MUCHEA TO WUBIN

Great Northern Highway

Muchea to Wubin Upgrade - Stage 2

MAIN ROADS WESTERN AUSTRALIA

Bindoon Bypass

Environment | Surface Water Assessment

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ARUP TRADING AS ASJV

JACOBS

Arup Jacobs Joint Venture

Level 11, Durack Centre
263 Adelaide Terrace
Perth WA 6000 Australia

T +61 8 9469 4199
F +61 8 9469 4488

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Document Owner	Contract Lead	Internal Technical Reviewer	Project Director
Manoj Shrestha Lydia Cetin	Lisa Boulden	Fiona Gilbert	
Manoj Shrestha Lydia Cetin	Lisa Boulden	Phil Pedruco	

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Glossary

Abbreviation	Description
AASS	Actual Acid Sulfate Soils
ANZECC	Australian and New Zealand Environment and Conservation Council
ASJV	Arup Jacobs Joint Venture
ASS	Acid Sulfate Soils
BGL	Below ground level
BH	Borehole
BoM	Bureau of Meteorology
CC wetland	Conservation Category wetland
CEMP	Construction Environment Management Plan
CN	Contract Number
CN0X	Contract XX – [Contract Name]
CNLS	Chittering Needonga Lake System
DBCA	Department of Biodiversity, Conservation and Attractions Geomorphic Wetlands
DoEE	Department of the Environment and Energy
DoW	Department of Water
DPaW	Department of Parks and Wildlife
DSEWPaC	Department of Sustainability Environment Water Planning and Community
DWER	Department of Water and Environmental Regulation
EBICG	Ellen Brook and Integrated Catchment
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESA	Environmentally Sensitive Area
ESD	Environmental Scoping Document
GDA94	Geocentric Datum of Australia 1994
GDE	Groundwater Dependent Ecosystems
GIS	Geographic Information System

Abbreviation	Description
GL	Gigaliter
GNH	Great Northern Highway
ha	Hectare
kL	Kiloliter
km	Kilometre
Main Roads	Main Roads Western Australia
M2W	Muchea to Wubin
MU wetland	Multiple Use wetland
M2W team	Muchea to Wubin Integrated Project Team, comprising Main Roads and industry partners Jacobs and Arup
mg/l	Milligram per liter
ML	Megaliter
mS/cm	milliSiemens per centimetre
PASS	Potenital Acid Sulfate Soils
RE wetland	Resource Enhancement wetland
RIWI Act	*Rights in Water and Irrigation* (Act)
SCP	Swan Coastal Plain
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Sediments
WA	Western Australia
WRC	Water and Rivers Commission

1. Introduction

In 2014 Main Roads Western Australia (Main Roads WA) established the Muchea to Wubin Integrated Project Team (M2W Team), comprising Main Roads and industry partners Arup and Jacobs (combining to form Arup Jacobs Joint Venture, ASJV), to conduct a comprehensive planning review of the full Muchea to Wubin link along the Great Northern Highway (GNH). This planning review is a critical component of the Great Northern Highway: Muchea to Wubin Upgrade Stage 2, which has been funded with $384.8 million from the Federal and State Governments.

Among the improvements to be considered as part of the planning review were additional passing lanes, flattening crests and easing curves, safer roadsides, more rest stops and additional facilities for heavy vehicles.

The review examined the previous upgrade strategy developed in the 1990s and, having carefully considered current requirements for the movement of people and freight, delivered a revised upgrade strategy.

The M2W team has identified and prioritised construction packages to be delivered over the four-year period from 2015/16 to 2018/19. The construction programme includes the currently funded sections Muchea North / Chittering (13km), Bindoon South (2km), New Norcia (7kms), Lyons East Road to Pithara (46km, including Miling) and Dalwallinu to Wubin realignment (16km) and identifies additional priority packages to be constructed as funding becomes available.

1.1 Description of the Proposed Project

As part of this package of works, Main Roads WA has proposed to construct the GNH–Bindoon Bypass, which involves the construction of a new 48 km section of highway in the Bindoon region within the Shire of Chittering. The Bindoon Bypass extends north from the existing GNH at the Chittering roadhouse through the localities of Bindoon, Mooliabeenee and Wannamal and then re-joins the GNH between Hay Flat Road and Calingiri Road as shown in Figure A.1.

1.2 Project Aims and Scope

The proposed project is required to be assessed under Part IV of the *Environmental Protection Act 1986* (EP Act) as determined by the WA Environmental Protection Authority (EPA). In order to inform the Environmental Review Document, requirements outlined in the *EPA Environmental Scoping Document (ESD): Hydrological Processes and Inland Waters Environmental Quality* (endorsed on 29/11/2017) for the Bindoon Bypass need to be addressed.

This study provides a high level, qualitative assessment of impacts on surface waters from the proposed road alignment project and may require further quantitative assessment during preparation of the detailed design. The scope of this study is as follows:

- Desktop study of existing environmental conditions of surface water catchments including water quality in the project area.
- Assessment of potential impacts on the surface water features near the project alignment.
- Identification and recommendation of potential mitigation options.
- Assessment of residual risks and impacts.

The summary of the requirements and where they are addressed in the report is provided in Table 1-1.

Table 1-1: EPA requirements for Hydrological Processes and Inland Waters Environmental Quality

No.	WA EPA environmental assessment requirements (*EP Act*). ESD 29/11/2017	Section where addressed in report
1	Identify and describe the values and significance of surface and groundwater hydrological and soil (hydrogeological) characteristics within the refined development envelope and the immediately adjacent area upstream and downstream of the development envelope in accordance with relevant policy and guidance. Identify and describe wetlands within and in proximity upstream and downstream to the refined development envelope. Describe these values in local, regional and State contexts as appropriate. Identify users of the identified values.	4.1, 4.2, 4.3, 4.4, 4.5
2.	Describe and assess the potential impacts (direct and indirect) as a result of both construction and operational elements of the proposal on water quantity (excess and deficit) and quality in relation to the surface and groundwater, waterways and their floodplains and wetlands in above in accordance with the relevant policy and guidance.	5.1, 5.2
3.	Once the development envelope has been refined, predict the extent, severity and duration of potential impacts to 1 above, including changes to local and regional surface and groundwater flows and levels (excess and deficit), groundwater drawdown, local surface and groundwater quality and impacts to surface and groundwater users as a result of construction and operation in accordance with the relevant policy and guidance set out below.	5.1, 5.2
4.	Describe any proposed mitigation to reduce the potential impacts of construction and operation of the proposal above. Provide maps of and justification for the location and number of any proposed culverts and stormwater infrastructure. Include any proposed management and/or monitoring plans and strategies (for example the Drainage Strategy for the Perth-Darwin National Highway (Swan Valley section proposal) that will be implemented pre- and post-construction to demonstrate and ensure the EPA's objectives can be met. Include any hydrological and hydrogeological assessments undertaken for dewatering and groundwater use.	6
5.	Identify, describe and quantify the potential residual impacts (direct and indirect) that may occur following implementation of the proposed mitigation measures and determine the significance of the residual impacts on the identified environmental values by applying the Residual Impact Significance Model (page 11) and WA Offset template (Appendix 1) in the WA *Environmental Offsets Guidelines* (2014). Provide spatial data defining the area of any identified significant residual impacts and proposed offsets in relation to the development envelope. Where significant residual impacts remain, propose an appropriate offsets package that is consistent with the WA *Environmental Offsets Policy and Guidelines.*	7

2. Regulatory Context

The project takes place within an existing regulatory framework of environmental and planning legislation, policies and guidelines. The key legislation, documents and policies relevant to the project are summarised in Table 2-1.

Table 2-1: Key legislatures and description

Regulatory Frameworks	Descriptions
Acts	
Environment Protection and Biodiversity Conservation (EPBC) Act 1999	The EPBC Act is the main environmental legislation for the Commonwealth Government to protect the matters of national environmental significance.
Environmental Protection (EP) Act, 1986	The EP Act provides legal framework for prevention, control and abatement of pollution and environmental harm and conservation, preservation, protection, enhancement and management of the environment. It is the primary legislative instrument for environmental assessment in Western Australia.
Rights in Water and Irrigation Act 1914	RIWI Act makes provision for the regulation, management, use and protection of water resources through issuing and restricting license and permits.
Policies	
Environmental Protection (Swan Coastal Plain Lakes) Policy, 1992	It aims to protect the beneficial uses and values of certain Lakes on the SCP through the prohibition of filling, mining, draining and effluent discharge into selected Lakes, unless authorised under the EP Act.
State Planning Policy 2.9 – Water resources, 2006	This policy provides guidance in the planning, protection and management of Western Australia water resources for meeting economic, social, cultural and environmental values.
WA Environmental Offsets Policy, 2011	The Western Australian Government's Environmental Offsets Policy seeks to protect and conserve environmental and biodiversity values for present and future generations. This policy ensures that economic and social development may occur while supporting long term environmental and conservation values
Guidelines and Manuals	
Guidelines for treatment of stormwater runoff from the road infrastructure, Austroads 2003.	Guidelines for the selection of road runoff treatment measures, hydrologic design standards and design computations for selected treatment measures.
Environment Protection Authority (EPA) Statement of Environmental Principles, Factors and Objectives, 2016	This Statement sets out the environmental principles, factors and associated objectives that underpin the environmental impact assessment process.
Water Quality Protection Note 44 Roads Near Sensitive Water Resources, 2006	*Roads Near Sensitive Water Resources* provides a general guide on issues of environmental concern, and offers potential solutions. It offers the Department's views on road siting, construction and management, guidance on acceptable practices for water resource protection and a

Regulatory Frameworks	Descriptions
	basis for the development of a multi-agency code or guideline.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)	The ANZECC guidelines: • Outline the important principles, objectives and philosophical basis underpinning the development and application of the guidelines • Outline the management framework recommended for applying the water quality guidelines to the natural and semi-natural marine and fresh water resources in Australia and New Zealand • Provide a summary of the water quality guidelines proposed to protect and manage the environmental values supported by the water resources • Provide advice on designing and implementing water quality monitoring and assessment programs
Department of Water *Stormwater management manual for Western Australia: A component of integrated water cycle management, 2004-2007*	This manual provides a consistent approach to consider a variety of stormwater management options that may be suitable to a range of built environments across Western Australia.
Environmental Factor Guideline – Hydrological Processes, December 2016	This guideline communicates how WA EPA considers the factor Hydrological Processes and its objective in the environmental impact assessment process.
Environmental Factor Guideline – Inland Waters Environmental Quality, December 2016	This guideline communicates how WA EPA considers the factor Inland Waters Environmental Quality and its objective in the environmental impact assessment process.
Western Australian Environmental Offset Guidelines	This guideline expands on the Environmental Offsets Policy 2011 to clarify the determination and application of environmental offsets in Western Australia so that the basis for decision-making on the offsets are consistent and accountable.

3. Methodology

The surface water assessment for the Bindoon Bypass comprised a desktop literature review and data analysis to identify existing surface water features and conditions, potential impacts of the project activities and appropriate mitigation options. Relevant environmental impact assessment guidelines from the WA and Commonwealth governments were referred to in preparation of this report. To meet the ESD requirements, the following tasks were performed:

- Review of the key Acts, regulations, policies and guidelines related to surface water use and protection in the project area to ensure legislative compliances during the road design. This included the following documents:
  - *Environment Protection and Biodiversity Conservation Act 1999*
  - *Environmental Protection Act 1986*
  - *Rights in Water and Irrigation Act 1914*
  - *State Planning Policy 2.9 – Water resources*
  - *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992*
  - *Statement of Environmental Principles, Factors and Objectives, December 2016*
  - *Environmental Factor Guideline – Hydrological Processes, December 2016*
  - *Environmental Factor Guideline – Inland Waters Environmental Quality, December 2016*
  - *Department of Water Stormwater management manual for Western Australia: A component of integrated water cycle management, 2004-2007*
  - *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)*
  - *Western Australian Environmental Offsets Guidelines, 2014*
- A review of the current published literature including environmental maps and databases, government reports, previous EIA reports, and journal articles relevant to the study area.
- A review of recent technical investigations for the Bindoon Bypass on:
  - Great Northern Highway Muchea to Wubin Upgrade – Stage 2: Groundwater Assessment (Dec 2017), prepared by ARUP Jacobs Joint Venture for Main Roads WA
  - Great Northern Highway, Bindoon Bypass Upgrades, Wetland Assessment, Interim report (Dec 2017), prepared by Focused Vision Consulting for ARUP Jacobs Joint Venture and Main Roads WA
  - Preliminary drainage design strategy prepared by ARUP Jacobs Joint Venture for Main Roads WA
- Flow and water quality data for the Brockman River and Lennard Brook were obtained from Department of Water and Environmental Regulation (DWER) and analysed. The water quality information is further complemented by other published literature, for example water quality snapshot report prepared by the Ellen Brook Integrated Catchment Group (EBICG, 2015a, b).

4. Existing Environmental Conditions

This section outlines the existing environmental conditions of the project area to inform the impact assessment of surface waters.

4.1 Catchment, Climate and Land use

The proposed alignment traverses three river catchments: Brockman River, Gingin Brook and Ellen Brook catchment as shown in Figure A.1. The major portion of the alignment runs through the Brockman River catchment, with a very small section crossing the Gingin Brook and Ellen Brook catchment area. Both Brockman River and Ellen Brook catchment are located within the greater Swan River System. Most of the Bindoon Bypass project alignment runs approximately parallel to the Brockman River intersecting several tributaries, and finally crosses the river itself at the northern part of the project area before re-joining the Great Northern Highway.

The study area has a Mediterranean climate with hot dry summers and cool wet winters. The rainfall data at lower Chittering (009009) and the Wannamal (009040) rainfall stations were collected from Bureau of Meteorology (BoM, 2018). The annual rainfall calculated for both stations is fairly consistent from year to year (Figure 4-1) with the long-term mean annual rainfall of 706 mm at Lower Chittering and 546 mm at Wannamal.

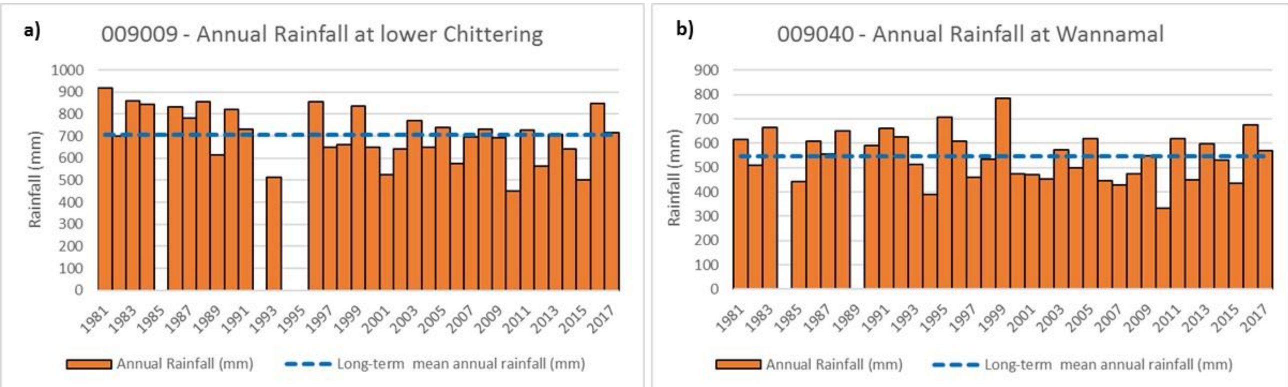

Figure 4-1: Annual Rainfall at a) Lower Chittering (009009) and b) Wannamal (009040).

The land use in the Brockman catchment is mostly freehold land used for agricultural and horticultural purposes including cropping, irrigated pasture and perennial horticulture. There are also some nature reserves, other reserved Crown lands and state forest areas in the catchment. A long history of land clearance has significantly contributed to land salinization from rising groundwater within the catchment (Smith, 2002).

4.2 Surface Water Hydrology

4.2.1 Hydrological Assessment

The project alignment intersects two main waterways - the Brockman River and Lennard Brook. The Brockman River is approximately 90 kilometres in length, and has a total catchment area of 1,520 km^2 (EBICG, 2015a). DWER routinely monitors the flow of the river at two sites. The upstream flow gauge Tanamerah (616006) is located a few kilometres upstream of the town of Bindoon covering an area of approximately 960 km^2. The second flow gauge, Yalliawirra (616019), is situated close to the confluence with the Avon River (Figure A.1). Mean annual flows for both stations are highly variable as shown in Figure 4-2 with a notable step change in the past ten years, when flows are substantially lower than the long-term average. This has been attributed to a decline in groundwater contribution, rather than a decline in rainfall, which appears to be less variable from year to year (DoW, 2010).

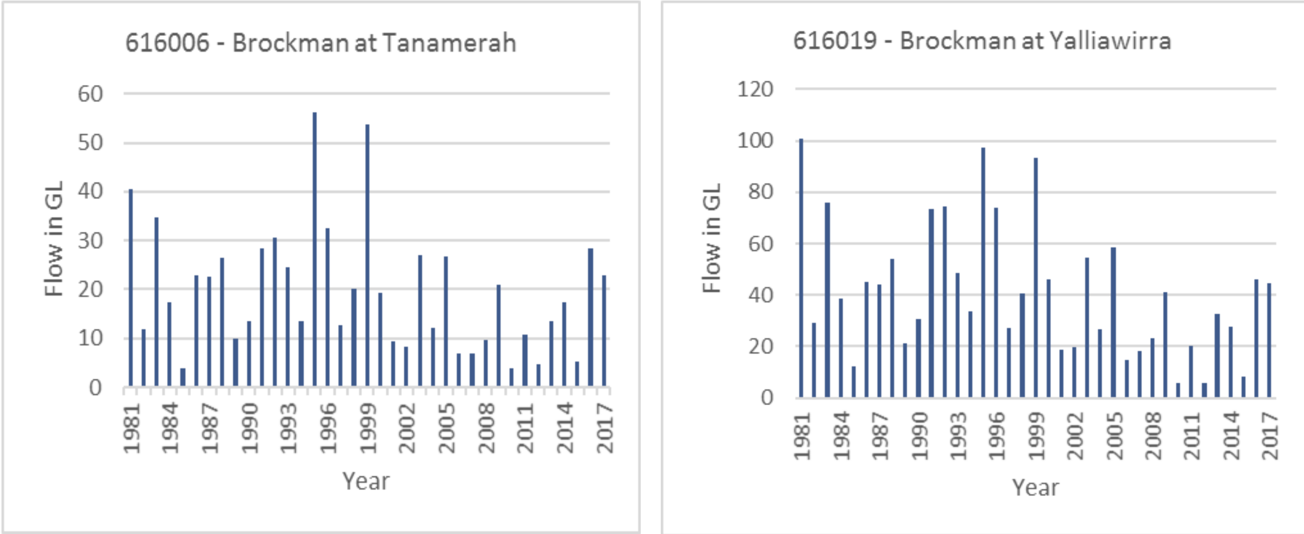

Figure 4-2: Mean annual flow for the Brockman River at Tanamerah and Yalliawirra.

River flows are highest during winter months (Figure 4-3), with the river ceasing to flow during summer, up to 36% of the time for Brockman River at Tanamerah, and 10% of the time for Brockman River at Yalliawirra (Figure 4-4).

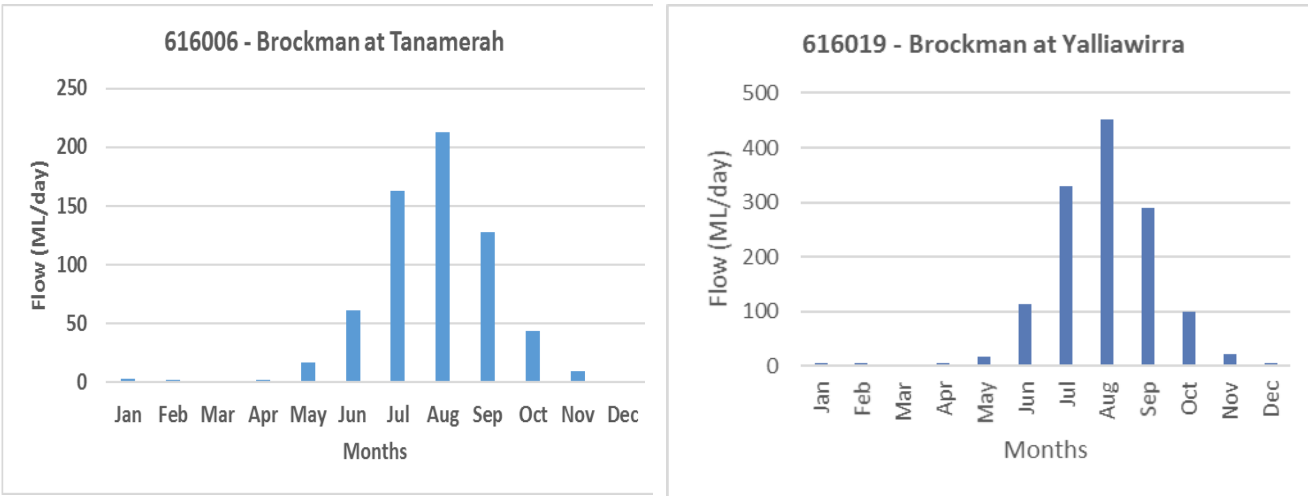

Figure 4-3: Mean monthly flow in the Brockman River at Tanamerah and Yalliawirra based on data from 1981 – 2017.

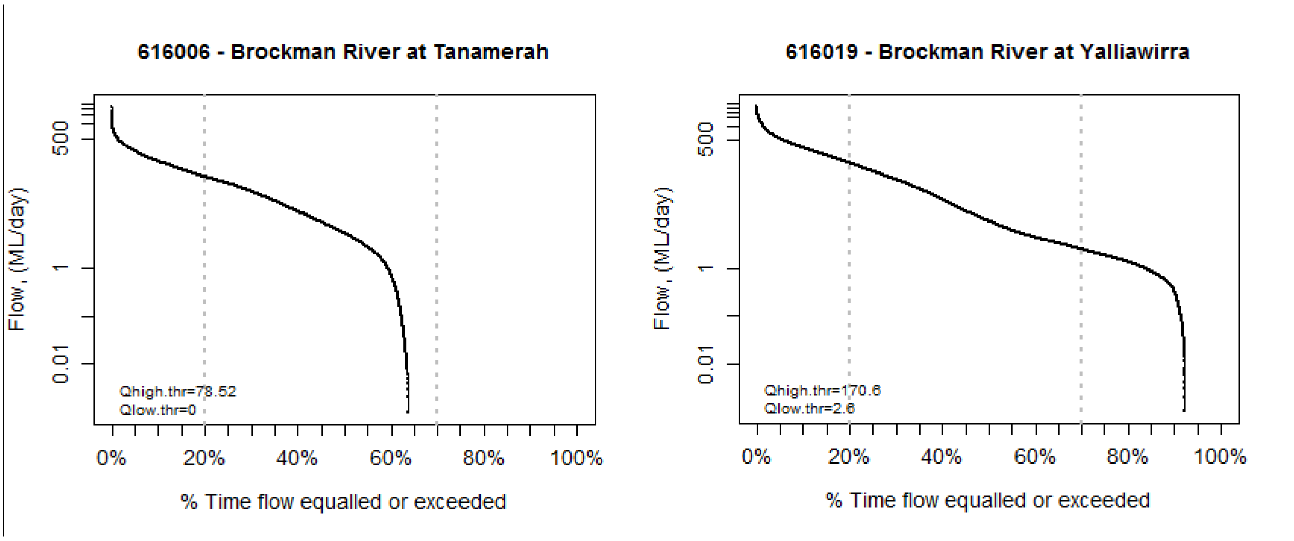

Figure 4-4: Flow Duration Curve for the Brockman River at Tanamerah and Yalliawirra. The y-axis is plotted on a logarithmic scale.

Lennard Brook is a perennial waterway with mean annual flows less variable than for the Brockman River, although a similar decrease in mean annual flows is observed in the past 10 years (Figure 4-5). Summer flows are maintained by groundwater discharge (Tuffs 2010), which results in higher summer flows (Figure 4-6) and no cease to flow periods (Figure 4-7).

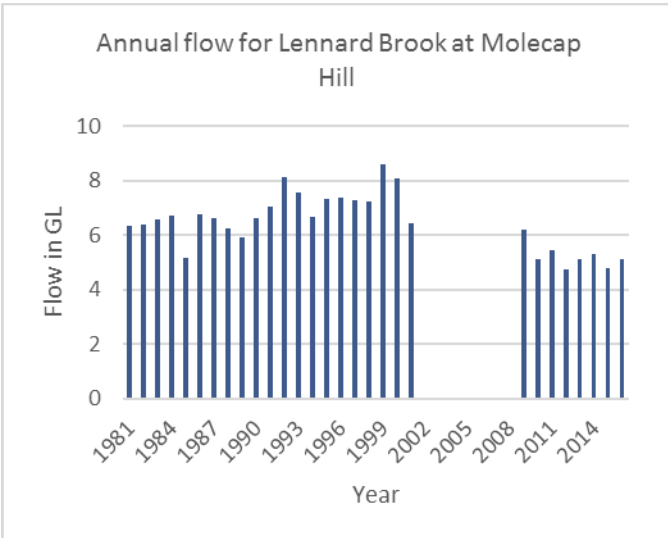

Figure 4-5: Mean annual flow for Lennard Brook at Molecap Hill (617165) based on data from 1981 – 2016. Gauging station was closed from 2002 – 2008.

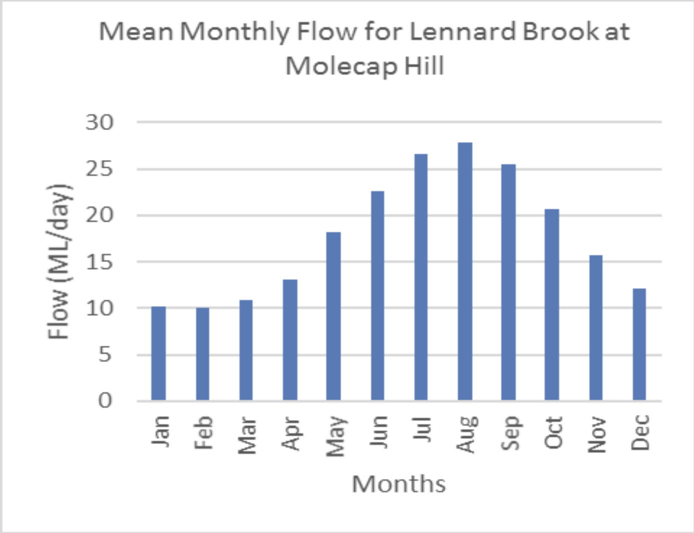

Figure 4-6: Mean monthly flow in the Lennard Brook at Molecap Hill (617165) based on data from 1981 – 2016.

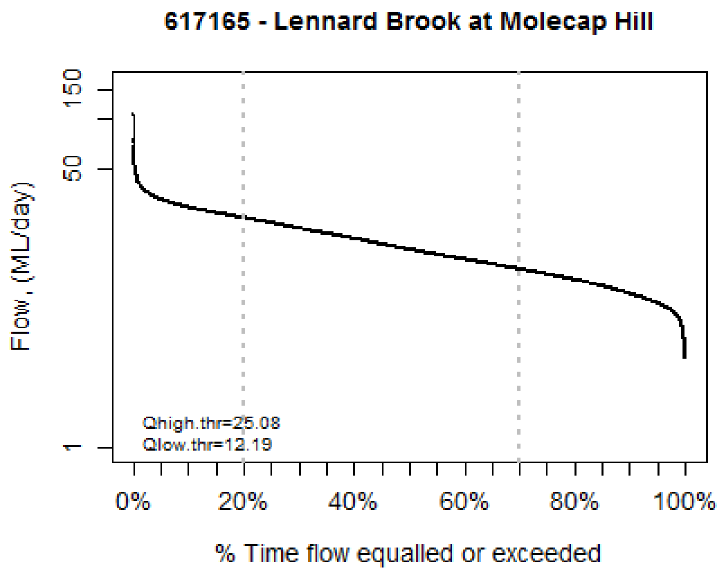

Figure 4-7: Flow duration curve for the Lennard Brook at Molecap Hill (617165).

4.2.2 Surface Water Users and Allocation Limits

The Bindoon Bypass alignment traverses the Swan River System Surface Water Area (Figure A.2), proclaimed under the *Rights in Water and Irrigation Act 1914* (RIWI Act). Therefore, surface water users require a water licence to lawfully take surface water under section 5C of the Act. Surface water in the project area is mainly used for irrigating orchards and vineyards, and for domestic purposes. Most water is taken by direct pumping in summer, with some dams capturing winter flow.

A water resource allocation plan (DoW, 2010) has been developed for Brockman River to maintain reliability of current supply. For Lennard Brook the allocation is regulated by the Gingin surface water allocation plan (DoW, 2011). Both catchments are close to full allocation as shown in Table 4-1, suggesting that the river is already at the upper limit of sustainable use, especially during summer months.

Although the Brockman River and Lennard Brook provide refuge to endemic freshwater fishes, two species of endemic freshwater crayfish, Oblong Turtle and Carter's Freshwater Mussel (Beatty et al. 2010), there are no regulatory environmental flow requirements stated in the water allocation plans. The Brockman River Water Allocation Plan states that in the driest year only 4% of the total summer flow is available for the environment.

Table 4-1: Allocation limits for the Brockman River and the Lennard Brook.

Resource	Allocation limit (kL/year)	Allocation limit components (kL/year)	
		Unlicensable (exempt use, including riparian rights)	Licensable (general licensing)
Brockman River[1]	481,890	18,000	463,890
Lennard Brook[2]	2,434,310	25,000	2,409,310

[1] – (DoW, 2010)
[2] – (DoW, 2011)

4.3 Wetlands and Lake

There are two nationally important wetlands listed in the Directory of Important Wetlands of Australia within the project vicinity. The Wannamal Lake system is located approximately 3.5 km north west of the project alignment, while the downstream Chittering-Needonga Lake System is approximately 3.8 km east from the project area (Figure A.3). Located close to the Wannamal Lake system are a number of smaller wetlands within the northern part of the Bindoon Bypass project area on private property as shown in Figure A.3. This wetland system consists of four wetlands listed in the Department of Biodiversity, Conservation and Attractions Geomorphic Wetlands of the Swan Coastal Plain dataset (DBCA, 2016) and are described in Table 4-2. The wetlands are fed by groundwater for the majority of the time, and experience low water levels in summer. Due to the proximity to the main river channel, the wetlands may receive some surface water inundation during large overbank flooding events.

Table 4-2: Geomorphic wetlands located within and in close proximity to proposal footprint

Wetland (UFI)[1]	Management Category[2]	Wetland type	Area (km^2)
12840	Conservation Category (CC) Wetland	floodplain	0.5
12838	Resource Enhancement (RE) Wetland	sumpland	0.13
12762	Multiple Use (MU) Wetland	palusplain	0.07
12841	Multiple Use (MU) Wetland	dampland	0.5

Source: Focused Vision (2017)
1: Unique Feature Identifier
2: Wetland Management category as defined by Hill et al. (1996)
Conservation Category wetland – wetlands supporting a high level of ecological attributes and functions (generally having intact vegetation and natural hydrological processes), or that have a reasonable level of functionality and are representative of wetland types that are rare or poorly protected.
Resource Enhancement wetland – wetlands that have been modified (degraded) but still support substantial ecological attributes (wetland dependent vegetation covering more than 10 %) and functions (hydrological properties that support wetland dependent vegetation and associated fauna) and have some potential to be restored to the conservation management category. Typically, such wetland still supports some elements of the original native vegetation, and hydrological function.
Multiple Use wetland – wetlands that are assessed as possessing few remaining ecological attributes and functions. While such wetlands can still play an important role in regional or landscape ecosystem management, including water management, they are considered to have low intrinsic ecological value. Typically, they have very little or no native vegetation remaining (less than 10 %).

The State Planning Policy 2.9 – Water Resources (WAPC, 2006) governs the protection, management, conservation and enhancement of environmental attributes, functions and values of Conservation Category wetlands. The management objectives focus on the preservation of such wetlands through the creation of parks and reserves, protected under Environmental Policies and application of covenants (WRC 2001).

The wetland assessment report (Focused Vision, 2017) states that certain areas of the Conservation Category wetland located in the project area are currently in a degraded state, and in transition between Conservation Category and Resource Enhancement wetland categories. Field visit confirmed that it is currently being used for seasonal grazing of stock by the land owner. Consultation with DBCA has confirmed the area of the Brockman River crossing does not appear to meet the requirements for Conservation Category and does not need to be assessed as such for the hydrological assessment.

4.4 Surface Water Quality

Key surface water quality parameters analysed, and their data sources are listed below:

- Electrical conductivity – daily data measured at the two flow gauges on the Brockman River, and published literature for the Lennard Brook.
- Nutrients, sediments and heavy metals – data are reproduced from a snapshot water quality monitoring program conducted in 2014 by the Ellen Brook Integrated Catchment Management Group (EBICG, 2015a, b).

A summary of the existing water quality conditions of surface water features within the study area is presented in Sections 4.4.1 to 4.4.4. No field sampling has been conducted as part of this study.

4.4.1 Stream Salinity

Considering the main waterways support extensive abstraction for agricultural production, salinity levels within the surface waters are of major concern, as well as causing potential risks to aquatic biological diversity. Both total dissolved solids (TDS) and electrical conductivity (EC) are commonly used to express the concentration of salts in water. Depending on salinity levels, the stream can be classified as fresh (marginal), brackish, saline and hyper saline as shown in Table 4-3.

Table 4-3 : Water Salinity classification (Adapted from Australian Water Resources Council, 1988)

Salinity (mg/l TDS)	Electrical Conductivity (EC) (mS/cm at 25 ^{o} C)	Description	Potential use
<1500	<2.3	Marginal	most purposes, upper limit for drinking
1500 - 3000	2.3 - 4.6	Brackish	limited irrigation, all livestock
3000 - 7000	4.6 - 10.8	Saline	most livestock (not pigs or horses)
7000 - 14000	10.8 - 21.5	Saline	some livestock (beef cattle, sheep)
>14000	> 21.5	Saline to hypersaline	limited industrial use up to 100000 mg/L

Continuous EC is recorded at the Brockman River at Tanamerah flow gauge from 1991, however, for the majority of the record EC readings during summer are generally zero because there is no flow in the river. A full EC record is available for 2017 (Figure 4-8), which shows that the river is brackish to saline (mean EC of 6.3 mS/cm) with higher salinity levels during the summer season. This is consistent with long-term stream salinity assessment conducted by Mayer et al. (2005), which estimated the mean annual salinity of 3400 mg/l at Tanamerah from 1993 to 2002 and categorised the stream as moderately saline. A study by Angell (2000) suggested that the salinity of the Brockman River is mainly attributed to the contribution from saline groundwater sources. The groundwater technical investigation highlighted that the groundwater salinity varies from fresh to saline in the project area.

There is no salinity data collected for the Lennard Brook catchment. A study conducted by the Department of Water (now DWER) (2012) measured salinity levels during February to April 2011 downstream of the Lennard Brook flow gauge sites and found that the stream is fresh with EC measurements below 1.5 mS/cm for the study period.

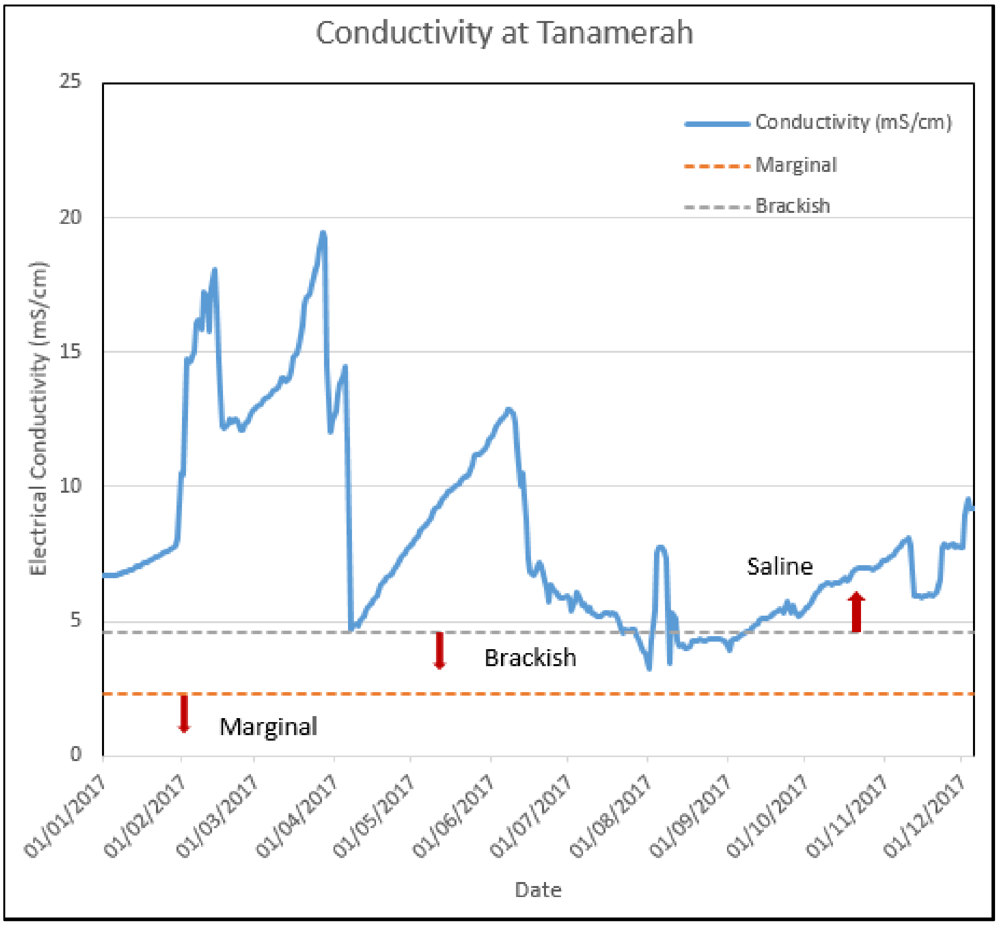

Figure 4-8 : Daily electrical conductivity measurement at Brockman River at Tanamerah (0616006) for the year 2017. The salinity classification was adopted from Australian Water Resources Council (1988).

4.4.2 Heavy Metals in Surface Water

Heavy metals can enter waterways from a variety of natural or anthropogenic sources and can cause acute toxicity to aquatic organisms at elevated concentrations. Heavy metals from road runoff typically includes cadmium, chromium, copper, nickel, lead and zinc. It has been found that the concentration of heavy metals in road runoff can commonly exceed the ANZECC (2000) guidelines, especially in heavily trafficked areas (AustRoads, 2000). A study conducted by Driscoll et al. (1990) in US highways found that the event mean concentration of heavy metals can be up to four times higher on highways with traffic volume greater 30, 000 vehicles per day compared to those highways with lesser traffic volumes. The traffic volume for the Bindoon bypass is estimated to be around 4,000 vehicles/day, hence it is expected that while there will be an increase in heavy metals it will be a minor impact that can be managed.

ANZECC trigger values are set for a number of metals and metalloids within freshwater environments. The appropriate trigger values for this study area are the 95% species protection limits for moderately disturbed areas. The trigger values for different heavy metals are provided in Table 4-4.

Table 4-4: ANZECC trigger values for different heavy metals in freshwater for slightly-moderately disturbed system (ANZECC 2000)

Metals	Trigger values for 95 % of species protection (mg/L)
Aluminum	0.055
Arsenic	0.024
Cadmium	0.0002
Chromium	0.001
Copper	0.0014
Lead	0.0034
Nickel	0.011
Zinc	0.008

There is very limited data available for different heavy metals for the Brockman River, and no data were available for the Lennard Brook catchment. A water quality monitoring snapshot program conducted by EBICG (EBICG, 2015) recorded heavy metal concentrations of aluminium, arsenic, chromium, copper, lead and zinc at 2 sites along the Brockman River (Gray Road and Yalliawirra) and 5 sites along tributaries on the 7 August and 19 September in 2014. Although the analysis is based on only two sampling dates, the EBICG (2015) study is still useful in providing some indication of current heavy metal concentrations.

The study found that the concentration of arsenic, chromium and lead were below the ANZECC trigger values on both sampling occasions for all monitoring sites. However, copper and zinc were reported to exceed the trigger values at only one location in the Marbling area, one of the tributaries of the lower Brockman River outside the project area. Aluminium was found to exceed the ANZECC trigger values for both sites at Brockman River, and its tributaries at Aquila and Marbling (Figure 4-9).

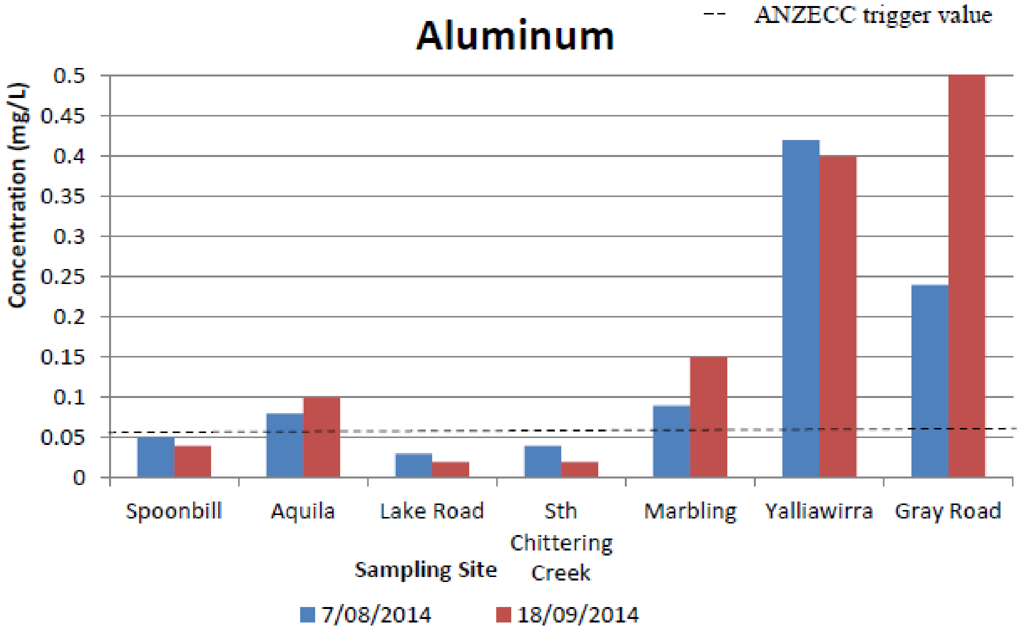

Figure 4-9: Aluminium concentration in surface water within the Brockman River catchment on the 7th August and the 18th of September 2014. (Source: EBICG, 2015a)

4.4.3 Nutrients in Surface Water

Nitrogen and phosphorus are key nutrients in freshwater systems, but both are generally limited, with low concentrations restricting plant growth. High concentrations, however, can contribute to excessive growth of algae and other aquatic plants, generally in association with high light level, low salinity, warm water temperature and low flow. Excessive plant and algal growth can lead to clogging of waterways, smothering of habitat and large diurnal variations in dissolved oxygen concentrations. These conditions can further impact aquatic biota including fish and macroinvertebrates.

The main source of nutrients in the Brockman River catchment include agricultural runoff, feed lots, cattle grazing, leakage from septic tracks, detergents and industrial effluents (EBICG, 2015).

ANZECC default trigger values for nutrients levels are set for slightly disturbed freshwater system for south-western Australia. These trigger values are used to assess risk of adverse effects due to nutrients in various ecosystem types. The default trigger values for nutrients are outlined in Table 4-5.

Table 4-5: ANZECC default trigger values for nutrient concentrations in south – Western Australia for lowland rivers

Nutrients	Default Trigger values (mg/L)
Total Nitrogen (TN)	1.2
Total Phosphorus (TP)	0.065

There is limited data collected on Total Nitrogen (TN) and Total Phosphorus (TP) for Brockman River and Lennard Brook. EBICG conducted an annual sampling of TN and TP for both Brockman River and Lennard Brook in 2014. They collected nutrient samples from twenty-six sites along the Brockman River and its tributaries on 7 August and 19 September in 2014, with five sites along the main stem of the Brockman River (Figure A.4). Four of the five sites at the Brockman River exceeded the ANZECC trigger values of 1.2 mg/l on August sampling (Figure 4-10), while none of these sites exceeded during the September samplings. TP concentration during the sampling period did not exceed the ANZECC guidelines for the lowland rivers for all twenty-six sites.

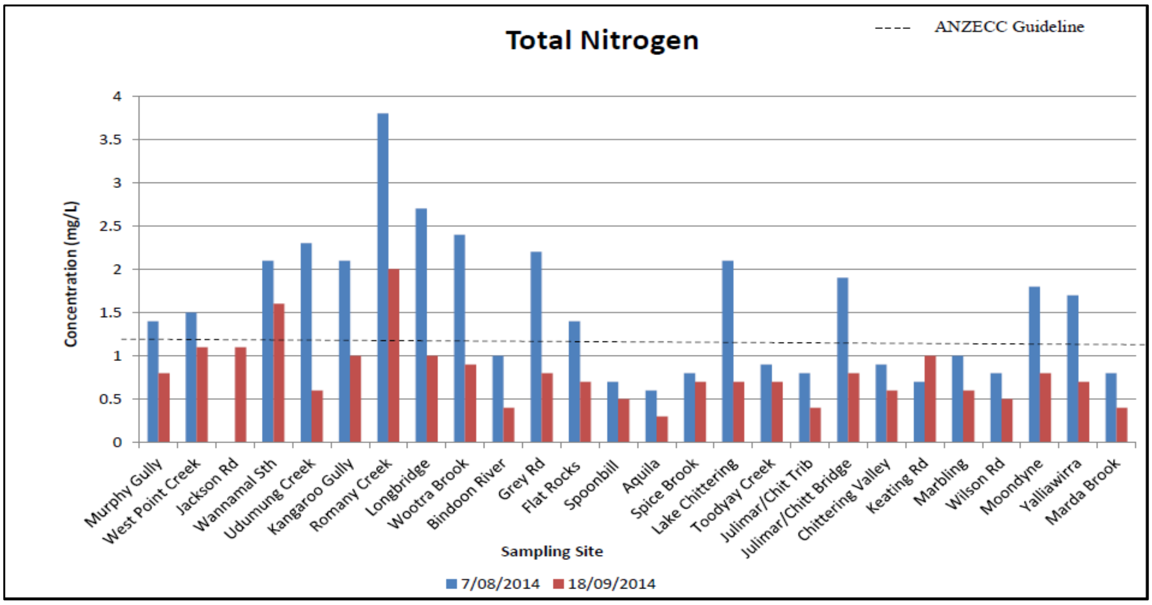

Figure 4-10: Total Nitrogen concentration in surface water within the Brockman River Catchment sampled on 7th August and 18th of September 2014. (EBICG, 2015a)

TN and TP samples were collected on four occasions between June and September; once in each month by EBICG at the Lennard Brook Road compared to the two occasions in the Brockman River as shown in Figure A.4. Data in Table 4-6 shows that both TN and TP exceeded the ANZECC trigger values of nutrients for all sampling occasions.

Table 4-6: Total Nitrogen (TN) and Total Phosphorus (TP) concentration for Lennard Brook (EBICG, 2015b)

Date	TN (mg/L)	TP (mg/L)
25/06/2014	3.7	0.14
30/07/2014	4.3	0.21
20/08/2014	3.7	0.21
22/09/2014	3.5	0.21

4.4.4 Sediments in Surface Water

Increased concentrations and loadings of suspended sediments can affect aquatic ecosystems by:

- reducing light penetration, with potential adverse effects on primary production;
- smothering benthic organisms and their habitats;
- causing reduced feeding rates and behavioural changes (avoidance) in fish, or blocking of fish gills.

Most of the sediment in rivers and streams enters the waterway from erosion of the stream channel or within the catchment (e.g. gully or hillslope erosion). Erosion is exacerbated by land clearance and landform disturbance.

Currently there is no ANZECC guideline for total suspended solids (TSS). Therefore, a value of 6 mg/L adopted by DWER as an interim trigger value is used for assessment. This trigger value was originally developed by Waters and Rivers Commissions for the Wilson Inlet report to community (WRC, 2000).

As with nutrients and heavy metals there is a scarcity of suspended sediments data in the project area. The study conducted by EBICG (2015) recorded TSS during August and September within the Brockman River, and found that several sites exceeded 6 mg/l as shown in Figure 4-11. Four of the five sites at Brockman River exceeded the guideline value during August, with the exception being the Wilson Road site. According to the study, the higher TSS levels are attributed to stock access to waterways, lack of riparian vegetation and high levels of cleared vegetation in the catchment.

The concentration of TSS monitored by EBICG for the Lennard Brook is provided in Table 4-7, which indicates sediment concentrations are within the DWER interim guideline value except in August.

Table 4-7: Total Suspended Solids (TSS) concentration for Lennard brook (EBICG, 2015b)

Date	TSS(mg/L)
25/06/2014	5
30/07/2014	6
20/08/2014	9
22/09/2014	5

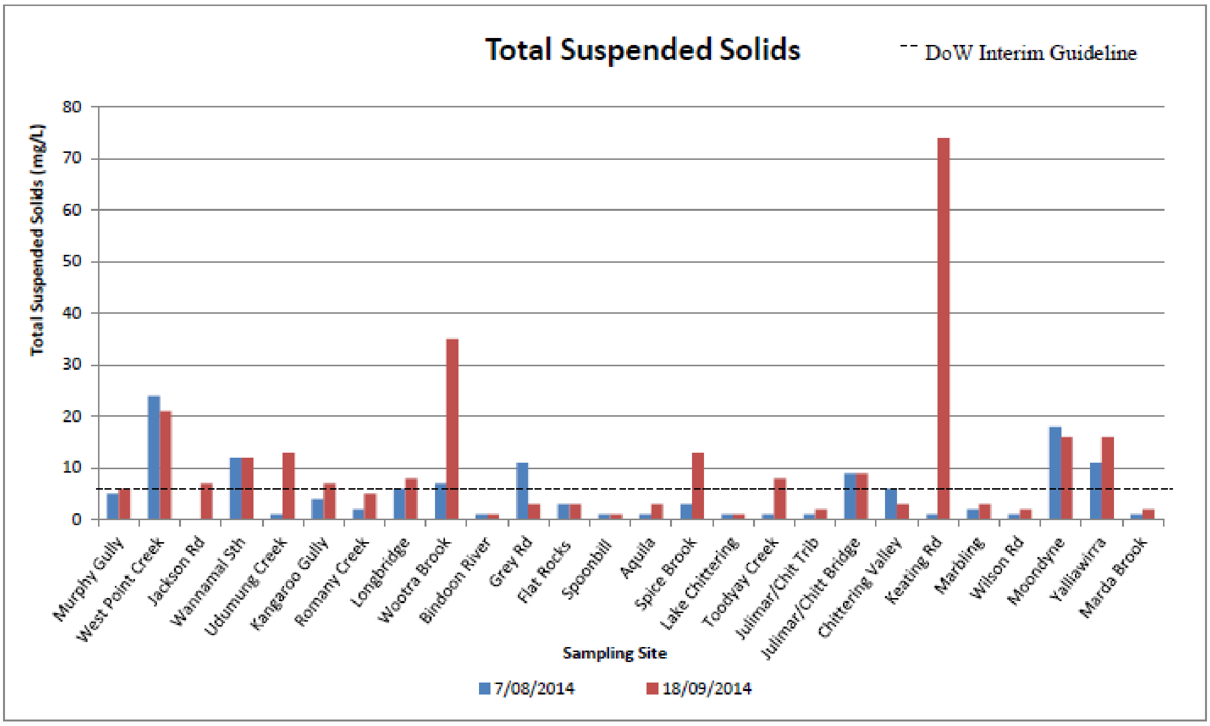

Figure 4-11: Total Suspended Solids (TSS) concentrations in surface water within the Brockman Rive Catchment sampled on 7th August and 18th of September 2014. (EBICG, 2015a). Department of Water (DoW) guideline refers to 6mg/L of TSS.

4.5 Acid Sulfate Soils

Acid Sulfate Soils (ASS) can occur naturally in Western Australia and pose a low risk to waterways when left in a waterlogged, undisturbed environment. However, through disturbance of these soils, such as excavation or drainage, the risk of soil acidification can increase by exposing ASS soils air, which produces sulfuric acids that leach into the surrounding soils and groundwater. During rainfall events, the acid can release heavy metals into waterways causing significant environmental degradation including fish kills, loss of biodiversity and contamination of groundwater resources.

Most of the Bindoon Bypass project alignment is situated in an area that has an extremely low probability (1 – 5 %) of occurrence of ASS as indicated by the Australian Atlas of Acid Sulfate Soils (CSIRO, 2011) (Figure A.5). However, there is a small section of the project area that is categorised as having a low probability (6 – 70%) of ASS occurrence. This is located in the northern section of the project alignment, near the wetland system, where the proposed bridge and culvert system will be built.

5. Potential Impacts

The construction and operation aspects of the Bindoon Bypass will have a number of impacts on surface water quantity and quality in the project area, such as:

- Changes in surface water runoff volumes due to vegetation clearing and increased imperviousness.
- Changes in surface flow path resulting from road embankments or other structures that may obstruct natural drainage.
- Changes in water quality due to disturbance of potential ASS, transportation of sediments from exposed soils, discharge of untreated saline waters during dewatering, accidental spills of toxic chemicals and pollutants from road runoff.
- Direct impacts to wetland areas and loss of wetland habitat as a result of road and bridge construction through wetland areas, vegetation clearance, and potential indirect impacts to wetland areas associated with changes in surface water or groundwater hydrology, and water quality.

5.1 Construction Phase Impacts

5.1.1 Changes in Surface Runoff

Vegetation clearance during the construction phase can increase surface runoff due to a reduction in interception, evapotranspiration and infiltration, especially during large rainfall events. As a result, clearing of vegetation during construction may result in a localised increase in surface water runoff volumes. Vegetation clearance of no more than 6.6 km^2 of land is expected within the project area, which is less than 1% of the total Brockman River catchment. This will likely result in insignificant changes in surface water runoff at a whole-of-catchment scale.

The proposed alignment indicates several meters of road cut and fill at several points. Where road cuts intersect with the groundwater table, it can cause groundwater to seep through the surface of road cuts, causing localised waterlogging or inundation. During construction phase this seepage water is generally collected to meet construction water requirements or can be directed to infiltration basin so that the impact is negligible.

Road fill and construction of road embankment can obstruct the path of surface runoff resulting in localised flooding upstream during high rainfall events. This can occur frequently on the southern section of the project alignment as it receives more rainfall than the northern section potentially leading to moderate impacts. However, these impacts will be managed through the appropriate drainage design strategy. Hence the impact of construction activities on alteration of surface flow is low, site-specific and event oriented.

5.1.2 Changes in Flow Regime

Temporary groundwater dewatering may be required to facilitate activities such as construction of a bridge over the Brockman River. Depending on the magnitude of dewatering required, release of excess groundwater to the watercourse may be required which can increase the volume of water and could pose a risk to channel stability, increase sedimentation, and have detrimental impacts on water quality (primarily salinity) and aquatic organisms if managed inappropriately. Figure 4-3 and 4-4 suggests that the flow at Brockman River at Tanamerah gauging station (which is approximately halfway down the length of Bindoon Bypass alignment) runs almost dry during the drier summer months (December to April) because of lack of groundwater contribution. Hence it is expected that groundwater levels will be at minimum during these months thus decreasing the likelihood of dewatering required for bridge foundations excavations. Even if dewatering is required, the flow volume will be very minimal and hence there will be negligible effects on the flow regime of the Brockman River.

If bridge footings are constructed during the wet periods in late winter – spring the amount of dewatering required will be higher due to the rise in groundwater table. Excavations for bridge foundations and the like are usually only in the order of 10 or 20 square metres and hence the likely volume of water extracted from such localised excavations is anticipated to be insignificant against the average winter flows that range from

43 – 213 ML/day. Any dewatering will consider the long term seasonal variation of stream flow so that there is minimal impact to the hydrological regime. As dewatering activities are temporary, lasting to less than 1 - 2 months the impact, if any, will be short-term.

5.1.3 Changes in Water Quality

Water pollution can impact the quality of drinking water sources (particularly for livestock), degrade and alter habitats/vegetation structure, adversely affect aquatic life and reduce the aesthetic value of water bodies for recreational users. Some of the impacts on water quality in the project area is described below:

Construction activities such as clearance of vegetation, stockpiling of soil and construction materials, cut excavation and fill placement can be the main source of sediments that can be transported to the waterways during rainfall events. Transportation of sediments into waterways is also typically associated with an increase in nutrient levels, as nutrients are often bound to sediment particles. Effective control of sediments and soils on the construction site will dictate the actual risk of impact.

Some section of the road construction may potentially intersect with the underlying Acid Sulphate Soils (ASS). Disturbance to these soils without due care during construction can cause leaching into groundwater with potential contamination. Furthermore, they can alter the water quality of receiving surface water bodies.

The accidental spill and/or release of hydrocarbons (asphalt, diesel, petrol and other automobile fluids) during construction phase of the road can pollute surface and ground water if proper collection and treatment measures are not implemented.

The groundwater technical investigation highlighted that the groundwater salinity varies from fresh to saline with higher salinity levels anticipated towards the southern end of the project area. Construction dewatering and abstraction of highly saline groundwater has the potential to exacerbate salinity concentrations of the Brockman River if discharged untreated. These risks can be well controlled by the implementation of appropriate management plans.

5.1.4 Impact to Wetlands

A 540 m section of road will intersect the wetland system and the Brockman River, with a combination of bridge and culvert system as a crossing option. The crossing footprint will impact upon an area of the CC wetland (UFI 12840) and an area of RE wetland (UFI 12838) with potential vegetation clearing. However, the wetland is already degraded as discussed in section 4.3 and thus vegetation clearing will have low impact to the ecological functions of the wetland, such as loss of habitat and nutrient retention capacity.

Furthermore, this area is underlain by soils with low probability of ASS occurrence (6-70%). This means that there is a possibility of occurrence of potential ASS (PASS), which when disturbed during the construction activities can oxidise to produce acidic soils or actual ASS (AASS). The conversion to AASS will have negative impacts on the water quality and biodiversity of the wetland.

Discharge of highly saline groundwater from dewatering activities to the wetland can affect the condition of the wetland. As excavations for bridge footing is likely to take place during the summer season, the likelihood of dewatering is minimal and hence decreasing the likelihood of increasing salinity level in the wetland and connected river system.

The upstream Wannamal Lake System is unlikely to be affected by construction activities given its distance from the road alignment. The lower section of the Chittering Needonga Lake System (CNLS), which is closer (3.8 km) to the road alignment is fed by some of the small streams close to the southern part of the road alignment. Construction activities and related water quality issues as discussed in section 5.1.3 such as increased sedimentation, accidental spills of hydrocarbon and potential discharge of highly saline water from dewatering and abstraction to the natural drainage without treatment may impact the CNLS.

5.2 Operation Phase Impacts

5.2.1 Changes in Hydrological Regime

During the operation phase, the built road surfaces that replaces previously pervious surface will result in increased runoff volumes. Given the size of the Brockman River catchment, the total runoff contribution from the Bindoon Bypass will be minor compared to the contribution from the whole of catchment. However, some of the small streams can be influenced by increased runoff and 'flashiness', depending on the amount of water draining to it. As a drainage strategy will be implemented to manage the excess water at source through water sensitive road design practices, the impacts from road runoff to the hydrological regime is considered low.

Preliminary flood modelling undertaken by the project team for the preferred option of bridge and culvert system has estimated a maximum afflux of 70 mm with a flood width of 304.5 m (an increase of 12 m from the baseline conditions) for a 100-year flood event upstream of the bridge. This increase in afflux and the width of the flood upstream presents negligible impacts to the wetlands. For more common events such as 5-year flood event, the increased afflux is only 20 mm with no increase in flood width.

5.2.2 Changes in Water Quality

Stormwater runoff from the road generally consists of gross litter and particulates, nutrients, petroleum products, and heavy metals from brake linings, tyres and other motor parts. Furthermore, spills from road accident if not handled properly can infiltrate into the groundwater and adjacent waterways and wetlands. Untreated stormwater, if directly discharged to the wetlands and waterways can increase the load of these pollutants and may result in negative impacts to the flora and fauna community. This is considered to potentially be a moderate impact, although it can be readily managed as discussed below.

5.2.3 Impact to Wetlands

Some of the potential impacts to wetlands are:

- Localised increase in stormwater runoff from the impervious road surface.
- Contamination associated with polluted road runoff or an accidental spill of harmful substance by a road user.
- Minor direct loss of wetland habitat and vegetation due to road and bridge structure footprint.
- Changes to the hydrological regime of the wetland areas due to changes in surface water or groundwater hydrology.

The extent of these impacts will depend on the final project design and therefore extent of the hydrological changes that are expected, the degree to which water quality impacts can be mitigated through design and control measures, and the extent of wetland vegetation loss.

6. Mitigation and Management

In order to minimise impacts from road construction and operation, various mitigation and management strategies have been considered. As the road alignment is in preliminary design stage, some alternative management strategies may arise as the design matures and further information becomes available. Main Roads is committed to achieving environmental outcomes through the implementation of appropriate management measures that are relevant to specific conditions on site, and which may vary from those described in this document. This approach is consistent with the Environmental Assessment Guideline for Recommending Environmental Conditions (EPA, 2013).

The following mitigation and management strategies are recommended:

- Implementation of the project drainage strategy during design and construction. The objective of the drainage strategy is to maintain drainage across the site to as close as practicable to the pre-development condition, and is in accordance with DEWR's principles of water resource management, as detailed in the Stormwater Management Manual for Western Australia (DoW, 2004) and the Decision Process for Stormwater Management in Western Australia (DoW, 2009).
- Effective site- relevant stormwater treatment measures such as swales, bio-retention systems and infiltration basins will be implemented to promote infiltration as close to the source as possible as well as treat the stormwater runoff before discharging to the wetland and waterways. This is often referred to as Water Sensitive Road Design.
- A site-specific erosion and sediment control plan will be developed as part of the Construction Environmental Management Plan (CEMP) to minimise environmental impacts of stormwater runoff during construction activities. It may include use of silt fences and sediment traps to be placed optimally to prevent soil export to waterways and wetlands, particularly during wet seasons.
- Interference with beds and banks associated with bridge construction over Brockman River and direct impacts to wetlands from road construction will be undertaken in accordance with an approved permit under the *Rights in Water and Irrigation Act 1914.*
- Any dewatering and abstraction of groundwater or pumping of surface water for construction will be undertaken in accordance with approved licences under the *Rights in Water and Irrigation Act 1914.*
- A dewatering management plan (including ASS and salinity management) will be developed as part of the CEMP (where required) and implemented in support of any application for dewatering and a groundwater licence operating strategy will be developed and implemented as necessary to support the supply of construction water. In addition, the abstracted groundwater salinity should not be significantly higher than the background salinity levels of the surface water in the area it is to be used or discharged to.
- If practical, construction of bridge footings will be scheduled during summer to reduce or avoid dewatering requirements. If dewatering is required, dewatering methods (e.g. well-point spears) that minimise the radius of influence in confirmed areas of ASS will be used.
- Following final design, a detailed ASS investigation will be undertaken to inform the development of an ASS Management Plan for work in higher risk locations.
- Maintain hydraulic connectivity between areas of wetland intersected by the road alignment through appropriate design of bridge and culvert system.
- A minimum vertical separation distance of two metres from the road sub-base to the high (wet season) water table will be retained for free-draining soils, to avoid waterlogging and allow for soil filtration of potential contaminants and aerobic microbial action.
- During operation of road, a routine inspection and maintenance schedule will be implemented with practical measures to minimise contamination of waters. These options may include collection and

removal of dead animals and road litter. Litter abatement programs such as way-stop litter bins; drainage litter traps may be implemented at key points.

- In order to assess whether the mitigation and management strategies are effective, water quality monitoring will be conducted at strategic locations prior to construction, throughout the construction period and for a period after project completion. The monitoring strategy will be detailed in the CEMP. This will include monitoring of EC, TSS, TN, TP, aluminium, cadmium, chromium, copper, nickel, lead, zinc and polycyclic aromatic hydrocarbons. Five locations are proposed (three in Brockman River and two in Lennard Brook) as shown in figure A.6.

7. Residual Impacts

The identified hydrological impacts in relation to surface water quantity and quality can be mitigated sufficiently through implementation of various strategies as described in Section 6. Therefore, the project has very minor insignificant residual impacts on existing hydrological and water quality characteristics of surface water features that include:

- Localised alteration to surface waters flows during construction phase, following mitigation these are considered to have low impacts.
- Increase in runoff volume and contaminant concentrations in streams due to drainage of road runoff during operation phase, following mitigation these are considered to have low impacts.
- Direct loss of wetland habitat will occur due to placement of road and bridge structures in wetland areas, these are considered to have low impact.
- Localised increase in flood depth and width in the floodplain of Brockman River upstream of the culvert system, the bridge configuration has been designed to minimise impacts which are considered to have low impact.

The proposal has been and will continue to be designed to ensure drainage across the site is maintained as close as practicable to the pre-development condition. A bridge will be constructed over Brockman River and wetland system and culverts will be used to manage flows beneath the road within local surface flow paths. Water pollution from the road is likely to be managed through the implementation of management measures in relation to the generation, storage, handling and release of pollutants (including TSS, ASS, hydrocarbons and chemicals), including construction of swales and an emergency spill response procedure.

A summary of the predicted impacts, management and mitigation measures and residual impacts on existing hydrological regimes and inland water quality is provided in Table 7-1.

Table 7-1: Summary surface water flow and quality potential impacts, mitigation and management and the residual impacts

ID	Aspect	Potential Impact	Magnitude of Impact	Mitigation and Management	Residual Impact
	Construction Phase				
1	Vegetation clearing	Localised increase in surface water runoff volume	Negligible	Implementation of a drainage management strategy.	Negligible Minor localised alteration to surface water flows.
2	Excavations for road cuts	Localised increase in surface water runoff volume	Low	• Road sub-surface will be constructed above the high (wet) groundwater table. • Where groundwater is intersected, seepage water will be collected for construction purpose or drained to infiltration basin based on drainage management strategy.	Negligible
3	Stockpiling of earthworks and fills, and storage of chemicals	Increased movement of sediments during and after rainfall events Accidental spills of chemical and hazardous materials with potential surface and groundwater contamination	Moderate	Development of a CEMP to prevent erosion and chemical spills and specify procedures to remediate in the event of contamination.	Low
4	Construction of Road embankments and fills	Obstruction of the natural drainage pathways, leading to local ponding upstream.	Moderate	Implementation of a drainage management strategy including the location of culverts to maintain flow connectivity	Low
5A	Construction of bridge foundations and culvert installation	Temporary increase in flow volume of the river if dewatering required	Low	Schedule construction of bridge footings during summer to avoid dewatering requirement, where possible	Low

ID	Aspect	Potential Impact	Magnitude of Impact	Mitigation and Management	Residual Impact
5B		Oxidation of potential ASS during excavation which can contaminate groundwater and surface water including wetland	Moderate	Prepare ASS management plan before construction. Reduce duration of dewatering and use dewatering methods (e.g. well - point spears) that minimise the radius of influence in confirmed ASS areas	Low
5C		Direct loss of wetland habitat due to placement of road and bridge structure	Low	Disturbance will be restricted to proposal footprint in the wetland system.	Low (Partial loss of wetland vegetation and minor direct loss of habitat)
6	Operation and maintenance of plant and machinery	• Increased erosion from the traffic of construction vehicles. • Accidental spills of hydrocarbons and chemicals that can contaminate the groundwater and surface water.	Moderate	Development of a CEMP to prevent erosion and chemical spills and specify procedures to remediate in the event of contamination.	Negligible
	Operation Phase				
7A	Physical presence of Road	Localised increase in stormwater runoff from road surface	Moderate	Effective, site-relevant stormwater treatment measures such as swales, bio-retention systems and infiltration basins will be implemented to promote infiltration as close to the source as possible, as well as treat the stormwater runoff before discharging to the wetland and waterways.	Low
7B		Increase pollutant load to the receiving water bodies from road runoff	Moderate		Low
8	Bridge and culvert system in the Brockman River	Localised flooding upstream of culvert system.	Moderate	Selection of the best alternative option that has the least impact to the existing hydrological characteristic of Brockman River through flood modelling study	Low Localised increase in flood depth and width in the floodplain of Brockman River upstream of the culvert system (ARUP, 2018)
9	Vehicle collision and spillage of hazardous waste	Accidental spills of chemical and hazardous materials	Low	Develop specific procedures to collect and remediate in the event of contamination.	Negligible

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Appendix A. Figures

A.1 Proposed Alignment and Surface Water Catchments

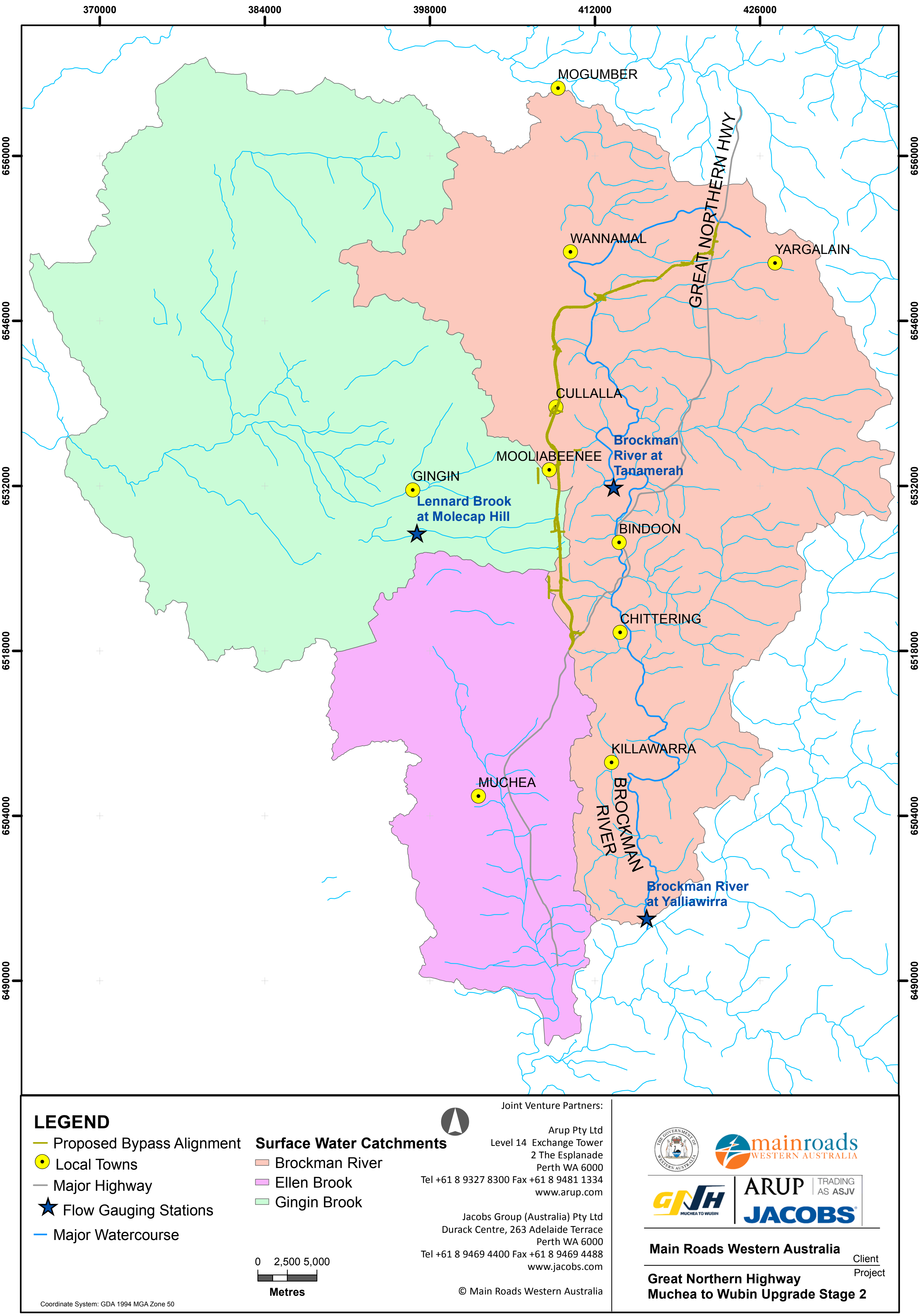
A.2 RIWI Act proclaimed surface water areas

A.3 Wetlands located within the vicinity of the project. Different category of wetland is provided in inset.

A.4 Sample locations within the Brockman River Catchment

A.5 Acid Sulfate Soils and their probability of occurrence

A.6 Proposed water quality monitoring sites



Joint Venture Partners:

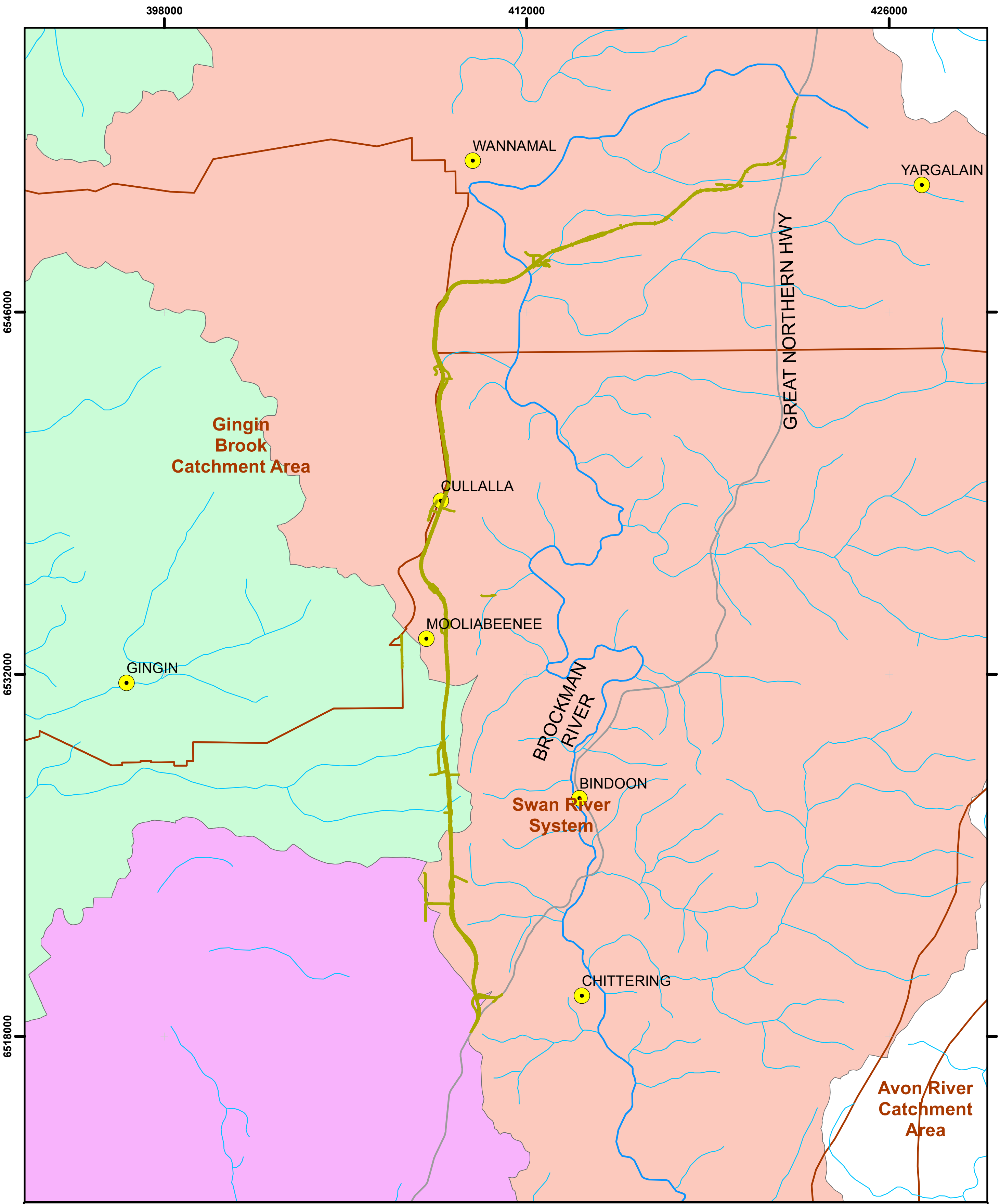
Arup Pty Ltd
Level 14 Exchange Tower
2 The Esplanade
Perth WA 6000
Tel +61 8 9327 8300 Fax +61 8 9481 1334
www.arup.com

Jacobs Group (Australia) Pty Ltd
Durack Centre, 263 Adelaide Terrace
Perth WA 6000
Tel +61 8 9469 4400 Fax +61 8 9469 4488
www.jacobs.com

Client: Main Roads Western Australia

Project: Great Northern Highway Muchea to Wubin Upgrade Stage 2

Figure A.1: Proposed Road Alignment and Surface Water Catchments



LEGEND

- Proposed Bypass Alignment
- Local Towns
- Major Highway
- Major Watercourse
- RIWI Act Surface Water Areas

Surface Water Catchments

- Brockman River
- Ellen Brook
- Gingin Brook

0 2,500 5,000

Metres

Coordinate System: GDA 1994 MGA Zone 50

Joint Venture Partners:

Arup Pty Ltd
Level 14 Exchange Tower
2 The Esplanade
Perth WA 6000
Tel +61 8 9327 8300 Fax +61 8 9481 1334
www.arup.com

Jacobs Group (Australia) Pty Ltd
Durack Centre, 263 Adelaide Terrace
Perth WA 6000
Tel +61 8 9469 4400 Fax +61 8 9469 4488
www.jacobs.com

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Figure A. 2: RIWI Act Proclaimed Surface Water Areas

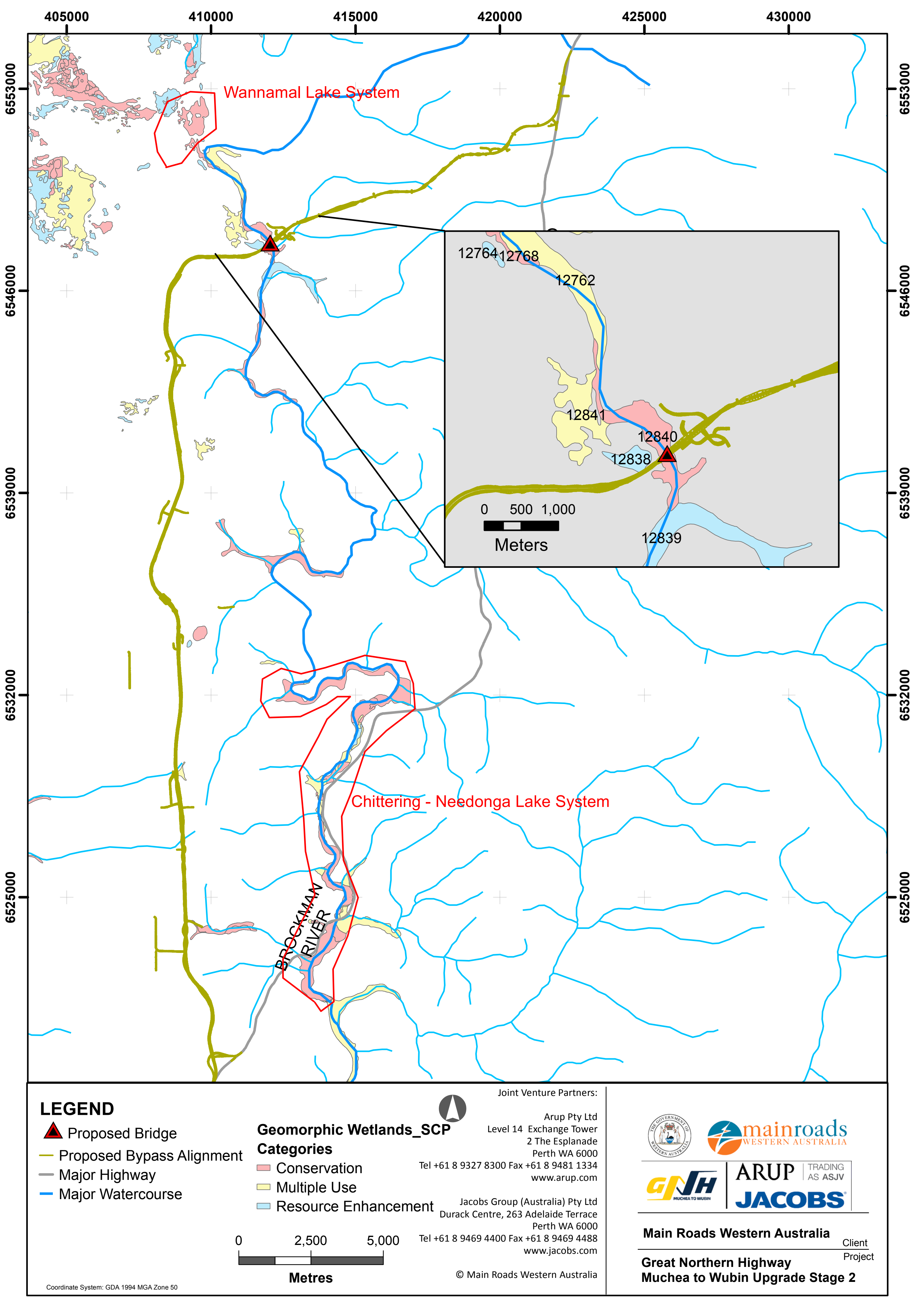
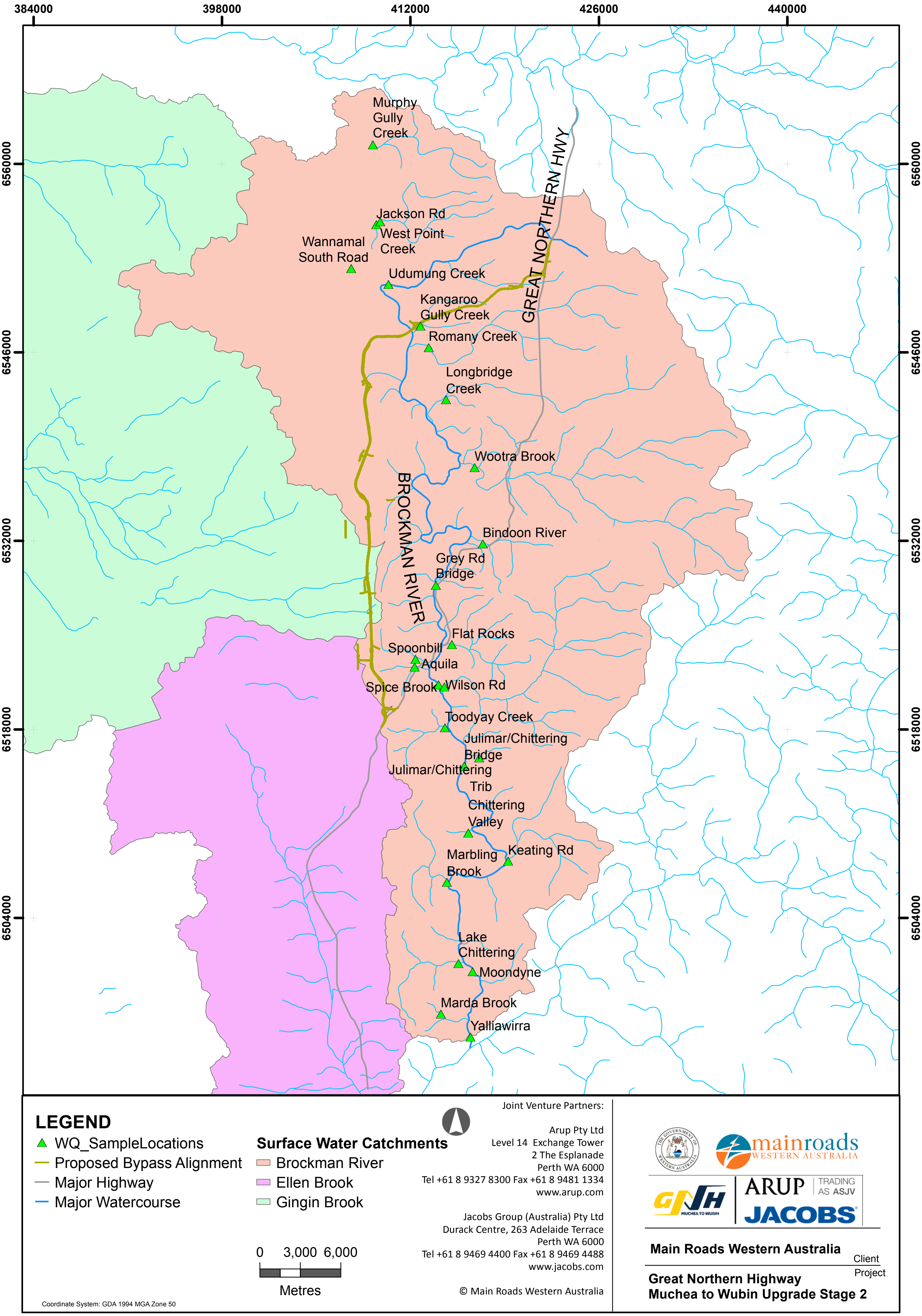


Figure A.3: Wetlands located within the vicinity of the project. Different management category of wetland is provided in inset.



Joint Venture Partners:

Arup Pty Ltd
Level 14 Exchange Tower
2 The Esplanade
Perth WA 6000
Tel +61 8 9327 8300 Fax +61 8 9481 1334
www.arup.com

Jacobs Group (Australia) Pty Ltd
Durack Centre, 263 Adelaide Terrace
Perth WA 6000
Tel +61 8 9469 4400 Fax +61 8 9469 4488
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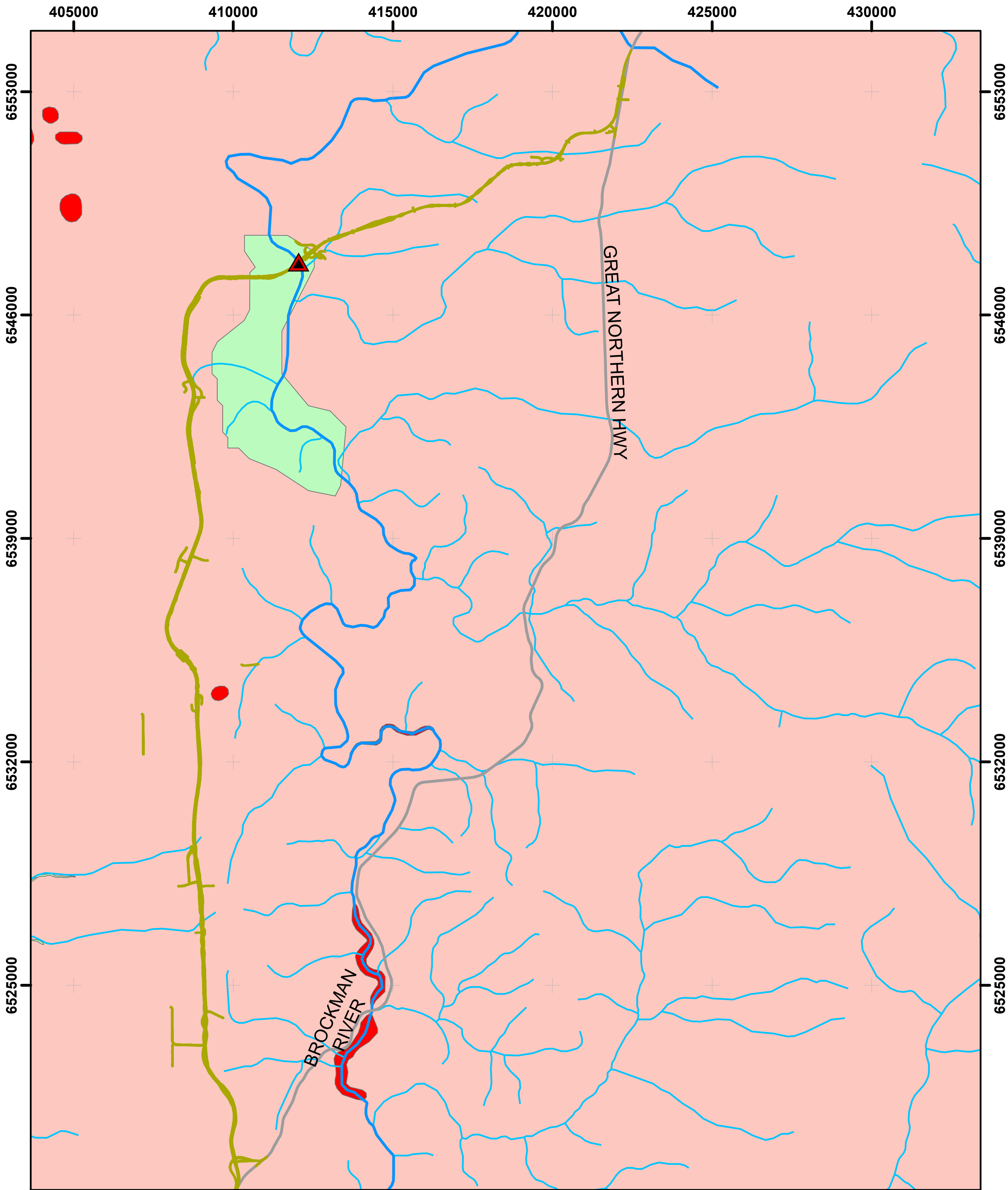
Figure A.4: Water Quality Sample Locations within the Brockman River Catchment (EBICG, 2015)



LEGEND

Australian Atlas of Acid Sulfate Soils Probability of Occurence

- A: High Probability; > 70 % chance
- B: Low; 6 - 70 % chance
- C: Extremely low; 1- 5 % chance
- Proposed Bridge
- Proposed Bypass Alignment
- Major Highway
- Major Watercourse

0 2,500 5,000

Metres

Coordinate System: GDA 1994 MGA Zone 50

Joint Venture Partners:

Arup Pty Ltd
Level 14 Exchange Tower
2 The Esplanade
Perth WA 6000
Tel +61 8 9327 8300 Fax +61 8 9481 1334
www.arup.com

Jacobs Group (Australia) Pty Ltd
Durack Centre, 263 Adelaide Terrace
Perth WA 6000
Tel +61 8 9469 4400 Fax +61 8 9469 4488
www.jacobs.com

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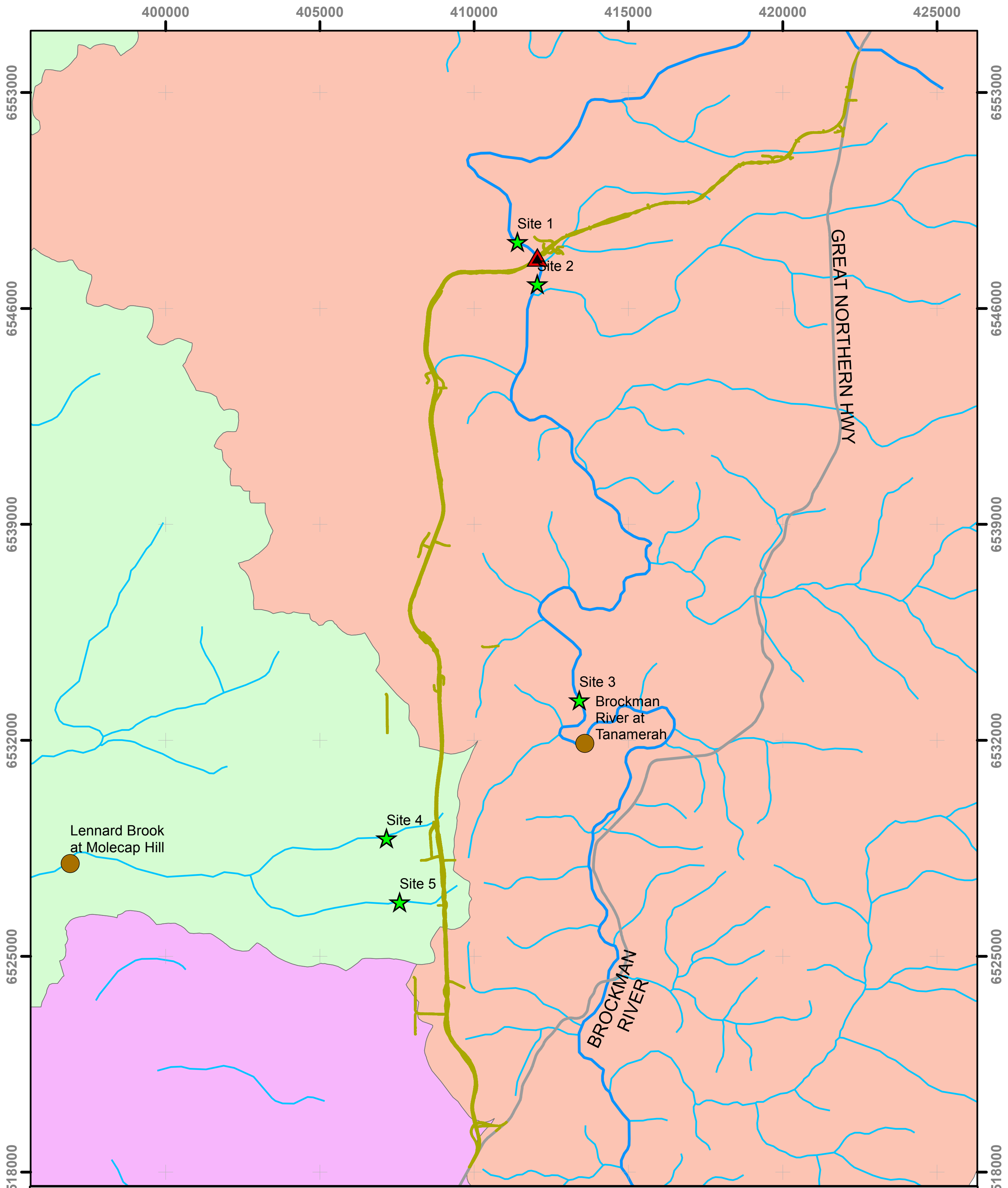
Figure A.5: Acid Sulfate Soils and their probability of occurrence



LEGEND

- Proposed Monitoring Sites
- FLow Gauging Stations
- Proposed Bridge
- Proposed Bypass Alignment
- Major Highway
- Major Watercourse

Surface Water Catchments

- Brockman River
- Ellen Brook
- Gingin Brook

0 2,500 5,000

Metres

Coordinate System: GDA 1994 MGA Zone 50

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Figure A.6: Proposed water quality monitoring sites