2.2 February 2010

During February 2010, potentially toxic species were detected in addition to potential taste- and odour-causing species. *Anabaena affinis* and *Anabaena spiroides* were two potentially toxic species found in the lake. In contrast with the November 2009 sampling, *Mougeotia* spp. was not the dominant species. Several species such as *Kirchneriella* spp., *Planktolyngbya contorta*, and *Planktolyngbya subtilis* were found to be abundant in the absence of *Mougeotia* spp. Algae identified during February 2010 are summarised in Table 8.

Table 8 Bibra Lake February 2010 algae genera/species

Genera	Lake Boundary	Middle of the Lake
Bacillariophyceae (Diatoms)		
Amphora spp.	Present	Present
Chaetoceros spp.	Present	-
Fragilaria spp.	-	Present
Navicula spp.	Present	Present
Synedra spp.	Present	-
Chlorophyceae (Green Algae)		
Actinastrum sp. *001*	Present	-
Closteridium sp.*003*	Present	-
Kirchneriella sp.*001*	**Abundant**	-
Microspora sp.*001*	-	Present
Scenedesmus spp.	Present	Present
Tetraedron minimum	Present	-
Cryptophyceae		
Cryptomonas spp.	Present	-
Cyanobacteria (Blue Green Algae)		
Anabaena affinis	Present	Present
Anabaena spiroides	Present	Present
Merismopedia sp. *002*	Present	-
Merismopedia sp.*003*	Present	-
Planktolyngbya contorta (s)	**Abundant**	Present
Planktolyngbya subtilis	**Abundant**	-
Synechocytis spp.	Present	Present
Euglenophyceae (Euglenoids)		
Euglena spp.	Present	-
Trachelomonas sp.*003*	Present	-
Prasinophyceae (Green Flagellates)		
Prasinophyte sp. *002*	Present	-
Prasinophyte sp. *006*	Present	-

Notes:
Potential taste- and odour-causing species are highlighted in yellow.
Potentially toxic species are highlighted in orange.
"-" indicates that the particular algae was not found in the samples.

4.1.1.2.3 August 2010

During August 2010, only three species of algae were found in the water column. *Synechocystis* spp. was the only potential taste- and odour-causing species found. A summary of algae identified during this sampling round is presented in Table 9.

Table 9 Bibra Lake August 2010 algae genera/species

Genera	Lake Boundary	Middle of the Lake
Chlorophyceae (Green Algae)		
Ankyra sp. *001*	Present	Present
Cyanobacteria (Blue Green Algae)		
Synechocystis spp.	Present	Present
Euglenophyceae (Euglenoids)		
Trachelomonas spp.	-	Present

Notes:
Potential taste- and odour-causing species are highlighted in yellow.
"-" indicates that the particular algae was not found in the samples.

4.1.2 Stormwater Quality

Results of stormwater samples taken from drains that discharge to Bibra Lake are presented in Appendix E and illustrated in Figure 4. Drains that discharge to Bibra Lake sampled as a part of this study were:

- Lower Hope Road (Site 6)
- Upper Bibra West (Site 7)
- Middle Bibra West (Site 8)
- Lower Bibra West (Site 9)
- Bibra South (Site 10)
- Bibra South-East 1 (Site 11)
- Bibra South-East 2 (Site 12); and
- Bibra South-East 3 (Site 13).

While each of these sites were targeted on the dates presented in Section 3.4.2, the ability of samplers to obtain samples in each of the drains depended on whether the drain was flowing at the time of sampling. This depended on the size and duration of the storm, the hydrological characteristics of the catchment draining to the discharge point and the speed with which samplers were able to access the monitoring site. A table of sampling dates is presented in Table 10. Generally the success of sample retrieval was good, notably at Sites 7 and 10, where samples were retrieved during each of the rainfall events. Sampling round 5 was conducted on 14-15/06/2010, however samples were retrieved only from drain at Site 7 due to low rainfall on the 14/06/2010. For this reason, results from 14/06/2010 are not included in analysis and presented in Appendix E. Lower sample retrieval rates were at Site 9, where samples were retrieved during three of the sampling rounds. Only two samples were retrieved at Site 6 and, while these results are presented in Appendix E data from this site have been excluded from any further analysis.

Table 10 Sampling retrieval success during stormwater monitoring programme

Drain Number	Sampling Round 1 14/04/2010	Sampling Round 2 21/05/2010	Sampling Round 3 22/05/2010	Sampling Round 4 27/05/2010	Sampling Round 5 15/06/2010	Sampling Round 6 8/07/2010	Sampling Round 7 12/08/2010	No of samples
6	×	×	×	×	×	✓	✓	2
7	✓	✓	✓	✓	✓	✓	✓	7
8	×	×	✓	✓	✓	×	✓	4
9	×	×	×	✓	✓	×	✓	3
10	✓	✓	✓	✓	✓	✓	✓	7
11	✓	×	×	✓	✓	✓	✓	5
12	✓	×	×	✓	✓	✓	✓	5
13	✓	×	×	✓	✓	✓	✓	5
No of Samples	5	2	3	7	7	6	8	

Notes:
✓ = sample successfully retrieved
× = no sample retrieved.

Sampling results for each of the parameters tested are summarised briefly in the following sections. Concentrations of analytes were below the limits of reporting for the majority of the chemical species tested. Where concentrations were above the LOR, they are discussed in the following sections.

4.1.2.1 Elements

Concentrations of arsenic and cadmium were below the LOR at all sites and for all sampling events. Results for aluminium, chromium, copper, iron, lead and zinc are presented in the following sections.

4.1.2.1.1 Aluminium

Spatial distributions of maximum, average and minimum concentrations of aluminium in stormwater flowing to Bibra Lake are presented in Figure 11. Aluminium generally exceeded the ANZECC/ARMCANZ (2000) guidelines for 95 percent species protection. Lower values were recorded during the sampling round 4 at Site 7, and at Sites 10 and 11. The maximum aluminium concentration was recorded at Site 8 (680 µg/L) during sampling round 4.

Average aluminium concentrations were higher at Site 8, at approximately 360 µg/L. There was little variation between average concentrations at other sites, with averages at all other sites ranging 140–220 µg/L**.**

4.1.2.1.2 Chromium

All detected total dissolved chromium concentrations were higher than the guideline value of 1 µg/L for Cr (VI) (refer to Section 3.3), with the highest concentration of 8.1 µg/L at Site 8 during sampling round 7.

4.1.2.1.3 Copper

Spatial distributions of maximum, average and minimum concentrations of copper in stormwater flowing to Bibra Lake are presented in Figure 12. Copper levels generally exceeded the ANZECC/ARMCANZ (2000) guideline values for 95 percent species protection and were highly spatially variable throughout the catchment draining to the lake. Copper did not exceed the guideline value at Site 13 during sampling rounds 5 and 7. The maximum copper concentration was recorded at Site 7 (34 µg/L) during sampling round 2.

Generally lower copper concentrations were recorded in the south-east of the study areas with averages of 7.4, 2.3 and 2.7 µg/L recorded at Sites 11, 12 and 13, respectively. Relatively low average concentrations (3.3 µg/L) were also recorded at Site 9 on the western side of Bibra Lake. Relatively low copper concentrations in stormwater at Site 9 contrasted with stormwater measurements at other sites on the western side of Bibra Lake, with higher average concentrations at Site 7 and Site 8 (14 µg/L at each).

4.1.2.1.4 Iron

Iron levels exceeded the DEC (2010) guideline value of 300 µg/L sporadically during the monitoring period. All recorded samples extracted from Site 4 exceeded the guideline value. Two samples recorded at Site 7 during round 2 and 6 exceeded the guideline. A single sample from each of the Sites 10 (round 2), 12 (round 6) and 13 (round 6) each exceeded the DEC (2010) guideline. The maximum iron concentration (930 µg/L) was recorded at Site 7 during sampling round 6.

4.1.2.1.5 Lead

Spatial distributions of maximum, average and minimum concentrations of lead in stormwater flowing to Bibra Lake are presented in Figure 13. Lead concentrations in stormwater draining to Bibra Lake were highly variable both spatially and temporally. Frequent exceedences of the ANZECC/ARMCANZ guideline for lead were recorded in samples taken at the majority of sites; at Sites 12 and 13 only a single small exceedence was recorded at each site during sampling round 6. The maximum concentration recorded for lead throughout the monitoring period was at Site 10 (21 µg/L) during round 6.

Average lead concentrations appeared to be lower in the south-western catchments draining to Bibra Lake. Average concentrations were lower at Sites 12 and 13 (2.8 and 2.5 µg/L, respectively) in the south-east. Similar to results for copper, relatively high average concentrations were found in catchments draining to the western and southern portion of the lake with Sites 7, 8 and 10 recording average concentrations of 8.4, 6.3 and 7.3 µg/L, respectively. These values contrasted with a relatively low average lead concentration at Site 9 (3.6 µg/L) in the west.

4.1.2.1.6 Zinc

Spatial distributions of maximum, average and minimum concentrations of zinc in stormwater flowing to Bibra Lake are presented in Figure 14. Zinc exceeded ANZECC/ARMCANZ guideline values at all monitored sites during each of the monitoring rounds. The maximum zinc concentration was recorded at Site 10 (180 µg/L) during sampling round 6.

Average results for zinc were similar to those recorded for lead and copper with relatively high concentrations recorded in the west and south, with a single contrasting site (Site 9) indicating relatively low concentrations of zinc. Average concentrations were 81, 73 and 73 µg/L at Sites 7, 8 and 10 respectively. The average concentration at Site 9 was 28 µg/L. Lower average concentrations were recorded in the extreme south-east of the Bibra Lake catchment with averages of 43 and 35 µg/L recorded at Sites 12 and 13.

4.1.2.2 Nutrients

Results for total phosphorus, total nitrogen and NOx are presented in the following sections.

4.1.2.2.1 Phosphorus

Exceedences of ANZECC/ARMCANZ (2000) guideline values for total phosphorus were found at most sites. Exceedences were recorded during each of the monitoring rounds at Site 13. No exceedences of the guideline were recorded at Site 9 during any of the monitoring rounds. The maximum phosphorus concentration (0.84 mg/L) was recorded at Site 7 during sampling round 2.

Spatial distributions of maximum, average and minimum concentrations of total phosphorus in stormwater flowing to Bibra Lake are presented in Figure 15. Higher average total phosphorus concentrations were recorded at Site 7 in the west (0.3 µg/L) and Site 10 in the south (0.2 µg/L), and were higher than the maximum concentrations recorded at other sites in the study area.

4.1.2.2.2 Nitrogen

Total nitrogen concentrations were generally below the ANZECC/ARMCANZ (2000) guideline values for south-western wetlands. Exceptions were at Site 7 (3.8 µg/L, round 6), Site 8 (6.5 µg/L, round 2), Site 10 (2.9 µg/L, 2.8 µg/L and 1.8 µg/L, rounds 2, 3 and 6, respectively) and Site 13 (2.8 µg/L, round 7).

Spatial distributions of maximum, average and minimum concentrations of total nitrogen in stormwater flowing to Bibra Lake are presented in Figure 16. High average concentrations were recorded at Sites 7, 8, 10 and 13 with averages of 2 µg/L, 2.1 µg/L, 1.4 µg/L and 1.3 µg/L, respectively. Lower average concentrations were evident at Sites 9 and 11 with 0.6 and 0.5 µg/L, respectively, and the lowest average concentrations were recorded at Site 12 (0.24 µg/L).

NOx concentrations varied throughout monitoring and regular exceedences of the ANZECC/ARMCANZ (2000) guidelines for 95 percent species protection occurred at Site 7 (rounds 3, 5 and 6), Site 8 (rounds 3, 4 and 7) and Site 10 (round 2 and 3). Concentrations at Site 13 exceeded the guideline value during round 6. The highest concentration was recorded at Site 8 during round 3 (5.6 µg/L).

Spatial distributions of maximum, average and minimum concentrations of NOx in stormwater flowing to Bibra Lake are presented in Figure 17. As discussed above, the higher average concentrations are at sites which regularly exceeded the ANZECC/ARMCANZ (2000) guidelines including Sites 7, 8 and 10 with average concentrations of 0.3, 1.5 and 0.5 µg/L, respectively. Average concentrations at all other sites were relatively low and did not exceed 0.075 µg/L.

4.1.2.3 Persistent Organic Contaminants

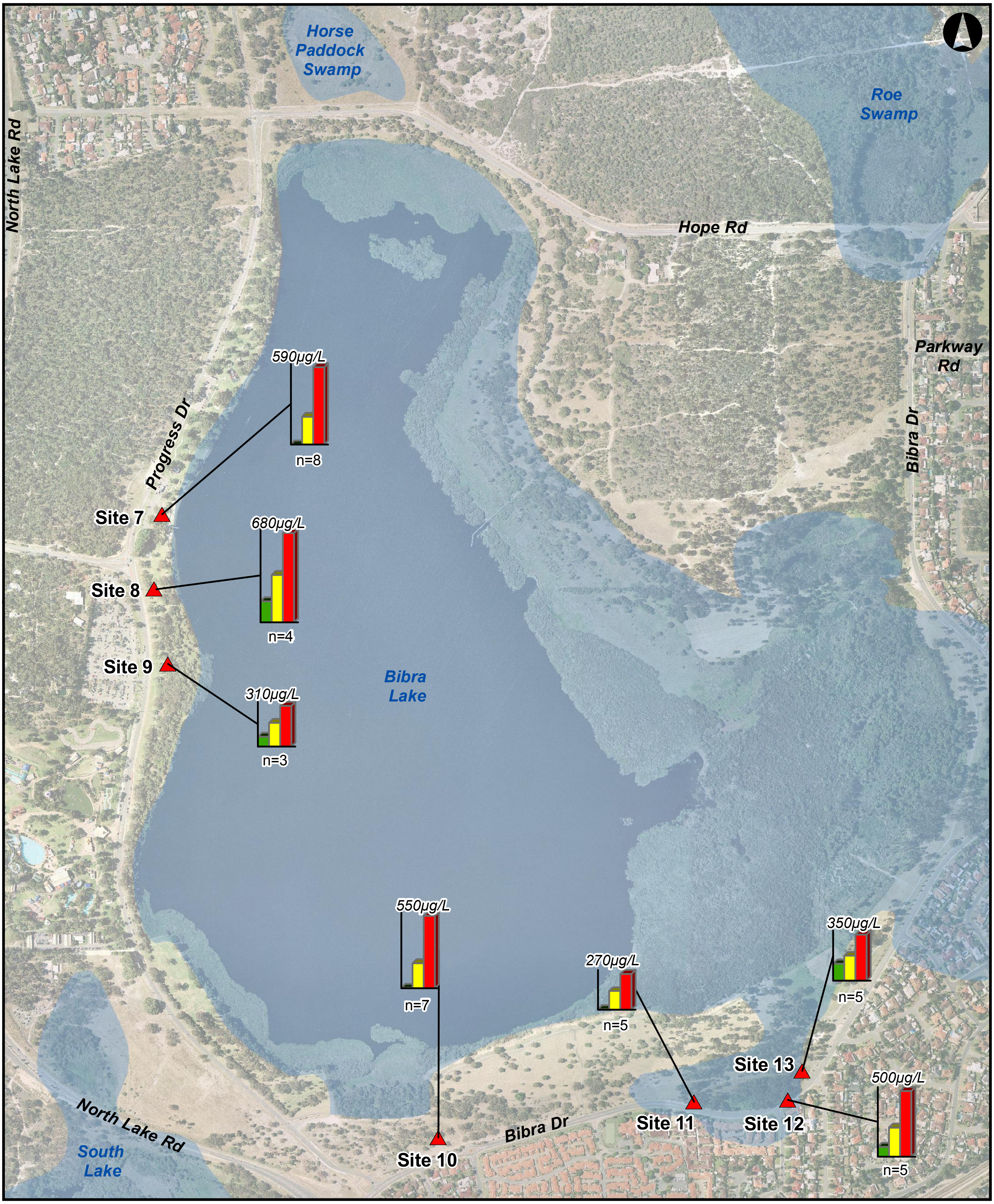
BTEX and PAH were generally below LOR throughout the monitoring period, except on one occasion when a BTEX concentration of 38 µg/L was detected at Site 8 during sampling round 5.

4.1.2.4 Total Petroleum Hydrocarbons

While BTEX concentrations were generally below detection limits, TPH was regularly detected in stormwater runoff. There are no ANZECC/ARMCANZ (2000) guidelines for concentrations of TPH. Concentrations of TPH at the various monitoring locations throughout the study area are presented in Figure 18, Figure 19 and Figure 20. Generally higher concentrations were recorded in the C_{15}-C_{28} and C_{29}–C_{36} range. The highest concentrations were recorded at Site 7 and Site 10 with 1700 µg/L (C_{15}-C_{28}) and 980 µg/L (C_{29}-C_{36}), respectively. As evidenced in the figures, generally higher TPH were present in stormwater runoff on the western side of Bibra Lake, particularly in the longer hydrocarbon chains.

4.1.2.5 Suspended Solids

Generally, suspended solids concentrations were below 40 mg/L, with two exceedences during sampling round 6 at Site 10 (150 mg/L) and Site 11 (67 mg/L), respectively. Suspended solids measured in the stormwater samples varied greatly between sampling events and sites, ranging from <2 mg/L to 150 mg/L.



Minimum, mean and maximum total aluminium (µg/L) in stormwater draining to Bibra Lake

Figure 11

0 100 200 300

Metres

1:10,000 (A4)

Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

Stormwater Sampling Site

maximum concentration

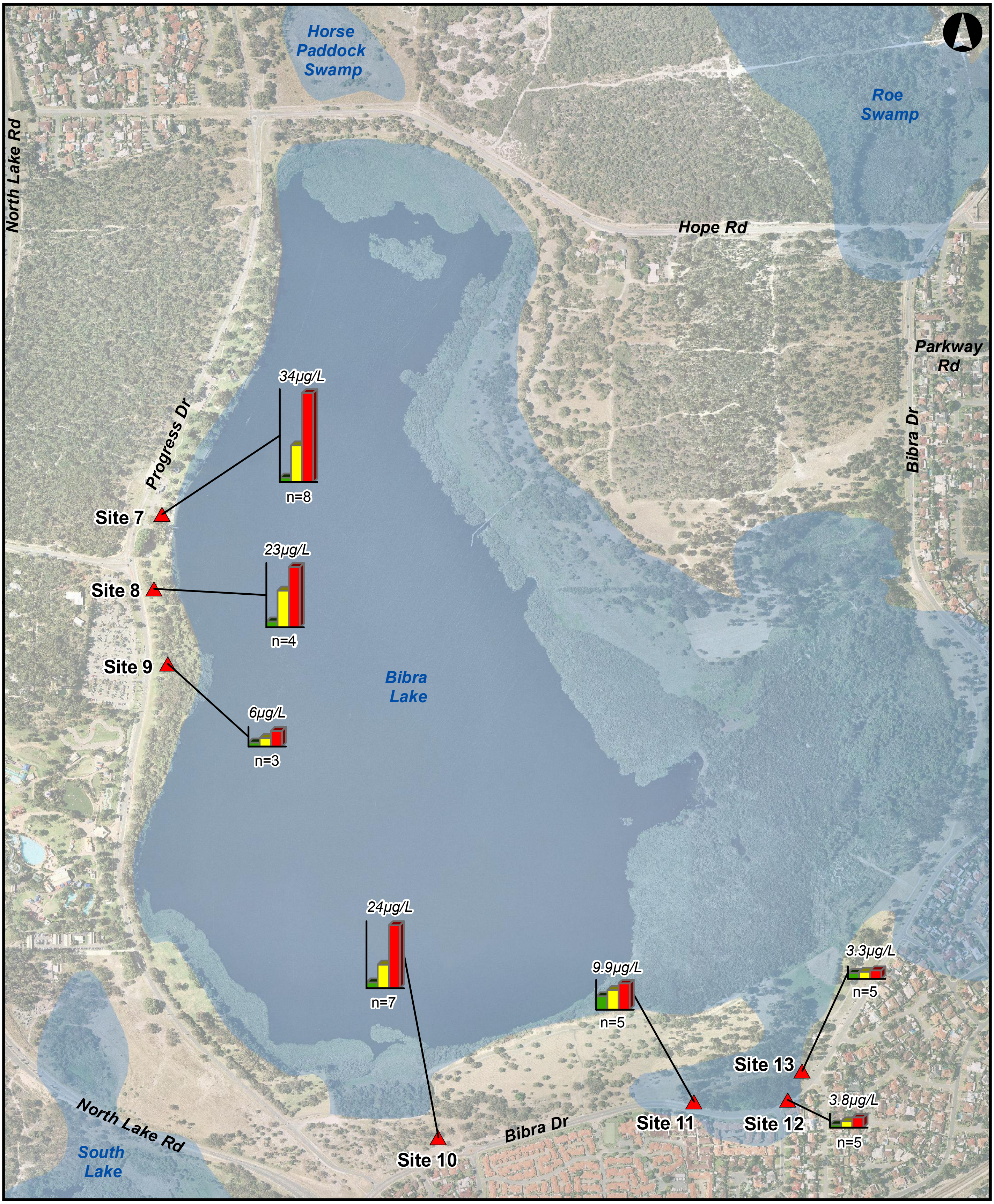
Min Mean Max

n = number of samples above limit of reporting

AECOM

Date Modified: 24/03/2011

Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Stormwater Sites - Aluminium.mxd



Minimum, mean and maximum total copper (µg/L) in stormwater draining to Bibra Lake

Figure 12

0 100 200 300
Metres
1:10,000 (A4)
Datum: GDA94 Projection: MGA z50

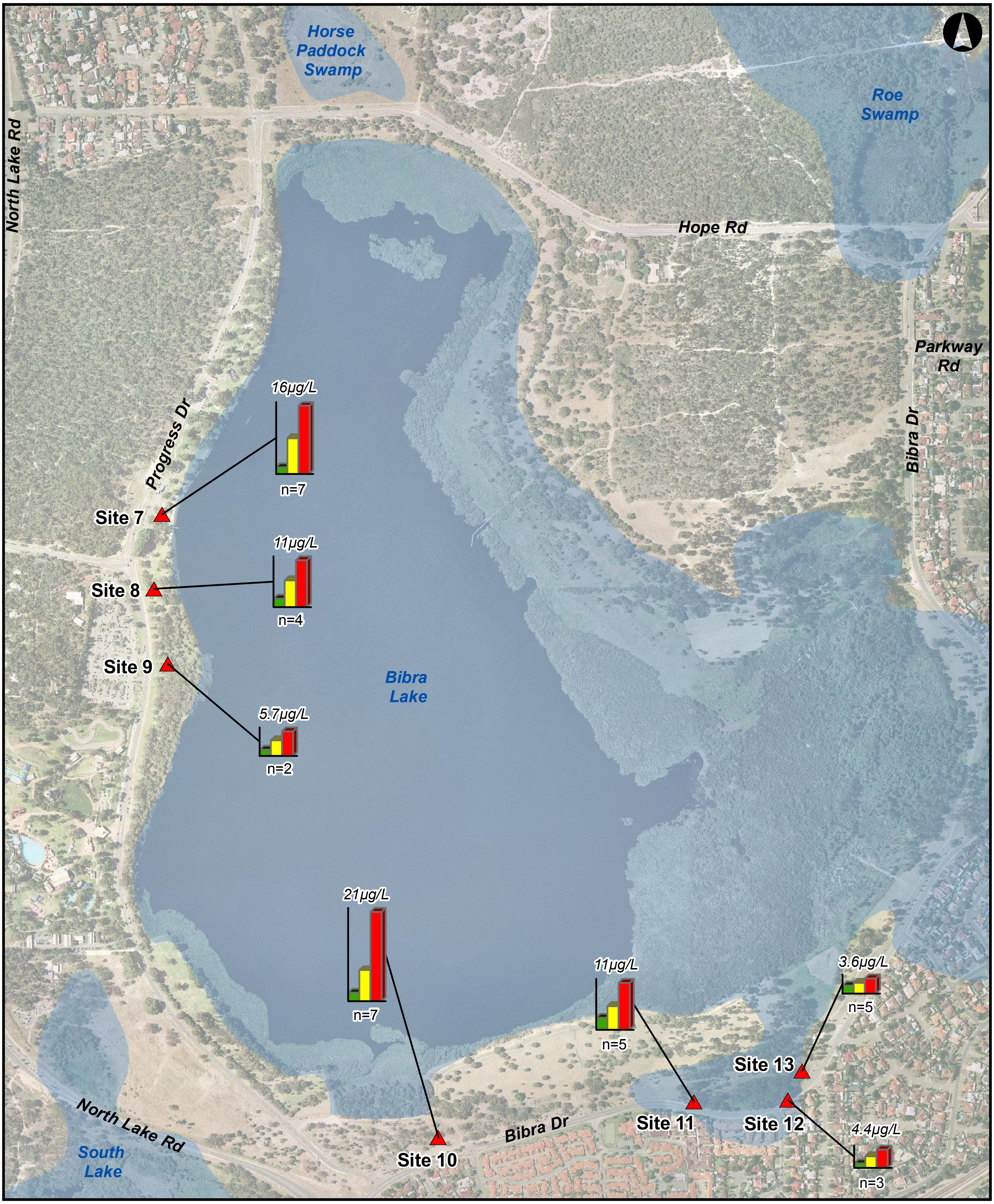
LEGEND

Wetlands
Stormwater Sampling Site

maximum concentration
Min Mean Max
n = number of samples above limit of reporting

AECOM

Date Modified: 24/03/2011
Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Stormwater Sites - Copper.mxd



Minimum, mean and maximum total lead (µg/L) in stormwater draining to Bibra Lake

Figure 13

0 100 200 300

Metres

1:10,000 (A4)

Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

Stormwater Sampling Site

maximum concentration

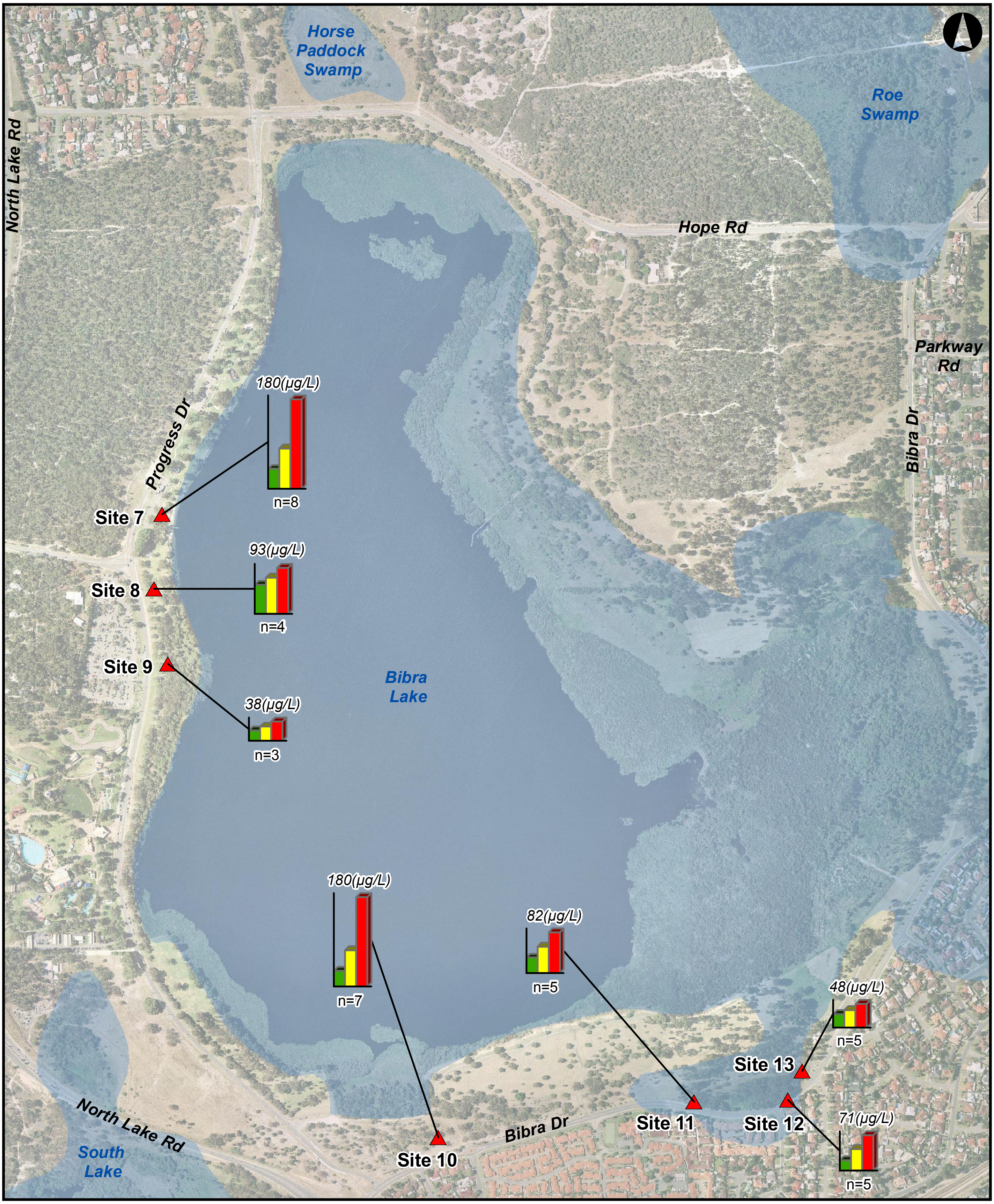
Min Mean Max

n = number of samples above limit of reporting

AECOM

Date Modified: 24/03/2011

Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Stormwater Sites - Lead.mxd



Minimum, mean and maximum total zinc (µg/L) in stormwater draining to Bibra Lake

Figure 14

0 100 200 300
Metres
1:10,000 (A4)
Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

Stormwater Sampling Site

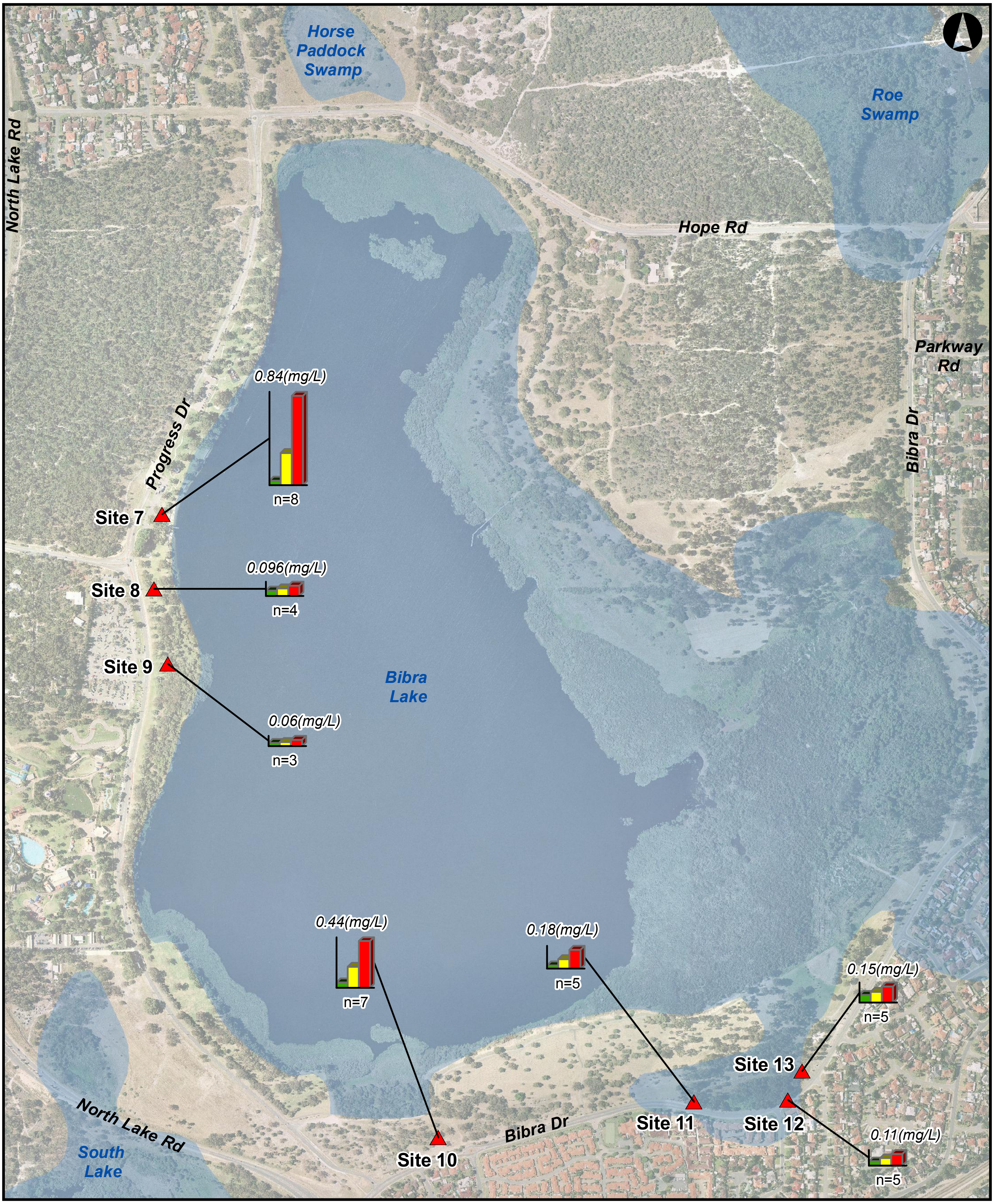
maximum concentration

Min Mean Max

n = number of samples above limit of reporting

AECOM

Date Modified: 24/03/2011
Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Stormwater Sites - Zinc.mxd



Minimum, mean and maximum total phosphorus (mg/L) in stormwater draining to Bibra Lake

Figure 15

0 100 200 300
Metres
1:10,000 (A4)
Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

Stormwater Sampling Site

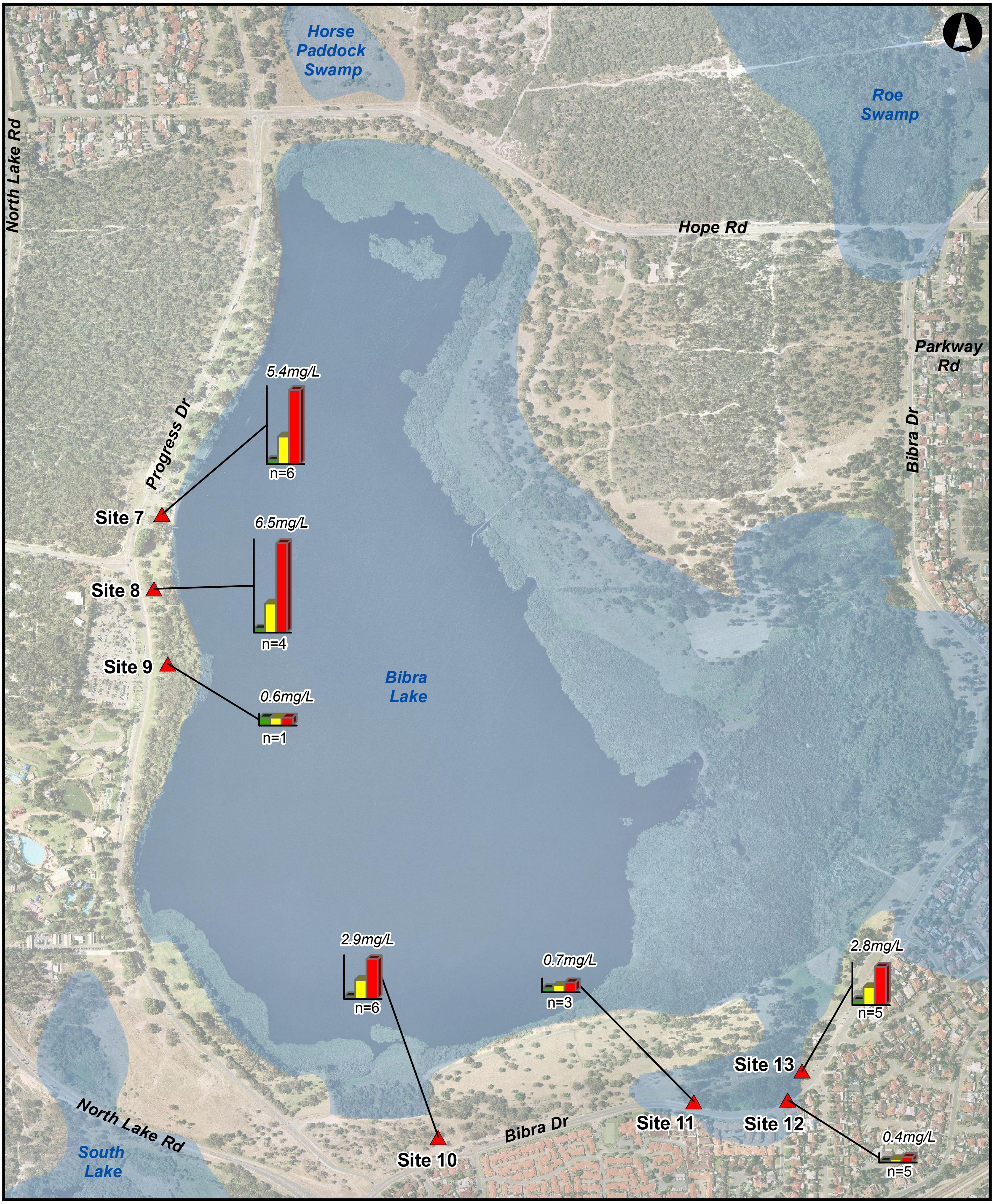
maximum concentration

Min Mean Max

n = number of samples above limit of reporting

AECOM

Date Modified: 24/03/2011
Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Stormwater Sites - Total Phosphorus.mxd



Minimum, mean and maximum total Nitrogen (mg/L) in stormwater draining to Bibra Lake

Figure 16

0 100 200 300

Metres

1:10,000 (A4)

Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

Stormwater Sampling Site

maximum concentration

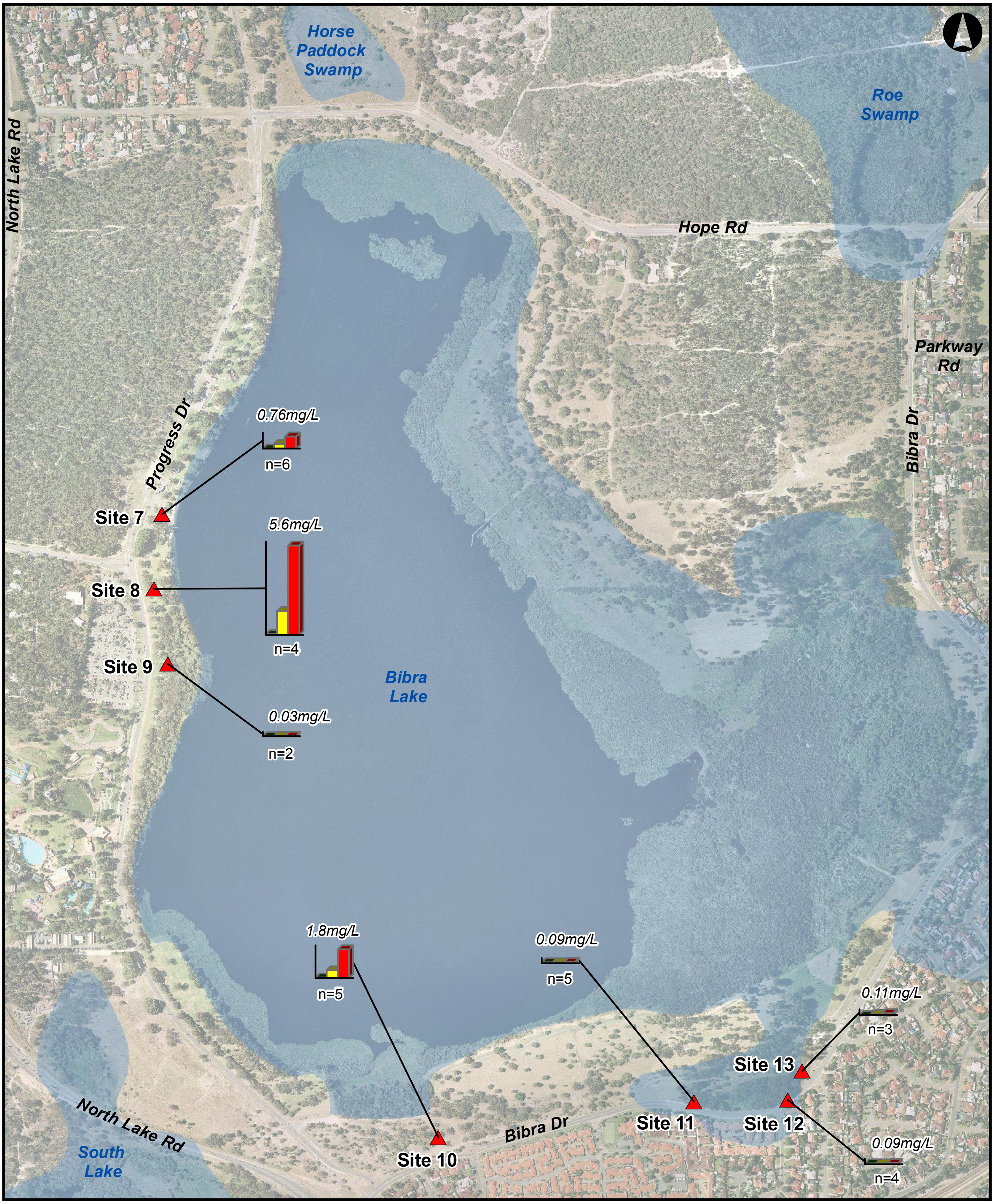
Min Mean Max

n = number of samples above limit of reporting

AECOM

Date Modified: 24/03/2011

Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Stormwater Sites - Total Nitrogen.mxd



Minimum, mean and maximum total NOx as N (mg/L) in stormwater draining to Bibra Lake

Figure 17

0 100 200 300
Metres
1:10,000 (A4)
Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

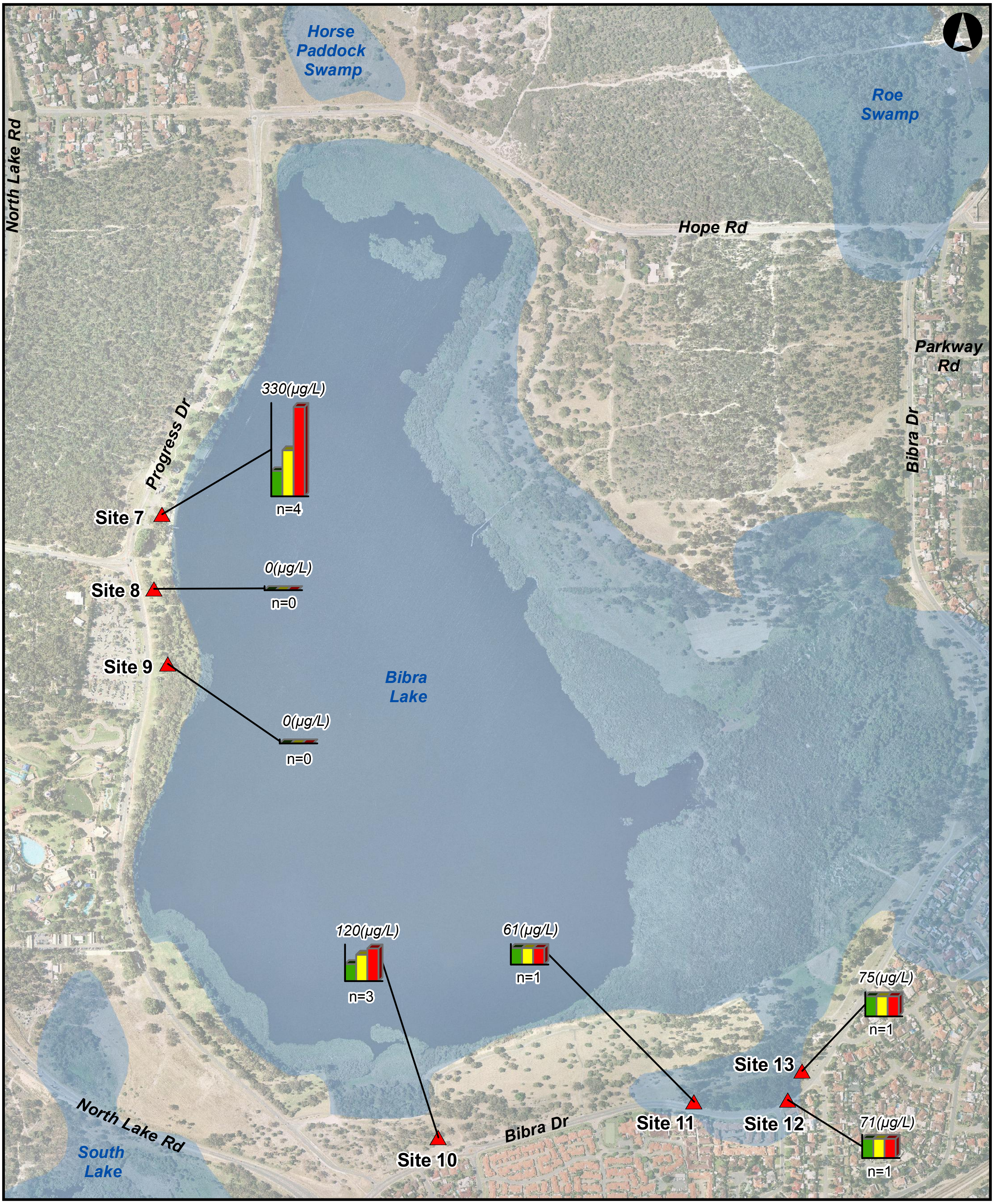
Stormwater Sampling Site

maximum concentration

Min Mean Max

n = number of samples above limit of reporting

AECOM



Minimum, mean and maximum total TPH C10-C14 (µg/L) in stormwater draining to Bibra Lake

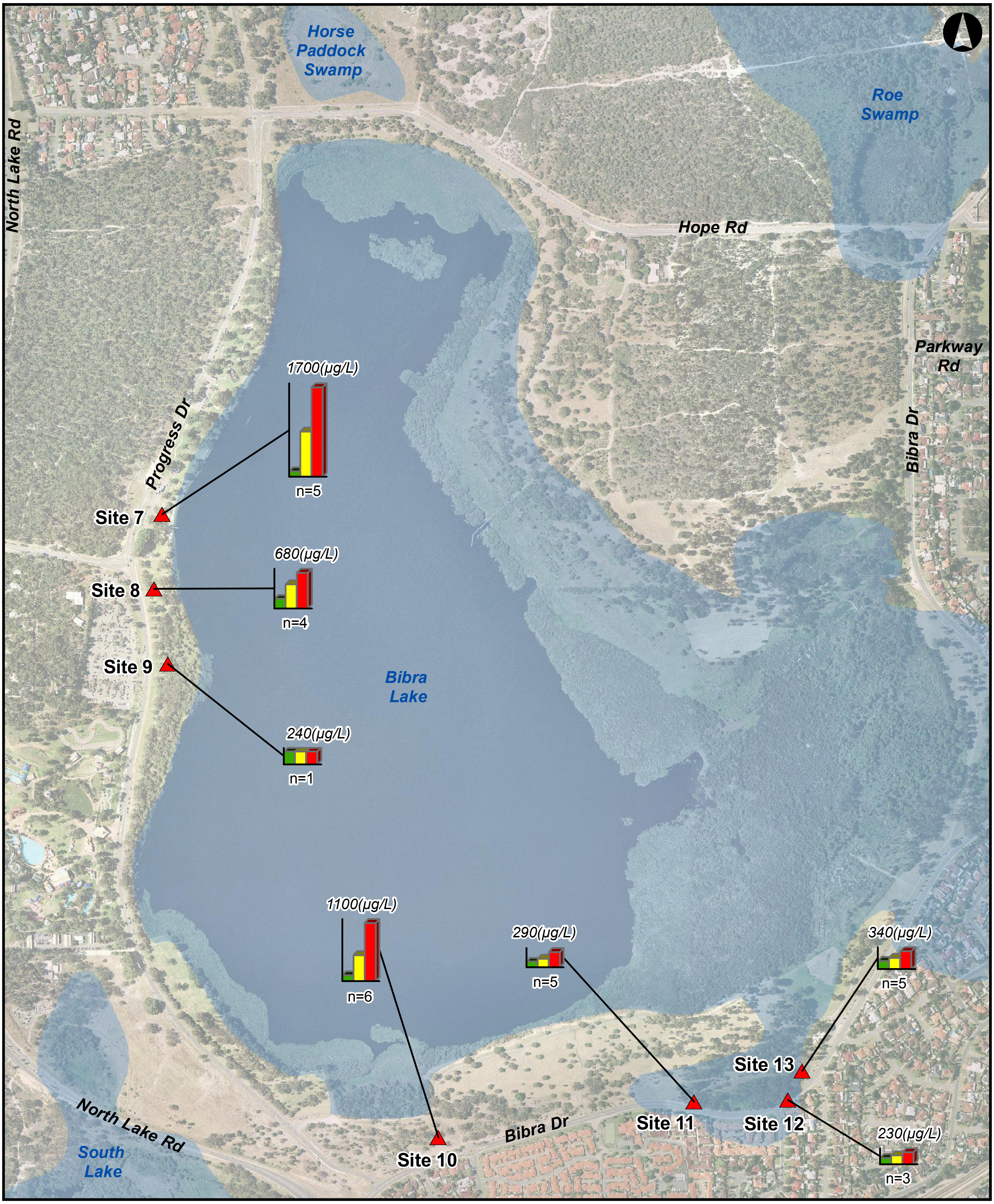
Figure 18

0 100 200 300
Metres
1:10,000 (A4)
Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands
Stormwater Sampling Site
maximum concentration
Min Mean Max
n = number of samples above limit of reporting

AECOM



Minimum, mean and maximum total TPH C15-C28 (µg/L) in stormwater draining to Bibra Lake

Figure 19

0 100 200 300
Metres
1:10,000 (A4)
Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

Stormwater Sampling Site

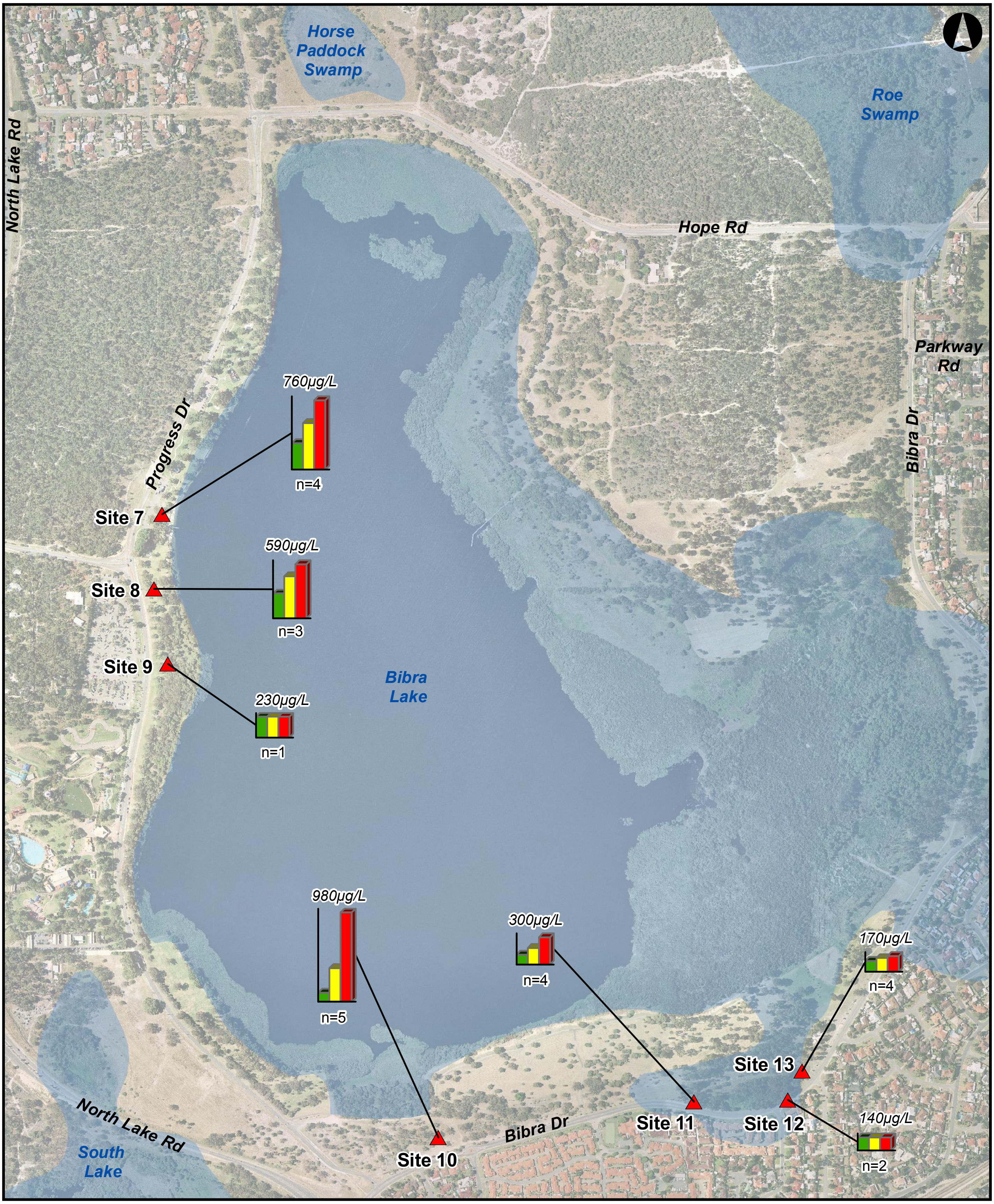
maximum concentration

Min Mean Max

n = number of samples above limit of reporting

AECOM

Date Modified: 24/03/2011
Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Stormwater Sites - TPH C15-C28.mxd



Minimum, mean and maximum total TPH C29-C36 (µg/L) in stormwater draining to Bibra Lake

Figure 20

0 100 200 300
Metres
1:10,000 (A4)
Datum: GDA94 Projection: MGA z50

LEGEND

Wetlands

Stormwater Sampling Site

maximum concentration

Min Mean Max

n = number of samples above limit of reporting

AECOM

4.1.3 Sediment Quality

Chemical analyses of Bibra Lake sediment samples are presented in Table 11 and concentrations of elements in the sediment, normalised to 1 percent TOC, are presented in Table 12. The concentrations of arsenic, cadmium, chromium, copper, lead and zinc in sediment samples from the Bibra Lake/North Lake area are illustrated in Figure 21.

Lead was the only element to exceed the guideline value at the Bibra North-East site, with concentrations of 66 mg/kg and 56 mg/kg at the Upper and Lower Horizons, respectively. Concentrations of all other elements were determined to be below the guideline limits. No guideline values are available for aluminium and iron in sediment. However, aluminium concentrations (95,000 mg/kg) were elevated at the Bibra South-East and Bibra South-West sites and iron concentrations (11,000 mg/kg) were elevated at the Bibra North-West site.

When concentrations were normalised to 1 percent TOC, none exceeded the guideline value. Furthermore, due to the high organic content of sediment at the Bibra North-West, Bibra North-East and Bibra South-West sites, concentrations were less than before normalisation. In contrast, Bibra South-East, Bibra Upper West, and Bibra Lower West sediment organic carbon concentrations were generally less than 1 percent and at these sites, the element concentrations were enhanced.

TPH fractions (C_{10}-C_{14}, C_{15}-C_{28}, and C_{29}-C_{36}) were detected in most tested Bibra Lake lacustrine surficial sediments except at the Bibra Upper West site. TPH concentrations were higher at the Bibra North-West site, where the highest TPH C_{15}-C_{28} (890 mg/kg) and TPH C_{29}-C_{36} (710 mg/kg) concentrations were found. Nevertheless, all TPHs fractions were below the guideline values.

PAHs were detected intermittently in Bibra Lake sediment. The Bibra North-East site contained the highest levels of PAHs compared to the other sites; however, the concentrations were all well below the ISQG-Low guideline value.

Organochlorine and organophosphate pesticides were not detected above LOR in any sediment samples from Bibra Lake.

Figure 21 illustrates the distribution of arsenic, cadmium, chromium, copper, lead and zinc in the sediment samples from the Bibra Lake/North Lake area. The concentrations of the elements presented in the figure are proportional to the maximum value in the sediment throughout the sampling area.

The figure indicates that the majority of the elements were found at Bibra North-West (BLN1), Bibra North-East (BLN2) and Horse Paddock Swamp (NL4). Bibra Upper West (BLWS2), Bibra Lower West (BLWS1), Bibra South-East (BLS2) and Murdoch Wetland (NL6) were the sites where the elements were found in low concentrations. Arsenic and chromium were detected in higher concentrations at site Bibra South-West (BLS1) compared to all other sites. Samples from Roe Swamp (NL5) reported higher lead concentrations compared to all other sites.

Table 11 Bibra Lake sediment analysis results (original concentration)

Analytes	Units	LOR	Guideline value*	Bibra North-West		Bibra North-East		Bibra South-West		Bibra South-East		Bibra Upper West		Bibra Lower West	
				Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Elements															
Aluminium	mg/kg	<5	-	6000	4700	6400	7500	22000	28000	290	95000	280	730	1200	1400
Arsenic	mg/kg	<0.4	20	5.9	4.8	3.5	4.9	12	8.9	<0.4	1.9	<0.4	0.48	0.73	1.1
Cadmium	mg/kg	<0.1	1.5	0.21	0.16	0.27	0.28	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	mg/kg	<0.1	80	20	15	18	19	60	65	0.92	5.3	0.9	2.3	3.5	4.3
Copper	mg/kg	<0.1	65	15	11	21	16	1.6	1.1	0.43	0.28	0.64	0.31	0.53	1
Iron	mg/kg	<5	-	11000	7900	4700	4800	1200	810	470	340	460	620	960	1300
Manganese	mg/kg	<0.5	-	99	74	11	10	13	5.6	1.8	1.1	6.1	5.7	9.1	12
Nickel	mg/kg	<0.1	21	9.1	7.2	8.4	6.4	3.5	3.3	0.43	0.48	0.41	0.35	0.56	0.88
Lead	mg/kg	<0.5	50	35	31	66	56	28	41	2.3	2.7	1.9	1.3	2.7	4.5
Selenium	mg/kg	<0.5	-	2.4	1.5	1.9	2.1	2.7	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	mg/kg	<0.5	200	90	71	62	69	3.6	2.6	3.7	1.5	3.5	2	4.5	7.2
BTEX															
Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethyl Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
m+p xylenes	mg/kg	<0.4	-	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
o-xylene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total BTEX	mg/kg	<1.2	-	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2
TPH															
TPH C6-C9	mg/kg	<10	100#	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
TPH C10-C14	mg/kg	<10	500#	51	130	11	10	10	<10	16	<10	<10	<10	10	12
TPH C15-C28	mg/kg	<50	1000#	750	890	160	130	140	93	75	<50	<50	<50	<50	91
TPH C29-C36	mg/kg	<50	-	620	710	230	170	200	140	57	56	<50	<50	<50	110
PAH**															

Analytes	Units	LOR	Guideline value*	Bibra North-West		Bibra North-East		Bibra South-West		Bibra South-East		Bibra Upper West		Bibra Lower West	
				Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Naphthalene	µg/kg	<5	160	<5	<5	0.6	0.6	2.1	<5	<5	<5	<5	<5	<5	<5
1-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
2-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthylene	µg/kg	<5	44	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthene	µg/kg	<5	16	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluorene	µg/kg	<5	19	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Phenanthrene	µg/kg	<5	240	2	2	1	8	<5	<5	<5	<5	<5	<5	<5	<5
Anthracene	µg/kg	<5	85	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene	µg/kg	<5	600	<5	4	4	4	4	2.8	<5	<5	<5	<5	<5	<5
Pyrene	µg/kg	<5	665	<5	3.2	3.8	3.7	3.2	2.9	<5	<5	<5	<5	<5	<5
Benz(a)anthracene	µg/kg	<5	261	<5	<5	3	2	<5	<5	<5	<5	<5	<5	<5	<5
Chrysene	µg/kg	<5	-	<5	<5	3	3	<5	<5	<5	<5	<5	<5	<5	<5
Benzo(b)&(k)fluoranthene	µg/kg	<10	-	<10	<10	5	5	<10	<10	<10	<10	<10	<10	<10	<10
Benzo(a)pyrene	µg/kg	<5	430	<5	<5	2.9	2.8	<5	<5	<5	<5	<5	<5	<5	<5
Indeno(1,2,3-cd)pyrene	µg/kg	<5	-	<5	<5	3	4	<5	<5	<5	<5	<5	<5	<5	<5
Dibenz(a,h)anthracene	µg/kg	<5	63	<5	<5	0.7	0.7	<5	<5	<5	<5	<5	<5	<5	<5
Benzo(g,h,i)perylene	µg/kg	<5	-	<5	<5	3	3	<5	<5	<5	<5	<5	<5	<5	<5
Coronene	µg/kg	<10	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Benzo(e)pyrene	µg/kg	<5	-	<5	<5	2.2	2.2	<5	<5	<5	<5	<5	<5	<5	<5
Perylene	µg/kg	<5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	16.4	<5	<5
Total PAHs (as above)	µg/kg	<100	4000	<100	15	34	34	12	<100	<100	<100	<100	<100	<100	<100
Organochlorine Pesticides															
Aldrin	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
alpha-BHC	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
beta-BHC	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
gamma-BHC (Lindane)	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
delta-BHC	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

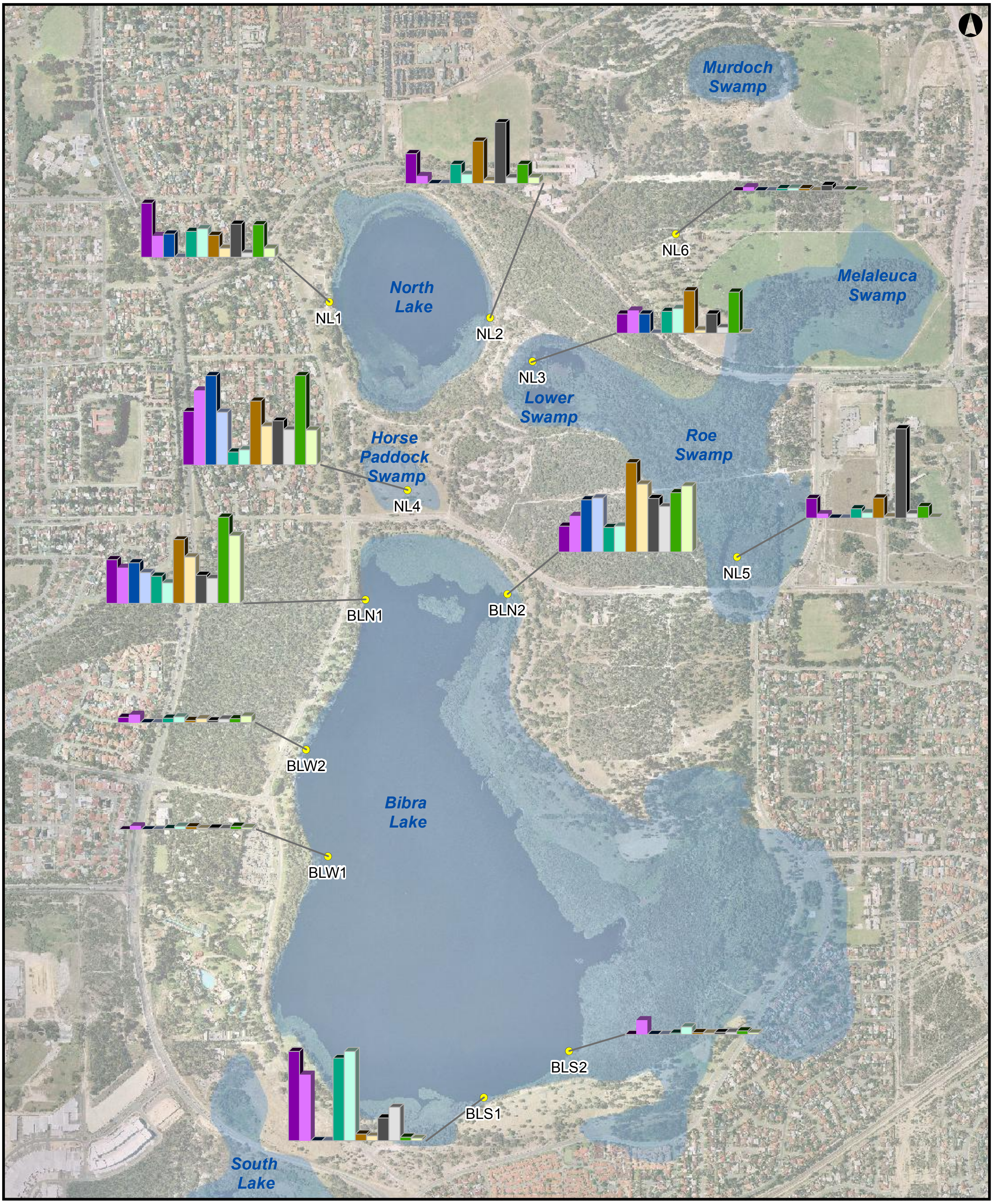
Analytes	Units	LOR	Guideline value*	Bibra North-West		Bibra North-East		Bibra South-West		Bibra South-East		Bibra Upper West		Bibra Lower West	
				Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
cis-Chlordane	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
trans-Chlordane	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
p,p'-DDD	µg/kg	<1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
p,p'-DDE	µg/kg	<1	2.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
p,p'-DDT	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dieldrin	µg/kg	<1	0.02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
alpha-Endosulfan	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
beta-Endosulfan	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan Sulphate	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin	µg/kg	<1	0.02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin ketone	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin aldehyde	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor epoxide	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hexachlorobenzene	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methoxychlor	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Oxychlordane	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Organophosphate Pesticides															
Dichlorvos	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Demeton-S-methyl	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Dimethoate	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Diazinon	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Chlorpyrifos-methyl	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Parathion-methyl	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Pirimiphos-methyl	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Fenitrothion	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Malathion	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-

Analytes	Units	LOR	Guideline value*	Bibra North-West		Bibra North-East		Bibra South-West		Bibra South-East		Bibra Upper West		Bibra Lower West	
				Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Chlorpyrifos	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Fenthion	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Parathion	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Chlorfenvinphos	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Bromophos-ethyl	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Methidathion	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Fenamiphos	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Prothiofos	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Ethion	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Carbophenothion	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Phosalone	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Azinphos-methyl	µg/kg	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-	<20	-
Other parameters															
Total Organic Carbon	%	<0.01	-	55.2	47.2	51.2	49.1	38.2	7.2	0.41	0.8	0.78	0.61	0.54	1.3
ORP (Redox Potential)	mV		-	260	240	280	270	310	300	300	300	270	270	270	280

Notes:
* ANZECC/ARMCANZ (2000) ISQG-Low
** Detectable PAH concentrations were normalised to 1 percent TOC
# Ecological Investigation Level (EIL) (DEC 2010a)
"-" indicates that the particular test was not conducted (a function of sampling plan).
Concentrations exceeding guideline values are highlighted in yellow.
Where the LOR higher than guideline values are highlighted in orange.
Note that all sediment samples were collected when the lake water level was at its lowest and the lake sediment was exposed to atmosphere.

Table 12 Bibra Lake sediment analysis results normalised to 1 percent TOC

Analytes	Units	LOR	Bibra North-West (BLN1)		Bibra North-East (BLN2)		Bibra South-West (BLS1)		Bibra South-East (BLS2)		Bibra Upper West (BLW2)		Bibra Lower West (BLW1)	
			Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Aluminium	mg/kg	<5	600	470	640	750	2200	3900	710	120000	360	1200	2200	1100
Arsenic	mg/kg	<0.4	0.59	0.48	0.35	0.49	1.2	1.24	<0.4	2.38	<0.4	0.79	1.35	0.85
Cadmium	mg/kg	<0.1	0.02	0.02	0.03	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	mg/kg	<0.1	2	1.5	1.8	1.9	6	9	2.2	6.6	1.2	3.8	6.5	3.3
Copper	mg/kg	<0.1	1.5	1.1	2.1	1.6	0.2	0.2	1.1	0.4	0.8	0.5	1	0.8
Iron	mg/kg	<5	1100	790	470	480	120	110	1100	430	590	1000	1800	1000
Manganese	mg/kg	<0.5	9.9	7.4	1.1	1	1.3	0.8	4.4	1.4	7.8	9.3	17	9.2
Nickel	mg/kg	<0.1	0.9	0.7	0.8	0.6	0.4	0.5	1.1	0.6	0.5	0.6	1.	0.7
Lead	mg/kg	<0.5	3.5	3.1	6.6	5.6	2.8	5.7	5.6	3.4	2.4	2.1	5	3.5
Selenium	mg/kg	<0.5	0.2	0.2	0.2	0.2	0.3	0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	mg/kg	<0.5	9	7.1	6.2	6.9	0.4	0.4	9	1.9	4.5	3.3	8.3	5.5



Bibra Lake/North Lake Sediment

arsenic, cadmium, chromium, copper, lead & zinc composition

April & May 2010

Figure 21

0 100 200 300 400 500 Metres

1:16,000 (A4)

Datum: GDA94 Projection: MGA z50

ANZECC/ARMCANZ 2000 - ISQG Low	*20 mg/kg*	*0.5 mg/kg*	*80 mg/kg*	*65 mg/kg*	*50 mg/kg*	*200 mg/kg*
Maximum Recorded Value	*12 mg/kg*	*0.46 mg/kg*	*65 mg/kg*	*21 mg/kg*	*110 mg/kg*	*93 mg/kg*
	upper / lower	upper / lower	upper / lower	upper / lower	upper / lower	upper / lower
	Arsenic	Cadmium	Chromium	Copper	Lead	Zinc

Sample Site

Wetlands

AECOM

Date Modified: 24/03/2011

Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_11_24__GW_Sediment_Sampling\Sampling_Sites_with_Graphs_v2-1.mxd

4.2 North Lake

4.2.1 Surface Water

Due to decreased water levels, no surface water samples were collected from any North Lake sites in February 2010 or from the North Lake Middle site in August 2010.

4.2.1.1 Chemical Parameters

4.2.1.1.1 Elements – Total

A summary of the total elements results is presented in Table 13.

During November 2009, aluminium and lead concentrations were higher than the guideline values at the North Lake West site, with means of 130 µg/L and 5.1 µg/L, respectively. Zinc levels were higher than the guideline value at both sites, with a maximum concentration of 23 µg/L at the North Lake West site. Cadmium, chromium and selenium concentrations were below LOR and guideline values at both sites. Overall, mean concentrations of elements appeared to be higher at North Lake West than the North Lake Middle site.

August 2010 water sampling results detected mean concentrations of aluminium (150 µg/L), lead (4.2 µg/L), zinc (33 µg/L), chromium (1.3 µg/L) and iron (9,600 µg/L), all of which were higher than the associated guideline values.

4.2.1.1.2 Elements – Dissolved

A summary of the dissolved elements results is presented in Table 14.

Concentrations of dissolved elements were analysed only for the August 2010 sampling event. Only aluminium, iron and zinc concentrations were reported to be higher than guideline values, with mean concentrations of 110 µg/L, 1200 µg/L and 29 µg/L, respectively. The majority of aluminium and zinc in the surface water are available in their dissolved forms. The dissolved concentrations comprise 73 percent and 88 percent of total aluminium and zinc, respectively. Dissolved iron, however, represents only 13 percent of the total iron found in the water column.

Other elements, such as arsenic, nickel, magnesium, silicon, barium, manganese and strontium, were detected mainly in the dissolved form, comprising 71 percent to 100 percent of their respective total concentrations. Conversely, dissolved chromium and dissolved potassium concentrations made up only 39 percent and 11 percent of their total concentrations, respectively.

Table 13 Total elements mean concentrations (± standard error, n=2) of North Lake surface water quality

Analytes	Unit	LOR	Guideline values	November 2009		August 2010
				North Lake Middle	North Lake West	North Lake West
Aluminium - Total	µg/L	<5	55	20±0.5	130±0	150±5
Arsenic - Total	µg/L	<1	24 as As (III) or 13 as As (V)	-	-	3.1±0.05
Cadmium - Total	µg/L	<0.2	0.2	<0.2	<0.2	<0.2
Chromium - Total	µg/L	<1	1 as Cr (VI)	<1	<1	1.3±0
Copper - Total	µg/L	<1	1.4	<1	1±0	<1
Iron - Total	µg/L	<50	300*	-	-	9600±100
Nickel - Total	µg/L	<1	11	<1	1.2±0	1.6±0
Lead - Total	µg/L	<1	3.4	<1	5.1±0.05	4.2±0.6
Selenium - Total	µg/L	<1	5*	<1	<1	<1
Zinc - Total	µg/L	<5	8	8±1.1	23±0.5	33±2.5
Magnesium - Total	mg/L	<0.1	-	-	-	25±0
Potassium - Total	mg/L	<0.1	-	-	-	220±5
Silicon - Total	mg/L	<0.01	-	-	-	15±0
Barium - Total	µg/L	<1	-	-	-	41±0
Manganese - Total	µg/L	<1	1900	-	-	330±5
Strontium - Total	µg/L	<5	-	-	-	1400±0

Notes:
Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.
*DEC 2010 Assessment levels for Soil, Sediment and Water.
Concentrations exceeding guideline values are highlighted in yellow.
"-" indicates that the particular test was not conducted (a function of sampling plan and standing surface water availability)

Table 14 **Dissolved elements mean concentrations (± standard error, n=2) and percent (%) of total elements of North Lake surface water quality during August 2010**

Analytes	Unit	LOR	Guideline values	North Lake West (NLWS)	
				Concentration	% of Total*
Aluminium - Dissolved	µg/L	<5	55	110±0	73%
Arsenic - Dissolved	µg/L	<1	24 as As (III) or 13 as As (V)	2.2±0.15	71%
Cadmium - Dissolved	µg/L	<0.2	0.2	<0.2	n/a
Chromium - Dissolved	µg/L	<1	1 as Cr (VI)	0.5±0.5	39%
Copper - Dissolved	µg/L	<1	1.4	<1	n/a
Iron - Dissolved	µg/L	<50	300*	1200±100	13%
Nickel - Dissolved	µg/L	<1	11	1.8±0	100%
Lead - Dissolved	µg/L	<1	3.4	0.8±0.8	19%
Selenium - Dissolved	µg/L	<1	5*	<1	n/a
Zinc - Dissolved	µg/L	<5	8	29±2.5	88%
Magnesium - Dissolved	mg/L	<0.1	-	220±5	100%
Potassium - Dissolved	mg/L	<0.1	-	25±0	11%
Silicon - Dissolved	mg/L	<0.01	-	17±0	100%
Barium - Dissolved	µg/L	<1	-	41±0	100%
Manganese - Dissolved	µg/L	<1	1900	400±5	100%
Strontium - Dissolved	µg/L	<5	-	1400±0	100%

Notes:
Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.
Concentrations exceeding guideline values are highlighted in yellow.
* percent of total indicates the dissolved elements percentage of the total elements. In case of the dissolved elements that are in higher concentration than the total elements, percent of total 100 percent is assumed.
n/a: not applicable.

4.2.1.1.3 Nutrients

A summary of results for nutrients in North Lake surface water samples is presented in Table 15.

During the November 2009 sampling event, chlorophyll *a* and total phosphorus concentrations were elevated at both sites, with maximum mean concentrations of 45 µg/L and 0.3 µg/L, respectively (Table 15). Total phosphorus concentrations were higher than the guideline value at both sites sampled. Additionally, total nitrogen was higher than the guideline value at the North Lake West site, with a mean concentration of 2.2 µg/L.

TN:TP ratios for the North Lake West site were measured at 7:1 and 5:1 during November 2009 and August 2010, respectively. Measurements at the North Lake Middle site indicated a higher TN:TP ratio of 15:1 in November 2009.

In August 2010, mean concentrations of chlorophyll *a* (180 µg/L), total phosphorus (0.4 µg/L), orthophosphate (0.08 µg/L) and total nitrogen (2.1 µg/L) were higher than the guideline values. Generally, nutrient concentrations during August 2010 were higher than those reported in November 2009.

NOx concentrations were below the guideline value during both November 2009 and August 2010.

Table 15 Nutrients mean concentrations (± standard error, n=2) of North Lake surface water quality

Analytes	Unit	LOR	Guideline values	November 2009		August 2010
				North Lake Middle (NLMD)	North Lake West (NLWS)	North Lake West (NLWS)
Chlorophyll *a*	µg/L	<0.02	30#	7.5±0.5	45±1.0	180±15
Total Phosphorus (TP)	mg/L	<0.04	0.06#	0.08±0	0.3±0.02	0.4±0.001
Orthophosphate	mg/L	<0.1	0.03#	<0.1	<0.1	0.08±0.01
NOx as N	mg/L	<0.01	0.1#	0.01±0	<0.01	0.02±0.01
Total Kjeldahl Nitrogen	mg/L	<0.1	-	1.2±0.1	2.2±0.15	2.1±0.5
Total Nitrogen (TN)	mg/L	<0.1	1.5#	1.2±0.1	2.2±0.15	2.1±0.5
TN:TP ratio	-	-	-	15:1	7:1	5:1

Notes:
ANZECC/ARMCANZ (2000) Guideline values for Wetlands in South-West Australia.
Concentrations exceeding guideline values are highlighted in yellow.

4.2.1.1.4 Total Suspended Solids, Biological Oxygen Demand and Electrical Conductivity

In November 2009, mean concentrations of TSS were higher at the North Lake West site than at North Lake Middle, 33 mg/L and 3 mg/L, respectively (Table 16). Similarly, BOD was also higher at the North Lake West site (6 mg/L) than the North Lake Middle site (<2 mg/L).

August 2010 sampling results indicated TSS and BOD concentrations to be higher than the November 2009 results, with mean concentrations of 43 mg/L and 6.5 mg/L, respectively.

The mean EC value at North Lake West was 1700 µS/cm in November 2009 and 4800 µS/cm in August 2010.

Table 16 Total Suspended Solids, Biological Oxygen Demand and Electrical Conductivity mean (± standard error, n=2) of North Lake surface water quality

Analytes	Unit	LOR	November 2009		August 2010
			North Lake Middle (NLMD)	North Lake West (NLWS)	North Lake West (NLWS)
Total Suspended Solids	mg/L	<2	3±0.5	33±3	43±4.5
Biological Oxygen Demand	mg/L	<2	<2	6±0	6.5±0.5
*Electrical Conductivity	µS/cm	n/a	-	1700±3 (n=85)	4800±41 (n=9)

Notes:
*Average electrical conductivity value through the water column, (n) indicates the number of readings taken by the water profiler instrument.
"-" indicates that the particular test was not conducted (a function of standing surface water availability)
n/a : not available

4.2.1.1.5 Total Petroleum Hydrocarbons

There are no guideline values for TPH concentrations in water. TPH C_{10}-C_{14}, TPH C_{15}-C_{28} and TPH C_{29}-C_{36} fractions were detected at the North Lake Middle site in November 2009, with average concentrations of 54 µg/L, 250 µg/L and 130 µg/L, respectively (Table 17). At the North Lake West site, only TPH C_{15}-C_{28} (260 µg/L) and TPH C_{29}-C_{36} (150 µg/L) were detected in November 2009. During the August 2010 sampling event, TPH C_{15}-C_{28} and TPH C_{29}-C_{36} were also detected, but at lower concentrations than in November 2009, averaging 200 µg/L and 60 µg/L, respectively.

Table 17 TPH mean concentrations (± standard error, n=2) of North Lake surface water quality

Analytes	Unit	LOR	November 2009		August 2010
			North Lake Middle	North Lake West	North Lake West
TPH C_6-C_9	µg/L	<25	<25	<25	<25
TPH C_{10}-C_{14}	µg/L	<50	54±0	<50	<50
TPH C_{15}-C_{28}	µg/L	<100	250±5	260±5	200±5
TPH C_{29}-C_{36}	µg/L	<100	130±5	150±5	60±60

4.2.1.1.6 Persistent Organic Contaminants

BTEX and PAHs were not found in any surface water samples collected from North Lake during the monitoring period.

Organochlorine and organophosphate pesticides, semi-volatile compounds (phthalates) and ultra-trace residues were analysed in surface water collected at the North Lake West site during the August 2010 sampling event. These analytes were permanently added to the testing program from February 2010 onwards. However, due to lack of water in North Lake from February 2010, no samples were obtained until August 2010. A summary of results from the monitoring period is presented in Appendix D.

4.2.1.2 Surface Water Stratification

A very shallow water column (less than 0.3 m) was recorded at the North Lake Middle site during November 2009, so the water profile was unable to be measured at this site. No water profile readings were taken during February 2010, as the lake was dry. Water profile readings were only able to be taken, when sufficient water was present in the western side of the lake, in August 2010. The following sections describe the water profile, as recorded in November 2009 and August 2010 at North Lake.

4.2.1.2.1 pH

pH measured at the North Lake West site decreased with depth, ranging from pH 6.86 to pH 6.94 (Figure 22a), above the ANZECC/ARMCANZ (2000) lower limit (pH 6.5) for fresh water lakes in south-west Australia.

During August 2010, pH at the western side of North Lake was pH 4.94–5.18, below the ANZECC/ARMCANZ (2000) lower limit of pH 6.5.

4.2.1.2.2 Turbidity

Turbidity profiled at the North Lake West site was relatively constant (4 NTU) throughout the water column (Figure 22b). The readings were higher at the bottom of the column, which may have been due to re-suspension of the sediment by the sensor.

Turbidity readings were considerably higher during August 2010 compared to November 2009, with readings at the North Lake West site ranging from 94 NTU to 150 NTU. Turbidity decreased with depth in August 2010, a different pattern to that in November 2009, when levels were either constant or increased slightly. Field observations indicated the presence of red particulate matter in the water in August 2010, which may have caused the higher turbidity readings.

4.2.1.2.3 Dissolved Oxygen

DO levels at North Lake West ranged from 6.2 mg/L to 8.3 mg/L in November 2009 and decreased with depth (although the levels were still above guideline values of 5 mg/L) (Figure 23a).

DO levels measured in August 2010 were higher than November 2009 measurements, ranging from 16 mg/L to 18 mg/L. The readings also showed minor variation throughout the water column; however, DO remained higher than guideline value.

4.2.1.2.4 Temperature

Temperature readings decreased slightly through the water column at the North Lake West site, (Figure 23b) ranging from 20.4°C at the surface to 20.1°C at the bottom of the water column. In August 2010, the water temperature was lower than in November 2009, ranging from 16.4°C at the surface to 14.1°C at the bottom.

4.2.1.2.5 Dissolved Salts

An EC reading of 1700 µS/cm was recorded at the North Lake West site and was consistent throughout the water column (Figure 24). EC readings were higher during August 2010 than in November 2009, with a value of 4800 µS/cm throughout the water column.

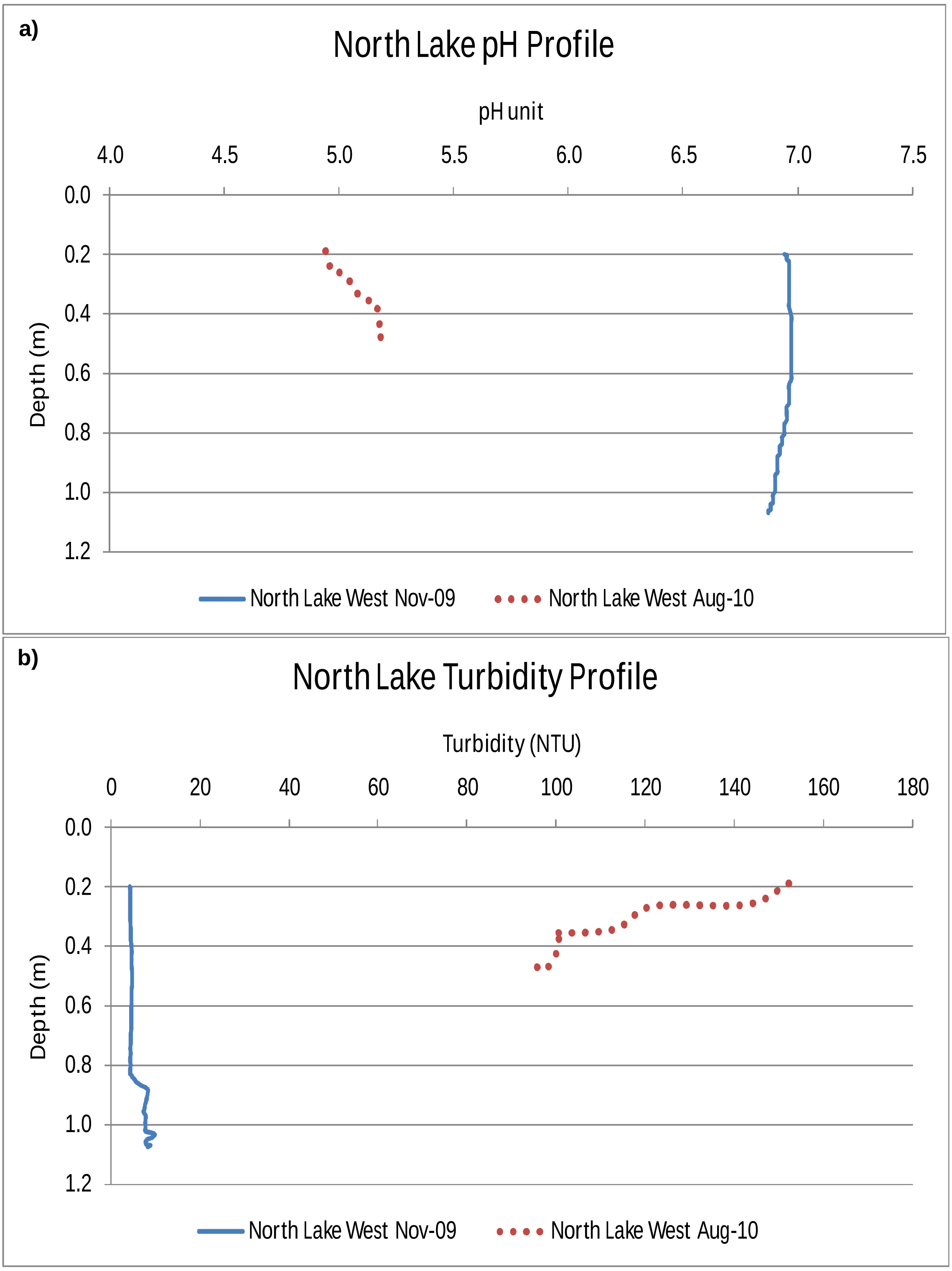


Figure 22 North Lake water profiles: a) pH profile, b) turbidity profile,

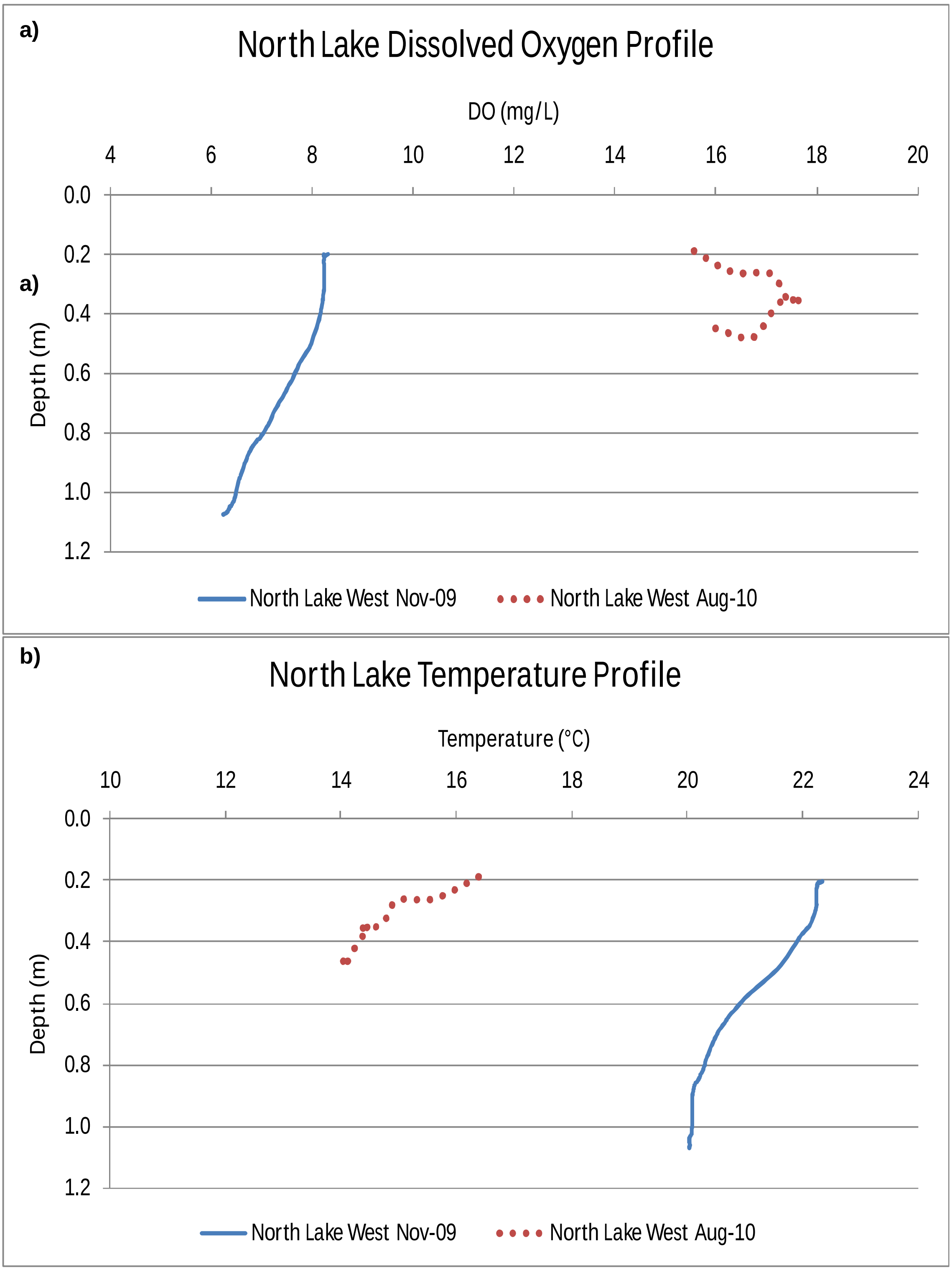


Figure 23 **North Lake water profiles: a) DO profile, b) temperature profile**

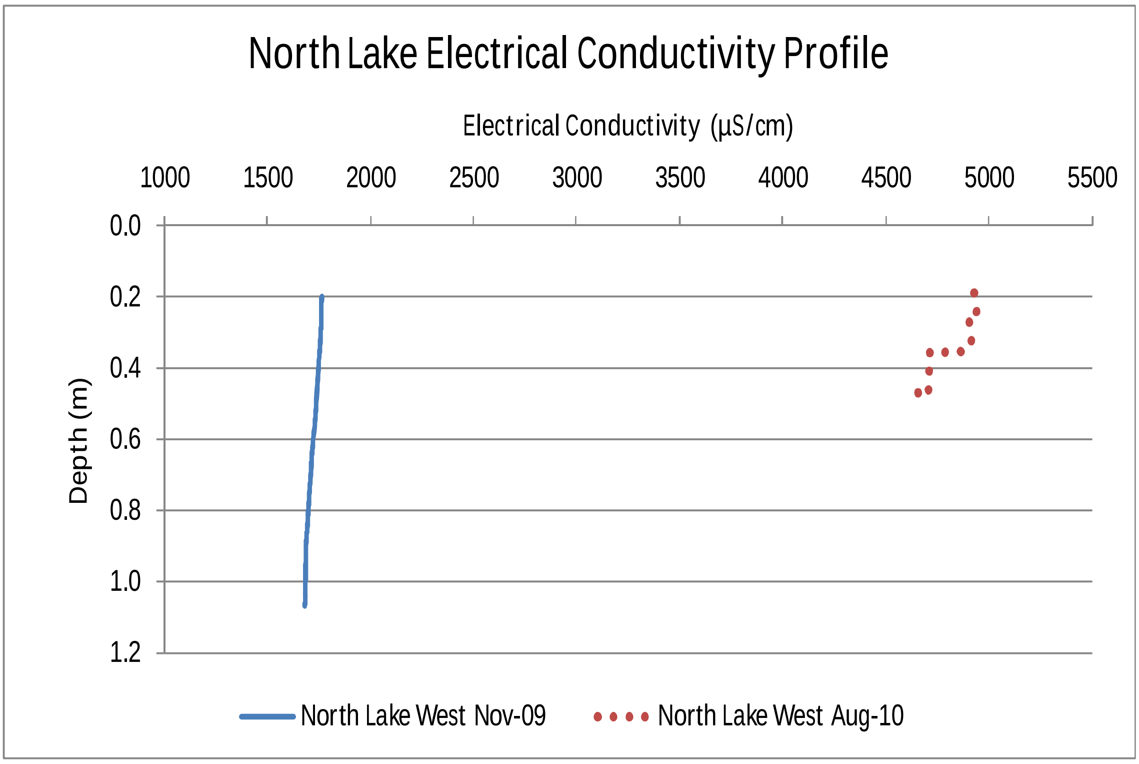


Figure 24 **North Lake water electrical conductivity profile**

4.2.1.3 Phytoplankton Community Composition

4.2.1.3.1 November 2009

Algae sampling at North Lake was only undertaken in November 2009 and August 2010, as there was insufficient water during February 2010. *Anabaena aphanizomenioides* was the only potentially toxic species identified in the lake when sampled in November 2009, along with several potential taste- and odour-causing algae species. Similar to the Bibra Lake November 2009 results (Section 4.1.3.1), *Mougeotia* spp. was found to be the dominant species. Species such as *Fragilaria* spp. and *Chlamydomonas* sp. *014* were abundant in the lake boundary zone, while *Navicula* spp., *Zygnemopsis* sp. *001* and *Cosmarium* spp. were found in large quantities in the middle of the lake. A summary of algae identified during the November 2009 sampling event is presented in Table 18.

Table 18 North Lake November 2009 algae genera/species

General	Lake Boundary	Middle of the Lake
Bacillariophyceae (Diatoms)		
Amphora spp.	Present	Present
Fragilaria spp.	**Abundant**	Present
Navicula spp.	-	**Abundant**
Nitzshia spp.	-	Present
Synedra spp.	-	Present
Chlorophyceae (Green algae)		
Ankistrodesmus sp. *007*	-	Present
Chlamydomonas sp 014	**Abundant**	-
Closterium spp.	-	Present
Cosmarium spp.	-	**Abundant**
Crucigenia spp.	-	Present
Kirchneriella sp. *001*	Present	-
Microspora sp. *001*	-	Present
Mougeotia sp. *001*	**Dominant**	**Dominant**
Oedogonium spp.	Present	-
Oocystis spp.	Present	Present
Scenedesmus spp.	Present	Present
Spirogyra spp.	-	Present
Zygnemopsis sp. *001*	-	**Abundant**
Cryptophyceae		
Chroomonas spp.	Present	-
Cyanobacteria (Blue Green Algae)		
Anabaena aphanizomenioides	Present	Present
Dactylococcopsis spp. 002	-	Present
Planktolyngbya contorta (s)	-	Present
Planktolyngbya subtilis	Present	Present
Pseudanabaena sp.*001*	Present	-
Spirulina spp	-	Present
Synechocytis spp.	Present	-
Euglenophyceae (Euglenoids)		
Euglena spp.	Present	Present
Prasinophyceae (Green Flagellates)		
Prasinophyte spp.	Present	-

Notes:
Potential taste- and odour-causing species are highlighted in yellow.
Potentially toxic species are highlighted in orange.
"-" indicates that the particular algae was not found in the samples.

4.2.1.3.2 August 2010

Three potential odour- and taste-causing algae were identified in the August 2010 samples, including *Synechocystis* spp., *Glenodinium* spp., and *Euglena* spp. *Trachelomonas* spp. appeared to be the dominant species. Algae identified during this sampling period are summarised in Table 19.

Table 19 North Lake August 2010 algae genera/species

Genera	Lake Boundary
Bacillariophyceae (Diatoms)	
Aulacosira sp. 002	Present
Navicula spp.	Present
Chlorophyceae (Green Algae)	
Microspora sp. 001	Present
Cyanobacteria (Blue Green Algae)	
Synechocystis spp.	Present
Dinophyceae (Dinoflagellates)	
Glenodinium spp.	Present
Euglenophyceae (Euglenoids)	
Euglena spp.	Present
Trachelomonas spp.	**Dominant**

Notes:
Potential taste- and odour-causing species are highlighted in yellow

4.2.2 Stormwater Quality

Results of stormwater analyses from drains that discharge to North Lake are presented in Appendix E. The drains that discharge to North Lake, included Farrington West and Farrington East drains (Figure 4).

Aluminium, chromium, copper, lead and zinc were consistently above the ANZECC/ARMCANZ (2000) 95 percent species protection guideline values throughout the sampling events, with maximum concentrations of 1100 µg/L, 5.8 µg/L, 39 µg/L, 21 µg/L and 150 µg/L, respectively. Iron was also found in the runoff, with a maximum concentration of 1000 µg/L at the Farrington East site exceeding the guideline value. Arsenic and cadmium were not detected in the stormwater runoff.

Total phosphorus concentrations were consistently above the guideline value, with a maximum concentration of 0.17 mg/L. Total nitrogen concentrations did not exceed the guideline limit, with a maximum concentration of 1.2 mg/L.

BTEX and PAHs were not detected in stormwater runoff from the drains. TPHs were detected, predominantly the C_{15}-C_{28} and C_{29}-C_{38} fractions, with maximum concentrations of 710 µg/L and 660 µg/L, respectively. There is no guideline value available for TPHs. TPH concentrations were higher at the Farrington East site compared to Farrington West.

Concentrations of suspended solids in the stormwater samples varied between sampling events and sites, ranging from 16 mg/L to 28 mg/L.

4.2.3 Sediment Quality

Results of laboratory analysis of contaminants in North Lake sediment are presented in Table 20 and the concentration of elements, normalised to 1 percent TOC, are presented in Table 21.

Lead was detected at a concentration above the guideline value (ISQG-Low, ANZECC/ARMCANZ 2000) at the North Lake East site (75 mg/kg) (Figure 10). Concentrations of all other elements were below the guideline values. Although there are no guideline values for aluminium and iron, these elements were detected in the lake sediment, with maximum concentrations of 7800 mg/kg and 14,000 mg/kg, respectively.

When normalised to 1 percent TOC, concentrations in the sediment were lower at both the North Lake West and North Lake East sites. This was due to the high organic content of the sediment, with 41 percent TOC at North Lake West. Lead concentration did not exceed the guideline value after normalisation to 1 percentTOC.

TPH were detected at both North Lake West and North Lake East sites. The highest concentrations of TPH were detected at the North Lake East site. PAH were generally below detection limits except for perylene, which was found at trace levels in bottom samples from both North Lake West and North Lake East. All detectable TPH were below the guideline values.

Table 20 North Lake sediment analysis results (original concentration)

Analytes	Unit	LOR	Guideline value*	North Lake West (NL1)		North Lake East (NL2)	
				Upper	Lower	Upper	Lower
Elements							
Aluminium	mg/kg	<5	-	7400	7800	3500	1900
Arsenic	mg/kg	<0.4	20	7.3	2.9	4	1
Cadmium	mg/kg	<0.1	1.5	0.12	<0.1	<0.1	<0.1
Chromium	mg/kg	<0.1	80	19	21	14	6.6
Copper	mg/kg	<0.1	65	5.2	2.1	10	0.75
Iron	mg/kg	<5	-	5200	2900	14000	1700
Manganese	mg/kg	<0.5	-	27	19	10	5.8
Nickel	mg/kg	<0.1	21	3.8	2.3	3.5	0.57
Lead	mg/kg	<0.5	50	41	5.4	75	6.9
Selenium	mg/kg	<0.5	-	2.6	2.7	1.3	0
Zinc	mg/kg	<0.5	200	34	9.3	20	6.3
BTEX							
Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
Toluene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
Ethyl Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
m+p xylenes	mg/kg	<0.4	-	<0.4	<0.4	<0.4	<0.4
o-xylene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
Total BTEX	mg/kg	<1.2	-	<1.2	<1.2	<1.2	<1.2
TPH							
TPH C6-C9	mg/kg	<10	100#	<10	<10	<10	<10
TPH C10-C14	mg/kg	<10	500#	14	<10	37	<10
TPH C15-C28	mg/kg	<50	1000#	240	180	450	90
TPH C29-C36	mg/kg	<50	-	510	460	790	170
PAH**							
Naphthalene	µg/kg	<5	160	<5	<5	<5	<5
1-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5
2-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5

Analytes	Unit	LOR	Guideline value*	North Lake West (NL1)		North Lake East (NL2)	
				Upper	Lower	Upper	Lower
Acenaphthylene	µg/kg	<5	44	<5	<5	<5	<5
Acenaphthene	µg/kg	<5	16	<5	<5	<5	<5
Fluorene	µg/kg	<5	19	<5	<5	<5	<5
Phenanthrene	µg/kg	<5	240	<5	<5	<5	<5
Anthracene	µg/kg	<5	85	<5	<5	<5	<5
Fluoranthene	µg/kg	<5	600	<5	<5	<5	<5
Pyrene	µg/kg	<5	665	<5	<5	<5	<5
Benz(a)anthracene	µg/kg	<5	261	<5	<5	<5	<5
Chrysene	µg/kg	<5	-	<5	<5	<5	<5
Benzo(b)&(k)fluoranthene	µg/kg	<10	-	<10	<10	<10	<10
Benzo(a)pyrene	µg/kg	<5	430	<5	<5	<5	<5
Indeno(1,2,3-cd)pyrene	µg/kg	<5	-	<5	<5	<5	<5
Dibenz(a,h)anthracene	µg/kg	<5	63	<5	<5	<5	<5
Benzo(g,h,i)perylene	µg/kg	<5	-	<5	<5	<5	<5
Coronene	µg/kg	<10	-	<10	<10	<10	<10
Benzo(e)pyrene	µg/kg	<5	-	<5	<5	<5	<5
Perylene	µg/kg	<5	-	<5	8	<5	33
Total PAHs (as above)	µg/kg	<1000##	4000	<1000	8	<1000	33
Other Analytes							
Total Organic Carbon	%	<0.01	-	41	41	9.8	3
ORP (Redox Potential)	mV		-	360	370	560	440

Notes:
* ANZECC/ARMCANZ (2000) ISQG-Low
**Detectable PAH concentrations were normalised to 1 percent TOC
Ecological Investigation Level (EIL), DEC (2010)
LOR was raised due to matrix interferences.
Concentrations exceeding guideline values are highlighted in yellow.
Note that all sediment samples were collected when the lake water level was at its lowest and lake sediments were exposed to the atmosphere.

Table 21 North Lake sediment analysis results normalised to 1 percent TOC

Analytes	Unit	LOR	North Lake West (NL1)		North Lake East (NL2)	
			Upper	Lower	Upper	Lower
Aluminium	mg/kg	<5	740	780	360	630
Arsenic	mg/kg	<0.4	0.73	0.29	0.41	0.33
Cadmium	mg/kg	<0.1	0.01	<0.1	<0.1	<0.1
Chromium	mg/kg	<0.1	1.9	2.1	1.4	2.2
Copper	mg/kg	<0.1	0.52	0.21	1.0	0.25
Iron	mg/kg	<5	520	290	1400	570
Manganese	mg/kg	<0.5	2.7	1.9	1.0	1.9
Nickel	mg/kg	<0.1	0.38	0.23	0.36	0.19
Lead	mg/kg	<0.5	4.1	0.54	7.7	2.3
Selenium	mg/kg	<0.5	0.26	0.27	0.13	<0.1
Zinc	mg/kg	<0.5	3.4	0.93	2.0	2.1

Notes:

* ANZECC/ARMCANZ (2000) ISQG-Low

4.3 Roe Swamp, Lower Swamp, Horse Paddock Swamp and Surrounding Sumplands

4.3.1 Wetland Sediment

The sediments from Roe Swamp, Lower Swamp, Horse Paddock Swamp and surrounding sumplands were sampled in May 2010 and August 2010.

4.3.1.1 May 2010

Laboratory analysis results from sediment samples taken on 28 May 2010 are presented in Table 22 and the concentrations of elements, normalised to 1 percent TOC, are presented in Table 23.

Concentrations of elements in sediment were below the guideline values except for lead, with 54 mg/kg and 110 mg/kg at Horse Paddock Swamp and Roe Swamp, respectively. Aluminium and iron concentrations were generally high in the area, with the highest concentrations in sediment in Horse Paddock Swamp. When normalised to 1 percent TOC, none of the concentrations exceeded the guideline values.

TPH were detected in sediments obtained from all sites except NL6 and Lower Swamp Lower Horizon. The concentrations of TPH fractions in Horse Paddock Swamp and Roe Swamp were highest. The highest TPH C_{15}-C_{28} fractions concentration was at the Roe Swamp Upper site (390 mg/kg) and the highest TPH C_{29}-C_{36} fractions concentration was at Horse Paddock Swamp Upper site (690 mg/kg). Horse Paddock Swamp (Lower Horizon) and Roe Swamp (Upper Horizon) were also the only sites where PAH were detected in the sediment, albeit in low concentrations. None of the TPH concentrations exceeded the guideline value.

Table 22 Roe Swamp, Lower Swamp, Horse Paddock Swamp and surrounding sumplands sediment analysis results (28 May 2010)

Analytes	Units	LOR	Guide line Level*	Lower Swamp (NL3)		Horse Paddock Swamp (NL4)		Roe Swamp (NL5)		NL6	
				Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Elements											
Aluminium	mg/kg	<5	-	7800	8200	9000	14000	6200	4000	700	910
Arsenic	mg/kg	<0.4	20	2.6	3.1	7.2	10	2.6	0.55	<0.4	0.44
Cadmium	mg/kg	<0.1	1.5	0.1	<0.1	0.46	0.27	<0.1	<0.1	<0.1	<0.1
Chromium	mg/kg	<0.1	80	16	18	9.2	11	6.6	3.7	1.4	1.8
Copper	mg/kg	<0.1	65	10	0.78	15	9.1	4.7	0.26	0.5	<0.1
Iron	mg/kg	<5	-	3800	3800	4500	2200	3600	820	800	980
Manganese	mg/kg	<0.5	-	21	2.2	26	5.8	7.2	1	2.2	1.8
Nickel	mg/kg	<0.1	21	2.8	1.7	4.1	2.7	4.6	0.41	0.63	0.15
Lead	mg/kg	<0.5	50	24	7.1	54	43	110	5.5	6.4	0.77
Selenium	mg/kg	<0.5	-	0.61	0	1.7	1.7	1.3	<0.5	<0.5	<0.5
Zinc	mg/kg	<0.5	200	43	0.87	93	36	12	0.9	0.9	<0.5
BTEX											
Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethyl Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
m+p xylenes	mg/kg	<0.4	-	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
o-xylene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total BTEX	mg/kg	<1.2	-	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2
TPH											
TPH C6-C9	mg/kg	<10	100#	<10	<10	<10	<10	<10	<10	<10	<10
TPH C10-C14	mg/kg	<10	500#	16	<10	16	<10	32	<10	19	<10
TPH C15-C28	mg/kg	<50	1000#	190	<50	240	80	390	80	110	<50

Analytes	Units	LOR	Guide line Level*	Lower Swamp (NL3)		Horse Paddock Swamp (NL4)		Roe Swamp (NL5)		NL6	
				Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
TPH C29-C36	mg/kg	<50	-	180	<50	690	190	570	93	230	<50
PAH**											
Naphthalene	µg/kg	<5	160	<5	<5	<5	<5	<5	<5	<5	<5
1-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5	<5	<5	<5	<5
2-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthylene	µg/kg	<5	44	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthene	µg/kg	<5	16	<5	<5	<5	<5	<5	<5	<5	<5
Fluorene	µg/kg	<5	19	<5	<5	<5	<5	<5	<5	<5	<5
Phenanthrene	µg/kg	<5	240	<5	<5	<5	<5	<5	<5	<5	<5
Anthracene	µg/kg	<5	85	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene	µg/kg	<5	600	<5	<5	<5	11	<5	<5	<5	<5
Pyrene	µg/kg	<5	665	<5	<5	<5	10	11	<5	<5	<5
Benz(a)anthracene	µg/kg	<5	261	<5	<5	<5	<5	6	<5	<5	<5
Chrysene	µg/kg	<5	-	<5	<5	<5	6.7	8	<5	<5	<5
Benzo(b)&(k)fluoranthene	µg/kg	<10	-	<10	<10	<10	<10	10	<10	<10	<10
Benzo(a)pyrene	µg/kg	<5	430	<5	<5	<5	<5	5.8	<5	<5	<5
Indeno(1,2,3-cd)pyrene	µg/kg	<5	-	<5	<5	<5	9.3	8	<5	<5	<5
Dibenz(a,h) anthracene	µg/kg	<5	63	<5	<5	<5	<5	<5	<5	<5	<5
Benzo(g,h,i)perylene	µg/kg	<5	-	<5	<5	<5	<5	5	<5	<5	<5
Coronene	µg/kg	<10	-	<10	<10	<10	<10	<10	<10	<10	<10
Benzo(e)pyrene	µg/kg	<5	-	<5	<5	<5	<5	<5	<5	<5	<5
Perylene	µg/kg	<5	-	<5	<5	<5	<5	<5	<5	<5	<5
Total PAHs (as above)	µg/kg	<1000 ##	4000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000
Other Analytes											
Total Organic Carbon	%	<0.01	-	8.1	2.5	24	7.5	48	2.5	0.56	0.21
ORP (Redox Potential)	mv		-	430	430	430	420	440	430	450	440

Notes:
* ANZECC/ARMCANZ (2000) ISQG-Low
**Detectable PAH concentrations were normalised to 1 percent TOC
Ecological Investigation Level (EIL) (DEC 2010a)
LOR was raised due to matrix interferences.
Concentrations exceeding guideline values are highlighted in yellow.
Note that all sediment samples were collected when the lake water level was at its lowest and the lake sediment was exposed to atmosphere.

Table 23 Roe Swamp, Lower Swamp, Horse Paddock Swamp and surrounding sumplands elements in sediment analysis results normalised to 1 percent TOC (28 May 2010)

Analytes	Units	LOR	Lower Swamp (NL3)		Horse Paddock Swamp (NL4)		Roe Swamp (NL5)		NL6	
			Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Aluminium	mg/kg	<5	960	3300	900	1900	620	1600	1250	4300
Arsenic	mg/kg	<0.4	0.32	1.24	0.72	1.3	0.26	0.22	<0.4	2.1
Cadmium	mg/kg	<0.1	0.01	<0.1	0.05	0.04	<0.1	<0.1	<0.1	<0.1
Chromium	mg/kg	<0.1	2	7.2	0.9	1.5	0.7	1.5	2.5	8.6
Copper	mg/kg	<0.1	1.2	0.3	1.5	1.2	0.47	0.1	0.9	<0.1
Iron	mg/kg	<5	470	1500	450	300	360	330	1400	4700
Manganese	mg/kg	<0.5	2.6	0.9	2.6	0.77	0.72	0.4	4	8.6
Nickel	mg/kg	<0.1	0.35	0.68	0.41	0.36	0.46	0.16	1.13	0.7
Lead	mg/kg	<0.5	3	2.8	5.4	5.7	11	2.2	11	3.7
Selenium	mg/kg	<0.5	0.08	<0.5	0.17	0.23	0.13	<0.5	<0.5	<0.5
Zinc	mg/kg	<0.5	5.3	0.35	9.3	4.8	1.2	0.36	1.6	<0.5

4.3.1.2 August 2010

Supplementary sediment samples were collected on 24 August 2010 at Horse Paddock Swamp and Roe Swamp, to obtain additional information on the sediment quality of the area. Analysis results are presented in Table 24.

Concentrations of elements were generally below the guideline values, except for lead which exceeded the guideline value in Horse Paddock Swamp Upper Horizon (71 mg/kg), Lower Horizon (67 mg/kg) and Roe Swamp Upper Horizon (450 mg/kg).

TPH, predominantly the heavier fractions (TPH C_{15}-C_{28} and TPH C_{29}-C_{36}), were again detected in Horse Paddock Swamp (Upper and Lower Horizons), as well as Roe Swamp (Upper Horizon). Overall, the highest TPH concentrations were found in Roe Swamp, (TPH C_{15}-C_{28}, 630 mg/kg; TPH C_{29}-C_{36}, 740 mg/kg). Furthermore, at the Roe Swamp site, the lighter TPH C_{10}-C_{14} fraction was found, at a concentration of 59 mg/kg. Nevertheless, none of the detected TPH concentrations exceeded the guideline value.

PAH were also detected at the same sites and sample depths as TPH. At Horse Paddock Swamp, PAH concentrations were generally low, with total concentrations of less than 100 mg/kg in both Upper and Lower horizons. The highest PAH concentrations were recorded in Roe Swamp (Upper Horizon) with a Total PAH concentration of 1400 µg/kg, which was below the guideline value (4000 µg/kg).

In general, organochlorine pesticides and organophosphate pesticide concentrations were below the LOR. However, the organochlorine pesticide, DDE was found at the Horse Paddock Swamp in Upper and Lower Horizons (0.2 µg/kg, upper; 0.4 µg/kg, lower). Trans-chlordane was also found in low concentrations at Horse Paddock Swamp Lower (0.2 µg/kg) and Roe Swamp Upper (1.3 µg/kg) sites.

Table 24 Horse Paddock Swamp and Roe Swamp sediment analysis results (24 August 2010)

Analytes	Units	LOR	Guideline value	Horse Paddock Swamp (NL4)		Roe Swamp (NL5)	
				Upper	Lower	Upper	Lower
Metals							
Aluminium	mg/kg	<5	-	7700	7400	9800	3000
Arsenic	mg/kg	<0.4	20	11	11	3.4	<0.4
Cadmium	mg/kg	<0.1	1.5	0.43	0.39	0.2	<0.1
Chromium	mg/kg	<0.1	80	13	12	16	2.9
Copper	mg/kg	<0.1	65	23	24	38	0.18
Iron	mg/kg	<5	-	6100	6200	6400	260
Manganese	mg/kg	<0.5	-	21	21	40	1.6
Nickel	mg/kg	<0.1	21	6.1	6	7.8	0.33
Lead	mg/kg	<0.5	50	71	67	450	3.7
Selenium	mg/kg	<0.5	-	2.2	1.7	1.5	<0.5
Zinc	mg/kg	<0.5	200	120	120	170	0.78
Nutrients							
Total Nitrogen	mg/kg	<20	-	15600	3000	290	11000
Total Kjeldahl Nitrogen	mg/kg	<20	-	15600	3000	290	11000
NOx as N	mg/kg	<0.1	-	6	1	0.4	8.6
Total Ammonia as N	mg/kg	<0.1	-	1.8	3.1	3.1	0.3
Phosphate as P	mg/kg	<0.1	-	1	0.7	0.2	0.2
Total Phosphorus	mg/kg	<1	-	2000	2100	1000	21
BTEX							
Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
Toluene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
Ethyl Benzene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
m+p xylenes	mg/kg	<0.4	-	<0.4	<0.4	<0.4	<0.4
o-xylene	mg/kg	<0.2	-	<0.2	<0.2	<0.2	<0.2
Total BTEX	mg/kg	<1.2	-	<1.2	<1.2	<1.2	<1.2
TPH							
TPH C6-C9	mg/kg	<10	100#	<10	<10	<10	<10
TPH C10-C14	mg/kg	<10	500#	<10	<10	59	<10
TPH C15-C28	mg/kg	<50	1000#	140	200	630	<50
TPH C29-C36	mg/kg	<50	-	290	390	740	<50
PAH**							
Naphthalene	µg/kg	<5	160	<5	<5	<5	<5
1-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5
2-Methylnaphthalene	µg/kg	<5	-	<5	<5	<5	<5
Acenaphthylene	µg/kg	<5	44	<5	<5	26	<5
Acenaphthene	µg/kg	<5	16	<5	<5	<5	<5
Fluorene	µg/kg	<5	19	<5	<5	<5	<5
Phenanthrene	µg/kg	<5	240	1	4	120	<5
Anthracene	µg/kg	<5	85	0.6	1.6	38	<5
Fluoranthene	µg/kg	<5	600	3	12	130	<5
Pyrene	µg/kg	<5	665	3.5	11	180	<5

Analytes	Units	LOR	Guideline value	Horse Paddock Swamp (NL4)		Roe Swamp (NL5)	
				Upper	Lower	Upper	Lower
Benz(a)anthracene	µg/kg	<5	261	2	8	64	<5
Chrysene	µg/kg	<5	-	3	8	130	<5
Benzo(b)&(k)fluoranthene	µg/kg	<10	-	6	20	260	<10
Benzo(a)pyrene	µg/kg	<5	430	2.8	10	100	<5
Indeno(1,2,3-cd)pyrene	µg/kg	<5	-	2	6	51	<5
Dibenz(a,h)anthracene	µg/kg	<5	63	<5	<5	6	<5
Benzo(g,h,i)perylene	µg/kg	<5	-	3	8	100	<5
Coronene	µg/kg	<10	-	<10	<10	22	<10
Benzo(e)pyrene	µg/kg	<5	-	2.2	7.4	140	<5
Perylene	µg/kg	<5	-	0.8	2	<5	<5
Total PAHs (as above)	µg/kg	<100	4000	31	98	1400	<100
Organochlorine Pesticides**							
Aldrin	µg/kg	<1	-	<1	<1	<1	<1
alpha-BHC	µg/kg	<1	-	<1	<1	<1	<1
beta-BHC	µg/kg	<1	-	<1	<1	<1	<1
gamma-BHC (Lindane)	µg/kg	<1	-	<1	<1	<1	<1
delta-BHC	µg/kg	<1	-	<1	<1	<1	<1
cis-Chlordane	µg/kg	<1	-	<1	<1	<1	<1
trans-Chlordane	µg/kg	<1	-	<1	**0.2**	**1.3**	<1
p,p'-DDD	µg/kg	<1	2	<1	<1	<1	<1
p,p'-DDE	µg/kg	<1	2.2	**0.2**	**0.4**	<1	<1
p,p'-DDT	µg/kg	<1	-	<1	<1	<1	<1
Dieldrin	µg/kg	<1	0.02	<1	<1	<1	<1
alpha-Endosulfan	µg/kg	<1	-	<1	<1	<1	<1
beta-Endosulfan	µg/kg	<1	-	<1	<1	<1	<1
Endosulfan Sulphate	µg/kg	<1	-	<1	<1	<1	<1
Endrin	µg/kg	<1	0.02	<1	<1	<1	<1
Endrin ketone	µg/kg	<1	-	<1	<1	<1	<1
Endrin aldehyde	µg/kg	<1	-	<1	<1	<1	<1
Heptachlor	µg/kg	<1	-	<1	<1	<1	<1
Heptachlor epoxide	µg/kg	<1	-	<1	<1	<1	<1
Hexachlorobenzene	µg/kg	<1	-	<1	<1	<1	<1
Methoxychlor	µg/kg	<1	-	<1	<1	<1	<1
Oxychlordane	µg/kg	<1	-	<1	<1	<1	<1
Organophosphate Pesticides							
Dichlorvos	µg/kg	<20	-	<20	-	<20	-
Demeton-S-methyl	µg/kg	<20	-	<20	-	<20	-
Dimethoate	µg/kg	<20	-	<20	-	<20	-
Diazinon	µg/kg	<20	-	<20	-	<20	-
Chlorpyrifos-methyl	µg/kg	<20	-	<20	-	<20	-
Parathion-methyl	µg/kg	<20	-	<20	-	<20	-
Pirimiphos-methyl	µg/kg	<20	-	<20	-	<20	-
Fenitrothion	µg/kg	<20	-	<20	-	<20	-

Analytes	Units	LOR	Guideline value	Horse Paddock Swamp (NL4)		Roe Swamp (NL5)	
				Upper	Lower	Upper	Lower
Malathion	µg/kg	<20	-	<20	-	<20	-
Chlorpyrifos	µg/kg	<20	-	<20	-	<20	-
Fenthion	µg/kg	<20	-	<20	-	<20	-
Parathion	µg/kg	<20	-	<20	-	<20	-
Chlorfenvinphos	µg/kg	<20	-	<20	-	<20	-
Bromophos-ethyl	µg/kg	<20	-	<20	-	<20	-
Methidathion	µg/kg	<20	-	<20	-	<20	-
Fenamiphos	µg/kg	<20	-	<20	-	<20	-
Prothiofos	µg/kg	<20	-	<20	-	<20	-
Ethion	µg/kg	<20	-	<20	-	<20	-
Carbophenothion	µg/kg	<20	-	<20	-	<20	-
Phosalone	µg/kg	<20	-	<20	-	<20	-
Azinphos-methyl	µg/kg	<20	-	<20	-	<20	-
Other Analytes							
Total Organic Carbon	%	<0.01	-	19.5	5.0	0.78	20.8
ORP (Redox Potential)	mV		-	320	330	340	350

Notes:
* ANZECC/ARMCANZ (2000) ISQG-Low
**Detectable PAH and Organochlorine pesticides concentrations were normalised to 1 percent TOC
Ecological Investigation Level (EIL) (DEC 2010a).
"-" indicates that the particular substance test was not conducted.
Concentrations exceeding guideline values are highlighted in yellow.

Table 25 Horse Paddock Swamp and Roe Swamp sediment analysis results (24 August 2010), normalised to 1 percent TOC

Analytes	Units	LOR	Horse Paddock Swamp (NL4)		Roe Swamp (NL5)	
			Upper	Lower	Upper	Lower
Aluminium	mg/kg	<5	770	1500	13000	770
Arsenic	mg/kg	<0.4	1.1	2.2	4.4	1.1
Cadmium	mg/kg	<0.1	0.04	0.08	0.26	0.04
Chromium	mg/kg	<0.1	1.3	2.4	21	1.3
Copper	mg/kg	<0.1	2.3	4.8	49	2.3
Iron	mg/kg	<5	610	1200	8200	610
Manganese	mg/kg	<0.5	2.1	4.2	51	2.1
Nickel	mg/kg	<0.1	0.61	1.2	10	0.61
Lead	mg/kg	<0.5	7.1	13	580	7.1
Selenium	mg/kg	<0.5	0.22	0.34	1.9	0.22
Zinc	mg/kg	<0.5	12	24	220	12

4.4 Groundwater

4.4.1 Hydrochemical signatures

Chemical properties of groundwater samples from the study area, based on major ions (carbonate, bicarbonate, calcium, magnesium, sodium, potassium, chloride, and sulphate), are plotted on a Piper-Trilinear diagram (using United States Geological Survey, GW Chart Software version 1.23.30), presented as Figure 25.

Major ions analysis indicated there were generally two types of groundwater in the area. Calcium and carbonate were generally in higher proportions than other major ions at site T1A and T2I (Figure 25), thus the groundwater at these sites can be classified as Ca^{2+}-Mg^{2+} dominated water. Groundwater at all other sites generally reported with a high proportion of sodium and chloride and can be classified as Cl^{-}-SO_4^{2-}/HCO_3^{-} type water. A summary of major ions analysis is presented in Table 26.

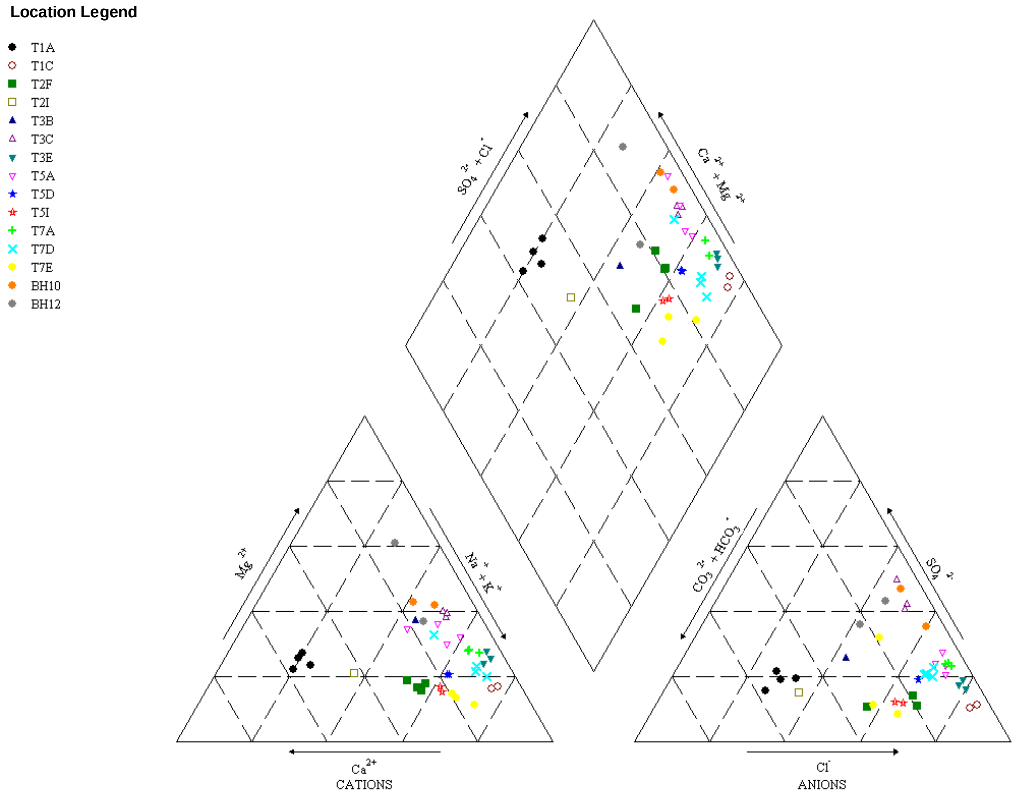


Figure 25 Groundwater Piper-Trilinear diagram (miliequivalent/L)

Table 26 Mean* concentration of major ions (± standard error) in groundwater

Analytes	Units	LOR	T1A	T1C	T2F	T2I	T3B	T3C	T3E	T5A	T5D	T5I	T7A	T7D	T7E	BH10	BH12
			n=5	n=2	n=5	n=1	n=4	n=2	n=4	n=5	n=3	n=2	n=4	n=5	n=4	n=3	n=3
Calcium	mg/L	<0.1	50 ±2.6	7.3 ±0.7	28 ±0.8	70	4 ±0.2	5.6 ±0.5	8 ±6.4	5 ±1.1	19 ±1.2	53 ±2.5	6 ±0.6	5 ±0.8	101 ±3	5.5± 0.8	5.5± 0.9
Magnesium	mg/L	<0.1	14 ±0.9	10 ±0.5	11 ±0.2	21	11 ±0.3	7.1 ±0.7	18 ±1.1	8 ±0.3	13 ±0.9	24 ±0	13 ±0.3	8 ±0.8	45 ±1.3	9.6± 1.6	7.3± 4
Sodium	mg/L	<0.1	22 ±3.9	89 ±3.5	63 ±2.3	66	26 ±0.9	12 ±0	79 ±10.1	25 ±1.9	67 ±2.8	170 ±10	54 ±0.3	40 ±3.3	420 ±38	19± 4	11± 1
Potassium	mg/L	<0.1	3 ±0.1	3.9 ±0.3	3.3 ±0.2	7.4	2.8 ±0.3	4.1 ±0.2	5.9 ±0.3	2.3 ±0.4	6.3 ±0.8	11 ±0.5	2.4 ±0.2	4 ±1.1	10 ±0.4	9± 4	6± 7
Chloride	mg/L	<1	50 ±6.7	160 ±5	120 ±3.7	110	42 ±1.3	23 ±2.5	160±8.1	50 ±1	120 ±6.7	270 ±25	93 ±2.6	64 ±2	610 ±17.4	46± 4	31± 2
Sulphate	mg/L	<2	44 ±6.4	27 ±0	30 ±1.2	59	48 ±4.1	18 ±1	48 ±3	22 ±1.2	46 ±2.4	69 ±4.5	42 ±0.7	27 ±0.9	170 ±98.3	44± 3	38± 2

Notes:
n= sampling frequency
*geometric mean

4.4.2 Groundwater Guideline Values

ANZECC/ARMCANZ (2000) does not provide any tool for benchmarking groundwater quality in terms of defined guideline values. In order to benchmark groundwater quality against relevant groundwater data, groundwater quality data were obtained from the DoW for bores in the immediate vicinity of the lakes and up hydraulic gradient from the Bibra and North Lakes to the top of the Jandakot Mound. Descriptive statistics for DoW groundwater quality data from a total of 31 DoW bores in the area are presented in Table 27 and pH is presented in Table 28.

The study area might, for the purpose of comparison, be classified as a slightly to moderately disturbed ecosystem. Therefore, the 80th percentile values of DoW (reference) data were derived as a conservative estimate of "adopted guideline values" to allow for benchmarking groundwater tested as a part of the South Metro Connect monitoring program. This method was derived from methods presented in ANZECC/ARMCANZ (2000) Section 3.3.2.4 for stressors that cause environmental problems at high concentrations. For pH, which may stress both low and high values, the 20th percentile of the reference data was also used to define a lower guideline value (Table 28).

Table 27 Descriptive statistics for physicochemical, dissolved elements and nutrients (Department of Water 2010).

Analytes	Units	n	No. of sites sampled	Min	Max	Mean*	80th percentile (adopted guideline value)
Physicochemical							
Bicarbonate Alkalinity	mg/L	25	23	7	330	68	220
Hardness	mg/L	30	24	12	390	85	190
Total Dissolved Salts	mg/L	90	7	180	2300	500	950
Elements – dissolved							
Aluminium	µg/L	85	8	5	16000	190	650
Arsenic	µg/L	2	23	2	10	4.5	8.4
Copper	µg/L	3	23	20	30	23	26
Iron	µg/L	113	30	53	170000	960	1900
Manganese	µg/L	11	23	20	140	32	50
Lead	µg/L	2	23	10	10	10	10
Zinc	µg/L	19	19	20	50	27	40
Nutrients							
Total Nitrogen	mg/L	57	11	0.3	8	1.2	2.6
Total Kjeldahl Nitrogen	mg/L	60	12	0.3	6.6	1.1	1.8
Total Phosphorus	mg/L	58	12	0.01	0.4	0.1	0.2

Notes:
n = number of detectable concentrations
*geometric mean

Table 28 Groundwater pH summary (Department of Water 2010)

	units	n	No. of sites sampled	Min	Max	Mean*	20th percentile (site specific lower guideline value)	80th percentile (site specific upper guideline value)
pH	pH unit	217	31	2.6	8.5	6.2	5.6	7.5

Notes:
n = number of readings
*geometric mean

4.4.3 Groundwater Chemical Analysis

Groundwater quality undertaken specifically for the South Metro Connect project is presented in the following sections with reference to the benchmarks calculated from DoW data. Groundwater results are presented as geometric mean. Laboratory data are presented in Appendix F.

4.4.3.1 Groundwater Physicochemical Properties

The results of physicochemical analyses of groundwater are summarised in Table 29 and Table 30.

The water hardness of the groundwater varied spatially throughout the study area. Generally, most of the groundwater in the area can be classified as moderate hardness with hardness in the range 60–120 mg/L. Water at Sites T1A, T2I, T5I and T7E was hard (120–179 mg/L) and at Sites T3B, T5A and T7D groundwater samples were soft (0–59 mg/L) (ANZECC/ARMCANZ 2000). The hardness of Bibra Lake/North Lake groundwater is similar to the reference data (DoW), with moderate hardness (average of 68 mg/L). None of the groundwater hardness exceed the adopted guideline value (190 mg/L).

Groundwater pH values were generally between the 20th and 80th percentile of the DoW reference data (pH 5.6–7.5). Values below the adopted guideline range were recorded at T1C, as low as pH 5.4. In the source of water/delivery zone (T1A, T3B, T3C, T5A, T7A, BH10 and BH12) and the wetland area (T1C, T2F, T3E, T5D and T7D), pH levels were varied from slightly acidic to close to neutral (pH 5.4–6.8). However, in the wetland area pH levels tended to be slightly more alkaline than in the source of water zone. In the impoundment zone/water storage area (T2I, T5I and T7E), pH levels were slightly higher than in the other two hydrological zones. pH levels at this zone was close to neutral to slightly alkaline (pH 6.7–7.2). In general, pH levels fluctuated monthly, with greater changes in pH observed in the delivery zone and the wetland area.

4.4.3.2 Groundwater Dissolved Salt Content

Total dissolved salt (TDS) concentrations exhibited a high degree of spatial variation ranging from 89 mg/L at T3B to 1700 mg/L at T7E. The only exceedence of the adopted guideline value (980 mg/L) was at T7E (1700 mg/L), but this was still within the of DoW reference data range of 180–2300 mg/L.

This study found that the salt concentrations of the source waters (T1A, T3C, T3B, T5A, T7A, BH10 and BH12) were low, within the range of 89 to 260 mg/L while the groundwater collected in close proximity to the lake and wetland area (T1C,T2F,T3E,T5D, and T7D) were found with a slightly higher salt content of 150-330 mg/L. The highest salt content was found in the groundwater sampled in the impoundment/ water storage area where salt concentration varied from 440 to 1700 mg/L.

4.4.3.3 Groundwater Dissolved Elements

Mean concentrations of dissolved elements in groundwater sampled specifically for the South Metro Connect project are summarised in Table 31 and Table 32.

Aluminium concentrations in the groundwater varied between sites and between sampling events. Mean aluminium concentrations exceeded the adopted guideline value (650 µg/L) at Sites T1C (1400 µg/L), T3B (740 µg/L), T3E (700 µg/L) and T7D (1900 µg/L). The lowest recorded aluminium concentration was 11 µg/L at T7E. Arsenic was first tested in groundwater samples collected in August 2010.

Arsenic concentrations were generally low and mostly below the detection level. However, at Site T2F the arsenic concentration was 31 µg/L, higher than the adopted guideline value (8.4 µg/L).

Chromium was below the detection limit at several sites (T1A, T2I, T5A, T7A, T7E and BH10). Where chromium was detected in the groundwater, concentrations ranged 1.1–10.2 µg/L, with the highest concentration at T1C. There were no DoW chromium data available to allow adopted guideline calculation.

Copper was below the detection limit (<1 µg/L) at all sites except BH10, where a concentration of 3.8 µg/L was recorded. The copper concentration at BH10 was below the adopted guideline value (26 µg/L). Iron concentrations in groundwater varied between 19 µg/L (T2F and T5A) and 2100 µg/L (T1C). The highest iron concentration exceeded the adopted guideline value of 1900 µg/L at T1C (2100 µg/L). A high iron concentration was recorded at T1A (1700 µg/L). Manganese concentrations varied between sites, with the lowest at T7D (1.3 µg/L) and the highest concentration at BH10 (43 µg/L), which was lower than the adopted guideline value of 50 µg/L.

Generally, nickel in groundwater was below the detection limit (1 µg/L). Detected nickel concentrations varied between sites and ranged between 1.4 µg/L at T2F and 6.4 µg/L at T5I. No adopted guideline value was calculated for nickel from DoW data.

Lead concentrations in the groundwater ranged between 1 µg/L at T3B and 1.7 µg/L at T1C. Lead was not detected at most sites. Lead concentrations did not exceed the adopted guideline value calculated from DoW data of 10 µg/L at any site or time during monitoring.

Selenium was generally not detected in the groundwater, except in samples at T5A and T7D where the concentrations were 1.1 µg/L and 3.4 µg/L respectively. No adopted guideline value was available for selenium from the DoW data.

Strontium concentrations varied between sites. The lowest was at T1C (21 µg/L) and the highest concentration was at T7E (460 µg/L). No adopted guideline value was available for strontium from the DoW data.

The lowest silicon concentration was recorded at T1A (1.3 µg/L), whilst the highest was at T7E (17 µg/L). No adopted guideline value for strontium was available from the calculated DoW data.

Zinc concentrations in the groundwater ranged between 7 µg/L (T5D) and 53 µg/L (T2I). The adopted guideline value of 40 µg/L was exceeded only at T2I (53 µg/L).

4.4.3.4 Groundwater Nutrients

A summary of the mean nutrient concentrations in the groundwater is presented in Table 33 and Table 34..

Orthophosphate levels in groundwater samples were generally low, ranging between 0.01 mg/L and 0.14 mg/L. Two sites indicated higher orthophosphate concentrations, with values of 0.47 µg/L and 0.49 µg/L recorded at T5D and BH12, respectively.

Total phosphorus concentrations in groundwater samples were highly variable and ranged between 0.02 mg/L (T3B and T5A) and 1.47 mg/L (BH12). Total phosphorus concentrations exceeding the adopted guideline value of 0.2 mg/L were recorded at Sites T1C (0.34 mg/L), T2I (0.34 mg/L), T5D (0.54 mg/L), T5I (0.5 mg/L), and BH12 (1.47 mg/L).

Total nitrogen varied between sites in the range from 0.29 mg/L (T7A) to 18 mg/L (T7E). The highest concentration was 18 mg/L at T7E, higher than the adopted guideline value (2.6 mg/L). Total nitrogen at BH12 was also higher than the adopted guideline value, at 3.6 mg/L. At all other sites total nitrogen concentrations were below the adopted guideline value.

Generally, total kjeldahl nitrogen concentrations were similar to the total nitrogen concentrations, in the range 0.1 mg/L (BH12) to 18 mg/L (T7E). The highest concentration was at T7E (18 mg/L). At Sites T1C (2 mg/L), T2I (1.9 mg/L) and T5I (2.1 mg/L) total kjeldahl nitrogen concentrations were higher than the adopted guideline value of 1.8 mg/L.

NOx concentrations varied between sites with concentrations ranging between 0.01 mg/L at T7A and 3.6 mg/L at BH12. Only at T7E was the NOx concentration below the detection limit (<0.01 mg/L).

Generally, total ammonia in the groundwater varied between 0.2 mg/kg at T1C and 1 mg/kg at T5D. However, total ammonia at T7E was considerably higher than all other sites, with a concentration of 17 mg/L.

4.4.4 Groundwater Total Petroleum Hydrocarbons

Mean TPH concentrations in the groundwater are summarised in Table 35.

The short chain hydrocarbons (C_6-C_9) were generally below detection limit (<25 µg/L), with the only detected concentrations at T5A (40 µg/L) and T3C (50 µg/L).

The highest TPH C_{10}–C_{14} concentration was at T3C (780 µg/L). Other sites with detected TPH C_{10} –C_{14} concentrations were T1C (300 µg/L), T5A (230 µg/L) and BH12 (59 µg/L).

TPH C_{15}-C_{28} was the highest at T1C with a concentration of 1200 µg/L, considerably higher than at any other site. Other sites with detected TPH C_{15}-C_{28} concentrations were T5I (180 µg/L), T7D (220 µg/L), T7E (130 µg/L) and BH12 (130 µg/L).

TPH C_{29}-C_{36} was not detected in groundwater at any sites.

4.4.5 Groundwater Pesticides/Herbicides

Organochlorine and organophosphate pesticides and herbicides were not detected in groundwater samples throughout the sampling rounds, except pirimiphos-methyl which was found at BH12 (0.05 µg/L) in September 2010. The summary results are presented in Appendix F.

Table 29 Mean* concentration of physicochemical properties (± standard error) in groundwater

Analytes	Units	LOR	Adopted Guideline Value**	T1A n=5	T1C n=2	T2F n=5	T2I n=1	T3B n=4	T3C n=2	T3E n=4
Carbonate Alkalinity as CaCO	mg/L	<1	-	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	<1	220	140±8.4	13±4.5	68 ±10.2	240	9±0.6	28±1.5	14±1
Hardness	mg/L	<1	190	180±9.7	61±0.5	110±2	260	57±1.4	43±4.5	100 ±12.9
pH	pH unit	<1	-	6.7±0.1	5.4±0.3	6.5±0.1	7.2	5.7±0.2	6.4±0.2	6±0.1
Total Dissolved Salts	mg/L	-	950	260±23.8	300±17.5	300±7	440	140±3.5	89±3	330 ±17.4
Turbidity	NTU	<0.1	-	3.5 ±67	7900 ±14500	8 ±29	1000	500±367	270 ±180	61±104

Notes:
*geometric mean
**Derived from DoW (2010) as 80th percentile upper limits, or for pH 20th and 80th percentile
"-" indicates that the particular substance test was not conducted
n= sampling frequency
Values higher than the adopted guideline level are highlighted in yellow.

Table 30 Mean* concentration of physicochemical properties (± standard error) in groundwater (continued)

Analytes	Units	LOR	Adopted Guideline Value**	T5A	T5D	T5I	T7A	T7D	T7E	BH10	BH12
				n=5	n=3	n=2	n=4	n=5	n=4	n=3	n=3
Carbonate Alkalinity as CaCO	mg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	<1	220	8±0.9	49±3.8	180±5	11±0.6	19±1	440±50	7±0.6	18±5.1
Hardness	mg/L	<1	190	46±3.6	100 ±5.2	230±7.5	67±2.4	46±5.2	440±13	62±3	66±5.4
pH	pH unit	<1	-	5.9 ±0.1	6.5 ±0.1	6.8 ±0.1	5.9 ±0.2	6.4 ±0.1	6.7±0	5.7± 0.1	6.3±0.1
Total Dissolved Salts	mg/L	-	950	120 ±3.7	300 ±20	670±45	220 ±7.4	150 ±5.3	1700 ±130.5	140± 7	120±16
Turbidity	NTU	<0.1	-	9±120	120±105	1200 ±2900	36±12	970 ±870	7±3	61±560	590± 420

Notes:
*geometric mean
**Derived from DoW (2010) as 80th percentile upper limits, or for pH 20th and 80th percentile
"-" indicates that the particular substance test was not conducted
n= sampling frequency
Values higher than the adopted guideline level are highlighted in yellow.

Table 31 Dissolved elements concentrations mean* (± standard error) in groundwater

Analytes	Units	LOR	Adopted Guideline Value**	T1A	T1C	T2F	T2I	T3C	T3B	T3E
				n=5	n=2	n=5	n=1	n=4	n=2	n=4
Aluminium	µg/L	<5	650	47 ±21	1400 ±1700	43 ±13	70	320 ±200	740 ±750	700 ±110
Arsenic	µg/L	<1	8.4	2.3 ±0.16	-	31 ±4.1	-	5.8 ±0.4	1.2 ±0.1	<1
Barium	µg/L	<1	-	29 ±2	46 ±2.5	70 ±0.6	120	67 ±2.1	57 ±5.5	25 ±2.5
Cadmium	µg/L	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	µg/L	<1	-	<1	**10.2 ±2.5**	1.1 ±0	<1	2.2 ±0.1	3.5 ±	1.6 ±0.1
Copper	µg/L	<1	26	<1	<1	<1	<1	<1	<1	<1
Iron	µg/L	<5	1900	1700 ±20	2100 ±1800	700 ±68	19	690 ±92	660 ±20	330 ±51
Manganese	µg/L	<1	50	1.4 ±0.16	10 ±0.75	34 ±1.02	19	10 ±0.9	3.3 ±0.5	3 ±0.5
Nickel	µg/L	<1	-	<1	2.9 ±0.9	1.4 ±0	2.1	2.9 ±0.6	<1	<1
Lead	µg/L	<1	10	1.4 ±0.23	1.7 ±0.3	<1	<1	1.1 ±0.1	1 ±0	1.1 ±0
Selenium	µg/L	<1	5[#]	<1	-	<1	-	<1	<1	<1
Strontium	µg/L	<5	-	260 ±9.3	21 ±2	82 ±0.84	230	28 ±1.4	30 ±2.5	25 ±3.3
Zinc	µg/L	<5	40	14 ±2.9	39 ±0	16 ±2.8	53	11 ±3.5	21. ±3.5	21 ±7.1
Silicon	mg/L	<0.05	-	1.3 ±0.07	5.9 ±0	6.5 ±0.12	3.3	4.4 ±0	3.4 ±0.5	6.4 ±0.2

Notes:
*geometric mean
**Derived from DoW (2010) as 80th percentile upper limits
"-" indicates that the particular substance test was not conducted
n= sampling frequency
Values higher than the adopted guideline level are highlighted in yellow

Table 32 Dissolved elements concentrations mean* (± standard error) in groundwater (continued)

Analytes	Units	LOR	Adopted Guideline Value**	T5A	T5D	T5I	T7A	T7D	T7E	BH10	BH12
				n=5	n=3	n=2	n=4	n=5	n=4	n=3	n=3
Aluminium	µg/L	<5	650	68 ±180	280 ±260	650 ±610	110 ±11	1900±1300	11 ±3	69± 71	110± 81
Arsenic	µg/L	<1	8.4	<1	<1	-	<1	<1	3 ±0.2	1.1± 0.04	1.2± 0
Barium	µg/L	<1	-	34 ±1.1	20 ±1.5	86 ±0.5	38 ±0.9	13 ±0.7	390 ±4.1	80± 7	32± 9
Cadmium	µg/L	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	µg/L	<1	-	<1	2.3 ±0	1.8 ±1.1	<1	5.4 ±0.4	<1	<1	4.1± 4.3
Copper	µg/L	<1	26	<1	<1	<1	<1	<1	<1	3.8± 0	<1
Iron	µg/L	<5	1900	16 ±20	89 ±35	580 ±920	1000 ±44	160 ±8	26 ±0	680± 97	50± 33
Manganese	µg/L	<1	50	3 ±0	6 ±0.2	14 ±5.6	7.2 ±0.4	1.3 ±0.2	14 ±0.9	43± 17	31± 7.8
Nickel	µg/L	<1	-	<1	<1	6.4 ±1.1	<1	<1	<1	2.7± 1	1.5± 0.2
Lead	µg/L	<1	10	1 ±0	1.6 ±0	1.4 ±0	<1	1.2 ±0.1	<1	<1	<1
Selenium	µg/L	<1	5#	1.1 ± 0	<1	-	<1	3.4 ±0.1	<1	<1	<1
Strontium	µg/L	<5	-	21 ±1.1	73 ±6.9	250 ±5	40 ±0.95	29 ±1.86	460 ±9.46	40± 5.1	44± 6.5
Zinc	µg/L	<5	40	16 ±7	7 ±0.5	28 ±0	13 ±4.3	16 ±10.5	10 ±2.1	27± 21	26± 27
Silicon	mg/L	<0.05	-	2.9 ±0.1	5.6 ±0.4	5.4 ±0.6	4 ±0	3.8 ±0.8	17 ±0.3	5.1± 0.2	6± 1.1

Notes:
*geometric mean
**Derived from DoW (2010) as 80th percentile upper limits
"-" indicates that the particular substance test was not conducted
n= sampling frequency
Values higher than the adopted guideline level are highlighted in yellow

Table 33 Nutrients concentrations mean* (± standard error) in groundwater

Analytes	Units	LOR	Adopted Guideline Value**	T1A	T1C	T2F	T2I	T3C	T3B	T3E
				n=5	n=2	n=5	n=1	n=4	n=2	n=4
Ortho Phosphate	mg/L	<0.01	-	0.04 ±	0.04 ±0.06	0.01 ±0.002	0.04	0.07 ±0.18	<0.01	0.03 ±0.022
Phosphorus - Total	mg/L	<0.02	0.2	<0.02	0.34 ±0.39	0.03 ±0.003	0.34	0.04 ±0.01	0.02±0	0.03 ±0
Total Nitrogen	mg/L	<0.1	2.6	0.4 ±0.1	2 ±4.8	0.5 ±0.1	1.9	0.5 ±0.1	0.3 ±0.4	1 ±0.2
Total Kjeldahl Nitrogen	mg/L	<0.1	1.8	0.4 ±0.1	2 ±4.8	0.5 ±0.1	1.9	0.4 ±0.1	0.8 ±0	1 ±0.2
NOx as N#	mg/L	<0.01	-	0.1 ±0	0.02 ±0.015	0.04 ±0	0.03	0.1 ±0.04	0.03 ±0.1	0.02 ±0.01
Nitrate as N	mg/L	<0.01	-	0.01 ±0	0.02 ±0.02	0.02 ±0	0.02	0.05 ±0.07	<0.01	0.01 ±0
Nitrite as N	mg/L	<0.01	-	0.05 ±0	<0.01	0.02 ±0	0.01	0.04 ±0.02	0.03 ±0.1	0.02 ±0.01
Total Ammonia as N	mg/L	<0.1	-	<0.1	0.2 ±0	0.3 ±0.02	0.4	0.3 ±0.07	<0.1	0.5 ±0.06

Notes:
*geometric mean
** Derived from DoW (2010) as 80th percentile upper limits
#sum of Nitrate as N and Nitrite as N concentrations
n= sampling frequency
Values higher than the adopted guideline level are highlighted in yellow.

Table 34 Nutrients concentrations mean* (± standard error) in groundwater (continued)

Analytes	Units	LOR	Adopted Guideline Value**	T5A	T5D	T5I	T7A	T7D	T7E	BH10	BH12
				n=5	n=3	n=2	n=4	n=5	n=4	n=3	n=3
Ortho Phosphate	mg/L	<0.01	-	0.02 ±0	0.47 ±0.03	0.08 ±0.04	0.013 ±0.0029	0.06 ±0.06	0.14 ±0.02	0.02± 0.02	0.49± 0.22
Phosphorus - Total	mg/L	<0.02	0.2	0.02 ±0.003	0.51 ±0.02	0.5 ±0.19	<0.02	0.04 ±0.02	0.2 ±0.01	0.18± 0	1.47± 0
Total Nitrogen	mg/L	<0.1	2.6	2.2 ±0.2	1.7 ±0.1	2.1 ±0.7	0.29 ±0.05	2.4 ±0.3	18±1.1	1.8± 0	3.6± 0.5
Total Kjeldahl Nitrogen	mg/L	<0.1	1.8	0.5 ±0	1.7 ±0.1	2.1 ±0.7	0.29 ±0.05	0.6 ±0.3	18 ±1.1	1.6± 0	0.1± 0
NOx as N#	mg/L	<0.01	-	2.1 ±0.1	0.02 ±0.01	0.04 ±0	0.01 ±0.003	2.16 ±0.22	<0.01	0.04± 0.09	3.6± 0.4
Nitrate as N	mg/L	<0.01	-	2.13 ±0.07	<0.01	0.02 ±0	0.01 ±0.004	1.93 ±0.19	<0.01	0.04± 0	3.4± 0.2
Nitrite as N	mg/L	<0.01	-	0.02 ±0.01	0.02 ±0.01	0.02 ±0	0.01 ±	0.21 ±0.04	<0.01	0.01± 0	0.01± 0
Total Ammonia as N	mg/L	<0.1	-	<0.1	1 ±0.03	0.7 ±0	<0.1	0.2 ±0.04	17 ±1.2	<0.1	<0.1

Notes:
*geometric mean
** Derived from DoW (2010) as 80th percentile upper limits
#sum of Nitrate as N and Nitrite as N concentrations
n= sampling frequency
Values higher than the adopted guideline level are highlighted in yellow.

Table 35 Total Petroleum Hydrocarbon concentrations mean* (± standard error) in groundwater

Analytes	Units	LOR	T1A	T1C	T2F	T2I	T3B	T3C	T3E	T5A	T5D	T5I	T7A	T7D	T7E	BH10	BH12
			n=5	n=2	n=5	n=1	n=2	n=4	n=4	n=5	n=3	n=2	n=4	n=5	n=4	n=3	n=3
TPH C6-C9	µg/L	<25	<25	<25	<25	<25	<25	50 ±0	<25	40 ±0	<25	<25	<25	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	<50	300 ±280	<50	<50	<50	780 ±0	<50	230 ±0	<50	<50	<50	<50	<50	<50	59± 0
TPH C15-C28	µg/L	<100	<100	1200 ±0	<100	<100	<100	<100	<100	<100	<100	180 ±0	<100	220 ±0	130 ±7.5	<100	130± 20
TPH C29-C36	µg/L	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100

Notes:
*geometric mean
n= sampling frequency

5.0 Discussion

In this section, the findings of this study are discussed and related to similar studies undertaken in the project area. It is divided into four areas:

- Bibra Lake;
- North Lake;
- Roe Swamp, Lower Swamp, Melaleuca Swamp, Horse Paddock Swamp and surrounding sumplands;
- and groundwater.

5.1 Bibra Lake

5.1.1 Water Quality

Water levels vary seasonally in Bibra Lake, with some parts of the lake drying out in summer and refilling in winter. Water in Bibra Lake was slightly alkaline with pH ranging from pH 8.17 to pH 8.75 throughout the monitoring period (Figure 9). Although results were generally similar over all seasons sampled, pH values in February 2010 were higher than those measured in August 2010 and November 2009. This was likely to be due to increased algal photosynthetic activity (Lewis and McCutchan 2009). Increased photosynthetic activity is associated with the consumption of dissolved carbon dioxide (CO_2), which leads to the production of hydroxide (OH^-), which in turn leads to an increase in pH (Kinnear *et al.* 1997). This explains the slightly elevated pH results in February 2010 and is supported by the higher chlorophyll *a* levels (an indicator of algal activity) measured in Bibra Lake in February 2010, compared to November 2009 and August 2010.

The water was brackish with dissolved salts (measured as EC) ranging approximately between 1,300 µS/cm in November 2009, µS/cm in February 2010 and 1800 µS/cm in August 2010 (Figure 9). In February 2010, the lake water level dropped significantly and became isolated at the deeper western side of the lake. Increased temperature, evaporative losses, less runoff input and reduced water level were likely the cause of the higher conductivity levels measured in February 2010 (EPA and Water Authority of Western Australia 1990).

The water in Bibra Lake appeared to be well oxygenated, with DO levels above 5 mg/L at all sites during the monitoring period (Figure 9). The highest DO level was recorded in February 2010, likely due to the increased algal activity in the lake at this time. Diurnal sampling was not undertaken; however, as algal activity was high in February 2010, it is likely that the DO was lower at night when photosynthetic activity ceased and only respiration occurred.

BOD is a surrogate measure of organic content in waters and was also measured during this study to assist in understanding the demand on available oxygen in the water column. In February 2010, BOD levels exceeded 10 mg/L (Table 5). The BOD levels suggest that the bacteria that break down the organic material will readily consume most of the oxygen in the water column. Lack of oxygen can have a number of effects on the system: the most obvious is the direct impact on the respiring biota in the lake; and oxygen availability can influence the binding and releasing of contaminants and nutrients (Burkett 2005). This, in turn, can affect the amount and toxicity of contaminants in the water column. For instance, zinc is an essential element for plant metabolism, but can be toxic to algae, and zinc’s toxicity is increased by low dissolved oxygen concentration (Clarke *et al.* 1990).

A study conducted by Phoenix Environmental Science (2010) found that the DO level were lower than 5 mg/L in October 2009 and December 2009 and most notable during December 2009 when water levels were much lower (Phoenix 2010). Dissolved salts levels (measured as EC) were between 1,200 µS/cm and 1,300 µS/cm. This study also found that the lake water level was low and declined rapidly from a maximum total depth of 80 cm in October 2009 to 25 cm in December 2010. Overall, the study found a decline in water quality between October 2009 and December 2009, indicated by a decrease in macroinvertebrate species diversity, which is typical of the Swan Coastal Plain (Phoenix 2010).

Differences in Bibra Lake physical water quality readings by Phoenix (2010) and the findings in this report are likely due to sampling locations and timing. Phoenix (2010) conducted their study mainly on the riparian vegetation at the fringe of the lake, in contrast to the study in this report, which sampled the open waters of Bibra Lake. These findings suggest there is a difference in water quality conditions between the fringe and middle of the lake (Phoenix 2010).

5.1.1.1 Elements

Aluminium, arsenic, chromium, copper, lead and zinc concentrations were noted to be higher than guideline levels at all surface water sampling sites. These elements, in addition to TPH, were detected in their highest concentrations at sites close to a nearby car park (Figure 4). The presence of arsenic and zinc in the water suggests that pesticides and fertilisers used in the surrounding area may be transported into Bibra Lake (George *et al.* 1996). However, tests for pesticides (organochlorine and organophosphate) in this study did not indicate the presence of these contaminants at concentrations above the limit of reporting.

Analysis of stormwater discharging into Bibra Lake indicates that this runoff contributes to the elements and TPH in the lake. Aluminium, chromium, copper, lead and zinc were detected at elevated concentrations in all Bibra Lake drains. It was noted that drains on the western side of Bibra Lake, near the car park, were discharging runoff containing comparatively higher TPH concentrations compared to other drains (Figure 4). These drains are likely to be contributing to the water quality status at adjacent surface waters.

The presence of elements and TPH in stormwater runoff is typical in urban drains, primarily due to the influence of vehicle traffic. Concentrations of cadmium, chromium, lead, copper and zinc can be correlated with the volume of vehicle traffic on the roads that drain to the stormwater drains (University of Wisconsin-Extension 1997). Vehicle wear and tear, which includes deterioration of brake pads and tyres, is the main source of cadmium, copper, iron, lead and zinc in runoff. Historically, exhaust fumes from vehicles can also be a source of lead.

Galvanised gutters and downpipes in roofing are one of the main sources of zinc in urban runoff. Other sources of contaminants are paints and plated elements, which can contain cadmium and chromium. Considering the highly urbanised surroundings of the study area, these sources may explain the contaminants detected in Bibra Lake.

5.1.1.2 Nutrients

High concentrations of total phosphorus and total nitrogen, exceeding guideline levels, were recorded in the surface water of Bibra Lake. Even higher nutrient concentrations were also found in the stormwater, which suggests that Bibra Lake receives nutrient input from runoff. This was also found in a study by Burkett (2005); however, that study indicated that the main controlling factor of nutrient concentrations in the water column is the nutrient release from the lake’s sediment. This nutrient release can be influenced by the wetting and drying cycle of the lake and the aerobic and anaerobic processes in the water column.

Seasonal changes in chlorophyll *a* occurred with medium concentrations in November 2009, increasing to very high concentrations in February 2010 (summer) and then decreasing to low concentrations in August 2010 (winter). This pattern was replicated in the phytoplankton abundance results, which are described in Section 5.1.2.

Phosphorus is the major nutrient controlling cyanobacterial blooms in many regions of the world, although nitrogen compounds can play a similar role. In contrast to planktonic algae, some cyanobacteria are able to escape aquatic nitrogen limitation by fixing atmospheric nitrogen. Thus, the availability of bioavailable nitrogen (such as nitrate and ammonia), or orthophosphate is an important factor in determining which algal species become dominant.

Within the study period, the total nitrogen to total phosphorus ratio (TN:TP) followed a similar pattern to chlorophyll *a* with ratios of 3:1 in November 2009 to 17:1 in February 2010. Based on data collected by City of Cockburn (1995-2009), nitrogen was identified as the main limiting factor during winter and spring months. As summer progresses phosphorus becomes limiting to growth. The results obtained in this study were similar to long-term City of Cockburn results, with highest TN:TP ratios occurring during February 2010.

A low TN:TP ratio supports the development of cyanobacterial bloom. The optimum nitrogen to phosphorus ratio for cyanobacteria to bloom is 10 – 16:1 while for eukaryotic algae is 16 – 23:1 (ed. Chorus and Bartram 1999). In spring, when nitrogen is the limiting factor, nitrogen-fixing algae such as species of cyanobacteria start to flourish and bloom as summer progresses.

5.1.1.3 Other Pollutants

TPH detected in the surface water and stormwater runoff were primarily the longer chain hydrocarbons, suggesting that the source may be diesel or oil leaking from vehicles (Foulsham 2009). The existing car parking area at the western side of Bibra Lake represents a potential contributor of TPH input into Bibra Lake.

5.1.2 Phytoplankton Community Assemblage

Phytoplankton was collected from Bibra Lake during the monitoring period in order to understand which algae were present during the seasons and how they influence the ecology of the wetland. A characteristic pattern of seasonal succession of algal communities is diatoms in association with rapidly growing small flagellates in winter and spring, followed by green algae in late spring and early summer, and then species in late summer and autumn which cannot easily be eaten by zooplankton, such as dinoflagellates, desmids and large yellow-green algae. In eutrophic and hypertrophic waters, cyanobacteria often dominate the summer phytoplankton. As winter approaches, in most water bodies, increasing turbulence and the lack of light during the winter leads to their replacement by diatoms (ed. Chorus and Bartram 1999).

During November 2009, chlorophyceae (green algae) was dominant in the lake, mainly *Mougeotia* and *Zygnemopsis.* These algae rarely occur in bloom, but are commonly found in patches in undisturbed wetlands (Chambers *et al.* 2005). Other chlorophyceae, such as *Chlamydomonas* and *Scenedesmus*, were also present; these are odour-causing species. Other potential taste- and odour-causing species were *Synedra* (diatoms), *Cryptomonas* (blue green algae)*, Synechocyctis* (green algae) and *Euglena* (euglenoids). There were no potentially toxic species found during November 2009.

In February 2010, *Mougeotia* (green algae) and *Scenedesmus* (green algae) were not found in the algae samples, but other species such as *Kirchneriella* spp (green algae), *Planktolyngbya contorta* (blue green algae) and *Planktolyngbya subtilis* (blue green algae) were abundant. Two potentially toxic cyanobacteria (blue green algae), *Anabaena affinis* and *Anabaena spiroides,* were found in the lakes' waters. *Anabaena*, usually in high concentration may produce the toxin Anatoxin–a, which can cause respiratory arrest, liver and gastro–intestinal damage (Chambers *et al.* 2005). *Anabaena* can also produce the cyclic peptide microcystin and saxitoxins, which can cause respiratory arrest and skin irritations that may lead to dermatitis (Chambers *et al.* 2005).

In August 2010, there was generally less species diversity than in November 2009 or February 2010 and no abundant species were found in the algae assembly. There was only one potential taste- and odour-causing species identified, *Synechocystis spp* (blue green algae)*,* and no toxic algae was found. This may be due to lower water temperatures in August 2010, or it could be a result of predation by copepods. When the algal samples were collected, large numbers of copepods were observed in the lake and some were collected in the water samples. These were probably Calanoid copepods, which are planktonic and generally feed on detritus and phytoplankton (Davis and Christids 1997).

5.1.3 Sediment Quality

Elements in sediment were generally found to be below available guideline levels. Lead was the only element detected at concentrations exceeding guideline levels, in sediment from the north-east side of the lake (Figure 21). However, lead concentrations did not exceed the ISQG-High guideline value (ANZECC/ARMCANZ 2000), therefore it is unlikely to have a detrimental effect and does not warrant further investigation.

Aluminium and iron are naturally present in the sediment in high concentrations (DoW 2007). Concentrations of elements in the sediment may have resulted from deposition of elements in water or via suspended sediment; however, under certain hydraulic or geochemical processes (e.g. acidic water conditions) these elements may be released back into the water.

Higher concentrations of arsenic and chromium in sediment in the south-west area of the lake (Figure 20) may be a result of historical uses of the area, such as landfill (EPA and Water Authority of Western Australia 1990). The northern part of the lake also contains higher concentrations of contaminants compared with the western and south-east areas of the lake (Figure 21).

TPH were detected in sediment samples, similar to surface water samples, mainly at the western side of Bibra Lake where the car park is located (Figure 18). Runoff containing petroleum products from vehicles may have contributed to the TPH concentrations in sediment. Low concentrations of PAHs were detected in the sediment, but not in surface water or stormwater. This suggests that there is no current input of PAHs into the lake and PAHs present may be due to historical inputs.

Sediments from the north and south-west sides of the lake contained high TOC content, an indication of the ability of the sediment to adsorb contaminants. Contaminants, such as PAH and elements, are commonly bound to the organic content of the sediment, thereby reducing their availability in the environment (DoW 2007; Östman *et al.* 2005). The high concentration of lead in the north-east area of the lake may indicate the amount of lead bound in the sediment, but it is not likely to be readily available to the environment. In contrast, at the west and south-east sides of the lake, the sediment generally contains less organic material. Contaminants at these sites are loosely bound to the sediment and therefore may move through the system more rapidly than in other parts of the lake.

5.1.4 Summary

In terms of seasonal variation, Bibra Lake water quality appeared to be in better condition in August 2010 (winter) and November 2009 (spring), with lower contaminant levels and no potentially toxic algae species during these seasons. In February 2010 (summer), however, there was an apparent increase of nutrients in the lake and a potential for toxic algal blooms to occur. The biological activity of the lake appears to be limited by phosphorus availability once cyanobacteria dominate the water column during summer. In winter and spring, the water column is nitrogen limited.

The main sources of pollutants in Bibra Lake are attributed to the vehicle traffic and urban activities that contribute the majority of elements and hydrocarbons. The lake sediment can act as a sink for these contaminants.

5.2 North Lake

5.2.1 Water Quality

It has been reported that the water level of North Lake fluctuates greatly and the lake undergoes a dry and wet phase every year (Segal and Hale 2000). Davis and Rolls (1987) monitored North Lake from April 1985 to 1986 and they reported that North Lake retained water throughout that year. North Lake groundwater recharge is maintained throughout summer, even when the water table is at low level (EPA and Water Authority of Western Australia 1990).

Conversely, this study found that North Lake dried up completely at the beginning of 2010. When North Lake was first sampled in November 2009 the water level was very low with a maximum water level around 30 cm. In February 2010, the lake was completely dry; it began to fill again in winter and reached a depth around one metre in August 2010. 2009/10 was a very dry period for south-west Western Australia and since the main contributor of water to North Lake is through direct precipitation followed by groundwater and Murdoch Drain (Bayley 1989; Burkett 2005), there was almost no water retained in the middle of North Lake throughout summer 2009/10.

Water pH was almost neutral with readings approximately pH 6.93 in November 2009 (Figure 23). Historical data for North Lake indicated that the lake was neutral with a yearly mean of pH 7.1 ± 0.13 (Davis and Rolls 1987). Additionally, high pH levels of up to pH 9.7 were recorded during continuous cyanobacterial blooms in 1988-1989 (Balla and Davis 1993). However, during August 2010, the water was found to be slightly acidic, with pH levels ranging from pH 4.94 to pH 5.18 (Figure 23).

Consistent with the study undertaken by Davis and Rolls (1987), the lake's water was coloured during the August 2010 months. The study suggested that this colouration may be due to humic and fulvic acids, which are released during the process of decomposition of organic material. This decomposition together with sediments drying out in summer can influence the pH of the lake, causing it to be slightly acidic.

The water in North Lake was brackish with dissolved salts (measured as EC) ranging from 1,700 µS/cm in November 2009 to 4,800 µS/cm in August 2010 (Figure 23). The low water level and possible low dilution of surface salt is the likely reason that the readings were higher than in the previous study by Davis and Roll (1987), which indicated that North Lake water stayed fresh throughout the year.

The DO level was well above the guideline level (5 mg/L), with maximum levels ranging between 11 mg/L in November 2009 and 18 mg/L in August 2010 (Figure 23). The BOD level was below the guideline level (10 mg/L) during both November 2009 and August 2010, indicating that oxygen in the water column is sufficient to support aerobic biological processes (Table 16).

Concurrent to this study, Phoenix Environmental Science (2010) conducted water quality monitoring for their macroinvertebrate study. The study found the water pH level was around 6.3 in October 2009 (spring) and was pH 5.87–5.98 in December 2009 (summer). DO levels varied between 1.42 mg/L and 5.31 mg/L in October 2009 and between 2.25 mg/L and 6.98 mg/L in December 2009. Dissolved salts (measured as EC) increased from 1575–1625 µS/cm in October 2009 to 1678–1765 µS/cm in December 2009 (Phoenix 2010). The study also found that North Lake water level was very low with a maximum depth less than 40 cm in October 2009 and 12 cm in December 2009.

The findings by Phoenix Environmental Science (2010) showed a periodic (seasonal) pattern in the North Lake water quality, decline in pH level and increase in dissolved salts content between October 2009 and December 2009. The water condition readings taken by Phoenix (2010) differ from the results in this report. This may be due to different sampling methodology, location and timing. However, in general, the two studies found that North Lake showed periodic (seasonal) change in water quality, which may be attributed to the low water levels and acidic condition of the lake.

5.2.1.1 Elements

Surface water sampled from the western shore of North Lake (Figure 4) recorded high levels of aluminium, lead and zinc, exceeding guideline values (Table 13). The presence of lead, in addition to traces of TPH, indicates that these pollutants are likely to have entered the lake via runoff from nearby sealed surfaces (Table 17). Elevated zinc levels suggest that its use in galvanised gutters and downpipes from adjacent residential areas may also be transported via runoff into the lake. This is supported by the findings of the stormwater monitoring, where high concentrations of elements, nutrients and TPH were detected in runoff discharged from stormwater drains around North Lake (Figure 4). This indicates that the lake may receive fresh inputs of these pollutants during rain periods. Additionally, iron was found in elevated concentrations during August 2010. This elevated iron concentration was likely due to the acidic water condition, releasing the iron bound in the sediment.

5.2.1.2 Nutrients

Total phosphorus concentrations exceed the guideline value at all sites in November 2009 and August 2010, while total nitrogen and chlorophyll *a* were only exceeded at the western site in the lake (Figure 16). Davis and Rolls (1987) also recorded elevated nutrients and chlorophyll *a* concentrations in North Lake in 1985 and 1986.

The TN:TP ratio for the North Lake West site was similar during November 2009 and August 2010, 7:1 and 5:1, respectively, whereas a ratio of 15:1 was recorded in the middle of the lake in November 2009. There was insufficient water to take samples of the middle of the lake in August 2010 to compare the two seasons. The majority of phosphorus and nitrogen input to North Lake came from Murdoch Drain and was supplemented by groundwater input from the eastern side (Burkett 2005).

The pollutants in North Lake have been identified as originating from urban runoff, agricultural runoff and groundwater (Bayley *et al.* 1989). Concentrations of pollutants in urban runoff are likely to reach their peak during the beginning of the rainy season when contaminants that have accumulated on the road surface are flushed by rain into the receiving water body. Agricultural runoff is mainly due to the application of fertiliser to the soil. A study by Bayley *et al.* (1989) identified that a large proportion of fertiliser applied on the area east of North Lake was lost to drainage, which eventually discharges to North Lake.

Segal and Hale (2000) suggested that through a combination of microbiological processes and aerobic and anaerobic conditions, phosphorus, ammonium and nitrate are released from sediment when the lake receives water. Ammonium and nitrate are only released from the lake sediment during the first flush (Segal and Hale 2000). Burkett (2005) suggested most of the annual phosphorus load is retained in the sediment. However, under low oxygen and/or high pH conditions, sediment-bound phosphorus would be readily released into the water column.

5.2.2 Phytoplankton Community Assemblage

In November 2009, *Mougeotia* (green algae) was found to be the dominant genera in the lake, similar to Bibra Lake's algae assemblage. Other species such as *Fragilaria* (diatoms) and *Chlamydomonas* (green algae) were abundant in the middle of North Lake while *Naviculla* (diatom), *Cosmarium* (green algae) and *Zygnemopsis* (green algae) were abundant in boundary areas of North Lake. Several algae known to have the potential to cause taste and odour problems, such as *Synedra* (diatoms), *Ankistrodemus* (green algae), *Chlamydomonas* (green algae), *Scenedesmus* (green algae), *Pseudanabaena* (blue green algae), *Synechocytis* (blue green) and *Euglena* (euglenoids), were also present in North Lake. In addition to these algae, one potentially toxic blue algae (*Anabaena aphanizomenioides*) was found in the middle and boundary areas of the lake. The potential health hazard of *Anabaena* is discussed in Section 5.1.2.

The samples collected in August 2010 were less diverse than other sampling events and there were no potentially toxic species found in water samples from the lake. However, potential odour-causing species, such as *Synechocystis* spp. (blue green algae), *Glenodinium* spp. (dinoflagellates), and *Euglena* spp. (euglenoids) were found in the lake.

Algae such as *Trachelomonas* (euglenoids) are known to cause a brown water coloration when in bloom (Chambers *et al.* 2005). *Trachelomonas* was dominant and in bloom, indicated by an elevated chlorophyll *a* concentration (175 µg/L) in the water column during August 2010 and may have also contributed to the water coloration, along with leachates from soil humus.

5.2.3 Sediment Quality

Sediment sampled from the North Lake reported elevated concentrations of aluminium, iron, lead and TPH fractions. Lead was present in concentrations above the ISQG-Low guideline levels on the eastern side of North Lake (Figure 21). However, lead concentrations did not exceed the ISQG-High guideline value (ANZECC/ARMCANZ 2000), therefore it is unlikely to have a detrimental effect and does not warrant further investigation.

The elevated concentrations of aluminium and iron in sediment are considered to be naturally-occurring (DoW 2007). Lead and longer chains of TPHs in the sediment can be associated with vehicle use on the roads (Foulsham 2009).

North Lake sediment contains high concentrations (more than one percent) of TOC at both the western and eastern sides of the lake. Concentrations of lead on the eastern shore of the lake may be attributed to the high organic carbon content. The longer chains of TPH (C_{15}-C_{28} and C_{29}-C_{36}) found in North Lake sediments may have accumulated in the sediment over a period of time, due to the tendency of the larger molecular weight constituent to adsorb to sediment and remain relatively immobile (Agency for Toxic Substances and Disease Registry 1999).

5.2.4 Summary

North Lake undergoes a wet and dry period annually. The lake dries out during summer and the water is recharged in winter. The year 2009–2010 has been recorded as a dry period with less rainfall than typical occurring in the study area. North Lake appeared to be in better condition in November 2009 than in August 2010, with lower amounts of pollutants detected in the water column. In August 2010, the North Lake water column was acidic with elevated chlorophyll *a* concentrations, and the dominant algae *Trachelomonas* was in bloom. The cause of acidic water conditions in North Lake during the sampling period was not clear, but it is likely to be related to the decomposition of organic materials.

In terms of pollutant input, North Lake receives input from urban runoff, agricultural runoff and groundwater. Urban runoff is associated with road use and vehicle traffic, and agricultural input is attributed to the fertiliser application in the soil. The lake sediments may accumulate elements, hydrocarbons and other contaminants from the water column. These pollutants are then released into the water column under the acidic water conditions where they can impact the wetland biota.

5.3 Roe Swamp, Lower Swamp, Horse Paddock Swamp and Surrounding Sumplands

The water levels in Roe Swamp, Lower Swamp, Horse Paddock Swamp and surrounding sumplands were very low or completely dry during 2009–2010; consequently, only sediment samples were collected during the monitoring period (Figure 4). Elevated concentrations of aluminium and iron were measured at these sites that are considered to be naturally occurring in the sediment. Elements such as chromium, copper, nickel, lead and zinc tended to be higher at Horse Paddock Swamp and Roe Swamp than the other two sites (Figure 21). Additional sediment samples were collected at Horse Paddock Swamp and Roe Swamp in August 2010 to verify these results. Similar or higher concentrations of copper, lead, nickel, PAH and TPH were reported. These sites are in close proximity to the road and may receive road runoff, accounting for the concentrations.

Lead concentrations above the guideline level at Horse Paddock Swamp and Roe Swamp may be attributed to high total organic content of the sediment. The availability of soluble elements decrease with time in soil with high organic matter content. This is because organic matter adsorbs elements more strongly than soil particles and may overestimate the actual concentration of bioavailable elements in the soil (Hlavay *et al.* 2004).

Additional data from Roe Swamp (August 2010) reported high concentrations of lead and zinc after adjustment for the organic carbon content of the sediment. This indicates that lead and zinc were not bound in the organic matter of the sediment and may be the result of a recent input of lead and zinc, which could be due to stormwater runoff from nearby sealed surfaces.

Traces of DDE were found in sediment collected from Horse Paddock Swamp in both surface and bottom samples in August 2010. This may be a result of residual impact from historical land use of the area. Hirschberg (1991) identified several historical land uses that may release contaminants into the area surrounding North Lake. DDE is a breakdown product of dichlorodiphenyltrichloroethane(DDT), an organochlorine pesticide banned in Australia since 1987 (DEWHA 1997). DDT is known for its persistence in the environment, with a half-life ranging from approximately 2.3 years to 17 years. DDE half-life is recorded to be more than 20 years in temperate region soils (Agency for Toxic Substances and Disease Registry 2002).

Traces of trans-chlordane were detected in sediment samples from Horse Paddock Swamp and Roe Swamp. Trans-chlordane is one of ten major constituents that compose chlordane, an organochlorine pesticide (Agency for Toxic Substances and Disease Registry 1997). Chlordane was once registered as insecticide, termiticide, wood preservative and herbicide; however, its use was discontinued in 1997 (Australian Pesticide and Veterinary Medicines Authority n.d.). The trace concentrations of trans-chlordane found in the sediment may also be due to historical use of the pesticide, since chlordane potentially persists in soil for more than 20 years (Agency for Toxic Substances and Disease Registry 1997).

The results from the two sampling events indicate that further investigation of the sediment is required to determine the extent of contamination present at Horse Paddock Swamp and Roe Swamp. It would also be worthwhile to extend the area examined to include all the wetland area within the proposed road alignment. This will serve several purposes:

- Assist in the assessment of the condition of the wetlands; and
- Provide background information to assess the effectiveness of mitigation measures, such as the proposed bioretention basins.

5.4 Groundwater Quality

Groundwater contains a range of natural chemical species as well as those resulting from anthropogenic activities. The dominance of sodium (Figure 25) and proximity of the study area to coastal areas suggests that the ion composition of groundwater is mainly determined by precipitation of airborne sea spray (Davis *et al.* 1993). Chloride and sulphate concentrations in groundwater are likely primarily sourced from rainfall. In general, the groundwater in the area showed a sulphate/chloride ratio of less than one, indicating the dominance of chloride in the water.

High concentrations of sodium and chloride may also be due to the muddy sediment in the aquifer, which characterises the poorly flushed wetland typical of the Swan Coastal Plain area (Burkett 2005). The high chloride concentration also indicates the impurity level of the groundwater, whereby the clogging nature of sediment permits only intermittent flushing of the groundwater and the impurities (sodium and chloride) are retained. There are two sites (T1A and T2I); however, that were dominated by calcium and magnesium, which indicate groundwater may flush more regularly compared to other areas. These sites are located in a residential area, further away from the wetland area.

Overall, higher sodium concentration in the groundwater compared to the calcium concentration may reflect the amount of flushing. Less groundwater flushing during the study period is attributed to the low rainfall recorded in 2010. Low rainfall is also reflected in very small increases in the groundwater level, particularly during early winter (Syrinx/VCSRG 2010).

Groundwater in the Bibra/North Lake area can be defined as fresh with dissolved salts content ranging from less than 150 mg/L to 1000 mg/L. Groundwater with dissolved salts concentrations of 1000–2000 mg/L were recorded in the South Lake wetland area. In a superficial aquifer, groundwater tends to be fresh with salts content less than 1000 mg/L, though there are patches of groundwater with salinity exceeding 1000 mg/L and limited occurrence with dissolved salts content higher than 2000 mg/L (Davidson 1995).

The wetland study by Syrinx/VCSRG (2010) divided the area into three zones: the “delivery zone” to the east, which corresponds to the Bassendean Sand; the “wetland functional zone” in the centre, which corresponds to the belt containing the chain of wetlands; and the “impoundment zone” to the west, which corresponds to the material underlying the Spearwood Dunes.

This study found that the groundwater salt level gradually increased as the groundwater flows from the delivery zone to the impoundment zone. Groundwater salt levels in the delivery zone was 89–260 mg/L, while in the impoundment zone the range was 440–1700 mg/L. It is likely that as the groundwater travels from delivery zone to the impoundment zone, it collects minerals from the soil. Increases in salt levels are also supported by increasing pH level from the delivery zone (pH 5.4–6.8) to the impoundment zone (pH 6.7–7.2). This pattern of change in groundwater salt level and pH level was also recorded by the Syrinx/VCSRG (2010) study.

The area between North Lake Road and Kwinana Freeway is mapped as having “very high vulnerability” to contamination. This is due to the presence of sand, peat and clay deposits in wetland areas having a shallow water table of less than three metres below ground surface (Appleyard 1993). Groundwater in this area is considered highly susceptible to contamination from agricultural, industrial and urban activities. Moreover sediments such as those found in urbanised wetlands can act both as a carrier and a possible source of contaminants in aquatic systems, and these materials may also affect groundwater (and soil) quality when disturbed (Ahlf and Förstner 2001). Furthermore, a concurrent investigation indicates the area is affected by acid sulphate soil (AECOM 2010). Acid sulphate soil may also have affected the groundwater within localised parts of the study area.

5.4.1 Elements

The first rainfall after an extended dry period is significant in groundwater sampling, during which rain infiltration leaches sand of nutrients, salts and elements after the dry period and transfers them in the short-term into the water table (Syrinx/VCSRG 2010). Aluminium and iron were detected in elevated concentrations in groundwater. These elements are considered to be naturally-occurring at elevated concentrations in the sediment and may be released into groundwater. Iron is present due to the hydrolysis and oxidation of dissolved ferrous iron and the presence of organic acids (Cargeeg *et al.* 1987). At the water table, the concentration of total dissolved iron is generally less than 1 mg/L; however, concentrations in excess of 1 mg/L were recorded in the delivery zone (eastern side of Bibra/North Lake). Elevated concentrations of aluminium and iron in the groundwater may be potentially affected by the presence of acid sulphate soils within the study area.

Lead was detected mainly at sites adjacent to roads (T1A, T1C, T5A, T5I and T7D) and could be attributed to the road runoff that infiltrates into the groundwater. However, detectable lead concentrations were also found at sites away from the roads (T3B, T3C, T3E, and T5D). These findings correspond to a similar study conducted by Syrinx Environmental (Syrinx/VCSRG 2010). The study indicated that a lead plume may be moving away from the groundwater delivery zone into the wetlands or other sources of lead may be present in the wetland area (Syrinx/VCSRG 2010).

Arsenic was detected at elevated concentrations, higher than the adopted guideline value, at one site at the margin of Lower Swamp (T2F). Arsenic was also detected at several other sites (T1A, T3B, T3C, T7E, BH10 and BH12), albeit at lower concentrations. It was suggested by Syrinx/VCSRG (2010) that arsenic in groundwater is associated with sites in the wetland margin. However, this study found that not all sites with detectable arsenic were located at the wetland margin (T1A and BH12). Low concentrations of arsenic found in the groundwater may be due to adsorption by hydrous iron oxide, given that the groundwater and the surrounding wetland sediment contain high levels of iron (Hem 1985). Low levels of arsenic may also originate from historical loads the application of pesticide (with arsenic compounds) that then enter the groundwater system.

Chromium was elevated at one site (T1C), but was generally undetected at most of the sites. Zinc was found in elevated concentrations at Site T2I and was detected at other sites throughout the monitoring periods. The chromium and zinc may originate from stormwater runoff from urban catchments that eventually leach out into the groundwater. This is supported by elevated concentrations of chromium and zinc in runoff from drains in the Bibra Lake and North Lake areas. Generally, concentrations of elements (i.e. copper, arsenic and lead) within groundwater in the Perth region is low but can escalate locally near point sources of contamination (Cargeeg *et al.* 1987). The contaminated sites database (CSD) maintained by the DEC (2010b) identified several sites within about 2 km south of the proposed project area that have been classified by the DEC. The groundwaters at these sites are identified to have been contaminated by elements and hydrocarbons. These sites may potentially contribute pollutants to the groundwater in the Bibra Lake and North Lake areas.

5.4.2 Nutrients

The majority of nitrogen measured in groundwater was in the form of nitrate, which may originate from septic tank leakage, landfill leaches, industrial waste discharges or fertiliser use (Townley *et al.* 1993; Burkett 2005). The highest nitrate concentration recorded in this study was 3.2 mg/L at a site in the groundwater delivery zone (BH12). The concentration of nitrate ions in groundwater commonly exceeds 0.1 mg/L within an urban area and less outside it (Cargeeg *et al.* 1987) depending on catchment use. A typical concentration of nitrate in groundwater in the Perth area under native vegetation is 0.5 mg/L but can be greater than 10 mg/L under urban areas, due to septic tank leakage and fertiliser application (Burkett 2005).

The majority of the groundwater total nitrogen concentrations were less than the adopted guideline value of 2.6 mg/L. However, elevated total nitrogen concentrations in groundwater were found at two sites: one at the groundwater delivery zone (BH12) and one near the South Lake wetland area (T7E), in the groundwater impoundment zone. Total nitrogen at T7E was between 16 and 21 mg/L (18 mg/L average), considerably higher than the adopted guideline level and overall concentrations recorded in the Bibra Lake and North Lake areas. It is possible that this elevated total nitrogen originated from past land use.

Nitrate is likely to be transported into the lake via groundwater inflow (Townley *et al.* 1993). Total nitrogen (including nitrate) concentration was compared between the Bibra Lake water column and groundwater flowing through the lake (T5D) in August 2010, when surface water and groundwater monitoring were conducted concurrently. The concentration of TN in the surface water was 2.4–2.7 mg/L and the TN in the groundwater was 1.7 mg/L, suggesting that as the groundwater flows through Bibra Lake, it supplies the lake with a load of total nitrogen.

There was a clear difference between North Lake nitrogen level in water column (NLWS 2.1 mg/L) and in the groundwater (T2F 0.2 mg/L) flowing through the lake in August 2010. Groundwater may provide North Lake with a small portion of its total nitrogen but it is not the main source (Burkett 2005). It is likely that the majority of total nitrogen in North Lake comes from other sources, such as surface water runoff or reprocessing and release from sediment. Bayley (1989) identified that Murdoch Drain was the main source of total nitrogen entering North Lake. The flow to Murdoch Drain has since been diverted to Murdoch Swamp, to reduce the nutrient loading on North Lake.

Total phosphorus concentrations in the groundwater were generally low, with concentrations less than the adopted guideline value (0.2 mg/L). Some sites (T1C, T2I, T5D, and T5I) showed total phosphorus concentrations higher than the adopted guideline values, between 0.34 and 0.51 mg/L. The highest phosphorus concentration recorded in this study was 1.47 mg/L at a site located in the groundwater delivery zone (BH12).

Phosphorus is less mobile than nitrate in groundwater since it is readily adsorbed into the soil surface. Therefore, the phosphorus load in groundwater flowing through Bibra Lake and North Lake will be adsorbed to the sediments. Spearwood Sand can adsorb phosphorus at a capacity of 200 mg P/kg soil, while it is 40 mg P/kg soil for Bassendean Sand (Townley *et al.* 1993). Since the Bibra Lake and North Lake occupy interdunal depressions in the Spearwood Dune system at the contact with the Bassendean Dune system, groundwater input of phosphorus into the lakes is limited (Davidson 1983).

Total phosphorus concentration in the Bibra Lake water column (0.3–0.4 mg/L) was comparable with the concentration in the groundwater flowing through the lake (T5D 0.5 mg/L) in August 2010. The majority of the Bibra Lake area consists of Bassendean Sand with limited adsorption capacity and phosphorus bound in the sand is readily released under low oxygen and high pH conditions (Burkett 2005). Therefore, under the right conditions, phosphorus bound in the sediment is released into the water column. This is also true for phosphorus originating from other sources. The majority of phosphorus in Bibra Lake originates from the lake bottom sediment that contributes an estimated 59 percent. Approximately 27 percent of the lake's total phosphorus load originates from the groundwater (Strategen 2008).

There was a considerable difference between North Lake (NLWS) total phosphorus in the water column (0.4 mg/L) and in groundwater (T2F 0.03 mg/L) in August 2010. This indicates the groundwater may provide North Lake with phosphorus, but it is not the main source. Bayley (1989) reported that groundwater has been a significant source of phosphorus into North Lake. It is possible that the low water level in North Lake during this monitoring may have reduced groundwater inflow to the lake, resulting in a lower phosphorus input to the water column. Other sources, such as surface water runoff or sediment-bound nutrient release, may have supplied the water column with phosphorus, increasing the internal loading.

5.4.3 Other Pollutants

5.4.3.1 Total Petroleum Hydrocarbon

The shorter chained TPH, which is lower in molecular weight such as gasoline, tend to migrate easily through soil and have the potential to contaminate groundwater. In contrast, longer chained TPH with higher molecular weights are generally more persistent and less mobile in soil, due to their tendency to adsorb to the soil (Agency for Toxic Substances and Disease Registry 1999). In this study, sediments in the Bibra Lake and North Lake area were found to contain mostly longer chains of TPH. The sediment may have received regular input of the TPH; while the longer chain TPH may accumulate in the sediment, the shorter chain TPH seeps out into the groundwater or degrades chemically

TPH concentrations were not detected at the majority of the groundwater monitoring sites. However, there were occasions where TPH concentrations were detected. The majority of TPHs detected were fractions C_{10}-C_{14} and C_{15} - C_{28}, which found at monitoring sites close to roads (T1C, T5A, T5I, T7D, T7E and BH 12). This indicates that the majority of TPH in the groundwater may have originated from petroleum products from road surface runoff. However, TPH was also detected at one site located at a distance from a nearby road (T3C), suggesting that TPH may have moved with groundwater flow.

5.4.3.2 Organophosphate Pesticides

Organophosphate pesticides tested in the groundwater were below the detection limit of the analytical laboratory through the monitoring except pirimiphos-methyl. Pirimiphos-methyl was detected at one site (BH12) with a concentration of 0.05 µg/L during September 2010. There is no guideline level that stipulates the recommended concentration of pirimiphos-methyl in groundwater. However, the International Programme on Chemical Safety (1983) suggested that the LC_{50} (lethal concentration that is sufficient to kill 50 percent of the test population) for rainbow trout in non-flowing water conditions is 0.25 mg/L, which is 5000 times greater than that detected in this study. It is possible that this detection may have originated from a recent pesticide application in the nearby residential area.

Pirimiphos-methyl is a pesticide that decomposes easily under sunlight and is readily hydrolysed by acid or basic solutions (IPCS 1983). Although pirimiphos-methyl has a low persistence pesticide, it is known to be toxic to fish and birds. However, the toxicity of pirimiphos-methyl to fish is highly reduced due its tendency to decompose in water and under direct sunlight, so posed no risk in the circumstance it was discovered here.

5.4.4 Summary

Groundwater quality in the study area varied between sites. The apparent pattern was a gradual increase in salts and pH levels as the groundwater flows from the delivery zone to the impoundment zone. This suggests groundwater flowing through the soil layer may also transport minerals contained in the soil.

The majority of elements and hydrocarbons in the groundwater are likely to have entered via road runoff, while nutrients may have originated from industrial/agricultural (fertiliser) activities in the area. Groundwater flowing beneath Bibra Lake and North Lake may contribute some of these pollutant into the lake's water column. Acid sulphate soil may also have affected the groundwater within localised parts of the study area.

5.5 Conclusion

The wetlands in the project area belong to the Eastern Chain of Beeliar Wetlands within the Swan Coastal Plain. These wetlands are protected by a variety of Commonwealth and State legislation and policies. The geomorphology and stratigraphy studies (Syrinx Environmental and Vick and Chris Semeniuk Research Group 2010) show variation in the sedimentary fill underlying the wetlands, which influences water movement, infiltration and water quality. Paleochannels, coarse sand layers and diagenesis were identified as potentially contributing to potential localised variation within the general east-west groundwater flows.

The typical water table rise with the onset of winter rain and consequent groundwater recharge was not observed during the monitoring period, a result of very low rainfall within the catchment and the region during 2010.

The project area and surrounds have been modified from a landscape dominated by agriculture, vegetated surfaces and other undeveloped areas in the mid-1970s to the mainly residential developments prevalent today. As a result of past and current land use practices, the wetlands and surrounding vegetated areas are not pristine as evidenced by the elevation in background concentrations of nutrients, elements and occasional detection of 'man-made' residues such as hydrocarbons and pesticides. Elevated concentrations of heavy metals, hydrocarbons and nutrients were recorded in the groundwater, stormwater, surface water and sediments within the project area. Algal blooms were recorded in the lakes during the monitoring period and previous studies have frequently reported blooms dominating large areas of North and Bibra Lakes.

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Appendix A

Sampling Location Details and Coordinates

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Appendix A Sampling Location Details and Coordinates

Site Number/ Code	Site Name	Site description	Coordinates	
			Easting	Southing
Surface Water				
BLNS	Bibra North	Bibra Lake, north deep site	115°49'28.45"	32°05'14.34"
BLWS1	Bibra North-West	Bibra Lake, western side near car park	115°49'19.36"	32°05'22.24"
BLWS2	Bibra West	Bibra Lake, western side near car park	115°49'18.52"	32°05'32.40"
BLSS	Bibra South	Bibra Lake, southern side near landfill	115°49'24.95"	32°05'48.05"
NLMD	North Lake Middle	North Lake, middle of the lake	115°49'26.08"	32°04'34.37"
NLWS	North Lake West	North Lake, Western side of the lake	115°49'21.00"	32°04'38.80"
Stormwater				
Site 1	Farrington West	Contains a weir or a dam wall. This drain flows to North Lake	115° 49' 18.68"	32° 4' 29.28"
Site 2	Horse Paddock Swamp Drain	Substantial rainfall needed for this drain to flow. Inflows flow into a soak well; the outflow pipe is joined to the top of the soak well. This drain flows to Horse Paddock.	115° 49' 21.77"	32° 4' 52.89"
Site 4	Farrington East	This large pipe has a grate over it and difficult to sample. This drain flows to Roe Swamp/Lower Swamp	115° 50' 12.34"	32° 4' 47.67"
Site 5	Upper Hope Road	Overgrown with vegetation and difficult to locate. This drain flows to Roe Swamp.	115° 50' 7.55"	32° 5' 7.63"
Site 6	Lower Hope Road	Easily accessible. Drains into a low seasonally inundated area. This drain flows to Bibra Lake.	115° 50' 8.61"	32° 5' 8.42"
Site 7	Upper Bibra West	Pipe leads into Bibra Lake on sand bank near park. This drain flows to Bibra Lake.	115° 49' 15.03"	32° 5' 25.07"
Site 8	Middle Bibra West	Near walking path. This drain flows to Bibra Lake.	115° 49' 14.40"	32° 5' 29.65"
Site 9	Lower Bibra West	This outfall is unlike the other drains, water flows to it a mulched area.	115° 49' 15.33"	32° 5' 34.27"
Site 10	Bibra South	Grassy area. This drain flows to Bibra Lake.	115° 49' 34.52"	32° 6' 3.61"
Site 11	Bibra South-East 1	Grassy area. This drain flows to Bibra Lake.	115° 49' 53.02"	32° 6' 1.57"
Site 12	Bibra South-East 2	Overgrown with vegetation, difficult to find unless flowing. This drain flows to Bibra Lake.	115° 49' 59.81"	32° 6' 1.54"
Site 13	Bibra South-East 3	Grassy area. This drain flows to Bibra Lake.	115° 50' 0.86"	32° 5' 59.76"
Sediment				
BLN1	Bibra North-West	North-western edge of the lake. Close to the pedestrian walkway and close to Progress Drive. Soil sample was similar to compost, activated sludge.	115° 49' 24.24"	32° 5' 8.53"
BLN2	Bibra North-East	North-eastern edge of the lake. The area was dry during the sampling. the site was near dense vegetation (Typha)	115° 49' 40.65"	32° 5' 8.17"
BLS1	Bibra South-West	South-western edge of the lake. Near to historical landfill area.	115° 49' 37.27"	32° 5' 57.72"
BLS2	Bibra South-	South-eastern edge of the lake. Large sediment	115° 49' 47.21"	32° 5' 53.24"

Site Number/ Code	Site Name	Site description	Coordinates	
			Easting	Southing
	East	grain and sandy, the area was moist during the time of sampling.		
BLW1 (BLM1)	Bibra Lower West	Western edge of the lake. The site is very close to the car park	115° 49' 19.57"	32° 5' 33.79"
BLW2 (BLM2)	Bibra Upper West	Western edge of the lake. The site is very close to the car park	115° 49' 17.19"	32° 5' 23.24"
NL1	North Lake West	Western edge of North Lake, near the public car park. The lake was dry; sediment/soil samples were peaty and slightly moist.	115° 49' 20.40"	32° 4' 39.21"
NL2	North Lake East	Eastern side of North Lake. Soil/sediment samples were peaty and slightly muddy with more moisture compared to samples taken from NL1.	115° 49' 39.02"	32° 4' 40.90"
NL3	Lower Swamp	Lower Swamp (Lower Swamp). The soil/sediment at the site was compact and appeared to have low moisture content.	115° 49' 43.85"	32° 4' 45.26"
NL4	Horse Paddock	Horse Paddock Swamp. The swamp was generally dry, but the soil was moist and soil/sediment samples were taken from the western edge of the swamp.	115° 49' 29.25"	32° 4' 57.79"
NL5	Roe Swamp	Western edge of Roe Swamp. The soil was muddy / clayey, water was present when sampling from bottom samples (± 30cm depth).	115° 50' 7.29"	32° 5' 4.76"
NL6	Murdoch Wetland	Wetlands near Murdoch University. The soil resembles woodland soil (coarse sand).	115° 50' 0.60"	32° 4' 32.85"
Groundwater				
T1A	-	North Lake transects, near Murdoch Drive	115° 50' 29.74"	32° 4' 14.22"
T1C	-	North Lake transect, Murdoch wetlands	115° 49' 58.51"	32° 4' 16.50"
T1F	-	North Lake transect, near North Lake Senior Campus	115° 48' 44.98"	32° 4' 16.01"
T2F	-	North Lake transect, northwest of Lower Swamp	115° 49' 44.56"	32° 4' 42.61"
T2I	-	North Lake transect, residential area west of North Lake	115° 49' 5.98"	32° 4' 40.99"
T3B	-	North Lake transect, eastern part of Roe Swamp near Bibra Drive.	115° 50' 14.60"	32° 4' 57.40"
T3C	-	North Lake transect, Eastern part of Roe Swamp	115° 50' 4.01"	32° 4' 57.99"
T3E	-	North Lake transect, Western Part of Roe Swamp	115° 49' 34.99"	32° 4' 57.01"
T3J	-	North Lake transect, residential area South-West of North Lake	115° 48' 51.89"	32° 4' 53.88"
T5A	-	Bibra Lake transect, residential area west of Bibra Lake	115° 50' 25.57"	32° 5' 24.20"
T5D	-	Bibra Lake transect, east of Bibra Lake	115° 49' 46.06"	32° 5' 26.37"
T5H	-	Bibra Lake transect, west of Bibra Lake	115° 49' 7.76"	32° 5' 26.47"
T5I	-	Bibra Lake transect, residential area west of Bibra Lake	115° 48' 45.81"	32° 5' 24.57"
T7A	-	Bibra Lake transect, southeast of Bibra Lake	115° 50' 24.89"	32° 5' 53.97"
T7D	-	Bibra Lake transect, south of Bibra Lake	115° 49' 34.75"	32° 6' 3.51"
T7E	-	Bibra Lake transect, wetlands area southwest of	115° 49' 3.58"	32° 6' 0.75"

Site Number/ Code	Site Name	Site description	Coordinates	
			Easting	Southing
		Bibra Lake,		
BH10	-	Near the site T3B, at the eastern side of Roe Swamp.	115° 50' 13.8"	32° 4' 59.3"
BH12	-	Near residential area on the eastern part of Hope Road	115° 50' 35.7"	32° 5' 6.8"

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Appendix B

Analytes Measured in Water and Sediment from Bibra Lake and North Lake

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Appendix B Analytes Measured in Water and Sediment from Bibra Lake and North Lake

Analytes Measured in the Surface Water, Stormwater, and Groundwater

Analytes	Limit of Reporting	Method
pH	0.1 pH unit	APHA 4500B
Bicarbonate/carbonate	1 mg/L	APHA 2320B
Hardness ($CaCO_3$)	1 mg/L	APHA 2340B
Chloride	1 mg/L	APHA 4500D
Sulphate	2 mg/L	Dept Mineral Resources – BaCrO4 Method
Sodium Na^+, Potassium K^+	0.1 mg/L	APHA 3500B
Calcium Ca^+, Magnesium Mg^+	0.1 mg/L	APHA 3111B
TSS	2 mg/L	APHA 2540D
Turbidity	0.1 NTU	APHA 2130B
Total Elements (Al, As, Ba, Cd, Cu, Fe, K, Pb, Mn, Mg, Ni, Si, Se, Sr, Zn)	1 – 20 µg/L	USEPA 200.8 – ICPMS
Dissolved Elements (Al, As, Ba, Cd, Cu, Fe, K, Pb, Mn, Mg, Ni, Si, Se, Sr, Zn)	1 – 20 µg/L	USEPA 200.7 – ICP-OES
Ammonia as N	0.1 mg/L	APHA 4500G
NO_x (Nitrate and Nitrite)	0.01 mg/L	APHA 4500F
Total N	0.1 mg/L	APHA 4500B
Orthophosphate as P	0.01 mg/L	APHA 4500F
Total Phosphorus	0.02 mg/L	USEPA 200.7 – ICP-OES
Biological Oxygen Demand	2 mg/L	APHA 5210B
Chlorophyll *a*	0.02 µg/L	Acid Correction – In house method
Total Petroleum Hydrocarbons (TPH) in standard ranges through to C36	25 – 100 µg/L	USEPA 8000 – GC/FID
Benzene, toluene, ethylbenzene, and xylenes (BTEX)	1 µg/L	USEPA 8260 – P&T GCMS
Polycyclic aromatic hydrocarbons (PAH)	1 µg/L	USEPA 8270 – GCMS
Organochlorine and Organophosphate pesticides	0.015 – 0.03 µg/L	USEPA 8270 – GCMS
Multi-residue Herbicide Screen	0.01 µg/L	USEPA 1694 – LCMSMS

Analytes Measured in the Sediment

Parameters	Limit of Reporting	Laboratory Analysis Method
Moisture content	0.10%	Gravimetric
Trace elements (Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Se, Zn)	0.1-5 mg/kg	USEPA 200.7 – ICP-OES
Total Nitrogen	20 mg/kg	Determined by calculation.
Total Kjeldahl Nitrogen (TKN)	20 mg/kg	Sample dried, split and crushed to -150um. Determined by APHA 4500B.
Nitrate NO3-N	0.5 mg/kg	1:5 soil/water extract. Determined by APHA 4500F.
Nitrite NO2-N	0.5 mg/kg	1:5 soil/water extract. Determined by APHA 4500F.
Oxidised Nitrogen NOx-N	0.5 mg/kg	1:5 soil/water extract. Determined by APHA 4500F.
Ammonia NH4-N	0.5 mg/kg	1:5 soil/water extract. Determined by APHA 4500G.
Benzene, toluene, ethylbenzene, and xylenes (BTEX)	0.2 mg/kg	USEPA 8270 – GCMS
Total Petroleum Hydrocarbons (TPH) in standard ranges through to C36	10-50 mg/kg	USEPA 8000 – GC/FID
Poly aromatic hydrocarbons (PAH)	5 mg/kg, total PAH (100 mg/kg)	USEPA 8270 – GCMS
Organochlorine Pesticides	1 mg/kg	USEPA 8270 – GCMS
Organophosphate Pesticides	20 mg/kg	USEPA 8270 – GCMS
Total Organic Carbon	0.01%	Handbook of Soil and Water. Sample dried, split and crushed to -150um. Dilute acid treatment, high temperature dry combustion furnace, infrared detection.
ORP (Redox Potential)	0.1 mV	Eh: redox potential
Field SPOCAS (pHfox)	-	Titrimetric and ICP-AES techniques
SPOCAS	-	Titrimetric and ICP-AES techniques

Appendix C

Quality Control

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Appendix C Quality Control

Stormwater Sampling Replicate Samples RPD

Sampling Dates			14/04/2010									21/05/2010			22/05/2010		
Sampling Sites			Site 4			Site 7			Site 10			Site 10			Site 7		
Analytes	Unit	LOR	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)
Aluminium - Total	µg/L	<5	710	690	2.9	180	180	0.0	140	140	0.0	550	460	17.8	160	170	6.1
Arsenic - Total	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Cadmium - Total	µg/L	<0.2	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0
Chromium - Total	µg/L	<1	3.5	3.5	0.0	2	2	0.0	0	0	0.0	2.4	2.1	13.3	1.2	1	18.2
Copper - Total	µg/L	<1	29	29	0.0	9.7	10	3.0	3.5	6.4	58.6	15	14	6.9	4.7	4.2	11.2
Iron - Total	µg/L	<5	840	800	4.9	180	170	5.7	140	130	7.4	790	650	19.4	150	150	0.0
Lead - Total	µg/L	<1	17	17	0.0	7.4	7.7	4.0	3.2	5.1	45.8	8.3	7.9	4.9	5.7	5.1	11.1
Zinc - Total	µg/L	<5	120	130	8.0	70	63	10.5	62	69	10.7	79	100	23.5	57	43	28
Phosphorus - Total	mg/L	<0.02	0.17	0.18	5.7	0.14	0.14	0.0	0.12	0.17	34.5	0.36	0.36	0.0	0.07	0.08	13.3
Benzene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Toluene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Ethyl Benzene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
m+p xylenes	µg/L	<4	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0
o-xylene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Total BTEX	µg/L	<11	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0
TPH C6-C9	µg/L	<25	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0
TPH C10-14	µg/L	<50	100	110	9.5	93	99	6.3	62	68	9.2	120	130	8.0	<50	<50	0.0
TPH C15-28	µg/L	<100	710	650	8.8	580	650	11.4	360	370	2.7	1100	1200	8.7	100	<100	66.7
TPH C29-36	µg/L	<100	390	420	7.4	290	390	29.4	130	140	7.4	390	400	2.5	<100	<100	0.0
Naphthalene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0

Sampling Dates			14/04/2010									21/05/2010			22/05/2010		
Sampling Sites			Site 4			Site 7			Site 10			Site 10			Site 7		
Fluorene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Phenanthrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Fluoranthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benz(a)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Chrysene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(b)&(k)fluoranthene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Benzo(a)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Indeno(1,2,3-cd)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Dibenz(a,h)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Total Suspended Solids	mg/L	<2	16	25	43.9	7	6	15.4	2	7	111	19	20	5.1	5	3	50
Total Nitrogen	mg/L	<0.1	1.2	0.3	120	0.4	0.4	0.0	0.3	0.5	50	2.9	2.5	14.8	0.8	1.7	72
Total Kjeldahl Nitrogen	mg/L	<0.1	1	<0.1	181	0.4	0.4	0.0	0.3	0.4	28.6	2.5	2.1	17.4	0.4	0.5	22.2
NOx as N	mg/L	<0.01	0.19	0.28	38.3	<0.01	0.04	156	<0.01	0.03	143	0.41	0.4	2.5	0.37	1.2	106

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow

Stormwater Sampling Replicate Samples RPD continued

Sampling Dates			27/05/2010			15/06/2010			8/07/2010			9/07/2010			12/08/2010		
Sampling Sites			Site 10			Site 8			Site 10			Site 6			Site 10		
Analytes	Unit	LOR	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)
Aluminium - Total	µg/L	<5	220	250	12.8	290	380	26.9	3.5	2.1	50	180	120	40	200	170	16.2
Arsenic - Total	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Cadmium - Total	µg/L	<0.2	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0
Chromium - Total	µg/L	<1	1.2	1.2	0.0	4.1	4	2.5	6.7	3.8	55.2	1.3	1.2	8.0	4.8	<1	162
Copper - Total	µg/L	<1	9.8	8	20.2	15	15	0.0	24	14	52.6	7.4	6.8	8.5	6.6	6.4	3.1
Iron - Total	µg/L	<5	240	320	28.6	400	490	20.2	3.7	2.5	38.7	170	120	34.5	310	240	25.5
Lead - Total	µg/L	<1	9.6	8.4	13.3	6.4	6.3	1.6	21	13	47.1	11	10	9.5	4.7	4.6	2.2
Zinc - Total	µg/L	<5	61	54	12.2	74	78	5.3	180	130	32.3	38	38	0.0	42	43	2.4
Phosphorus - Total	mg/L	<0.02	0.07	0.06	15.4	0.05	0.05	0.0	0.44	0.23	62.7	0.04	0.03	28.6	0.05	0.08	46.2
Benzene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Toluene	µg/L	<2	<2	<2	0.0	17	16	6.1	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Ethyl Benzene	µg/L	<2	<2	<2	0.0	3	3	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
m+p xylenes	µg/L	<4	<4	<4	0.0	12	12	0.0	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0
o-xylene	µg/L	<2	<2	<2	0.0	6	6	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Total BTEX	µg/L	<11	<11	<11	0.0	38	37	2.7	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0
TPH C6-C9	µg/L	<25	<25	<25	0.0	54	54	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0
TPH C10-14	µg/L	<50	<50	<50	0.0	<50	<50	0.0	110	<50	126	<50	<50	0.0	<50	<50	0.0
TPH C15-28	µg/L	<100	230	220	4.4	630	520	19.1	780	290	91.6	130	170	26.7	110	110	0.0
TPH C29-36	µg/L	<100	230	190	19	530	500	5.8	980	370	90.4	160	160	0.0	<100	110	75
Naphthalene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Fluorene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Phenanthrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0

Sampling Dates			27/05/2010			15/06/2010			8/07/2010			9/07/2010			12/08/2010		
Sampling Sites			Site 10			Site 8			Site 10			Site 6			Site 10		
Anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Fluoranthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benz(a)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Chrysene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(b)&(k)fluoranthene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Benzo(a)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Indeno(1,2,3-cd)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Dibenz(a,h)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Total Suspended Solids	mg/L	<2	8	2	120	14	13	7.4	150	120	22.2	5	4	22.2	5	7	33.3
Total Nitrogen	mg/L	<0.1	0.4	0.5	22.2	0.3	0.2	40.0	1.8	0.5	113	0.2	0.3	40	0.1	0.4	120
Total Kjeldahl Nitrogen	mg/L	<0.1	0.3	0.3	0.0	0.2	0.1	66.7	1.8	0.4	127	0.2	0.3	40	0.2	0.5	85.7
NOx as N	mg/L	<0.01	0.08	0.2	85.7	0.07	0.07	0.0	<0.01	0.09	179	0.04	0.04	0.0	0.06	0.07	15.4

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow.

Stormwater Sampling Duplicate Samples RPD

Sampling Dates			21/05/2010			22/05/2010			27/05/2010			14/06/2010		
Sampling Sites			Site 9			Site 1			Site 7			Site 7		
Analytes	**Unit**	**LOR**	**Original**	**Duplicate**	**RPD(%)**	**Original**	**Duplicate**	**RPD(%)**	**Original**	**Duplicate**	**RPD(%)**	**Original**	**Duplicate**	**RPD(%)**
Aluminium - Total	µg/L	<5	590	650	9.7	650	620	4.7	51	52	1.9	210	220	4.7
Arsenic - Total	µg/L	<1	<1	1.1	75	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Cadmium - Total	µg/L	<0.2	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0
Chromium - Total	µg/L	<1	3.3	3.5	5.9	2.4	2.4	0.0	<1	<1	0.0	2.3	2.3	0.0
Copper - Total	µg/L	<1	34	34	0.0	11	12	8.7	1.8	1.9	5.4	16	17	6.1
Iron - Total	µg/L	<5	610	660	7.9	640	640	0.0	50	39	24.7	200	210	4.9
Lead - Total	µg/L	<1	16	17	6.1	19	20	5.1	<1	<1	0.0	5.4	5.5	1.8
Zinc - Total	µg/L	<5	180	210	15.4	69	130	61.3	40	35	13.3	58	67	14.4
Phosphorus - Total	mg/L	<0.02	0.84	0.86	2.4	0.16	0.16	0.0	0.04	0.04	0.0	0.21	0.21	0.0
Benzene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Toluene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Ethyl Benzene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
m+p xylenes	µg/L	<4	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0
o-xylene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Total BTEX	µg/L	<11	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0
TPH C6-C9	µg/L	<25	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0
TPH C10-14	µg/L	<50	330	410	21.6	<50	75	100	<50	<50	0.0	110	100	9.5
TPH C15-28	µg/L	<100	1700	2000	16.2	130	380	98.0	<100	<100	0.0	810	850	4.8
TPH C29-36	µg/L	<100	760	880	14.6	110	180	48.3	<100	<100	0.0	400	480	18.2
Naphthalene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Fluorene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Phenanthrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0

Sampling Dates			21/05/2010			22/05/2010			27/05/2010			14/06/2010		
Sampling Sites			Site 9			Site 1			Site 7			Site 7		
Anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Fluoranthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benz(a)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Chrysene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(b)&(k)fluoranthene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Benzo(a)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Indeno(1,2,3-cd)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Dibenz(a,h)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Total Suspended Solids	mg/L	<2	26	34	26.7	28	29	3.5	<2	<2	0.0	4	<2	120
Total Nitrogen	mg/L	<0.1	5.4	5.9	8.8	1.1	3.1	95.2	<0.1	1.2	184	1.5	1.4	6.9
Total Kjeldahl Nitrogen	mg/L	<0.1	5.4	5.9	8.8	0.9	1.2	28.6	<0.1	0.3	143	1.2	1.1	8.7
NOx as N	mg/L	<0.01	0.01	0.01	0.0	0.07	1.9	186	<0.01	0.9	198	0.32	0.32	0.0

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow.

Stormwater Sampling Duplicate Samples RPD continued

Sampling Dates			15/06/2010			8/07/2010			9/07/2010			12/082010		
Sampling Sites			Site 7			Site 7			Site 4			Site 7		
Analytes	**Unit**	**LOR**	**Original**	**Duplicate**	**RPD(%)**	**Original**	**Duplicate**	**RPD(%)**	**Original**	**Duplicate**	**RPD(%)**	**Original**	**Duplicate**	**RPD(%)**
Aluminium - Total	µg/L	<5	98	85	14.2	2	2.3	14	940	890	5.5	160	150	6.5
Arsenic - Total	µg/L	<1	<1	<1	0.0	2	1.9	5.1	<1	<1	0.0	<1	<1	0.0
Cadmium - Total	µg/L	<0.2	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0
Chromium - Total	µg/L	<1	<1	<1	0.0	5.3	5.8	9.0	5.8	3.2	57.8	<1	<1	0.0
Copper - Total	µg/L	<1	2.2	2.2	0.0	25	25	0.0	27	26	3.8	3.3	3.1	6.2
Iron - Total	µg/L	<5	80	75	6.5	930	1000	7.3	960	860	11	120	110	8.7
Lead - Total	µg/L	<1	1.3	1.3	0.0	13	13	0.0	15	15	0.0	1.6	1.5	6.5
Zinc - Total	µg/L	<5	30	33	9.5	79	79	0.0	150	120	22.2	51	25	68.4
Phosphorus - Total	mg/L	<0.02	0.06	0.06	0.0	0.39	0.39	0.0	0.07	0.07	0.0	0.05	0.05	0.0
Benzene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Toluene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Ethyl Benzene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
m+p xylenes	µg/L	<4	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0	<4	<4	0.0
o-xylene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Total BTEX	µg/L	<11	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0	<11	<11	0.0
TPH C6-C9	µg/L	<25	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0
TPH C10-14	µg/L	<50	<50	<50	0.0	130	140	7.4	<50	<50	0.0	<50	<50	0.0
TPH C15-28	µg/L	<100	<100	<100	0.0	1100	1000	9.5	560	500	11.3	<100	<100	0.0
TPH C29-36	µg/L	<100	<100	<100	0.0	590	450	26.9	660	570	14.6	<100	<100	0.0
Naphthalene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Acenaphthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Fluorene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Phenanthrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0

Sampling Dates			15/06/2010			8/07/2010			9/07/2010			12/082010		
Sampling Sites			Site 7			Site 7			Site 4			Site 7		
Anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Fluoranthene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benz(a)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Chrysene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(b)&(k)fluoranthene	µg/L	<2	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0	<2	<2	0.0
Benzo(a)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Indeno(1,2,3-cd)pyrene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Dibenz(a,h)anthracene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Total Suspended Solids	mg/L	<2	4	4	0.0	22	21	4.7	28	29	3.5	3	2	40
Total Nitrogen	mg/L	<0.1	<0.1	<0.1	0.0	3.8	3.6	5.4	0.6	0.7	15.4	0.3	0.2	40
Total Kjeldahl Nitrogen	mg/L	<0.1	<0.1	<0.1	0.0	3	2.9	3.4	0.5	0.6	18.2	0.3	0.2	40
NOx as N	mg/L	<0.01	0.02	0.02	0.0	0.76	0.72	5.4	0.11	0.09	20	0.03	0.02	40

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow.

Groundwater Sampling Replicate Samples RPD

Sampling dates			20/05/2010			21/06/2010			22/06/2010			20/07/2010			21/07/2010			24/08/2010		
Sites			T1A			T7D			T7E			T7D			T7D			T7D		
Analytes	Units	LOR	Original	Replicate	RPD (%)	Original	Replicate	RPD (%)	Original	Replicate	RPD (%)	Original	Replicate	RPD (%)	Original	Replicate	RPD (%)	Original	Replicate	RPD (%)
pH	pH unit	<1	6.5	6.5	0.0	6.4	6.4	0.0	6.7	6.8	1.5	6.7	6.6	1.5	6.7	6.6	1.5	6.3	6.2	1.6
Carbonate	mg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Bicarbonate	mg/L	-	130	130	0.0	19	19	0.0	380	370	2.7	19	18	5.4	43	43	0.0	21	19	10
Hardness	mg/L	-	170	160	6.1	49	49	0.0	410	430	4.8	42	44	4.7	92	89	3.3	38	40	5.1
Calcium - Total	mg/L	<0.1	46	45	2.2	5.3	5.5	3.7	96	100	4.1	5.3	5	5.8	17	16	6.1	4.2	4.6	9.1
Magnesium - Total	mg/L	<0.1	13	12	8.0	8.6	8.5	1.2	42	43	2.4	7.1	7.6	6.8	12	12	0.0	6.8	6.9	1.5
Sodium - Total	mg/L	<0.1	17	20	16.2	46	38	19	520	570	9.2	41	38	7.6	65	65	0.0	45	43	4.5
Potassium - Total	mg/L	<0.1	3.3	3	9.5	3.6	3.7	2.7	9.6	9.8	2.1	3.4	3.2	6.1	5.6	5.7	1.8	3.5	3.6	2.8
Turbidity	NTU	-	300	300	0.0	450	450	0.0	6.6	7	5.9	750	750	0.0	380	450	17	550	660	18
Total Dissolved Salts	mg/L	-	235	230	2.2	160	165	3.1	1960	2150	9.2	145	155	6.7	280	270	3.6	150	155	3.3
Chloride	mg/L	<1	43	42	2.4	72	62	15	580	600	3.4	61	59	3.3	110	110	0.0	64	62	3.2
Sulphate	mg/L	<2	38	37	2.7	28	27	3.6	510	620	20	26	26	0.0	43	43	0.0	27	27	0.0
Orthophosphate as P	mg/L	<0.01	0.04	0.03	29	0.3	0.3	0.0	0.09	0.09	0.0	<0.01	<0.01	0.0	0.5	0.53	5.8	0.02	0.03	40
Phosphorus - Total	mg/L	<0.04	<0.04	<0.04	0.0	0.02	0.04	67	0.21	0.2	4.9	0.05	0.04	22	0.56	0.56	0.0	0.02	0.04	67
Total Nitrogen	mg/L	<0.1	0.7	0.6	15	2.4	2.2	8.7	18	18	0.0	3.4	3.7	8.5	1.5	1.5	0.0	1.8	1.9	5.4
Total Kjeldahl Nitrogen	mg/L	<0.1	0.6	0.6	0.0	0.4	0.2	67	18	18	0.0	0.3	0.6	67	1.5	1.5	0.0	<0.1	<0.1	0.0
Nitrate as N	mg/L	<0.01	0.01	0.01	0.0	1.7	1.7	0.0	<0.01	<0.01	0.0	2.7	2.6	3.8	0	0	0.0	1.7	1.7	0.0
Nitrite as N	mg/L	<0.01	0.05	0.03	50	0.28	0.27	3.6	<0.01	<0.01	0.0	0.36	0.49	31	0.04	0.03	29	0.13	0.17	27
Total Ammonia as N	mg/L	<0.1	<0.1	<0.1	0.0	0.2	0.2	0.0	17	17	0.0	0.3	0.3	0.0	1.1	1.1	0.0	<0.1	<0.1	0.0
Aluminium - Dissolved	µg/L	<5	140	150	6.9	83	67	21	16	16	0.0	2900	3700	24	950	460	70	4900	1500	110
Barium - Dissolved	µg/L	<1	25	24	4.1	15	13	14	10	8.5	16.2	11	12	8.7	18	19	5.4	13	14	7.4
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2	0.0	<0.2	<0.2	0.0	390	380	2.6	<0.2	<0.2	0.0	<0.2	<0.2	0.0	<0.2	<0.2	0.0
Chromium - Dissolved	µg/L	<1	<1	<1	0.0	5.1	3.1	49	<1	<1	0.0	5.6	7.2	25	2.3	1.3	56	7	5.5	24
Copper - Dissolved	µg/L	<1	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0

Sampling dates			20/05/2010			21/06/2010			22/06/2010			20/07/2010			21/07/2010			24/08/2010		
Sites			T1A			T7D			T7E			T7D			T7D			T7D		
Iron - Dissolved	µg/L	<5	1700	1700	0.0	130	96	30	<5	<5	0.0	160	200	22	170	150	13	180	140	25
Manganese - Dissolved	µg/L	<1	1.7	<1	110	1.8	<1	110	26	21	21	<1	1.1	75	6.1	6.9	12	1.1	<1	75
Nickel - Dissolved	µg/L	<1	<1	<1	0.0	<1	<1	0.0	13	13	0.0	<1	<1	0.0	<1	<1	0.0	<1	<1	0.0
Lead - Dissolved	µg/L	<1	2.1	1.8	15.4	1.4	<1	95	<1	<1	0.0	<1	<1	0.0	1.6	2.8	55	1.1	<1	38
Strontium - Dissolved	µg/L	<5	240	220	8.7	30	29	3.4	<5	<5	0.0	27	27	0.0	62	63	1.6	31	31	0.0
Zinc - Dissolved	µg/L	<5	24	14	53	40	13	100	450	450	0.0	<5	<5	0.0	<5	17	150	<5	<5	0.0
Silicon - Dissolved	mg/L	<0.05	1.3	1.3	0.0	2.7	2.9	7.1	5.6	10	56	3.1	2.8	10	6.4	6.0	6.5	4.5	4.3	4.5
TPH C6-C9	µg/L	<25	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0	<25	<25	0.0
TPH C10-14	µg/L	<50	<50	<50	0.0	<50	<50	0.0	<50	<50	0.0	<50	<50	0.0	<50	<50	0.0	<50	<50	0.0
TPH C15-28	µg/L	<100	<100	<100	0.0	220	120	59	110	130	17	<100	<100	0.0	<100	<100	0.0	<100	<100	0.0
TPH C29-36	µg/L	<100	<100	<100	0.0	<100	<100	0.0	<100	<100	0.0	<100	<100	0.0	<100	<100	0.0	<100	<100	0.0
Arsenic - Dissolved	µg/L	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	0.0
Selenium - Dissolved	µg/L	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.6	3.3	8.7
Magnesium - Dissolved	mg/L	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	6.8	1.5
Potassium - Dissolved	mg/L	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	3.5	0.0

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow.

Groundwater Sampling Replicate Samples RPD Continued

Sampling dates			23/09/2010			24/09/2010		
Sites			T3B			T7E		
Analytes	unit	LOR	Original	Replicate	RPD(%)	Original	Replicate	RPD(%)
pH	pH unit	<1	6.3	6.2	1.6	6.8	6.9	1.5
Carbonate	mg/L	<1	<1	<1	0.0	<1	<1	0.0
Bicarbonate	mg/L	-	29	30	3.4	380	370	2.7
Hardness	mg/L	-	48	47	2.1	430	440	2.3
Calcium - Total	mg/L	<0.1	6.2	5.9	5.0	100	100	0.0
Magnesium - Total	mg/L	<0.1	7.8	8.3	6.2	44	45	2.2
Sodium - Total	mg/L	<0.1	12	13	8.0	350	355	1.4
Potassium - Total	mg/L	<0.1	3.9	4.1	5.0	10	10	0.0
Turbidity	NTU	-	140	310	76	16	20	22
Total Dissolved Salts	mg/L	-	92	95	3.2	1410	1440	2.1
Chloride	mg/L	<1	26	26	0.0	575	580	0.9
Sulphate	mg/L	<2	19	17	11	89	95	6.5
Orthophosphate as P	mg/L	<0.01	<0.01	<0.01	0.0	0.17	0.15	13
Phosphorus - Total	mg/L	<0.04	<0.02	<0.02	0.0	0.19	0.18	5.4
Total Nitrogen	mg/L	<0.1	0.8	0.4	67	16	17	6.1
Total Kjeldahl Nitrogen	mg/L	<0.1	0.8	0.4	67	16	17	6.1
Nitrate as N	mg/L	<0.01	<0.01	<0.01	0.0	<0.01	<0.01	0.0
Nitrite as N	mg/L	<0.01	0.01	0.01	0.0	<0.01	<0.01	0.0
Total Ammonia as N	mg/L	<0.1	<0.1	<0.1	0.0	16	17	6.1
Aluminium - Dissolved	µg/L	<5	300	410	31	6.9	7.5	8.3
Barium - Dissolved	µg/L	<1	62	62	0.0	380	380	0.0
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2	0.0	<0.2	<0.2	0.0
Chromium - Dissolved	µg/L	<1	0	1.1	75	0	0	0.0
Copper - Dissolved	µg/L	<1	<1	<1	0.0	<1	<1	0.0

Sampling dates			23/09/2010			24/09/2010		
Sites			T3B			T7E		
Iron - Dissolved	µg/L	<5	680	710	4.3	<5	<5	0.0
Manganese - Dissolved	µg/L	<1	3.8	3.8	0.0	13	13	0.0
Nickel - Dissolved	µg/L	<1	<1	<1	0.0	<1	<1	0.0
Lead - Dissolved	µg/L	<1	<1	<1	0.0	<1	<1	0.0
Strontium - Dissolved	µg/L	<5	32	32	0.0	450	450	0.0
Zinc - Dissolved	µg/L	<5	18	20	11	15	9.9	41
Silicon - Dissolved	mg/L	<0.05	2.9	2.9	0.0	17	18	5.7
TPH C6-C9	µg/L	<25	<25	<25	0.0	<25	<25	0.0
TPH C10-14	µg/L	<50	<50	<50	0.0	<50	<50	0.0
TPH C15-28	µg/L	<100	<100	<100	0.0	140	140	0.0
TPH C29-36	µg/L	<100	<100	<100	0.0	<100	<100	0.0
Arsenic - Dissolved	µg/L	<1	1.1	1	9.5	2.7	2.7	0.0
Selenium - Dissolved	µg/L	<1	<1	<1	0.0	<1	<1	0.0
Magnesium - Dissolved	mg/L	<0.1	7.8	8	2.5	43	44	2.3
Potassium - Dissolved	mg/L	<0.1	3.9	4.1	5.0	9.8	9.6	2.1

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow.

Groundwater Sampling Rinsate S Results

Analytes	Units	LOR	May-10	
			Rinsate	Rinsate II
Aluminium - Dissolved	µg/L	<5	<5	17
Barium - Dissolved	µg/L	<1	<1	<1
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2
Chromium - Dissolved	µg/L	<1	<1	<1
Copper - Dissolved	µg/L	<1	3.1	3.3
Iron - Dissolved	µg/L	<5	<5	5.4
Manganese - Dissolved	µg/L	<1	<1	<1
Nickel - Dissolved	µg/L	<1	<1	<1
Lead - Disssolved	µg/L	<1	<1	<1
Strontium - Dissolved	µg/L	<5	<5	<5
Zinc - Dissolved	µg/L	<5	<5	8.7
Silicon - Dissolved	mg/L	<0.05	0.21	0.22

Analytes	Units	LOR	Jun-10		Jul-10	Aug-10	Sep-10	
			Rinsate	Rinsate II	Rinsate	Rinsate	Rinsate	Rinsate II
Aluminium - Total	µg/L	<5	22	<5	<5	<5	<5	8.9
Barium - Total	µg/L	<1	<1	<1	<1	<1	<1	<1
Cadmium - Total	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium - Total	µg/L	<1	<1	<1	<1	<1	<1	<1
Copper - Total	µg/L	<1	5.3	3.1	3.9	7.2	5.1	5
Iron - Total	µg/L	<5	12	<5	<5	<5	<5	8.1
Manganese - Total	µg/L	<1	<1	<1	<1	<1	<1	<1
Nickel - Total	µg/L	<1	1.8	<1	<1	<1	<1	<1
Lead - Total	µg/L	<1	<1	<1	<1	<1	<1	<1
Strontium - Total	µg/L	<5	<5	<5	<5	<5	<5	<5
Zinc - Total	µg/L	<5	19	11	13	28	20	20
Silicon - Total	mg/L	<0.05	1.9	0.93	0.58	0.94	0.58	0.56
Arsenic- total	µg/L	<1	-	-	-	<1	<1	<1
Selenium - total	µg/L	<1	-	-	-	<1	<1	<1

Sediment Sampling Replicate Samples

Sampling Date			28/05/2010		
Sampling site			NL1		
Analytes	**Unit**	**LOR**	**Original**	**Replicate**	**RPD(%)**
Aluminium	mg/kg	<5	7400	5900	22.56
Arsenic	mg/kg	<0.4	7.3	6	19.55
Cadmium	mg/kg	<0.1	0.12	0.11	8.70
Chromium	mg/kg	<0.1	19	16	17.14
Copper	mg/kg	<0.1	5.2	6.3	19.13
Iron	mg/kg	<5	5200	4200	21.28
Manganese	mg/kg	<0.5	27	21	25.00
Nickel	mg/kg	<0.1	3.8	3.4	11.11
Lead	mg/kg	<0.5	41	63	42.31
Selenium	mg/kg	<0.5	2.6	2.1	21.28
Zinc	mg/kg	<0.5	34	30	12.50
Benzene	mg/kg	<0.2	0	0	0.00
Toluene	mg/kg	<0.2	0	0	0.00
Ethyl Benzene	mg/kg	<0.2	0	0	0.00
m+p xylenes	mg/kg	<0.4	0	0	0.00
o-xylene	mg/kg	<0.2	0	0	0.00
Total BTEX	mg/kg	<1.2	0	0	0.00
TPH C6-C9	mg/kg	<10	0	0	0.00
TPH C10-14	mg/kg	<10	14	28	66.67
TPH C15-28	mg/kg	<50	240	340	34.48
TPH C29-36	mg/kg	<50	510	640	22.61
Naphthalene	µg/kg	<5	0	0	0.00
1-Methylnaphthalene	µg/kg	<5	0	0	0.00
2-Methylnaphthalene	µg/kg	<5	0	0	0.00
Acenaphthylene	µg/kg	<5	0	0	0.00
Acenaphthene	µg/kg	<5	0	0	0.00
Fluorene	µg/kg	<5	0	0	0.00
Phenanthrene	µg/kg	<5	0	0	0.00
Anthracene	µg/kg	<5	0	0	0.00
Fluoranthene	µg/kg	<5	0	0	0.00
Pyrene	µg/kg	<5	0	0	0.00
Benz(a)anthracene	µg/kg	<5	0	0	0.00
Chrysene	µg/kg	<5	0	0	0.00
Benzo(b)&(k)fluoranthene	µg/kg	<10	0	0	0.00
Benzo(a)pyrene	µg/kg	<5	0	0	0.00
Indeno(1,2,3-cd)pyrene	µg/kg	<5	0	0	0.00
Dibenz(a,h)anthracene	µg/kg	<5	0	0	0.00
Benzo(g,h,i)perylene	µg/kg	<5	0	0	0.00
Coronene	µg/kg	<10	0	0	0.00
Benzo(e)pyrene	µg/kg	<5	0	0	0.00
Perylene	µg/kg	<5	0	0	0.00

Sampling Date			28/05/2010		
Sampling site			NL1		
Total PAHs (as above)	µg/kg	<100	0	0	0.00
Total Organic Carbon	%	<0.01	41	40	2.47
ORP (Redox Potential)	mV		360	370	2.74

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow.

Sediment Sampling Replicate Samples Continued

Sampling Date			24/08/2010		
Sampling Site			NL4		
Analytes	**Units**	**LOR**	**Original**	**Replicate**	**RPD(%)**
Aluminium	mg/kg	<5	7700	8700	12.2
Arsenic	mg/kg	<0.4	11	3	114.3
Cadmium	mg/kg	<0.1	0.43	<0.1	158.3
Chromium	mg/kg	<0.1	13	8.2	45.3
Copper	mg/kg	<0.1	23	3.3	149.8
Iron	mg/kg	<5	6100	740	156.7
Manganese	mg/kg	<0.5	21	3.1	148.5
Nickel	mg/kg	<0.1	6.1	1.9	105.0
Lead	mg/kg	<0.5	71	28	86.9
Selenium	mg/kg	<0.5	2.2	1.2	58.8
Zinc	mg/kg	<0.5	120	12	163.6
Benzene	mg/kg	<0.2	<0.2	<0.2	0.0
Toluene	mg/kg	<0.2	<0.2	<0.2	0.0
Ethyl Benzene	mg/kg	<0.2	<0.2	<0.2	0.0
m+p xylenes	mg/kg	<0.4	<0.4	<0.4	0.0
o-xylene	mg/kg	<0.2	<0.2	<0.2	0.0
Total BTEX	mg/kg	<1.2	<1.2	<1.2	0.0
TPH C6-C9	mg/kg	<10	<10	<10	0.0
TPH C10-14	mg/kg	<10	<10	<10	0.0
TPH C15-28	mg/kg	<50	140	<50	94.7
TPH C29-36	mg/kg	<50	290	58	133.3
Naphthalene	µg/kg	<5	<5	<5	0.0
1-Methylnaphthalene	µg/kg	<5	<5	<5	0.0
2-Methylnaphthalene	µg/kg	<5	<5	<5	0.0
Acenaphthylene	µg/kg	<5	<5	<5	0.0
Acenaphthene	µg/kg	<5	<5	<5	0.0
Fluorene	µg/kg	<5	<5	<5	0.0
Phenanthrene	µg/kg	<5	10	<5	120.0
Anthracene	µg/kg	<5	6	<5	82.4
Fluoranthene	µg/kg	<5	30	20	40.0

Sampling Date			24/08/2010		
Sampling Site			NL4		
Pyrene	µg/kg	<5	35	18	64.2
Benz(a)anthracene	µg/kg	<5	20	20	0.0
Chrysene	µg/kg	<5	30	20	40.0
Benzo(b)&(k)fluoranthene	µg/kg	<10	60	50	18.2
Benzo(a)pyrene	µg/kg	<5	28	26	7.4
Indeno(1,2,3-cd)pyrene	µg/kg	<5	20	20	0.0
Dibenz(a,h)anthracene	µg/kg	<5	<5	7	94.7
Benzo(g,h,i)perylene	µg/kg	<5	30	20	40.0
Coronene	µg/kg	<10	<10	<10	0.0
Benzo(e)pyrene	µg/kg	<5	22	19	14.6
Perylene	µg/kg	<5	8	7	13.3
Total PAHs (as above)	µg/kg	<100	310	220	34.0
Aldrin	µg/kg	<1	<1	<1	0.0
alpha-BHC	µg/kg	<1	<1	<1	0.0
beta-BHC	µg/kg	<1	<1	<1	0.0
gamma-BHC (Lindane)	µg/kg	<1	<1	<1	0.0
delta-BHC	µg/kg	<1	<1	<1	0.0
cis-Chlordane	µg/kg	<1	<1	<1	0.0
trans-Chlordane	µg/kg	<1	<1	<1	0.0
p,p'-DDD	µg/kg	<1	<1	<1	0.0
p,p'-DDE	µg/kg	<1	2	<1	120.0
p,p'-DDT	µg/kg	<1	<1	<1	0.0
Dieldrin	µg/kg	<1	<1	<1	0.0
alpha-Endosulfan	µg/kg	<1	<1	<1	0.0
beta-Endosulfan	µg/kg	<1	<1	<1	0.0
Endosulfan Sulphate	µg/kg	<1	<1	<1	0.0
Endrin	µg/kg	<1	<1	<1	0.0
Endrin ketone	µg/kg	<1	<1	<1	0.0
Endrin aldehyde	µg/kg	<1	<1	<1	0.0
Heptachlor	µg/kg	<1	<1	<1	0.0
Heptachlor epoxide	µg/kg	<1	<1	<1	0.0
Hexachlorobenzene	µg/kg	<1	<1	<1	0.0
Methoxychlor	µg/kg	<1	<1	<1	0.0
Oxychlordane	µg/kg	<1	<1	<1	0.0
Dichlorvos	µg/kg	<20	<20	<20	0.0
Demeton-S-methyl	µg/kg	<20	<20	<20	0.0
Dimethoate	µg/kg	<20	<20	<20	0.0
Diazinon	µg/kg	<20	<20	<20	0.0
Chlorpyrifos-methyl	µg/kg	<20	<20	<20	0.0
Parathion-methyl	µg/kg	<20	<20	<20	0.0
Pirimiphos-methyl	µg/kg	<20	<20	<20	0.0
Fenitrothion	µg/kg	<20	<20	<20	0.0
Malathion	µg/kg	<20	<20	<20	0.0

Sampling Date			24/08/2010		
Sampling Site			NL4		
Chlorpyrifos	µg/kg	<20	<20	<20	0.0
Fenthion	µg/kg	<20	<20	<20	0.0
Parathion	µg/kg	<20	<20	<20	0.0
Chlorfenvinphos	µg/kg	<20	<20	<20	0.0
Bromophos-ethyl	µg/kg	<20	<20	<20	0.0
Methidathion	µg/kg	<20	<20	<20	0.0
Fenamiphos	µg/kg	<20	<20	<20	0.0
Prothiofos	µg/kg	<20	<20	<20	0.0
Ethion	µg/kg	<20	<20	<20	0.0
Carbophenothion	µg/kg	<20	<20	<20	0.0
Phosalone	µg/kg	<20	<20	<20	0.0
Azinphos-methyl	µg/kg	<20	<20	<20	0.0
Total Organic Carbon	%	<0.01	19.5	22.2	12.9
*ORP (Redox Potential)	mV		320	320	0.0
Total Nitrogen	mg/kg	<20	15600	16600	6.2
Total Kjeldahl Nitrogen	mg/kg	<20	15600	16600	6.2
NOx as N	mg/kg	<0.1	6	8.6	35.6
Total Ammonia as N	mg/kg	<0.1	1.8	1.6	11.8
Phosphate as P	mg/kg	<0.1	1	1.5	40.0
Phosphorus	mg/kg	<1	2000	870	78.7

RPD = Relative Percent Difference
Pass <=30 percent
Pass-1 >30 percent, Analysis Result <10 times LOR
Pass-2 <=50 percent, Analysis Result >10 and <20 times LOR
LOR denotes less than laboratory limit of reporting
Where less than values are reported (<), half of the reported LOR value has been used to calculate the RPD
RPD that is not within the pass criteria are highlighted in yellow.

Sediment Sampling Rinsate Results

28/05/2010			
Analytes	Unit	LOR	Rinsate
Aluminium - Total	µg/L	<5	50
Arsenic - Total	µg/L	<1	<1
Cadmium - Total	µg/L	<0.2	<0.2
Chromium - Total	µg/L	<1	<1
Copper - Total	µg/L	<1	1.6
Iron - Total	µg/L	<5	65
Manganese - Total	µg/L	<1	1.1
Nickel - Total	µg/L	<1	<1
Lead - Total	µg/L	<1	<1
Selenium - Total	µg/L	<1	<1
Zinc - Total	µg/L	<5	12

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Appendix D

Bibra Lake and North Lake Persistent Organic Contaminants Summary Results

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Appendix D Bibra Lake and North Lake Persistent Organic Contaminants Summary Results

Bibra Lake Persistent Organic Contaminant Summary Results

	Units	LOR	Guideline Level	November 2009				February 2010		August 2010			
				Bibra North	Bibra North West	Bibra West	Bibra South	Bibra North West	Bibra West	Bibra North	Bibra North West	Bibra West	Bibra South
BTEX													
Benzene	µg/L	<1	950	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethyl Benzene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
m+p xylenes	µg/L	<4	-	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
o-xylene	µg/L	<2	350	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total BTEX	µg/L	<11	-	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11
PAH													
Naphthalene	µg/L	<1	16	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthylene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Phenanthrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benz(a)anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benzo(b)&(k)fluoranthene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Indeno(,,-cd)pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibenz(a,h)anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

	Units	LOR	Guideline Level	November 2009				February 2010		August 2010			
				Bibra North	Bibra North West	Bibra West	Bibra South	Bibra North West	Bibra West	Bibra North	Bibra North West	Bibra West	Bibra South
Organochlorine Pesticides													
Aldrin	µg/L	<0.03	1**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
alpha-BHC	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
beta-BHC	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
gamma-BHC (Lindane)	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
delta-BHC	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
cis-Chlordane	µg/L	<0.03	0.08*	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
trans-Chlordane	µg/L	<0.03	0.08*	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
p,p'-DDD	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
p,p'-DDE	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
p,p'-DDT	µg/L	<0.03	0.01	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Dieldrin	µg/L	<0.03	1**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
alpha-Endosulfan	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
beta-Endosulfan	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Endosulfan Sulphate	µg/L	<0.03	0.2	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Endrin	µg/L	<0.03	0.02	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Endrin ketone	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Endrin aldehyde	µg/L	<0.1	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Heptachlor	µg/L	<0.03	0.09	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Heptachlor epoxide	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Hexachlorobenzene	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Methoxychlor	µg/L	<0.1	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Mirex	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Organophosphate Pesticides**													
Azinphos-methyl	µg/L	<0.5	0.02	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Bromophos-ethyl	µg/L	<0.03	20**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Carbophenothion	µg/L	<0.03	1**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03

	Units	LOR	Guideline Level	November 2009				February 2010		August 2010			
				Bibra North	Bibra North West	Bibra West	Bibra South	Bibra North West	Bibra West	Bibra North	Bibra North West	Bibra West	Bibra South
Chlorfenvinphos	µg/L	<0.03	10**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Chlorpyrifos	µg/L	<0.015	0.01	-	-	-	-	<0.015	-	<0.015	<0.015	<0.015	<0.015
Chlorpyrifos-methyl	µg/L	<0.015	-	-	-	-	-	<0.015	-	<0.015	<0.015	<0.015	<0.015
Diazinon	µg/L	<0.015	0.01	-	-	-	-	<0.015	-	<0.015	<0.015	<0.015	<0.015
Demeton-S-methyl	µg/L	<0.1	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Demeton-S	µg/L	<0.03	30**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Dimethoate	µg/L	<0.1	0.15	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Dichlorvos	µg/L	<2	20**	-	-	-	-	<2	-	<2	<2	<2	<2
Ethion	µg/L	<0.03	6**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Fenitrothion	µg/L	<0.1	0.2	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Fenthion	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Fenamiphos	µg/L	<0.1	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Malathion	µg/L	<0.1	0.05	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Methidathion	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Parathion	µg/L	<0.015	0.004	-	-	-	-	<0.015	-	<0.015	<0.015	<0.015	<0.015
Parathion-methyl	µg/L	<0.5	6**	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Phosalone	µg/L	<0.03	-	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Pirimiphos-methyl	µg/L	<0.03	60**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Profenofos	µg/L	<0.03	0.6**	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Prothiofos	µg/L	<0.1	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Trifluralin	µg/L	<0.03	4.4	-	-	-	-	<0.03	-	<0.03	<0.03	<0.03	<0.03
Semi-volatile Compound													
Dimethyl phthalate	µg/L	<2	3700	-	-	-	-	<2	-	<2	<2	<2	<2
Diethyl phthalate	µg/L	<2	1000	-	-	-	-	<2	-	<2	<2	<2	<2
Di-n-butyl phthalate	µg/L	<2	26	-	-	-	-	<2	-	<2	<2	<2	<2
Butyl benzyl phthalate	µg/L	<2	-	-	-	-	-	<2	-	<2	<2	<2	<2
Bis(-ethylhexyl) phthalate	µg/L	<4	-	-	-	-	-	<4	-	<4	<4	<4	<4

	Units	LOR	Guideline Level	November 2009				February 2010		August 2010			
				Bibra North	Bibra North West	Bibra West	Bibra South	Bibra North West	Bibra West	Bibra North	Bibra North West	Bibra West	Bibra South
Di-n-octyl phthalate	µg/L	<2	-	-	-	-	-	<2	-	<2	<2	<2	<2
Ultra-trace Residue													
Ametryn	µg/L	<0.5	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Asulam	µg/L	<1	100**	-	-	-	-	<1	-	<1	<1	<1	<1
Desethyl atrazine	µg/L	<1	-	-	-	-	-	<1	-	<1	<1	<1	<1
Desisopropyl atrazine	µg/L	<1	-	-	-	-	-	<1	-	<1	<1	<1	<1
Atrazine	µg/L	<0.5	13	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Bromacil	µg/L	<1	-	-	-	-	-	<1	-	<1	<1	<1	<1
Diuron	µg/L	<0.5	40**	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Fluazifop-p-butyl	µg/L	<0.5	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Fluometuron	µg/L	<0.5	100**	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Haloxyfop	µg/L	<1	-	-	-	-	-	<1	-	<1	<1	<1	<1
Hexazinone	µg/L	<0.5	600**	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Imazethapyr	µg/L	<1	-	-	-	-	-	<1	-	<1	<1	<1	<1
Imidacloprid	µg/L	<1	-	-	-	-	-	<1	-	<1	<1	<1	<1
Metribuzin	µg/L	<0.5	5**	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Prometryn	µg/L	<0.5	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Sethoxydim	µg/L	<0.5	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Simazine	µg/L	<0.5	3.2	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Tebuthiuron	µg/L	<0.5	2.2	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5
Terbutryn	µg/L	<0.5	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	<0.5

Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.

*Guideline values are adopted form DEC (2010) assessment levels for soil, sediment and water.

**Guideline levels are adopted from EPA 1993, guideline levels for Pesticides in Australian Water.

ANZECC/ARMCANZ (2000) Guideline values for Wetlands in South-West Australia.

“-“ indicates that the particular substance test was not conducted (a function of sampling plan and standing surface water availability).

North Lake Persistent Organic Contaminant Summary Results

Analytes	Unit	LOR	Guideline values	November 2009		August 2010
				North Lake Middle	North Lake West	North Lake West
BTEX						
Benzene	µg/L	<1	950	<1	<1	<1
Toluene	µg/L	<2	-	<2	<2	<2
Ethyl Benzene	µg/L	<2	-	<2	<2	<2
m+p xylenes	µg/L	<4	-	<4	<4	<4
o-xylene	µg/L	<2	350	<2	<2	<2
Total BTEX	µg/L	<11	-	<11	<11	<11
PAH						
Naphthalene	µg/L	<1	16	<1	<1	<1
Acenaphthylene	µg/L	<1	-	<1	<1	<1
Acenaphthene	µg/L	<1	-	<1	<1	<1
Fluorene	µg/L	<1	-	<1	<1	<1
Phenanthrene	µg/L	<1	-	<1	<1	<1
Anthracene	µg/L	<1	-	<1	<1	<1
Fluoranthene	µg/L	<1	-	<1	<1	<1
Pyrene	µg/L	<1	-	<1	<1	<1
Benz(a)anthracene	µg/L	<1	-	<1	<1	<1
Chrysene	µg/L	<1	-	<1	<1	<1
Benzo(b)&(k)fluoranthene	µg/L	<2	-	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	-	<1	<1	<1
Indeno(,,-cd)pyrene	µg/L	<1	-	<1	<1	<1
Dibenz(a,h)anthracene	µg/L	<1	-	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	-	<1	<1	<1
Organochlorine Pesticides						
Aldrin	µg/L	<0.03	1**	-	-	<0.03
alpha-BHC	µg/L	<0.03	-	-	-	<0.03
beta-BHC	µg/L	<0.03	-	-	-	<0.03
gamma-BHC (Lindane)	µg/L	<0.03	-	-	-	<0.03
delta-BHC	µg/L	<0.03	-	-	-	<0.03
cis-Chlordane	µg/L	<0.03	0.08*	-	-	<0.03
trans-Chlordane	µg/L	<0.03	0.08*	-	-	<0.03
p,p'-DDD	µg/L	<0.03	-	-	-	<0.03
p,p'-DDE	µg/L	<0.03	-	-	-	<0.03
p,p'-DDT	µg/L	<0.03	0.01	-	-	<0.03
Dieldrin	µg/L	<0.03	1**	-	-	<0.03
alpha-Endosulfan	µg/L	<0.03	-	-	-	<0.03
beta-Endosulfan	µg/L	<0.03	-	-	-	<0.03

Analytes	Unit	LOR	Guideline values	November 2009		August 2010
				North Lake Middle	North Lake West	North Lake West
Endosulfan Sulphate	µg/L	<0.03	0.2	-	-	<0.03
Endrin	µg/L	<0.03	0.02	-	-	<0.03
Endrin ketone	µg/L	<0.03	-	-	-	<0.03
Endrin aldehyde	µg/L	<0.1	-	-	-	<0.1
Heptachlor	µg/L	<0.03	0.09	-	-	<0.03
Heptachlor epoxide	µg/L	<0.03	-	-	-	<0.03
Hexachlorobenzene	µg/L	<0.03	-	-	-	<0.03
Methoxychlor	µg/L	<0.1	-	-	-	<0.1
Mirex	µg/L	<0.03	-	-	-	<0.03
Organophosphate Pesticides**						
Azinphos-methyl	µg/L	<0.5	0.02	-	-	<0.5
Bromophos-ethyl	µg/L	<0.03	20**	-	-	<0.03
Carbophenothion	µg/L	<0.03	1**	-	-	<0.03
Chlorfenvinphos	µg/L	<0.03	10**	-	-	<0.03
Chlorpyrifos	µg/L	<0.015	0.01	-	-	<0.015
Chlorpyrifos-methyl	µg/L	<0.015	-	-	-	<0.015
Diazinon	µg/L	<0.015	0.01	-	-	<0.015
Demeton-S-methyl	µg/L	<0.1	-	-	-	<0.1
Demeton-S	µg/L	<0.03	30**	-	-	<0.03
Dimethoate	µg/L	<0.1	0.15	-	-	<0.1
Dichlorvos	µg/L	<2	20**	-	-	<2
Ethion	µg/L	<0.03	6**	-	-	<0.03
Fenitrothion	µg/L	<0.1	0.2	-	-	<0.1
Fenthion	µg/L	<0.03	-	-	-	<0.03
Fenamiphos	µg/L	<0.1	-	-	-	<0.1
Malathion	µg/L	<0.1	0.05	-	-	<0.1
Methidathion	µg/L	<0.03	-	-	-	<0.03
Parathion	µg/L	<0.015	0.004	-	-	<0.015
Parathion-methyl	µg/L	<0.5	6**	-	-	<0.5
Phosalone	µg/L	<0.03	-	-	-	<0.03
Pirimiphos-methyl	µg/L	<0.03	60**	-	-	<0.03
Profenofos	µg/L	<0.03	0.6**	-	-	<0.03
Prothiofos	µg/L	<0.1	-	-	-	<0.1
Trifluralin	µg/L	<0.03	4.4	-	-	<0.03

Analytes	Unit	LOR	Guideline values	November 2009		August 2010
				North Lake Middle	North Lake West	North Lake West
Semi-volatile Compound						
Dimethyl phthalate	µg/L	<2	3700	-	-	<2
Diethyl phthalate	µg/L	<2	1000	-	-	<2
Di-n-butyl phthalate	µg/L	<2	26	-	-	<2
Butyl benzyl phthalate	µg/L	<2	-	-	-	<2
Bis(-ethylhexyl) phthalate	µg/L	<4	-	-	-	<4
Di-n-octyl phthalate	µg/L	<2	-	-	-	<2
Ultra-trace Residue						
Ametryn	µg/L	<0.5	-	-	-	<0.5
Asulam	µg/L	<1	100**	-	-	<1
Desethyl atrazine	µg/L	<1	-	-	-	<1
Desisopropyl atrazine	µg/L	<1	-	-	-	<1
Atrazine	µg/L	<0.5	13	-	-	<0.5
Bromacil	µg/L	<1	-	-	-	<1
Diuron	µg/L	<0.5	40**	-	-	<0.5
Fluazifop-p-butyl	µg/L	<0.5	-	-	-	<0.5
Fluometuron	µg/L	<0.5	100**	-	-	<0.5
Haloxyfop	µg/L	<1	-	-	-	<1
Hexazinone	µg/L	<0.5	600**	-	-	<0.5
Imazethapyr	µg/L	<1	-	-	-	<1
Imidacloprid	µg/L	<1	-	-	-	<1
Metribuzin	µg/L	<0.5	5**	-	-	<0.5
Prometryn	µg/L	<0.5	-	-	-	<0.5
Sethoxydim	µg/L	<0.5	-	-	-	<0.5
Simazine	µg/L	<0.5	3.2	-	-	<0.5
Tebuthiuron	µg/L	<0.5	2.2	-	-	<0.5
Terbutryn	µg/L	<0.5	-	-	-	<0.5

Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.
*Guideline values are adopted form DEC (2010) assessment levels for soil, sediment and water.
**Guideline levels are adopted from EPA 1993, guideline levels for Pesticides in Australian Water.
ANZECC/ARMCANZ (2000) Guideline values for Wetlands in South-West Australia.
“-“ indicates that the particular substance test was not conducted (a function of sampling plan and standing surface water availability).

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Appendix E

Stormwater Quality Sampling Results

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Appendix E Stormwater Quality Sampling Results

Stormwater Quality Sampling Results Table

Analytes	Unit	LOR	*Guideline values	Sites																				
				Farrington West (Site 1)	Farrington East (Site 4)			Lower Hope Road (Site 6)		Upper Bibra West (Site 7)								Middle Bibra West (Site 8)				Lower Bibra West (Site 9)		
Sampling round				**3**	**1**	**6**	**7**	**6**	**7**	**1**	**2**	**3**	**4**	**5******	**5**	**6**	**7**	**3**	**4**	**5**	**7**	**4**	**5**	**7**
Aluminium	µg/L	<5	55	650	710	940	1100	180	96	180	590	160	51	210	98	2	160	160	680	290	310	310	160	75
Arsenic	µg/L	<1	24 as As (III) or 13 as As (V)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	µg/L	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	µg/L	<1	1 as Cr (VI)	2.4	3.5	5.8	4.9	1.3	<1	2	3.3	1.2	<1	2.3	<1	5.3	<1	<1	6	4.1	8.1	1.3	<1	<1
Copper	µg/L	<1	1.4	11	29	27	39	7.4	4.9	9.7	34	4.7	1.8	16	2.2	25	3.3	2.3	23	15	16	6	2.3	1.6
Iron	µg/L	<5	300	640	840	960	1000	170	110	180	610	150	50	200	80	930	120	130	700	400	330	340	160	67
Lead	µg/L	<1	3.4	19	17	15	21	11	6.6	7.4	16	5.7	<1	5.4	1.3	13	1.6	2	11	6.4	5.6	5.7	1.4	<1
Zinc	µg/L	<5	8	69	120	150	150	38	36	70	180	57	40	58	30	79	51	59	93	74	64	38	26	20
Total Phosphorus	mg/L	<0.02	0.06#	0.16	0.17	0.07	0.07	0.04	0.04	0.14	0.84	0.07	0.04	0.21	0.06	0.39	0.05	0.096	0.09	0.05	0.05	0.06	0.03	0.03
Total Nitrogen	mg/L	<0.1	1.5#	1.1	1.2	0.6	1.1	0.2	0.7	0.4	5.4	0.8	<0.1	1.5	<0.1	3.8	0.3	6.5	0.8	0.3	0.8	0.6	<0.1	<0.1
Kjeldahl Nitrogen	mg/L	<0.1	-	0.9	1	0.5	0.9	0.2	0.5	0.4	5.4	0.4	<0.1	1.2	<0.1	3	0.3	0.9	0.6	0.2	0.7	0.5	<0.1	<0.1
Nox as N	mg/L	<0.01	0.1#	0.07	0.19	0.11	0.21	0.04	0.17	<0.01	0.01	0.37	<0.01	0.32	0.02	0.76	0.03	5.6	0.16	0.07	0.12	0.03	0.02	<0.01
Benzene	µg/L	<1	950	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	17	<2	<2	<2	<2
Ethyl Benzene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	3	<2	<2	<2	<2
m+p xylenes	µg/L	<4	-	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	12	<4	<4	<4	<4
o-xylene	µg/L	<2	350	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	6	<2	<2	<2	<2
BTEX	µg/L	<11	-	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	38	<11	<11	<11	<11
TPH C6-C9	µg/L	<25	-	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	54	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	-	<50	100	<50	<50	<50	<50	93	330	<50	<50	110	<50	130	<50	<50	<50	<50	<50	<50	<50	<50
TPH C15-C28	µg/L	<100	-	130	710	560	410	130	<100	580	1700	100	<100	810	<100	1100	<100	180	680	630	340	240	<100	<100
TPH C29-C36	µg/L	<100	-	110	390	660	320	160	<100	290	760	<100	<100	400	<100	590	<100	<100	590	530	270	230	<100	<100
Naphthalene	µg/L	<1	16	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthylene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Phenanthrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benz(a)anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benzo(b)&(k)fluoranthene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Indeno(1,2,3-cd)pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibenz(a,h)anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Analytes	Unit	LOR	*Guideline values	Sites: Farrington West (Site 1)	Farrington East (Site 4)			Lower Hope Road (Site 6)		Upper Bibra West (Site 7)								Middle Bibra West (Site 8)				Lower Bibra West (Site 9)		
Benzo(g,h,i)perylene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Suspended Solids	mg/L	<2	-	28	16	28	20	5	2	7	26	5	<2	4	4	22	3	11	12	14	3	13	4	<2

*Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.

** Sampling Round 5 on 14/06/2010, Sample was retrieved only from drain at Site 7.

ANZECC/ARMCANZ (2000) Guideline values for Wetlands in South-West Australia.

Concentration exceeding guideline values is highlighted in yellow.

Stormwater Quality Sampling Results Table Continued

Analytes	Unit	LOR	*Guideline values	Sites: Bibra South (Site 10)							Bibra South-East 1 (site 11)					Bibra South-East 2 (Site 12)					Bibra South-East 3 (Site 13)				
Sampling round				**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**4**	**5**	**6**	**7**	**1**	**4**	**5**	**6**	**7**	**1**	**4**	**5**	**6**	**7**
Aluminium	µg/L	<5	55	140	550	120	220	120	3.5	200	220	270	120	1.2	110	260	160	74	500	88	160	170	130	350	150
Arsenic	µg/L	<1	24 as As (III) or 13 as As (V)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	µg/L	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	µg/L	<1	1 as Cr (VI)	<1	2.4	<1	1.2	<1	6.7	4.8	<1	1.1	<1	2.3	<1	<1	<1	<1	1.2	<1	<1	<1	<1	1.4	<1
Copper	µg/L	<1	1.4	3.5	15	2.3	9.8	2.8	24	6.6	5.1	9.9	5.7	9.9	6.6	3.3	1.7	1.1	3.8	1.4	3.1	2.4	2.2	3.3	2.7
Iron	µg/L	<5	300	140	790	100	240	130	3.7	310	220	280	130	1.5	120	250	150	56	570	85	150	180	140	370	150
Lead	µg/L	<1	3.4	3.2	8.3	2.2	9.6	2	21	4.7	3.3	7.6	2.8	11	3.5	2.9	1.1	<1	4.4	<1	2.9	2.1	2.2	3.6	1.9
Zinc	µg/L	<5	8	62	79	32	61	57	180	42	47	58	48	82	31	41	34	49	71	21	48	29	27	32	41
Total Phosphorus	mg/L	<0.02	0.06#	0.12	0.36	0.12	0.07	0.05	0.44	0.05	0.12	0.08	0.05	0.18	0.03	0.1	0.05	0.04	0.11	0.04	0.14	0.08	0.07	0.15	0.094
Total Nitrogen	mg/L	<0.1	1.5#	0.3	2.9	2.8	0.4	<0.1	1.8	0.2	0.4	0.7	<0.1	<0.1	0.3	0.4	0.2	0.2	0.3	0.1	1.3	0.4	0.4	1.4	2.8
Kjeldahl Nitrogen	mg/L	<0.1	-	0.3	2.5	1	0.3	<0.1	1.8	0.1	0.3	0.6	<0.1	<0.1	0.3	0.4	0.1	0.1	0.2	<0.1	1.3	0.4	0.4	1.3	2.7
Nox as N	mg/L	<0.01	0.1#	<0.01	0.41	1.8	0.08	0.05	<0.01	0.06	0.09	0.08	0.06	0.06	0.07	<0.01	0.06	0.05	0.09	0.05	<0.01	<0.01	0.01	0.11	0.05
Benzene	µg/L	<1	950	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	<2	-	<2	<2	2.3	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethyl Benzene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
m+p xylenes	µg/L	<4	-	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
o-xylene	µg/L	<2	350	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
BTEX	µg/L	<11	-	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11
TPH C6-C9	µg/L	<25	-	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	-	62	120	<50	<50	<50	110	<50	61	<50	<50	<50	<50	71	<50	<50	<50	<50	75	<50	<50	<50	<50
TPH C15-C28	µg/L	<100	-	360	1100	340	230	<100	780	110	160	290	110	110	160	230	170	<100	120	<100	340	200	150	210	160
TPH C29-C36	µg/L	<100	-	130	390	100	230	<100	980	<100	<100	300	110	170	140	<100	140	<100	140	<100	<100	120	170	160	140
Naphthalene	µg/L	<1	16	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthylene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Phenanthrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benz(a)anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Analytes	Unit	LOR	*Guideline values	Sites																					
				Bibra South (Site 10)							Bibra South-East 1 (site 11)					Bibra South-East 2 (Site 12)					Bibra South-East 3 (Site 13)				
Chrysene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benzo(b)&(k)fluoranthene	µg/L	<2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Indeno(1,2,3-cd)pyrene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibenz(a,h)anthracene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Suspended Solids	mg/L	<2	-	2	19	2	8	3	150	5	9	12	3	67	2	10	2	<2	25	3	5	3	31	32	34

*Guideline values are adopted from ANZECC/ARMCANZ (2000) freshwater 95 percent species protection level.

[#] ANZECC/ARMCANZ (2000) Guideline values for Wetlands in South-West Australia.

Concentration exceeding guideline values is highlighted in yellow.

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Appendix F

Groundwater Quality Sampling Results

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Appendix F Groundwater Quality Sampling Results

Groundwater Results Summary Table

Analytes	Units	LOR	T1A					T1C		T2F					T2I
			May-10	Jun-10	Jul-10	Aug-10	Sep-10	May-10	Jun-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	May-10
pH	pH unit	<1	6.5	6.8	6.8	6.7	6.9	5.2	5.7	6.5	6.5	6.8	6.4	6.4	7.2
Carbonate Alkalinity as CaCO	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	<1	130	140	120	170	140	9	18	54	58	62	110	70	240
Hardness	mg/L	<1	170	160	170	200	210	61	62	115	110	110	120	110	260
Calcium	mg/L	<0.1	46	47	45	55	58	8	6.6	28	25	28	30	27	70
Magnesium	mg/L	<0.1	13	11	14	15	16	10	11	11	11	10	11	10	21
Sodium	mg/L	<0.1	17	17	18	27	37	86	93	55	65	67	68	63	66
Potassium	mg/L	<0.1	3.3	2.7	2.8	3.1	2.9	4.3	3.6	3.8	3.2	3.3	3.5	2.9	7.4
Turbidity	NTU	<0.1	300	6.3	0.8	0.1	<0.1	31000	2000	150	8.4	6.7	1.8	1.6	1000
Total Dissolved Salts	mg/L	-	235	220	230	305	340	3	315	270	300	300	310	305	435
Chloride	mg/L	<1	43	38	49	52	77	150	160	110	120	130	110	120	105
Sulphate	mg/L	<2	38	30	39	56	65	27	27	31	34	28	28	28	59
Ortho P	mg/L	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	0.01	0.13	0.02	<0.01	0.01	0.01	0.01	0.04
Phosphorus - Total	mg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.91	0.13	<0.04	0.02	0.03	0.03	<0.04	0.34
Total Nitrogen	mg/L	<0.1	0.7	<0.1	0.4	<0.1	0.2	10	0.4	0.9	0.5	0.7	0.2	0.3	1.9
Total Kjeldahl Nitrogen	mg/L	<0.1	0.6	<0.1	0.4	<0.1	0.2	10	0.4	0.9	0.5	0.7	0.2	0.3	1.9
Nox as N	mg/L	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	0.01	0.04	0.04	<0.01	<0.01	<0.01	<0.01	0.03
Nitrate as N	mg/L	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.04	0.02	<0.01	<0.01	<0.01	<0.01	0.02
Nitrite as N	mg/L	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.01
Total Ammonia as N	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.3	0.3	0.3	0.2	0.3	0.4
Aluminium - Dissolved	µg/L	<5	140	45	35	42	25	530	3900	99	34	38	40	28	70
Arsenic - Dissolved	µg/L	<1	-	-	-	2.6	2.1	-	-	-	-	-	38	25	-
Barium - Dissolved	µg/L	<1	25	26	28	29	36	49	44	71	71	69	68	69	120
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	8	13	1.1	<1	<1	<1	<1	<1
Copper - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron - Dissolved	µg/L	<5	1700	1700	1700	1600	1700	950	4600	910	800	700	620	520	19
Manganese - Dissolved	µg/L	<1	1.7	<1	<1	<1	1.2	9.5	11	37	33	35	33	31	19
Nickel - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	3.9	2.1	1.4	<1	<1	<1	<1	2.1
Lead - Disssolved	µg/L	<1	2.1	1	<1	1.1	1.7	2	1.4	<1	<1	<1	<1	<1	<1
Selenium - Dissolved	µg/L	<1	-	-	-	<1	<1	-	-	-	-	-	<1	<1	-
Strontium - Dissolved	µg/L	<5	240	250	260	280	290	19	23	83	79	82	82	84	230
Zinc - Dissolved	µg/L	<5	24	17	9.2	15	8.3	<5	39	26	17	11	11	18	53
Silicon - Dissolved	mg/L	<0.05	1.3	1.5	1.5	1.2	1.2	5.9	5.9	6.2	6.5	6.7	6.4	6.9	3.3
TPH C6-C9	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	<50	<50	<50	<50	<50	680	130	<50	<50	<50	<50	<50	<50
TPH C15-C28	µg/L	<100	<100	<100	<100	<100	<100	1200	<100	<100	<100	<100	<100	<100	<100
TPH C29-C36	µg/L	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Aldrin	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-

Analytes	Units	LOR	T1A					T1C		T2F					T2I
			May-10	Jun-10	Jul-10	Aug-10	Sep-10	May-10	Jun-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	May-10
alpha-BHC	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
beta-BHC	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
gamma-BHC (Lindane)	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
delta-BHC	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
cis-Chlordane	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
trans-Chlordane	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
p,p'-DDD	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
p,p'-DDE	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
p,p'-DDT	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Dieldrin	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
alpha-Endosulfan	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
beta-Endosulfan	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Endosulfan Sulphate	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Endrin	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Endrin ketone	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Endrin aldehyde	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-
Heptachlor	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Heptachlor epoxide	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Hexachlorobenzene	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Methoxychlor	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-
Mirex	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Azinphos-methyl	µg/L	<0.5	-	-	<0.5	<0.5	<0.5	<0.5	-	<0.5	-	-	-	-	-
Bromophos-ethyl	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Carbophenothion	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Chlorfenvinphos	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Chlorpyrifos	µg/L	<0.015	-	-	<0.015	<0.015	<0.015	<0.015	-	<0.015	-	-	-	-	-
Chlorpyrifos-methyl	µg/L	<0.015	-	-	<0.015	<0.015	<0.015	<0.015	-	<0.015	-	-	-	-	-
Diazinon	µg/L	<0.015	-	-	<0.015	<0.015	<0.015	<0.015	-	<0.015	-	-	-	-	-
Demeton-S-methyl	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-
Demeton-S	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Dimethoate	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-
Dichlorvos	µg/L	<2	-	-	<2	<2	<2	<2	-	<2	-	-	-	-	-
Ethion	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Fenitrothion	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-
Fenthion	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Fenamiphos	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-
Malathion	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-
Methidathion	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Parathion	µg/L	<0.015	-	-	<0.015	<0.015	<0.015	<0.015	-	<0.015	-	-	-	-	-
Parathion-methyl	µg/L	<0.5	-	-	<0.5	<0.5	<0.5	<0.5	-	<0.5	-	-	-	-	-
Phosalone	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Pirimiphos-methyl	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Profenofos	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Prothiofos	µg/L	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-

			T1A					T1C		T2F					T2I
Analytes	Units	LOR	May-10	Jun-10	Jul-10	Aug-10	Sep-10	May-10	Jun-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	May-10
Trifluralin	µg/L	<0.03	-	-	<0.03	<0.03	<0.03	<0.03	-	<0.03	-	-	-	-	-
Ametryn	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Asulam	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Desethyl atrazine	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Desisopropyl atrazine	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Atrazine	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Bromacil	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Diuron	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Fluazifop-p-butyl	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Fluometuron	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Haloxyfop	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Hexazinone	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Imazethapyr	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Imidacloprid	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Metribuzin	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Prometryn	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Sethoxydim	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Simazine	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Tebuthiuron	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Terbutryn	µg/L	<1	-	-	<1	<1	<1	<1	-	<1	-	-	-	-	-
Magnesium - Dissolved	mg/L	<0.1	-	-	-	15	16	-	-	-	-	-	11	12	-
Potassium - Dissolved	mg/L	<0.1	-	-	-	3.1	2.9	-	-	-	-	-	3.4	2.9	-

Groundwater Results Summary Table Continued

			T3C				T3B		T3E			
Analytes	Units	LOR	Jun-10	Jul-10	Aug-10	Sep-10	Aug-10	Sep-10	Jun-10	Jul-10	Aug-10	Sep-10
pH	pH unit	<1	5.2	5.8	5.9	5.9	6.6	6.3	6.4	5.7	6.1	5.9
Carbonate Alkalinity as CaCO	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	<1	8	9	11	9	26	29	12	13	16	16
Hardness	mg/L	<1	61	56	55	56	39	48	98	94	80	140
Calcium	mg/L	<0.1	4.7	4.2	3.9	4.2	5.1	6.2	4.7	7.8	4.1	31
Magnesium	mg/L	<0.1	12	11	11	11	6.4	7.8	21	18	17	16
Sodium	mg/L	<0.1	29	25	26	26	12	12	94	95	85	52
Potassium	mg/L	<0.1	3.8	2.7	2.8	2.2	4.4	3.9	6.7	6	6	5.1
Turbidity	NTU	<0.1	1800	480	350	210	500	140	450	200	14	11
Total Dissolved Salts	mg/L	-	145	140	130	145	86	92	360	360	315	290
Chloride	mg/L	<1	40	41	42	46	21	26	170	170	144	140
Sulphate	mg/L	<2	60	46	45	41	17	19	57	47	44	45
Ortho P	mg/L	<0.01	0.65	0.02	0.03	<0.01	0.04	<0.01	0.11	0.03	0.02	0.02
Phosphorus - Total	mg/L	<0.04	0.06	0.05	0.03	<0.04	0.02	<0.04	0.04	0.04	0.03	0.02
Total Nitrogen	mg/L	<0.1	0.6	0.4	<0.1	0.5	0.1	0.8	1.1	1.5	0.5	1.1

Analytes	Units	LOR	T3C Jun-10	T3C Jul-10	T3C Aug-10	T3C Sep-10	T3B Aug-10	T3B Sep-10	T3E Jun-10	T3E Jul-10	T3E Aug-10	T3E Sep-10
Total Kjeldahl Nitrogen	mg/L	<0.1	0.4	0.3	<0.1	0.5	<0.1	0.8	1.1	1.5	0.5	1.1
Nox as N	mg/L	<0.01	0.22	0.08	0.08	0.01	0.11	0.01	<0.01	0.01	0.01	<0.01
Nitrate as N	mg/L	<0.01	0.22	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Nitrite as N	mg/L	<0.01	<0.01	0.07	0.08	0.01	0.11	0.01	0.04	<0.01	0.01	<0.01
Total Ammonia as N	mg/L	<0.1	0.4	0.2	<0.1	<0.1	<0.1	<0.1	0.6	0.6	0.4	0.4
Aluminium - Dissolved	µg/L	<5	310	1000	240	140	1800	300	970	860	590	490
Arsenic - Dissolved	µg/L	<1	-	-	6.3	5.3	1.3	1.1	-	-	<1	<1
Barium - Dissolved	µg/L	<1	66	69	72	62	51	62	31	29	21	22
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium - Dissolved	µg/L	<1	2.4	2	<1	<1	3.5	<1	1.8	1.7	1.7	1.2
Copper - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron - Dissolved	µg/L	<5	470	680	890	810	640	680	470	370	270	250
Manganese - Dissolved	µg/L	<1	13	10	10	8.9	2.9	3.8	4.4	3.5	2.2	2.2
Nickel - Dissolved	µg/L	<1	4.7	3.2	2.4	1.9	<1	<1	<1	<1	<1	<1
Lead - Disssolved	µg/L	<1	1.2	1	<1	<1	1	<1	1.2	1.1	<1	<1
Selenium - Dissolved	µg/L	<1	-	-	<1	<1	<1	<1	-	-	<1	<1
Strontium - Dissolved	µg/L	<5	32	26	29	26	27	32	33	29	21	19
Zinc - Dissolved	µg/L	<5	14	22	7	7.8	25	18	36	37	21	6.8
Silicon - Dissolved	mg/L	<0.05	4.3	4.5	4.4	4.3	3.9	2.9	6.8	6.7	6	6.2
TPH C6-C9	µg/L	<25	50	<25	<25	<25	<25	<25	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	780	<50	<50	<50	<50	<50	<50	<50	<50	<50
TPH C15-C28	µg/L	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
TPH C29-C36	µg/L	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Aldrin	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
alpha-BHC	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
beta-BHC	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
gamma-BHC (Lindane)	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
delta-BHC	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
cis-Chlordane	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
trans-Chlordane	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
p,p'-DDD	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
p,p'-DDE	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
p,p'-DDT	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Dieldrin	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
alpha-Endosulfan	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
beta-Endosulfan	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Endosulfan Sulphate	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Endrin	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Endrin ketone	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Endrin aldehyde	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1
Heptachlor	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Heptachlor epoxide	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Hexachlorobenzene	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Methoxychlor	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1

Analytes	Units	LOR	T3C Jun-10	T3C Jul-10	T3C Aug-10	T3C Sep-10	T3B Aug-10	T3B Sep-10	T3E Jun-10	T3E Jul-10	T3E Aug-10	T3E Sep-10
Mirex	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Azinphos-methyl	µg/L	<0.5	-	<0.5	<0.5	<0.5	<0.5	-	-	<0.5	<0.5	<0.5
Bromophos-ethyl	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Carbophenothion	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Chlorfenvinphos	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Chlorpyrifos	µg/L	<0.015	-	<0.015	<0.015	<0.015	<0.015	-	-	<0.015	<0.015	<0.015
Chlorpyrifos-methyl	µg/L	<0.015	-	<0.015	<0.015	<0.015	<0.015	-	-	<0.015	<0.015	<0.015
Diazinon	µg/L	<0.015	-	<0.015	<0.015	<0.015	<0.015	-	-	<0.015	<0.015	<0.015
Demeton-S-methyl	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1
Demeton-S	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Dimethoate	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1
Dichlorvos	µg/L	<2	-	<2	<2	<2	<2	-	-	<2	<2	<2
Ethion	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Fenitrothion	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1
Fenthion	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Fenamiphos	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1
Malathion	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1
Methidathion	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Parathion	µg/L	<0.015	-	<0.015	<0.015	<0.015	<0.015	-	-	<0.015	<0.015	<0.015
Parathion-methyl	µg/L	<0.5	-	<0.5	<0.5	<0.5	<0.5	-	-	<0.5	<0.5	<0.5
Phosalone	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Pirimiphos-methyl	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Profenofos	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Prothiofos	µg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	<0.1
Trifluralin	µg/L	<0.03	-	<0.03	<0.03	<0.03	<0.03	-	-	<0.03	<0.03	<0.03
Ametryn	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Asulam	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Desethyl atrazine	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Desisopropyl atrazine	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Atrazine	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Bromacil	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Diuron	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Fluazifop-p-butyl	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Fluometuron	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Haloxyfop	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Hexazinone	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Imazethapyr	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Imidacloprid	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Metribuzin	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Prometryn	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Sethoxydim	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Simazine	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Tebuthiuron	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1
Terbutryn	µg/L	<1	-	<1	<1	<1	<1	-	-	<1	<1	<1

Analytes	Units	LOR	T3C				T3B		T3E			
			Jun-10	Jul-10	Aug-10	Sep-10	Aug-10	Sep-10	Jun-10	Jul-10	Aug-10	Sep-10
Magnesium - Dissolved	mg/L	<0.1	-	-	11	11	6.5	7.8	-	-	17	16
Potassium - Dissolved	mg/L	<0.1	-	-	2.8	2.2	4.6	3.9	-	-	6.1	5

Groundwater Results Summary Table Continued

Analytes	Units	LOR	T5A					T5D			T5I	
			May-10	Jun-10	Jul-10	Aug-10	Sep-10	Jul-10	Aug-10	Sep-10	May-10	Jul-10
pH	pH unit	<1	5.6	5.9	6.2	6.1	5.7	6.7	6.5	6.4	6.8	6.9
Carbonate Alkalinity as CaCO	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	<1	7	5	10	8	9	43	49	56	170	180
Hardness	mg/L	<1	52	57	47	41	37	92	99	110	225	240
Calcium	mg/L	<0.1	5.4	8.6	5.6	3.4	2.5	17	18	21	51	56
Magnesium	mg/L	<0.1	9.4	8.5	7.9	7.8	7.4	12	13	15	24	24
Sodium	mg/L	<0.1	23	19	27	26	30	65	64	73	160	180
Potassium	mg/L	<0.1	3.7	2.2	2.1	2.3	1.6	5.6	8.1	5.6	11	10
Turbidity	NTU	<0.1	600	4.9	3.3	3.6	1.4	380	70	60	250	6000
Total Dissolved Salts	mg/L	-	110	110	115	115	130	280	280	340	630	720
Chloride	mg/L	<1	51	46	50	49	52	110	110	130	250	300
Sulphate	mg/L	<2	23	25	24	19	20	43	45	51	65	74
Ortho P	mg/L	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.5	0.49	0.42	0.05	0.13
Phosphorus - Total	mg/L	<0.04	<0.04	<0.04	0.03	0.02	<0.04	0.56	0.5	0.48	0.35	0.72
Total Nitrogen	mg/L	<0.1	2.8	2	2.1	2	2.4	1.5	1.7	2	1.5	2.9
Total Kjeldahl Nitrogen	mg/L	<0.1	0.5	<0.1	<0.1	<0.1	<0.1	1.5	1.7	2	1.5	2.9
Nox as N	mg/L	<0.01	2.24	2	2.11	2	2.4	0.04	0.01	<0.01	0.04	<0.01
Nitrate as N	mg/L	<0.01	2.2	2	2.1	2	2.4	<0.01	<0.01	<0.01	0.02	<0.01
Nitrite as N	mg/L	<0.01	0.04	<0.01	0.01	<0.01	<0.01	0.04	0.01	<0.01	0.02	<0.01
Total Ammonia as N	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.1	1	1	0.7	0.7
Aluminium - Dissolved	µg/L	<5	66	23	33	32	920	950	200	120	280	1500
Arsenic - Dissolved	µg/L	<1	-	-	-	<1	<1	-	<1	<1	-	-
Barium - Dissolved	µg/L	<1	38	34	34	35	31	18	19	23	86	87
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	2.3	<1	<1	1	3.2
Copper - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron - Dissolved	µg/L	<5	98	8.3	<5	8	11	170	71	59	2000	170
Manganese - Dissolved	µg/L	<1	3.2	<1	<1	<1	<1	6.1	6	5.6	21	9.8
Nickel - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	7.5	5.4
Lead - Disssolved	µg/L	<1	1	1	<1	<1	<1	1.6	<1	<1	<1	1.4
Selenium - Dissolved	µg/L	<1	-	-	-	<1	1.1	-	<1	<1	-	-
Strontium - Dissolved	µg/L	<5	26	20	21	21	20	62	73	86	250	240
Zinc - Dissolved	µg/L	<5	12	14	10	<5	43	<5	6.9	8.1	28	<5
Silicon - Dissolved	mg/L	<0.05	2.9	2.7	3	2.9	3	6.4	5.3	5.3	4.9	6
TPH C6-C9	µg/L	<25	40	<25	<25	<25	<25	<25	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	230	<50	<50	<50	<50	<50	<50	<50	<50	<50

Analytes	Units	LOR	T5A					T5D			T5I	
			May-10	Jun-10	Jul-10	Aug-10	Sep-10	Jul-10	Aug-10	Sep-10	May-10	Jul-10
TPH C15-C28	µg/L	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	180
TPH C29-C36	µg/L	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Aldrin	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
alpha-BHC	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
beta-BHC	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
gamma-BHC (Lindane)	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
delta-BHC	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
cis-Chlordane	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
trans-Chlordane	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
p,p'-DDD	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
p,p'-DDE	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
p,p'-DDT	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Dieldrin	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
alpha-Endosulfan	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
beta-Endosulfan	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Endosulfan Sulphate	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Endrin	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Endrin ketone	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Endrin aldehyde	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Heptachlor	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Heptachlor epoxide	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Hexachlorobenzene	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Methoxychlor	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Mirex	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Azinphos-methyl	µg/L	<0.5	<0.5	-	<0.5	<0.5	<0.5	-	-	-	<0.5	-
Bromophos-ethyl	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Carbophenothion	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Chlorfenvinphos	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Chlorpyrifos	µg/L	<0.015	<0.015	-	<0.015	<0.015	<0.015	-	-	-	<0.015	-
Chlorpyrifos-methyl	µg/L	<0.015	<0.015	-	<0.015	<0.015	<0.015	-	-	-	<0.015	-
Diazinon	µg/L	<0.015	<0.015	-	<0.015	<0.015	<0.015	-	-	-	<0.015	-
Demeton-S-methyl	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Demeton-S	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Dimethoate	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Dichlorvos	µg/L	<2	<2	-	<2	<2	<2	-	-	-	<2	-
Ethion	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Fenitrothion	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Fenthion	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Fenamiphos	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Malathion	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Methidathion	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Parathion	µg/L	<0.015	<0.015	-	<0.015	<0.015	<0.015	-	-	-	<0.015	-
Parathion-methyl	µg/L	<0.5	<0.5	-	<0.5	<0.5	<0.5	-	-	-	<0.5	-
Phosalone	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-

Analytes	Units	LOR	T5A May-10	T5A Jun-10	T5A Jul-10	T5A Aug-10	T5A Sep-10	T5D Jul-10	T5D Aug-10	T5D Sep-10	T5I May-10	T5I Jul-10
Pirimiphos-methyl	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Profenofos	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Prothiofos	µg/L	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	-	-	<0.1	-
Trifluralin	µg/L	<0.03	<0.03	-	<0.03	<0.03	<0.03	-	-	-	<0.03	-
Ametryn	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Asulam	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Desethyl atrazine	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Desisopropyl atrazine	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Atrazine	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Bromacil	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Diuron	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Fluazifop-p-butyl	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Fluometuron	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Haloxyfop	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Hexazinone	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Imazethapyr	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Imidacloprid	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Metribuzin	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Prometryn	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Sethoxydim	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Simazine	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Tebuthiuron	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Terbutryn	µg/L	<1	<1	-	<1	<1	<1	-	-	-	<1	-
Magnesium - Dissolved	mg/L	<0.1	-	-	-	7.7	7.4	-	13	15	-	-
Potassium - Dissolved	mg/L	<0.1	-	-	-	2.2	1.6	-	8.1	5.6	-	-

Groundwater Results Summary Table Continued

Analytes	Units	LOR	T7A Jun-10	T7A Jul-10	T7A Aug-10	T7A Sep-10	T7D May-10	T7D Jun-10	T7D Jul-10	T7D Aug-10	T7D Sep-10	T7E Jun-10	T7E Jul-10	T7E Aug-10	T7E Sep-10
pH	pH unit	<1	6.3	5.8	6.2	5.5	6	6.4	6.7	6.3	6.6	6.7	6.7	6.6	6.8
Carbonate Alkalinity as CaCO	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	<1	10	10	12	12	15	19	19	21	20	380	430	590	380
Hardness	mg/L	<1	70	69	60	70	66	49	42	38	38	410	440	470	430
Calcium	mg/L	<0.1	6.6	6.3	4.2	6.6	8.4	5.3	5.3	4.2	4.4	96	100	110	100
Magnesium	mg/L	<0.1	13	13	12	13	11	8.6	7.1	6.8	6.6	42	46	48	44
Sodium	mg/L	<0.1	55	54	54	54	28	46	41	45	43	520	380	450	350
Potassium	mg/L	<0.1	2.3	2.8	2.6	2	8.8	3.6	3.4	3.5	2.6	9.6	11	11	10
Turbidity	NTU	<0.1	10	60	65	45	5000	450	750	550	900	6.6	6.9	2.9	16
Total Dissolved Salts	mg/L	-	235	210	200	215	165	160	145	150	135	1960	1480	1800	1410
Chloride	mg/L	<1	100	94	88	91	64	72	61	64	61	580	635	640	575
Sulphate	mg/L	<2	43	43	40	42	29	28	26	27	24	510	110	170	89
Ortho P	mg/L	<0.01	0.02	<0.01	0.01	0.01	0.2	0.3	<0.01	0.02	0.01	0.09	0.15	0.19	0.17

Analytes	Units	LOR	T7A Jun-10	T7A Jul-10	T7A Aug-10	T7A Sep-10	T7D May-10	T7D Jun-10	T7D Jul-10	T7D Aug-10	T7D Sep-10	T7E Jun-10	T7E Jul-10	T7E Aug-10	T7E Sep-10
Phosphorus - Total	mg/L	<0.04	<0.04	<0.04	<0.04	<0.04	0.15	0.02	0.05	0.02	0.04	0.21	0.21	0.21	0.19
Total Nitrogen	mg/L	<0.1	0.3	0.4	<0.1	0.2	2	2.4	3.4	1.8	2.8	18	21	17	16
Total Kjeldahl Nitrogen	mg/L	<0.1	0.3	0.4	<0.1	0.2	1.8	0.4	0.3	<0.1	0.7	18	21	17	16
Nox as N	mg/L	<0.01	0.02	0.01	0.01	<0.01	2.01	1.98	3.06	1.83	2.1	<0.01	<0.1	<0.01	<0.01
Nitrate as N	mg/L	<0.01	0.02	0.01	<0.01	<0.01	1.8	1.7	2.7	1.7	1.9	<0.01	<0.01	<0.01	<0.01
Nitrite as N	mg/L	<0.01	<0.01	<0.01	0.01	<0.01	0.21	0.28	0.36	0.13	0.16	<0.01	<0.01	<0.01	<0.01
Total Ammonia as N	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.2	0.3	<0.1	0.1	17	21	16	16
Aluminium - Dissolved	µg/L	<5	86	110	140	100	7900	83	2900	4900	2400	10	11	19	6.9
Arsenic - Dissolved	µg/L	<1	-	-	<1	<1	-	-	-	<1	<1	-	-	3.3	2.7
Barium - Dissolved	µg/L	<1	40	39	38	36	14	15	11	13	12	390	400	390	380
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium - Dissolved	µg/L	<1	<1	<1	<1	<1	4.4	5.1	5.6	7	5.1	<1	<1	<1	<1
Copper - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron - Dissolved	µg/L	<5	1100	1100	1000	920	160	130	160	180	160	26	<5	<5	<5
Manganese - Dissolved	µg/L	<1	8.2	6.9	7.4	6.3	1.6	1.8	<1	1.1	1	13	14	17	13
Nickel - Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Lead - Disssolved	µg/L	<1	<1	<1	<1	<1	1.2	1.4	<1	1.1	1.1	<1	<1	<1	<1
Selenium - Dissolved	µg/L	<1	-	-	<1	<1	-	-	-	3.6	3.3	-	-	<1	<1
Strontium - Dissolved	µg/L	<5	41	40	41	37	35	30	27	31	24	450	460	490	450
Zinc - Dissolved	µg/L	<5	16	26	12	5.7	6.8	40	<5	<5	<5	5.6	8.2	12	15
Silicon - Dissolved	mg/L	<0.05	3.9	4.1	4.1	4	7	2.7	3.1	4.5	2.9	16	17	17	17
TPH C6-C9	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
TPH C15-C28	µg/L	<100	<100	<100	<100	<100	<100	220	<100	<100	<100	110	140	140	140
TPH C29-C36	µg/L	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Aldrin	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
alpha-BHC	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
beta-BHC	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
gamma-BHC (Lindane)	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
delta-BHC	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
cis-Chlordane	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
trans-Chlordane	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
p,p'-DDD	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
p,p'-DDE	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
p,p'-DDT	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Dieldrin	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
alpha-Endosulfan	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
beta-Endosulfan	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Endosulfan Sulphate	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Endrin	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Endrin ketone	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Endrin aldehyde	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Heptachlor	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Heptachlor epoxide	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-

Analytes	Units	LOR	T7A				T7D					T7E			
			Jun-10	Jul-10	Aug-10	Sep-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Jun-10	Jul-10	Aug-10	Sep-10
Hexachlorobenzene	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Methoxychlor	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Mirex	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Azinphos-methyl	µg/L	<0.5	-	-	-	-	<0.5	-	-	-	-	-	-	-	-
Bromophos-ethyl	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Carbophenothion	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Chlorfenvinphos	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Chlorpyrifos	µg/L	<0.015	-	-	-	-	<0.015	-	-	-	-	-	-	-	-
Chlorpyrifos-methyl	µg/L	<0.015	-	-	-	-	<0.015	-	-	-	-	-	-	-	-
Diazinon	µg/L	<0.015	-	-	-	-	<0.015	-	-	-	-	-	-	-	-
Demeton-S-methyl	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Demeton-S	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Dimethoate	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Dichlorvos	µg/L	<2	-	-	-	-	<2	-	-	-	-	-	-	-	-
Ethion	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Fenitrothion	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Fenthion	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Fenamiphos	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Malathion	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Methidathion	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Parathion	µg/L	<0.015	-	-	-	-	<0.015	-	-	-	-	-	-	-	-
Parathion-methyl	µg/L	<0.5	-	-	-	-	<0.5	-	-	-	-	-	-	-	-
Phosalone	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Pirimiphos-methyl	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Profenofos	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Prothiofos	µg/L	<0.1	-	-	-	-	<0.1	-	-	-	-	-	-	-	-
Trifluralin	µg/L	<0.03	-	-	-	-	<0.03	-	-	-	-	-	-	-	-
Ametryn	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Asulam	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Desethyl atrazine	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Desisopropyl atrazine	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Atrazine	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Bromacil	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Diuron	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Fluazifop-p-butyl	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Fluometuron	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Haloxyfop	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Hexazinone	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Imazethapyr	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Imidacloprid	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Metribuzin	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Prometryn	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Sethoxydim	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Simazine	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-

			T7A				T7D					T7E			
Analytes	Units	LOR	Jun-10	Jul-10	Aug-10	Sep-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Jun-10	Jul-10	Aug-10	Sep-10
Tebuthiuron	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Terbutryn	µg/L	<1	-	-	-	-	<1	-	-	-	-	-	-	-	-
Magnesium - Dissolved	mg/L	<0.1	-	-	12	13	-	-	-	6.7	6.5	-	-	47	43
Potassium - Dissolved	mg/L	<0.1	-	-	2.6	1.9	-	-	-	3.5	2.5	-	-	11	9.8

Groundwater Results Summary Table Continued

			BH10			BH12		
Analytes	Units	LOR	Feb-10	Aug-10	Sep-10	Feb-10	Aug-10	Sep-10
pH	pH unit	<1	5.5	5.9	5.6	6.5	6.2	6.3
Carbonate Alkalinity as CaCO	mg/L	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	<1	8	7	6	29	12	16
Hardness	mg/L	<1	68	62	57	59	64	77
Calcium	mg/L	<0.1	7.3	4.9	4.7	7	4	6
Magnesium	mg/L	<0.1	6.7	12	11	2	13	15
Sodium	mg/L	<0.1	12	22	27	10	9	13
Potassium	mg/L	<0.1	18	6.4	5.6	23	3.6	2.9
Turbidity	NTU	<0.1	1700	12	11	1600	450	280
Total Dissolved Salts	mg/L	-	155	145	130	145	90	130
Chloride	mg/L	<1	38	50	50	32	27	33
Sulphate	mg/L	<2	51	40	42	37	35	42
Ortho P	mg/L	<0.01	0.05	0.01	<0.01	1	0.34	0.34
Phosphorus - Total	mg/L	<0.04	0.18	<0.02	<0.04	1.7	1.7	1.1
Total Nitrogen	mg/L	<0.1	1.8	<0.1	<0.1	4.1	3.2	3.7
Total Kjeldahl Nitrogen	mg/L	<0.1	1.6	<0.1	<0.1	0.1	<0.1	<0.1
Nox as N	mg/L	<0.01	0.19	0.01	0.04	4	3.2	3.71
Nitrate as N	mg/L	<0.01	-	<0.01	0.04	-	3.2	3.7
Nitrite as N	mg/L	<0.01	-	0.01	<0.01	-	<0.01	0.01
Total Ammonia as N	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aluminium - Dissolved	µg/L	<5	23	250	57	19	290	220
Arsenic - Dissolved	µg/L	<1	<0.5	1.1	1	<0.5	<1	1.2
Barium - Dissolved	µg/L	<1	68	93	82	18	47	39
Cadmium - Dissolved	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium - Dissolved	µg/L	<1	<1	<1	<1	15	2.1	2.2
Copper - Dissolved	µg/L	<1	<1	3.8	<1	<1	<1	<1
Iron - Dissolved	µg/L	<5	500	790	790	11	120	95
Manganese - Dissolved	µg/L	<1	83	44	22	19	46	34
Nickel - Dissolved	µg/L	<1	4.2	1.8	<1	<1	1.7	1.3
Lead - Disssolved	µg/L	<1	<1	<1	<1	<1	<1	<1
Selenium - Dissolved	µg/L	<1	-	<1	<1	-	<1	<1
Strontium - Dissolved	µg/L	<5	38	51	34	58	38	39
Zinc - Dissolved	µg/L	<5	80	18	14	74	<5	8.8
Silicon - Dissolved	mg/L	<0.05	5.3	5.3	4.8	8.2	5.1	5

Analytes	Units	LOR	BH10			BH12		
			Feb-10	Aug-10	Sep-10	Feb-10	Aug-10	Sep-10
TPH C6-C9	µg/L	<25	<25	<25	<25	<25	<25	<25
TPH C10-C14	µg/L	<50	<50	<50	<50	59	<50	<50
TPH C15-C28	µg/L	<100	<100	<100	<100	160	<100	110
TPH C29-C36	µg/L	<100	<100	<100	<100	<100	<100	<100
Aldrin	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
alpha-BHC	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
beta-BHC	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
gamma-BHC (Lindane)	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
delta-BHC	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
cis-Chlordane	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
trans-Chlordane	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
p,p'-DDD	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
p,p'-DDE	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
p,p'-DDT	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Dieldrin	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
alpha-Endosulfan	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
beta-Endosulfan	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Endosulfan Sulphate	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Endrin	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Endrin ketone	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Endrin aldehyde	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Heptachlor	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Heptachlor epoxide	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Hexachlorobenzene	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Methoxychlor	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mirex	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Azinphos-methyl	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Bromophos-ethyl	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Carbophenothion	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Chlorfenvinphos	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Chlorpyrifos	µg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Chlorpyrifos-methyl	µg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Diazinon	µg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Demeton-S-methyl	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Demeton-S	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Dimethoate	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dichlorvos	µg/L	<2	<2	<2	<2	<2	<2	<2
Ethion	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fenitrothion	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fenthion	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fenamiphos	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Malathion	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Methidathion	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Parathion	µg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015

Analytes	Units	LOR	BH10			BH12		
			Feb-10	Aug-10	Sep-10	Feb-10	Aug-10	Sep-10
Parathion-methyl	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phosalone	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Pirimiphos-methyl	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.05
Profenofos	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Prothiofos	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Trifluralin	µg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Ametryn	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Asulam	µg/L	<1	<1	<1	-	<1	<1	-
Desethyl atrazine	µg/L	<1	<1	<1	-	<1	<1	-
Desisopropyl atrazine	µg/L	<1	<1	<1	-	<1	<1	-
Atrazine	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Bromacil	µg/L	<1	<1	<1	-	<1	<1	-
Diuron	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Fluazifop-p-butyl	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Fluometuron	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Haloxyfop	µg/L	<1	<1	<1	-	<1	<1	-
Hexazinone	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Imazethapyr	µg/L	<1	<1	<1	-	<1	<1	-
Imidacloprid	µg/L	<1	<1	<1	-	<1	<1	-
Metribuzin	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Prometryn	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Sethoxydim	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Simazine	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Tebuthiuron	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Terbutryn	µg/L	<1	<0.5	<1	-	<0.5	<1	-
Magnesium - Dissolved	mg/L	<0.1	-	12	11	-	13	14
Potassium - Dissolved	mg/L	<0.1	-	6.4	5.6	-	3.5	2.6