Transport
for NSW

NSW GOVERNMENT

Technical Paper 10

Hydrology, Flooding and Water Quality Assessment

Parramatta Light Rail Stage 2
Environmental Impact Statement

Issue and Revision Record

Revision	Date	Description
Final	28/10/2022	Final for exhibition

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ABBREVIATIONS AND ACRONYMS

Acronym	Description
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AIP	Aquifer Interference Policy
ANZECC	Australia and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASS	Acid sulfate soils
BGL	Below Ground Level
BoM	Bureau of Meteorology
BTOC	Below Top of Casing
CCIMP	Construction Coastal Impacts Management Plan
CEMP	Construction Environmental Management Plan
CHA	Coastal Hazard Assessment
CZMP	Coastal Zone Management Plan
DECCW	Department of Environment, Climate Change and Water
DEM	Digital Elevation Model
DO	Dissolved oxygen
DPE	Department of Planning and Environment
DPI	Department of Primary Industries
ECL	East Coast Lows
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EMPLAN	Parramatta Local Emergency Management Plan
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPA	Environment Protection Authority
EPL	Environment Protection Licence
EY	Exceedances per year
ESCMP	Erosion and Sediment Control Management Plan
FFA	Flood Frequency Analysis
FM Act	*Fisheries Management Act 1993* (NSW)
FMO	Flooding Management Objective

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Acronym	Description
FPL	Flood Planning Level
FRP	Filterable reactive phosphorus
GDE	Groundwater Dependant Ecosystems
GPOP	Greater Parramatta and the Olympic Peninsula
GPT	Gross Pollutant Trap
IFD	Intensity Frequency Duration
IPCC	Intergovernmental Panel on Climate Change
LEP	Local Environment Plan
LGA	Local Government Area
mAHD	Metres relative to the Australian Height Datum
mbgl	Metres below ground level
mg/L	Milligrams per litre
ml/yr	Megalitres per year
mm	millimetres
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NOx	Oxides of nitrogen
NOW	NSW Office of Water
NPWS	National Parks and Wildlife Service
NQWMS	National Water Quality Management Strategy
NSW	New South Wales
NTU	Nephelometric Turbidity Units
OEH	NSW Office of Environment and Heritage
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RMS	Roads and Maritime Services
PREMC	Parramatta River Estuary Management Committee
RCP	Representative Concentration Pathway
SDG	Sustainable Design Guidelines
SEARs	Secretary's environmental assessment requirements
SEPP	State Environmental Planning Policy
SES	NSW State Emergency Service
SLR	Sea Level Rise
SOPA	Sydney Olympic Park Authority
SSD	State Significant Development

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Acronym	Description
SSI	State Significant Infrastructure
SSTV	Site Specific Trigger Values
SWMP	Soil and Water Management Plan
TN	Total nitrogen
TP	Total phosphorus
TPH	Total Petroleum Hydrocarbons
TRH	Total Recoverable Hydrocarbons
TSS	Total suspended solids
µg/L	Microgram/litre
µS/cm	MicroSiemens per centimetre
VOC	Volatile Organic Compounds
WM Act	*Water Management Act 2000* (NSW)
WQO	Water Quality Objective
WSP	Water Sharing Plan
WSUD	Water Sensitive Urban Design

Glossary

Term	Description
Acid Sulfate Soil	Soils or sediments that contain iron sulfides that, when disturbed and exposed to oxygen, generate sulfuric acid and toxic quantities of aluminium and other heavy metals.
Annual Exceedance Probability	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study Annual Exceedance Probability (AEP) has been used consistently to define the probability of occurrence of flooding. The following relationships between AEP and Annual Recurrence Interval (ARI) applies to this study (Ball *et al*, 2019). EY refers to 'Exceedances per year' and applies to flood events that would be expecting very frequently within one year.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.50
	1	63.2	1.58	1.00
Frequent	0.69	50.00	2	1.44
	0.5	39.35	2.54	2.00
	0.22	20.00	5	4.48
	0.2	18.13	5.52	5.00
Infrequent	0.11	10.00	10.00	9.49
	0.05	5.00	20	20.0
	0.02	2.00	50	50.0
	0.01	1.00	100	100
Rare	0.005	0.50	200	200
	0.002	0.20	500	500
	0.001	0.10	1000	1000
Extremely Rare	0.0005	0.05	2000	2000
	0.0002	0.02	5000	5000
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Extreme			PMP	

Term	Description
AS 5100	AS 5100 *Bridge Design* was adopted for the design of bridges and related structures on the classified road network in NSW on 7 May 2004
Australian Rainfall and Runoff	Australian Rainfall and Runoff is a national guideline document used for the estimation of design flood characteristics in Australia. Reference is made to either ARR1987 (3rd edition) or ARR2019 (4th edition) as specified
Average Recurrence Interval	The long-term average number of years between the occurrences of a flood as big as or larger than the selected flood event. For example, floods with a discharge as great as or greater than the 20-year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. Also refer to Average Exceedance Probability (AEP), which is the industry standard terminology for definition of design flood events.

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Term	Description
Blue Book	*Managing Urban Stormwater: Soils and Construction* (Landcom 2004) which provides guidance on the design, construction and implementation of measures to improve stormwater management, primary erosion and sediment control during the construction phase of urban development
catchment	The land area draining through the mainstream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
DRAINS	The DRAINS program typically performs design and analysis calculations for urban stormwater systems and models the flood behaviour on both rural and urban catchments. The user data inputs required by DRAINS include catchment areas, flow path lengths, time of concentration, pervious and impervious areas, IFD rainfall intensities and flow path roughness. Modelling is performed through the development of a network of pipes, pits, overland flows and nodes to represent both the proposed and existing scenarios on site.
ERSED	Erosion and Sediment
facility	Project construction facilities include construction compounds and laydown areas.
flood planning level	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.
GPOP	Greater Parramatta and the Olympic Peninsula
Guideline (water quality)	Numerical concentration limit or narrative statement recommended to support and maintain a designated water use
hydrology	The study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
IECA	International Erosion Control Association
MUSIC	The model for urban stormwater improvement conceptualisation is a decision support system for simulating the performance of stormwater management measures. MUSIC is owned and distributed by the eWater Cooperative Research Centre (CRC) through the eWater Toolkit.
Probable Maximum Flood	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation (PMP) coupled with the worst flood producing catchment conditions. The PMF defines the extent of flood prone land, that is, the floodplain.
project alignment	The project alignment refers to the physical horizontal and vertical location, position and direction of the light rail tracks.
project site	The project site refers to the area that would be directly disturbed by construction of the project (for example, as a result of ground disturbance and the construction of foundations for structures). It includes the location of construction activities, compounds and work sites, and the location of permanent infrastructure.
the project	The project (for which Transport is seeking approval) is the construction and operation of Stage 2 of Parramatta Light Rail.

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Term	Description
Transport for NSW	Transport for NSW is the lead agency of the NSW Transport cluster.
Triangulated irregular network	Triangulated irregular networks are a means of digital representation of three-dimensional surface by triangulating a set of points or vertices. Connecting the vertices together forms a network of triangles in this case representing either the existing situation or a proposed design scenario. The data points are sourced from field recorded spot elevations through a variety of means including conventional surveying and remote sensing techniques. Generally, this will be referred to throughout this report as a modelled surface topography.
tributary	River or stream flowing into a larger river or lake
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.
water year	The Australian water year, also known as a hydrological year, is a period of 12 months starting from1 July and finishing 30 June.
wetland	Land either permanently or temporarily covered by water. These areas are usually characterised by vegetation of a moist soil or aquatic type

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Executive summary

Parramatta Light Rail will deliver an integrated light rail service that supports the population and employment growth expected throughout the Greater Parramatta and the Olympic Peninsula area (GPOP). It will integrate with existing and future modes of transport, including buses, trains, ferries and active transport (pedestrian and cycle networks), as well as Sydney Metro West services and the existing road network.

Parramatta Light Rail will be delivered in stages to keep pace with development. The construction and operation of Parramatta Light Rail Stage 1 was approved by the NSW Minister for Planning in May 2018; major construction is underway, with the track installation complete and light rail stop construction in progress. Stage 1 is expected to start operating in 2024. Transport for NSW is now proposing to construct and operate Stage 2 of Parramatta Light Rail (hereafter referred to as “the project”).

The project comprises two main elements:

- construction of around 10 kilometres of light rail infrastructure between Camellia and the Carter Street precinct adjacent to Sydney Olympic Park
- operation of about 13 kilometres of light rail alignment between the Parramatta CBD and the Carter Street precinct, including a section of infrastructure constructed by Parramatta Light Rail Stage 1 between Camellia and the Parramatta CBD.

The project is subject to assessment by the Department of Planning and Environment and approval by the Minister for Planning under Division 5.2 of the (NSW) *Environmental Planning and Assessment Act 1979* (EP&A Act).

The project is also determined to be a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) and requires approval from the Australian Minister for the Environment and Water.

This hydrology, flooding and water quality technical paper is one of several technical papers that form part of the environmental impact statement (EIS) for this project. The purpose of this technical paper is to identify and assess the potential impacts of this project in relation to hydrology, flooding and water quality during construction and operation. In doing so, it responds directly to the Secretary’s Environmental Assessment Requirements (SEARs) outlined in Section 1.3.

Objectives

The objectives of this technical paper are to:

- characterise existing flooding behaviour and identify flood risks during construction and operation of the light rail and associated facilities
- assess hydrology, flooding and water quality impacts on surface and groundwater which could occur as a consequence of this project
- identify mitigation measures for this project
- undertake an assessment of the potential cumulative impacts of this project with other proposed developments in the area.

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Assessment methodology

Hydrology and flooding assessment

The hydrology and flooding assessment undertaken and documented in this technical paper includes the following steps:

- evaluate available historic catchment information
- develop suitable Flood Management Objectives (FMO) to guide the assessment and management of flood-related matters associated with the project
- develop models with the latest available data that is consistent with relevant best practice guidelines. Form a baseline for assessment of impacts and amend baseline models to reflect the proposed operation scenario
- review the potential impacts associated with the project against the agreed FMOs and prepare appropriate mitigation measures to minimise these impacts.

Groundwater assessment

A desktop study evaluated the existing hydrogeological conditions of the project site and its locality by identifying the existing geology, aquifers, surface conditions, soils and fill covers. This was supplemented with available borehole data and core log information, vegetation, project details and any other factors considered relevant to identifying potential risks associated with the construction activities and operation of the project.

An analytical modelling approach was adopted based on methods to determine groundwater seepage from aquifers into project excavations.

Mitigation measures have been recommended to minimise impacts to groundwater.

Surface water assessment

The surface water assessment undertaken and documented in this technical paper includes the following steps:

- evaluate the existing catchment environment, water quality, water users, identification of environmental values and project-specific water quality objectives
- identify potential construction and operational water quality impacts
- identify appropriate mitigation measures to minimise impacts and protect water quality.

Existing conditions

Catchment context

The project site is wholly located within the Parramatta River Catchment. The Parramatta River Catchment covers a large area of Western Sydney, approximately 252.4 square kilometres, and spanning over several local government areas (LGAs) before discharging into Sydney Harbour at the confluence of Lane Cove River.

The qualities of the existing environment have been outlined, including the catchment topography and drainage near the study area, the climate and rainfall of the area, existing water quality conditions the conditions and considerations for the receiving waterways and the associated treatment approach.

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Hydrology and flooding

Sections of the project site are located on the floodplain of the Parramatta River and are subject to mainstream and overland flooding. Mainstream flooding results from the Parramatta River and its tributaries, including Haslams Creek. Overland flooding results from overflows from stormwater systems which were typically designed and constructed to convey rainfall runoff for frequent storm events.

The flooded extent of the Parramatta River floodplain is largely limited to the river and open spaces up to the one per cent annual exceedance probability (AEP) flood event. In larger events there is further inundation of properties beyond the limits of open space, and large portions of Camellia become inundated.

Groundwater

The project's EIS Chapter 18 (Soils and contamination) identified the potential presence of contamination in groundwater, with the main contaminants of concern being (but not limited to) hexavalent chromium, petroleum hydrocarbons, chlorinated hydrocarbons, copper, nickel and zinc in Rydalmere, Ermington Melrose Park and Camellia.

The recorded groundwater levels vary between 0.54 and 3.34 metres below ground level. The shallow water levels are mostly encountered in areas adjacent to the Parramatta River, at the proposed road crossing at Boronia Street, and at the proposed new bridge across the low lying part of the Ken Newman Park. Most of the geotechnical boreholes drilled in other parts of the project site did not encounter water.

Surface water

Water quality within the study area appears to be improving in recent years as a result of management undertaken by the Parramatta River Catchment Group, however wastewater overflows and stormwater continue to contribute to poor water quality conditions in the Parramatta River (City of Parramatta Council, 2016). Data obtained from the City of Parramatta Council water quality monitoring program (2012-2016) and Parramatta Light Rail Stage 1 pre-construction water sampling (2019-2020) has provided the baseline water quality in the vicinity of the project site.

When compared with the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018), the two combined sets of monitoring results showed chlorophyll-a, electrical conductivity, pH, dissolved oxygen, turbidity, aluminium, copper, manganese and iron levels exceeding the water quality trigger values for these parameters, during both wet and dry weather events.

Potential impacts – construction

Surface hydrology

Most construction activity is contained within existing road reserves, with additional areas required for bridge and bridge approach construction, and construction compounds. Construction compound areas are typically on higher ground within the context of the local topography. This is to improve the access and functionality of the construction site during periods of inclement weather, but also serves to reduce the incidence of impacts to surface water flow and mitigate risks should a spill occur within the compound site.

Changes in runoff volumes are anticipated to be minor due to the small footprint of disturbed land required for construction, and the like-for-like replacement of road pavement with provision for the light rail, resulting in the existing flow regimes being largely maintained.

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Groundwater

Due to the presence of shallow contaminated groundwater near the Parramatta River, extraction of groundwater during excavation could result in contamination of the receiving surface waterways if the groundwater is not treated adequately prior to discharging into surface waterways. There is also the potential for construction workers to either ingest or have contact with contaminated groundwater during excavation activities. If encountered at construction sites, groundwater would be managed in accordance with the *Transport for NSW Water Discharge and Reuse Guideline* (Transport for NSW, 2015). In addition, there is potential across the project site for increased migration of contaminants (where present) into surrounding areas via leaching, overland flow and/or subsurface flow (water and/or vapour) or dust, with the potential to impact on receiving environments, nearby watercourses and the surrounding community.

Flooding

Consideration of flood risk and potential flood impact during construction activities was carried out for construction compounds, light rail alignment, road adjustments and bridge construction and modification.

Flooding during construction activities has the potential to result in delays to construction and damage to plant and materials. It may also pose a safety risk to construction personnel.

There is potential for a change in flood behaviour as a result of changes to site topography and installation of temporary buildings and other structures within the floodplain.

Water quality

Construction of the bridges between Camellia and Rydalmere and between Melrose Park and Wentworth Point would involve works on the banks of, and within, the Parramatta River. The bridge construction activities likely to have the greatest potential impact on receiving waterways would include:

- establishing temporary work platforms on the northern and southern banks of the Parramatta River to provide access to piers located within the river
- constructing the bridge piers from the temporary work platforms
- constructing bridge abutments on the northern and southern banks of the river using reinforced earth construction on piles
- installing precast bridge segments from the temporary work platforms, barges or banks using cranes.

Without mitigation activities, there is a potential for water quality impacts from all construction activities, both in-river and out of river, to further degrade water quality. In terms of impact, construction activities have the potential to adversely impact downstream waterways through release of sediment, pollution, hazardous materials and/or construction materials from the construction site. Surface waters at most risk are those in close proximity to site compounds, track works, road works, excavation sites, spoil placement, vegetation removal, worksites and other locations where significant earthworks might occur, including the construction and removal of built features.

Soil and water mitigation and management measures would be implemented at all construction sites and would minimise contaminant discharge to receiving waterways at out of river construction sites and would limit the impact of in-river construction sites.

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Potential impacts – operation

Surface hydrology

Typical impacts would include changes to the frequency and level of inundation from flooding as a result of the bridge structures. The relatively short period of inundation from mainstream flood flows triggered by storms in the Parramatta River catchment mean impacts are short term experienced during the peak of major flood events. As a result, these impacts are expected to be highly localised and would not result in any significant impacts to these areas.

Groundwater

During operation, the nominal seepage into the Boronia Street cutting would be the only groundwater take. Given the nominal seepage, it is considered that the stormwater drainage system proposed as part of the project would appropriately manage this flow.

Impacts to groundwater quality are also considered unlikely during operation, as maintenance activities would be unlikely to involve excavation at depths where there is the potential to encounter groundwater. Additionally, all maintenance activities would be undertaken in accordance with standard operating procedures, limiting the potential for leaks and spills that could impact groundwater quality.

Flooding

During operation, typical impacts include an increase in flood levels caused by blockages to existing flood flow paths, an increase in flood water velocity at proposed drainage outlets or an increase in flood hazard where flood water velocity or depth has been increased. Mitigation of these impacts has been achieved either by localised re-grading of ground levels or additional cross culverts and drainage to prevent flow paths becoming blocked.

The two new bridges increase flood levels at properties which are already impacted by flooding, including foreshore properties. In-stream structures may promote channel scouring resulting in further increase of erosion and impact on mangroves and interference with natural flow regimes. Channel migration may change the position of the low flow path and localised changes to the bed and instream habitat may occur.

Drainage system upgrades would increase the capacity of the local storm water system and reduce potential impacts to adjacent properties during flood events. Proposed light rail stops may alter localised flood behaviour by introducing increased hardstand areas and flow path obstructions.

Surface water quality

During operation, the project has the potential to impact and degrade the water quality of receiving waterways through the discharge of polluted water flows or airborne contaminants. Pollutants during the operational phase include:

- suspended and dissolved compounds in rainwater flows from impervious areas
- gross pollutants such as litter from light rail stops and ancillary facilities
- chemical pollutants (e.g. oils, grease and total petroleum hydrocarbons (TPH) from use and transfer of fuels) from light rail vehicles and other vehicles along the line.

The most likely source of pollutants would be the concentrated flows resulting from newly impervious surfaces such as roofs and paved areas, generally associated with light rail stops, which can cause impacts to water quality of receiving waterways through increased pollutant loading and runoff volumes. Maintenance activities have the potential to generate chemical pollutants, particularly at ancillary facilities. However, these activities would be limited to the Camellia stabling and maintenance facility and works would be undertaken in accordance with standard operating procedures.

Overall, the project is anticipated to contribute to a reduction in contaminant sources from current road operations (brake dust, motor oil etc. from buses and light motor vehicles) through the anticipated reduction in light motor vehicle traffic.

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Proposed management and mitigation measures

Mitigation and management measures are proposed, where appropriate, to limit the flooding, hydrology and water quality impacts of this project on surrounding properties and the environment.

Localised changes to overland flows associated with the project are generally limited in their scale to the immediate vicinity of the project site. Potential flooding and stormwater impacts during construction and operation have been addressed by the inclusion of mitigation measures. Such measures would include design refinement to achieve the flood management objectives.

Management plans would be prepared and implemented to minimise water quality impacts during construction, such as spill containment and erosion and sediment controls. The location and specification of proposed water quality treatment devices such as Gross Pollutant Traps, sediment basins or biofiltration swales and other Water Sensitive Urban Design treatment measures would be considered in the drainage design and implemented, where reasonable and feasible. A baseline and ongoing water quality monitoring program is proposed to ensure ongoing compliance with the project-specific water quality objectives.

In terms of residual operational impacts, negligible increases to flood depths along key roads are predicted in both the one per cent annual exceedance probability and probable maximum flood events, though some of these areas are already predicted to be substantially flooded under existing conditions.

Application of appropriate design standards and industry best practice, as well as mitigation measures throughout the life of the construction and operation of the project would minimise impacts to the receiving waterbodies around this project.

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1 Introduction

1.1 Parramatta Light Rail

The NSW Government's Greater Sydney Region Plan *A Metropolis of Three Cities* (Greater Sydney Commission, 2018) outlines a vision for a three-city metropolis. The Central River City covers the four local government areas of the City of Parramatta, Blacktown City, Cumberland City and The Hills Shire. *A Metropolis of Three Cities* highlights Greater Parramatta as the focal point for the Central River City, with employment growth and public transport being of key importance.

The Greater Parramatta and the Olympic Peninsula area (GPOP), which extends from Westmead and Parramatta in the west to Sydney Olympic Park to the east, is fast emerging as the heart of Sydney's Central River City and is set to grow and change significantly over the next 20 years. Forecasts predict that GPOP will accommodate almost 170,000 new residents by 2041. Employment opportunities will also grow, with an additional 100,000 jobs predicted by 2041 (SGS, 2017).

Parramatta Light Rail will deliver an integrated light rail service that supports the population and employment growth expected throughout GPOP. It will integrate with existing and future modes of transport, including buses, trains, ferries and active transport (pedestrian and cycle networks), as well as Sydney Metro West services and the existing road network.

Parramatta Light Rail will be delivered in stages to keep pace with development:

- Stage 1 will connect Westmead to Carlingford via the Parramatta central business district (CBD) and Camellia. The construction and operation of Parramatta Light Rail Stage 1 was approved by the NSW Minister for Planning in May 2018. Major construction is underway, with the track installation complete and light rail stop construction in progress. Stage 1 is expected to start operating in 2024. Further information on Stage 1 is available at Parramatta Light Rail
- Transport for NSW is now proposing to construct and operate Stage 2 of Parramatta Light Rail ('the project'). Stage 2 would connect the Parramatta CBD and Stage 1 to Camellia, Rydalmere, Ermington, Melrose Park, Wentworth Point and Sydney Olympic Park.

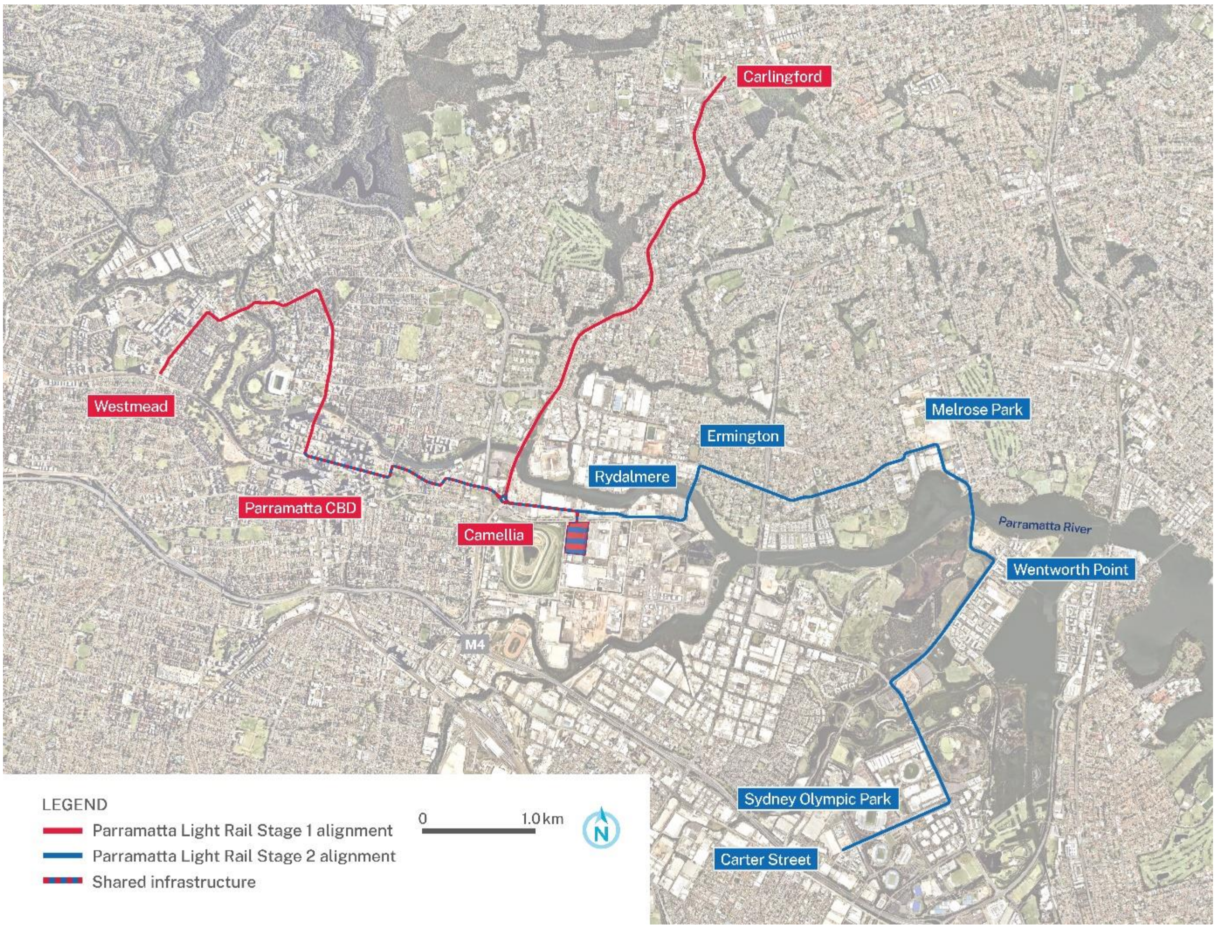

Figure 1-1 Parramatta Light Rail network

1.2 Project overview

The project comprises two main elements:

- construction of about 10 kilometres of light rail infrastructure between Camellia and the Carter Street precinct adjacent to Sydney Olympic Park.
- operation of about 13 kilometres of light rail alignment between the Parramatta CBD and the Carter Street precinct, including a section of infrastructure constructed by Parramatta Light Rail Stage 1 between Camellia and the Parramatta CBD.

Further information on the location of the project, and a description of the project site for the purposes of this document, is provided in the environmental impact statement (EIS).

1.2.1 Key features

The key features of the project, which are shown on Figure 1-2, include:

Light rail track and bridges

- a new 10 kilometre long dual light rail track, with 14 stops, between the Parramatta Light Rail Stage 1 line in Camellia and the Carter Street precinct adjacent to Sydney Olympic Park
- two bridges over the Parramatta River between Camellia and Rydalmere, and between Melrose Park and Wentworth Point
- a bridge over Silverwater Road between Rydalmere and Ermington
- other bridge works in Ken Newman Park and Sydney Olympic Park.

Active and public transport integration

The project would also deliver:

- about 8.5 kilometres of new active transport links between Camellia and the Carter Street precinct, which would connect with the existing cycling and pedestrian network
- interchanges with other forms of public transport, including trains, ferries, buses and Sydney Metro West, with the main interchanges located in the Parramatta CBD, Rydalmere and Sydney Olympic Park
- a light rail and pedestrian zone (no through vehicle access) within Sydney Olympic Park along Dawn Fraser Avenue between Australia Avenue and Olympic Boulevard
- bus access over the proposed bridge between Melrose Park and Wentworth Point.

Other works

Works proposed to support the project's operation:

- turnback facilities, including along part of Macquarie Street in the Parramatta CBD
- adjustments to the Parramatta Light Rail Stage 1 stabling and maintenance facility at Camellia
- five new traction power substations to convert electricity to a form suitable for use by light rail vehicles
- new and improved open spaces and recreation facilities at Ken Newman Park, the Atkins Road stop and Archer Park.

Further information on the project's design features is provided in the EIS (see Chapter 6 (Project description – infrastructure and operation)).

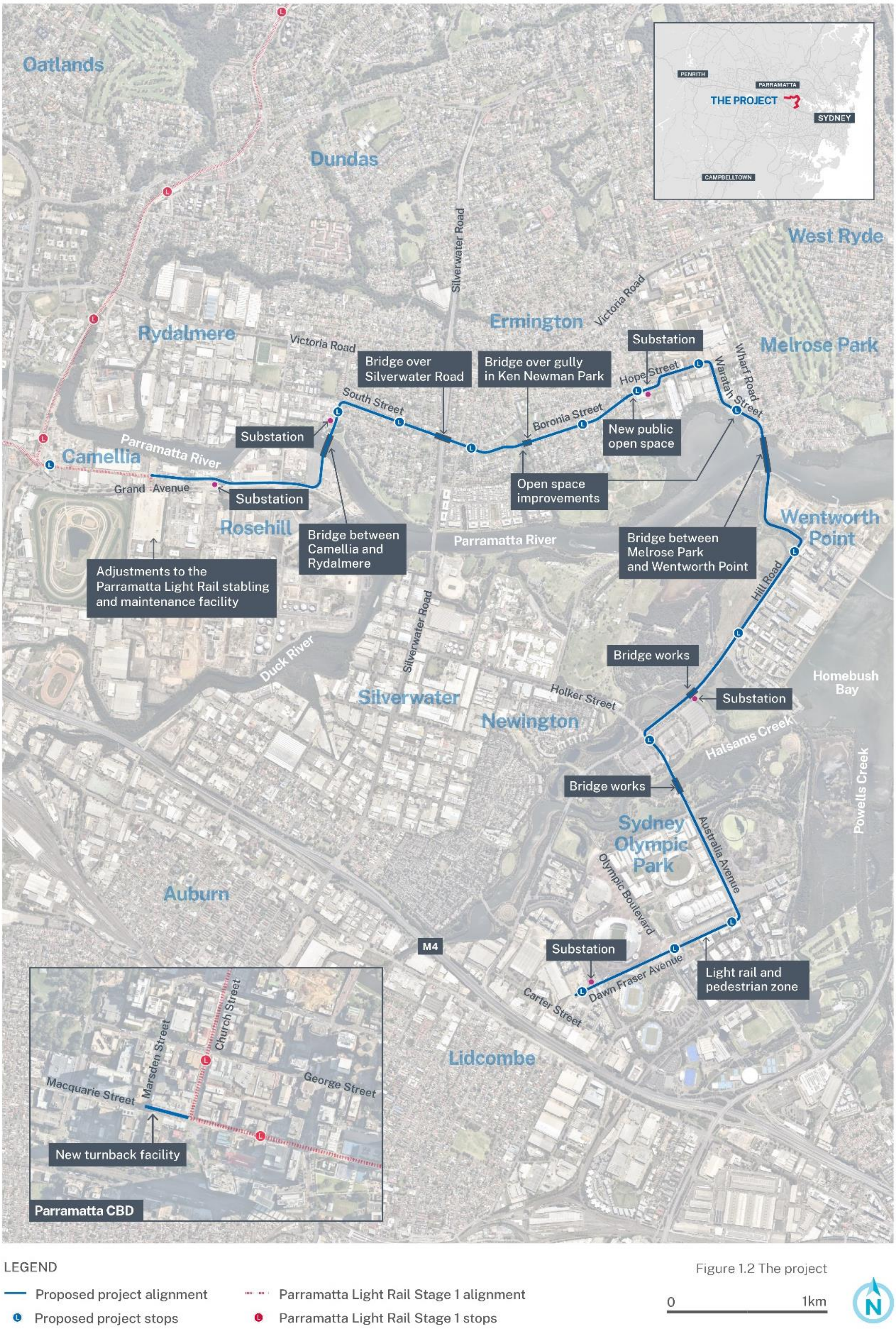

Figure 1-2 Key features of the project

1.2.2 Operation

The project would operate between the Parramatta CBD and the Carter Street precinct, using a section of the Parramatta Light Rail Stage 1 alignment and the alignment constructed as part of the project.

Between the Parramatta CBD and Camellia, the project would operate along about three kilometres of the Parramatta Light Rail Stage 1 alignment. Parramatta Light Rail Stage 2 services would terminate at the Stage 1 Parramatta Square stop to allow customers direct and convenient access to Parramatta's CBD, and interchange with Stage 1 light rail services, trains, buses and Sydney Metro West.

From Camellia, the project would operate along the light rail infrastructure proposed as part of Stage 2, terminating at the proposed Carter Street stop.

The project would operate as a turn-up-and-go light rail service from 5am to 1am, seven days a week, as for Parramatta Light Rail Stage 1. The project would have travel times of around 31 minutes from the Carter Street stop in Lidcombe to the proposed Sandown Boulevard stop in Camellia, and a further seven minutes to the Parramatta Square stop in the Parramatta CBD.

Further information on the project's operation is provided in the EIS (see Chapter 6 (Project description – infrastructure and operation)).

1.2.3 Timing

It is anticipated that construction would start in 2025, subject to obtaining all necessary approvals, and the first passenger services are proposed to start from 2030/31.

An indicative construction methodology is provided in the EIS (see Chapter 7 (Project description – construction)).

1.2.4 Approval requirements

The project is State significant infrastructure and is subject to approval by the NSW Minister for Planning under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act).

The project is also determined to be a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) and requires approval from the Australian Minister for the Environment and Water.

1.3 Purpose and scope of this report

The EIS has been prepared to support an application for approval of the project in accordance with Division 5.2 of the EP&A Act. It addresses the environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs).

This report has been prepared as part of the EIS to assess the potential hydrology, flooding and water quality impacts from constructing and operating the project. The report:

- addresses the relevant SEARs listed in Table 1-1
- describes the existing environment with respect to hydrology, flooding and water quality
- assesses the impacts of constructing and operating the project on hydrology, flooding and water quality
- recommends measures to mitigate and manage the impacts identified.

The methodology for the assessment is described in Chapter 3.

The main issues and desired performance outcomes for the project's water quality, flooding and hydrology would include:

- minimisation of the long-term impacts on water quality, hydrology and flooding (including drawdown, flow rates and volumes)
- maintaining or improving the environmental values of nearby connected and affected water sources, groundwater and dependent ecological systems including estuarine and if applicable, marine water.
- the sustainable use of water resources.

Further information regarding the project's potential to encounter contamination, including the presence of existing contamination management systems, is provided in the EIS Chapter 18 (Soils and contamination).

Table 1-1 SEARs addressed in this report

SEARs Ref #	Requirement	Where addressed in this paper
5	**Flooding**	
5.1	Changes to flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including:	Section 4.2 includes discussion on changes in flood behaviour for the following flood events: • 5% annual exceedance probability (AEP) • 1% AEP • Probable maximum flood (PMF) The assessment covers the present day scenarios and scenarios that account for climate change, sea level rise and an increase in storm intensity.
5.1 (a)	• any detrimental increases in the potential flood affectation of other properties, assets and infrastructure	Section 5.2.1 provides an assessment of flooding impacts during construction including from construction compounds, light rail alignment, roads and bridge construction. Section 5.2.2 provides an assessment of flooding impacts during operation, including finished design surface and bridge structure impacts.
5.1 (b)	• consistency (or inconsistency) with applicable Council floodplain risk management plans	Section 5.2.4 establishes the consistency of the study against applicable Council floodplain risk management plans.
5.1 (c)	• compatibility with the flood hazard of the land	Section 5.2.4 discusses compatibility with the flood hazard of the land. Appendix C1 contains maps showing the existing flood hazards in the study area.

SEARs Ref #	Requirement	Where addressed in this paper
5.1 (d)	• compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land	Section 5.2.1 provides an assessment of flooding impacts during construction including from construction compounds, light rail alignment, roads and bridge construction in relation to the hydraulic function of water ways and the land. Section 5.2.2 provides an assessment of flooding impacts during operation, including finished design surface and bridge structure impacts in the relation to the hydraulic function of waterways and the land.
5.1 (e)	• downstream velocity and scour potential	Changes in velocity and scour are described in Section 5.2 including Section 5.2.2 Flooding from local drainage systems.
5.1 (f)	• impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Services and Council	Section 3.3.4 outlines consultation process with stakeholders including councils and the NSW State Emergency Service.
5.1 (g)	• any impacts the development may have on the social and economic costs to the community as consequence of flooding	Section 5.2.3 outlines Social and economic costs to the community.
5.2	• Flood management objectives and outcomes must be clearly identified and substantiated to address the characteristics of the environment and relevant legislative, management and guidance requirements	Section 3.1.3 describes the project-specific flood management objectives (FMOs). Section 5.2.2 outlines the assessment against the FMOs.
10	**Water - Hydrology**	
10.1	• Describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the *Framework for Biodiversity Assessment* (OEH, 2018).	Chapter 4 describes the existing surface water, waterbodies and groundwater resources. This includes the stream order for watercourses in the study area (refer Section 1.1.1).

SEARs Ref #	Requirement	Where addressed in this paper
10.2	• Assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:-	Section 3.1.1 and Section 3.1.2 describe the methodology for the hydrology modelling assessment. Sections 5.3.1 describes construction impacts to surface hydrology including changes to flow volumes and impact on compounds. Sections 5.3.2 describes operation impacts to surface hydrology, including modelling outcomes and changes in annual runoff. Section 5.4 provides the groundwater impact assessment for construction and operation including impact on groundwater levels, flow and connectivity, and groundwater dependent ecosystems.
10.2 (a)	• natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), nutrient flow, aquatic connectivity and access to habitat for spawning and refuge	Section 3.3 describes the methodology adopted to assess the impacts to surface water quality associated with construction and operation. Sections 5.3 describes the potential (unmitigated) impacts from construction and operation of the project.
10.2 (b)	• impacts from any permanent and temporary interruption of groundwater flow	Section 3.2.2 describes the Analytical groundwater modelling method used to assess impacts from interruption of groundwater. Section 5.4 outlines the impact on groundwater levels, flow and connectivity and groundwater dependent ecosystems due to construction and operation.
10.2 (c)	• direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses	Sections 5.3.1 describes construction impacts on surface hydrology Section 5.3.2 describes operational impacts on surface hydrology including bridge structure impacts on erosion and operational impacts on riparian areas and riverbanks Further information regarding the impacts to riparian vegetation and aquatic habitats is provided in Technical Paper 9 (Biodiversity Development Assessment Report)

SEARs Ref #	Requirement	Where addressed in this paper
10.2 (d)	• changes to environmental water availability, both regulated /licensed and unrelated / rules-based sources of such water	Sections 5.3.1 describes construction impacts on surface hydrology and potential changes to environmental water availability Section 5.4 describes the project's impacts on groundwater including Section 5.4.1 outlining Impact on groundwater levels, flow and connectivity
10.2 (e)	• minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems	Section 5.3 describes the changes to flow volumes during construction and the change in annual runoff volumes during operation
10.3	• Identify any requirements for baseline monitoring of hydrological attributes	Section 4.1 describes the baseline hydrological assessment for the Parramatta River catchment with flood impacts described in Section 5.2.
11	• **Water - Quality** Water quality impacts, including:	
11.1 (a)	• stating the ambient NSW WQO and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values	Section 3.3.2 describes the NSW water quality objectives (WQOs) and environmental values for receiving waters. Section 4.9 describes the existing water quality and existing environmental values for the receiving waters.
11.1 (b)	• identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment	Section 4.1.2 outlines urban catchment breakdown in the study area. Section 4.9 describes existing water quality data in catchment and waterways within the study area. Section 6.2.1 discusses potential impacts to surface water runoff and runoff volumes by discharge point on the receiving environment.
11.1 (c)	• identify the rainfall event that the water quality protection measures will be designed to cope with	Section 6.2.1 outlines the rainfall event that the water quality protection measures will be designed to cope with.

SEARs Ref #	Requirement	Where addressed in this paper
11.1 (d)	• assess the significance of any identified impacts including consideration of the relevant environmental values and ambient water quality outcomes	Section 4.9 describes existing water quality data in catchment and waterways within the study area. Section 6.1 outlines Construction impacts related to water quality. Section 6.2 outlines Operational impacts related to water quality.
11.1 (e)	• demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: • where the NSW WQOs for receiving waters is currently being met, they will continue to be protected, and • where the NSW WQOs are not currently being met, activities will work toward their achievement over time	Section 6.2.1 describes how construction would, to the extent that the project can influence, ensure that where the NSW WQOs are not being met, activities will work towards their achievement. Section 6.2.1outlines proposed water treatment prior to stormwater water discharge into receiving waters to achieve WQOs.
11.1 (f)	justify, if required, why the WQOs cannot be maintained or achieved over time	Section 6.1.1 outlines impacts for the project against the water quality and river flow objectives.
11.1 (g)	demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented	Section 6.2.1 details the Proposed treatment prior to stormwater discharge. Table 8-1 outlines a summary of potential impacts and recommended management measures.
11.1 (h)	identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments	Section 4.9.8 describes sensitive receiving environments. Section 6.1 outlines Construction impacts. Section 6.2 outlines Operational impacts. Table 8-1 outlines recommended management measures that aim to minimise impacts on sensitive receiving environments.
11.1 (i)	identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality	Section 8.3 describes the proposed water quality monitoring program including indicative monitoring phasing, frequency, locations, and water quality parameters.

2 Relevant legislation and guidelines

This section presents the relevant legislative and policy context as it pertains to this hydrology, flooding and water quality assessment.

2.1 Commonwealth policy

2.1.1 National Water Quality Management Strategy

The *National Water Quality Management Strategy* (NWQMS) is the adopted national approach to protecting and improving water quality in Australia. It consists of a number of guideline documents, with specific documents relating to the protection of surface water and groundwater resources.

2.1.2 Guidelines for Groundwater Quality Protection in Australia (Australian Government, 2013)

This is the primary document relevant to the assessment of groundwater risks in the study area. This document sets out a high-level risk-based approach to protecting or improving groundwater quality for a range of groundwater beneficial uses (called environmental values). The beneficial uses are as follows:

- aquatic ecosystems, comprising the animals, plants and micro-organisms that live in water, and the physical and chemical environment and climatic conditions with which they interact
- primary industries, including irrigation and general water users, stock drinking water, aquaculture and human consumption of aquatic foods
- recreation and aesthetic values, including recreational activities such as swimming and boating, and the aesthetic appeal of water bodies
- drinking water, which is required to be safe to use and aesthetically pleasing
- industrial water, such as water used for industrial processes including cooling towers, process water or wash water
- cultural and spiritual values, which may relate to a range of uses and issues of a water source, particularly for indigenous people, including spiritual relationships, sacred sites, customary use, the plants and animals associated with water, drinking water or recreational activities.

2.1.3 The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) is a key guideline within the NWQMS that is used to identify catchment and waterway specific water quality management goals. These guidelines are an updated version of the previous guidelines, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000).

The ANZECC/ARMCANZ (2000) and ANZG (2018) guidelines provide a process for assessing existing water quality condition and developing water quality objectives to sustain current or likely future environmental values for water resources. Guideline trigger values for water quality indicators are provided for different environmental values as generic starting points for assessing water quality where site specific information is not available.

The guideline trigger values are used to evaluate the existing water quality conditions against long-term water quality goals. It should be noted that the trigger values have not been designed for direct application in activities such as discharge consents, recycled water quality or stormwater quality. These guideline trigger values are provided for various levels of protection of waterways which are considered when describing the existing water quality and key indicators of concern. The ANZG

(2018) guidelines provide updated databases to derive guideline values for toxicants and sediments in aquaculture and aquatic foods, physical and chemical stressors and for guideline values for agricultural water users. These databases and values have not been updated for all regions of Australia and in some regions, the values as used in the previous ANZECC 2000 guidelines still apply (including southeast coast inland water ecoregion).

The project environmental values, based on ANZG (2018) guideline trigger values for the selected toxicants, would be for the protection of 95 per cent of species in slightly disturbed to moderately disturbed systems. For physical and chemical stressors, the ANZG 2018 guidelines are the same as the ANZECC 2000 and provide guideline trigger values for slightly disturbed ecosystems in lowland rivers in south-east Australia, as shown in Table 2-1.

Table 2-1 ANZG 2018 guideline water quality trigger values for physical and chemical stressors for slightly disturbed estuarine ecosystems in south-east NSW

Parameter	Trigger Value or Criteria
Chlorophyll-a (µg/L)	4
Total Phosphorous (TP) (µg/L)	30
Filterable Reactive Phosphorus (FRP) (µg/L)	5
Total Nitrogen (TN) (µg/L)	300
Oxides of nitrogen (NOx) (µg/L)	15
Ammonia (NH4) (µg/L)	15
Dissolved Oxygen (DO)	80%-110%
Turbidity (NTU)	0.5 to 10
pH	7-8.5

2.2 NSW legislation

2.2.1 State Environmental Planning Policy (Resilience and Hazards) 2021

The State Environmental Planning Policy (Resilience and Hazards) 2021 consolidated and repealed the provisions of the SEPP (Coastal Management) 2018 on 1 March 2022. Section 2.2.1 of the Resilience and Hazards SEPP outlines coastal management areas. Chapter 2 of the Resilience and Hazards SEPP contains planning provisions from the Coastal Management SEPP for land use planning within the coastal zone consistent with the *Coastal Management Act 2016*.

The requirements of the *Coastal Management Act 2016* and the Resilience and Hazards SEPP, as relevant to the project, are described in the EIS Chapter 17 (Water).

2.2.2 Water Management Act 2000 and Water Act 1912

The Water Management Act 2000 (WM Act) and the *Water Act 1912* are pieces of legislation for the management of water in NSW and contain provisions for the licensing of water access and use. The WM Act and the *Water Act 1912* are administered by the NSW Department of Planning and Environment (Water) (DPE (Water)), with Water NSW as the regulator and DPE (Water) as the policy maker. The *Water Act 1912* is being progressively phased out and replaced by the WM Act. The applicability of this Act is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions.

The intent and objectives of the WM Act have been considered as part of this assessment. Provisions of the WM Act require the development of management plans to deal with flooding regimes and the way they are managed in relation to risks to property and life and to ecological impacts. The WM Act also defines approvals required for carrying out works situated near a river or floodplain via flood work approvals or drainage work approvals and has considered the *Guidelines for Controlled Activities on Waterfront Land* refer to Section 2.4.3.

2.2.3 Water sharing plans

Water sharing plans (WSPs) were established following the introduction of the *Water Management Act 2000* and provide the basis for equitable sharing of surface water and groundwater between water users, including the environment. If an activity leads to a take from a groundwater or surface water source covered by a WSP, then approval and/or a licence is required.

In December 2019 the NSW government introduced an exemption in the Water Management (General) Regulation 2018 that allows a small volume of groundwater to be taken through certain aquifer interference activities without the need for a water access licence. Exemption from needing a water access licence. Under the exemption, a person can take up to 3 megalitres of groundwater through an aquifer interference activity per authorised project per water year without needing to obtain a water access licence, provided: a) the water is not taken primarily for consumption or supply; and b) the person claiming the exemption keeps a record of the water taken under the exemption and provides this to the Minister within 28 days of the end of the water year; and c) the records are kept for 5 years.

It is also noted that Transport for NSW, as a transport authority, is exempt under Clause 18 (1) of the Water Management (General) Regulation 2011 from the requirement to hold an access licence.

Surface water sharing plan

The project site falls within the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011*. The relevant water source is the Northern Sydney Rivers Water Source.

Groundwater sharing plan

With respect to groundwater, the project lies within the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*. The relevant water source is the Sydney Basin Central Groundwater Source.

2.2.4 Protection of the Environment Operations Act 1997

Section 120 of the *Protection of the Environment Operations Act 1997* (POEO Act) prohibits the pollution of waters by any person. If a person is charged with the offence of pollution of waters, Section 122 of the POEO Act provides a defence if the pollution was regulated by an environment protection licence (EPL), and conditions of that licence were not breached in relation to the pollution of waters.

2.3 NSW policy

2.3.1 NSW Aquifer Interference Policy

The *NSW Aquifer Interference Policy* (AIP) (Office of Water, 2012) is a component of the *NSW Strategic Regional Land Use Policy* and was introduced in September 2012. The AIP defines the regime for protecting and managing impacts of aquifer interference activities on NSW's water resources and strikes a balance between the water needs of towns, farmers, industry and the environment. It clarifies the requirements for obtaining groundwater extraction licences and the assessment process under the *Water Management Act 2000*.

The *Water Management Act 2000* defines a number of aquifer interference activities including penetration or interference with, and obstruction of water flow within, an aquifer. Taking and disposing of groundwater from an aquifer are also defined as being aquifer interference activities.

The AIP requires that for an aquifer interference activity meet the minimal impact considerations. Any change in groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.

Groundwater along the project is likely to be used by aquatic ecosystems, and primary industries to account for small-scale domestic use of groundwater. However, this varies locally depending on ambient groundwater conditions.

The AIP also provides a framework for assessing the impacts of aquifer interference activities on water resources. To assess potential impacts, groundwater sources are categorised as either highly productive or less productive, with sub-categories for alluvial, coastal sands, porous rock, and fractured rock aquifers.

2.3.2 NSW Water Quality and River Flow Objectives

The *NSW Water Quality and River Flow Objectives* (NSW Department of Environment, Climate Change and Water, 2006), in line with the NWQMS, provide a number of environmental objectives for Parramatta River and Sydney Harbour catchments. These objectives are guided by the ANZG (2018) guidelines (refer to Section 2.1.3). The *NSW Water Quality and River Flow Objectives* (NSW Department of Environment, Climate Change and Water, 2006) provide a number of environmental values for the Parramatta River catchment. The water quality objectives relate to fresh and estuarine surface waters and in this report, they are relevant to the Parramatta River catchment and a number of tributary watercourses of the catchment. Surface and groundwater quality must therefore be maintained to a level that does not degrade any receiving surface water environments. The guidelines set out:

- the community's values and uses for NSW rivers, creeks, estuaries, and lakes (i.e., healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water)
- a range of water quality indicators to help assess whether the current condition of waterways supports those values and uses.

For the Upper Parramatta River, which is highly urbanised and largely impacted by stormwater and wastewater overflows, the nominated environmental values include: aquatic ecosystems, visual amenity, secondary contact recreation and primary contact recreation. These are further discussed in the following sections.

Aquatic ecosystems

Aquatic ecosystems can range from freshwater to marine and comprise the animals, plants and micro-organisms that live in water and the physical and chemical environment in which they interact. Aquatic ecosystems have been impacted by multiple pressures including changes in flow regime, modification and destruction of key habitats, development and poor water quality. A number of naturally occurring physical and chemical stressors can cause degradation of aquatic ecosystems. For the purposes of this technical paper, these stressors include nutrients, dissolved oxygen (DO), pH, metals, salinity and turbidity (suspended solids).

Visual amenity

The aesthetic appearance of a water body is an important aspect with respect to recreation. As such, the water should be free from noticeable pollution, floating debris, oil, scum and other matter. Substances that produce objectionable colour, odour, taste or turbidity and substances and conditions that produce undesirable aquatic life should not be apparent (NHMRC, 2008). The key aesthetic indicators are transparency, odour and colour.

Primary and secondary contact recreation

Recreational activities in and around the water are highly valued by the community in the project site and therefore the protection of the water for recreational use is necessary. There are two main categories of recreational water use, including:

- primary contact recreation – this implies direct contact with the water via bodily immersion or submersion with a high potential for water to be ingested. Activities classified as primary contact recreation include swimming, diving and water skiing
- secondary contact recreation – This implies that some direct contact with the water would be made but where ingestion is unlikely, such as the activities of boating, fishing and wading.

Aquaculture and consumption of aquatic foods

Aquaculture generally involves the production of food for human consumption and suitable water quality is needed for maintaining sustainable aquaculture operations. Increased toxicant concentrations in a water body (from impacts such as spills or contaminated sediments) can accumulate in the tissues of seafood that are likely to be consumed by humans (DECCW, 2006). Current signage along the Parramatta River advises that due to contamination, particularly dioxins, a ban on consumption of seafood has been imposed.

Note: ANZG 2018 guideline values on which these NSW State objectives were based are discussed in Section 2.1.3.

2.3.3 Floodplain Development Manual

The Floodplain Development Manual (NSW Department of Infrastructure, Planning and Natural Resources, 2005) incorporates the *NSW Flood Prone Land Policy*, which aims to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods. The policy also recognises the benefits of use, occupation and development of flood prone land.

This manual indicates that responsibility for management of flood risk generally sits with local government (with some exceptions noted in the *Local Government Act 1993*). The manual assists councils to balance the conflicting objectives of the floodplain through a risk management process.

The manual recommends against applying rigid and prescriptive criteria for assessing developments in flood prone land, and instead advocates that “a merit approach shall be adopted for all development decisions in the floodplain to take into account social, economic and ecological factors, as well as flooding considerations”.

This aligns with the approach being taken in assessing impacts from the project and in developing a range of mitigation measures to minimise impacts.

Lower Parramatta River Floodplain Risk Management Study (SKM, 2005)

The study undertaken by SKM in 2005 for the City of Parramatta Council, focused on aspects of flooding in Lower Parramatta River which provided outcomes that support the Council’s strategy and vision for the waterways. The study outcomes are used to outline existing flood behaviour data for regional modelling in this report (refer to Section 4.2).

2.4 Planning controls

2.4.1 Parramatta Local Environment Plan (LEP) 2011

Section 5.22 of the EP&A Act provides that environmental planning instruments (such as Local Environment Plans (LEPs)) do not apply to State significant projects (such as Parramatta Light Rail Stage 2). Notwithstanding, local environmental planning instruments have been considered as part of the development of the project.

The Parramatta LEP 2011 outlines flood-related planning controls applicable to development at or below flood planning level in Section 6.3. The LEP defines flood planning level as 1:100 Average Recurrence Interval (ARI) flood event plus 0.5 metre freeboard (the height of a building's lowest floor level above the ARI flood level).

Section 5.21 of the Parramatta LEP 2011 outlines the minimum requirements for land lower than the Flood Planning Level, which is defined as land the 100-year ARI flood level plus 0.5 metre freeboard.

The LEP notes that development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development:

(a) is compatible with the flood function and behaviour on the land, and

(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

(d) incorporates appropriate measures to manage risk to life in the event of a flood, and

(e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses.

These objectives are consistent with the SEARs provided for the project and have been considered in the definition of the project-specific flood management objectives (FMOs).

2.4.2 Developments adjacent to National Parks and Wildlife Service lands

The *Developments adjacent to National Parks and Wildlife Service lands – Guidelines for consent and planning authorities* (National Parks and Wildlife Service (NPWS), 2020) provide councils and other consent authorities potential issues that need to be considered when assessing proposals adjacent to NPWS land, in particular, their impacts on a park, its values and NPWS management of the park.

Newington Nature Reserve is gazetted as a Nature Reserve under the *National Parks and Wildlife Act 1974* (NPW Act) and defined as part of the parklands of Sydney Olympic Park, by the *Sydney Olympic Park Authority Act 2001* (SOPA Act). The reserve is located within SOPA land, adjacent to the project site (refer to Figure 4-14).

Relevant aspects of the guidelines in relation to Newington Nature Reserve are:

- erosion and sediment controls
- stormwater runoff
- threats to ecological connectivity and groundwater-dependent ecosystems.

2.4.3 Guidelines for controlled activities on waterfront land

The *Guidelines for Controlled Activities on Waterfront Land* (NSW Department of Industry, Natural Resources Access Regulator, 2018) is a current area of focus by the Natural Resources Access Regulator (NRAR) established under the *NSW Natural Resources Access Regulator Act 2017*. This guideline outlines the requirements for undertaking controlled activities on waterfront land in relation to riparian corridors with a view to allowing for a range of works and activities so long as they cause minimal harm.

Controlled activities include modifications to a watercourse, such as erosion control works and channel realignment construction of watercourse crossings such as bridges, causeways and bed level crossings, and ancillary works such as roads sand and gravel extraction.

Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary. Riparian corridors form a transition zone between the land and the river or watercourse. The main applicable section of this guideline requires the water crossing method of watercourse types of the 4th order, which includes estuaries, wetlands and parts of rivers influenced by tidal waters, such as the Parramatta River, to be a bridge.

2.5 Relevant best practice guidelines

The following best practice guidelines have been applied in assessments undertaken in this technical paper.

2.5.1 Australian Rainfall and Runoff

Australian Rainfall and Runoff (ARR*)* (Ball et al., 2019) is a national guideline document used for the estimation of design flood characteristics in Australia. It was first published in 1958 with major revisions in 1987 (ARR1987) and 2019 (ARR2019). ARR2019 is accompanied by Intensity Frequency Duration (IFD) design rainfall values (developed and published by the Bureau of Meteorology (BoM) in 2016) based on an additional 30 years of available data compared with the IFD design rainfall values which were published with ARR1987.

The guidelines require practitioners to apply their judgement about the appropriateness of a method to the particular situation and data. Further guidance in the *Revised 2016 Design Rainfall Investigations into the need for and Derivation of Local Techniques* (Office of Environment and Heritage, 2018) notes that the revised 2019 IFD data is a much better representation of design rainfall estimates so has been adopted for this study.

In the absence of historical data, models for quantitative flooding used for the project have been developed based on recommended parameters for the local region as outlined in ARR2019.

2.5.2 Parramatta Local Emergency Management Plan

The Parramatta Local Emergency Management Plan (PLEMP) (2018) has been prepared by the Parramatta Local Emergency Management Committee in compliance with the *State Emergency & Rescue Management Act 1989.*

The PLEMP details arrangements for, prevention of, preparation for, response to and recovery from emergencies within the LGA.

The plan has identified hazards having the potential to create an emergency and relevant to this assessment. The hazards include storm events directly related to flood risks such as East Coast Lows (ECL) and severe thunderstorms.

ECLs are intense low-pressure systems which on average occur several times each year off the eastern coast of Australia. ECLs will often intensify rapidly overnight making them one of the more dangerous weather systems to affect the NSW coast.

ECLs can generate one or more of:

- gale or storm force winds along the coast and adjacent waters
- heavy widespread rainfall leading to flash and/or major river flooding.

2.5.3 NSW State Flood Plan

The *NSW State Flood Plan* (NSW State Emergency Service, 2021) is a sub plan to the NSW Emergency Management Plan (EMPLAN) and is endorsed by the NSW State Emergency Management Committee (SEMC). The EMPLAN sets out the state level emergency management arrangements for prevention, preparation, response, and initial recovery for flooding at the strategic level.

2.5.4 Fifth Assessment Report (Synthesis Report Climate Change)

The Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC) is the fifth in a series of such reports and was completed in 2014. It provides a guide to future climate change projections that are based on Representative Concentration Pathways (RCPs). The Sixth Assessment Report (AR6) is currently being finalised by the IPCC. Working Group II and III contributions were released in February and April 2022 respectively, however, are subject to edits. The final synthesis report will be available by early 2023. Therefore, this assessment has adopted the values of the AR5 report. Outcomes and recommendations of the AR6 report would be factored into the next stages of design).

The RCPs are a greenhouse gas concentration trajectory adopted by the IPCC. There are four pathways described and used for climate modelling to inform the AR5, they are labelled after a possible range of radiative forcing values for the year 2100.

- RCP2.6 – Global CO2 emissions peak by 2020 and decline to around zero by 2080.
- RCP4.5 – Global CO2 emissions peak around mid-century at around 50 per cent higher than 2000 levels and then decline rapidly over 30 years and then stabilise at half of 2000 levels.
- RCP6 – Global CO2 emissions double by 2060 and then dramatically fall but remain well above current levels.
- RCP8.5 – Global CO2 emissions continue to increase rapidly through the early and mid-parts of the century.

The RCPs are consistent with a wide range of possible changes in future anthropogenic greenhouse gas emissions and provide guidance on likely increases in rainfall intensity and sea levels based on these pathways.

The climate change uplift factors incorporated in the hydrology and flooding modelling in this assessment are in accordance with ARR guidelines on climate projections, presented for IPCC AR5 Representative Concentration Pathways (RCP), as outlined in Section 3.1.2.

2.5.5 Managing urban stormwater series

The soils and construction series provide guidance on how to reduce the impacts of land disturbance on waterways by better management of soil erosion and sediment control. This series, commonly referred to as the ‘Blue Book’, includes the following publications relevant to this project:

- *Managing Urban Stormwater: Soils and Construction – Volume 1, 4th edition* (Landcom, 2004)
- *Managing Urban Stormwater: Soils and construction – Volume 2D, Main road construction* (Department of Environment and Climate Change, 2008).

2.5.6 International Erosion Control Association Best Practice Erosion and Sediment Control

International Erosion Control Association (IECA, Australasia) Best Practice Erosion and Sediment Control (BPESC) guide contains the necessary strategies and techniques assist erosion and sediment control practitioners to reduce the degradation of land and water from uncontrolled erosion and sedimentation.

This guide includes the *Best Practice Erosion and Sediment Control – for building and construction sites* (IECA, 2008) which would be relevant to the management of erosion and sediment control for this project.

2.5.7 Water Quality Guidelines

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software was used to undertake water quality modelling. The model parameters were extracted from *NSW MUSIC Modelling Guidelines – August 2015* by BMT WBM*.* This document was used as City of Parramatta Council's website made reference to the guideline. The main parameters extracted from this guideline are outlined below:

- default Rainfall Threshold Value
- pervious Area Rainfall-Runoff Parameters
- stormwater Pollutant Parameters.

The MUSIC model demonstrates performance of mitigation measures against a range of pollutants, with relevant authorities including Transport for NSW and City of Parramatta Council setting water quality targets for water quality improvement devices within the project.

2.5.8 Transport for NSW Sustainable Design Guidelines

The *Transport for NSW Sustainable Design Guidelines Version 4.0* (2017) outline a range of initiatives to improve the sustainability performance of transport infrastructure. There are three parts which includes:

- the design guidelines
- supporting tools appendices
- the checklist to demonstrate achievement of the required sustainable design guidelines rating.

There are 14 compulsory requirements and two sub requirements that must be considered when delivering a project. Each compulsory requirement has five performance levels (P1 – P5) where P1 is the minimum requirements and is compulsory in order to achieve a rating. Relevant requirements associated with this technical paper include:

- compulsory Requirement 3 – Climate change risk
- compulsory Requirement 6 – Water sensitive urban design.

2.5.9 Transport for NSW Water Discharge and Reuse Guideline

The purpose of the *Transport for NSW Water Discharge and Reuse Guideline* (2015) is to provide guidance to site personnel for managing, discharging and reusing excess water on Transport for NSW construction sites. It applies to the discharge of water from all sources on site, including sediment basins, temporary and informal basins and ponds, excavations, pits, boreholes, low points, storage bins, and any other areas on a construction site that may receive and store water.

This guideline includes references to some of the relevant legislative and regulatory requirements but is not intended to replace them. It is not intended to replace any requirements for vegetation management identified as part of the environmental impact assessment process.

2.5.10 Sydney Olympic Park Authority Stormwater Management and Water Sensitive Urban Design Policy

The *Sydney Olympic Park Authority Stormwater Management and Water Sensitive Urban Design* policy sets Sydney Olympic Park Authority's requirements for stormwater management during design, planning and construction of developments. Sydney Olympic Park Authority is committed to holistic stormwater management, with a particular emphasis on mitigating the detrimental local and downstream impacts on the environment from poor quality and/or an excessive volume of stormwater flowing from developments during and after construction.

Sydney Olympic Park Authority's policy aims to achieve this by:

- promoting appropriate water sensitive urban design in development
- optimising local harvesting and on-site utilisation of stormwater
- requiring proper management of stormwater from construction sites
- requiring appropriate management of discharge of stormwater from and within development sites post-construction.

Development within Sydney Olympic Park must:

- comply with best practice water sensitive urban design practices
- comply with best practice stormwater quality and quantity targets
- manage stormwater from construction sites to best practice standards.

Best practice within Sydney Olympic Park includes allowing for appropriate and innovative offsets in circumstances where there are genuine physical constraints, due to the intrinsic nature of the particular site, which limit an on-site design and control solution (as may be approved by Sydney Olympic Park Authority on a case-by-case basis).

2.5.11 Parramatta Floodplain Risk Management Policy

City of Parramatta Council's *Parramatta Floodplain Risk Policy* applies to all flood prone land anywhere within the City of Parramatta LGA. The primary objective of the policy is to encourage measures that reduce or eliminate the impact of flooding. The policy establishes Council's strategic approach to floodplain risk management for the whole LGA. Four principles influence the policy:

- Flood prone land is a valuable resource that should be managed and developed, subject to a merit approach that provides due consideration to social, economic and environmental criteria, as well as any flooding criteria, as identified in flood studies, independent assessments or strategically developed floodplain risk management studies and plans.
- Both mainstream and overland flooding are to be considered when assessing flood risk.
- Flood prone land should not be sterilised by unnecessarily precluding development through the application of rigid and prescriptive criteria, however inappropriate proposals should not be accepted.
- Measures to increase resilience across the LGA should be encouraged so as to reduce the long-term effects of flooding when it occurs.

3 Assessment methodology

The methodology adopted to assess the impact of this project is outlined below. This approach has been developed in line with relevant legislation and guidelines and with reference to the SEARs.

The relevant study areas are as follows:

- Parramatta River between James Ruse Drive and Ryde Bridge. This includes the following tributaries shown on Figure 4-2:
  - Duck River.
  - Haslams Creek.
  - Powell's Creek.
  - Vineyard Creek.
  - Subiaco Creek.
  - Archer Creek.
  - Charity Creek
- Local stormwater catchments that the project crosses. This includes the suburbs of:
  - Camellia.
  - Rydalmere.
  - Ermington.
  - Melrose Park.
  - Wentworth Point.
  - Sydney Olympic Park.
- Groundwater zones within two kilometres of the project site.

3.1 Hydrology and flooding assessment

A hydrology and flood impact assessment has been carried out for the project as described in Section 5.2. The approach to the flooding assessment is summarised in the flow diagram in Figure 3-1.

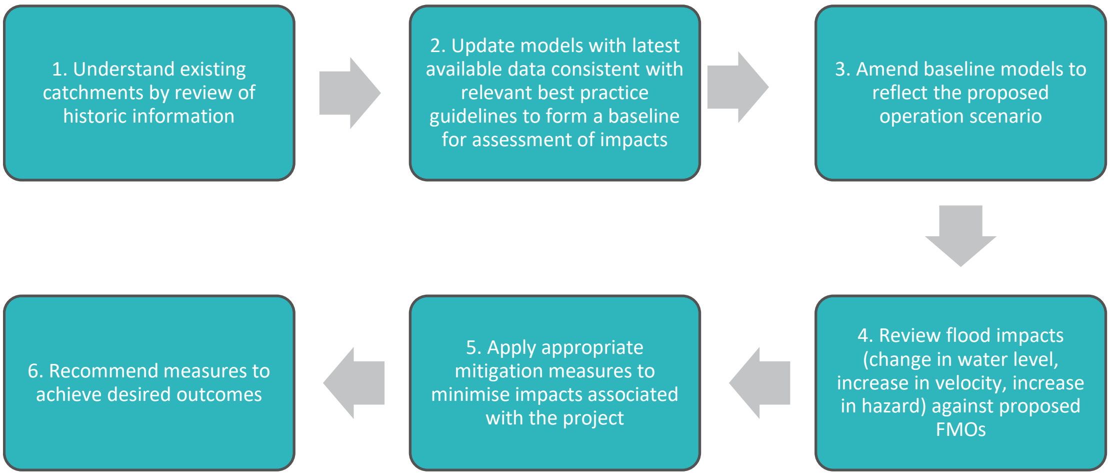

Figure 3-1 Flooding assessment methodology

Flood maps have been developed with flood hazard categories in accordance with the *Australian Institute for Disaster Resilience - Australian Institute of Disaster Resilience Guideline* (2017b). Refer to Appendix C1 which includes mapping associated with the existing (baseline) and impact (operations) assessments, respectively.

3.1.1 Assessment overview

Assessment of the potential impacts of this project on flooding has considered flood events up to the PMF. Impacts to be addressed include (but are not limited to):

- potential increases in flood risk and flood affectation on adjacent properties and assets as well as potential impacts to any emergency management arrangements
- land use compatibility in relation to flood hazard
- compatibility with council floodplain risk management and local management plan in terms of safe velocities and depths for pedestrians and vehicles
- where required mitigation and management measures have been identified.

A quantitative flooding assessment has been undertaken across the study area. This assessment is based on validated flood models which have been updated using detailed survey, where available. Flood impacts have been established for construction and operational stages using design information available at the time of this report.

The flooding assessment has been prepared to compare the project performance against the FMOs outlined in Section 3.1.3. The general approach is in accordance with the flow diagram in Figure 3-1, with a modelled surface topography and formal drainage network to represent the baseline and “with project” scenarios. The topographical changes “with project” scenario comprise either a 3-dimensional corridor for the track alignment, or a triangulated irregular network surface at stops and design surface interfaces with existing ground levels.

Existing publicly available community emergency management arrangements have been reviewed in order to understand important transport routes for evacuation. As outlined in Section 3.3.4, targeted consultation with relevant stakeholders including Sydney Olympic Park Authority, the City of Parramatta Council, the City of Ryde Council and the SES has commenced for areas in which the project may have an impact upon existing community emergency management arrangements for flooding. Transport for NSW would continue engagement with these stakeholders through design development to minimise impacts. Further detail on the consultation process is included in Section 8.2.

3.1.2 Modelling assessment

A combination of hydrological and hydraulic modelling has been adopted in this flooding assessment. This includes hydrological modelling to generate inflow hydrographs which are subsequently applied either as river inflows or directly (rain on grid) to the digital elevation model (DEM) in the hydraulic modelling software (TUFLOW).

Assumptions

A TUFLOW one-dimensional/two-dimensional hydraulic model has been adopted for this project to convert runoff rates from the hydrological model into flow depths and velocities for both the baseline (existing environment) scenario and the “with project” scenario. The choice of model used for assessments within this technical paper was largely based on the availability of existing models.

The model has been prepared for a range of infrequent flood events along with the extreme flood event. The flood events which will be presented for each assessment are the five per cent AEP, one per cent AEP and PMF events. These events represent:

- a lower magnitude flood where local drainage systems are designed to manage overland flow,
- the major flood conditions where local drainage systems are typically exceeded, and
- the extreme event for review of evacuation strategies.

Climate change has been directly incorporated into each assessment for the varying AEP magnitude flood event as separate climate change scenarios. The climate change uplift factors are incorporated in accordance with *Australian Rainfall and Runoff guidelines* (Ball et al., 2019) on climate projections (see Section 2.5.3. for the full range of IPCC RCPs).

IPCC RCP8.5 for the end of the century is adopted for the consideration of future climate conditions with respect to flooding (18.6 per cent increase in rainfall intensity in the Parramatta River catchment) as it is a conservative approach representing a “do nothing” climate change abatement scenario. Likewise, sea level rise is incorporated into the flood model as a downstream boundary condition (up to 900 millimetre sea level rise by the end of the century in accordance with the *NSW Sea Level Rise Policy Statement* (DECCW, 2009).

These climate change projections (including those associated with sea level rise) would be subject to review and update during design development using the latest rainfall intensity and sea level rise projections.

The flood model for the project has been updated from the previous assessments undertaken in earlier design stages in 2019 to more accurately reflect existing and design conditions (refer to Appendix C1 and C2 for detailed figures). Local council drainage assets from the City of Parramatta and Sydney Olympic Park were added to the model to allow for assessment of the impact the drainage network has on surface flows.

The model was also updated to achieve a better ground surface resolution. The model adopts Sub Grid Sampling, a feature built-in to the hydraulic modelling software that allows a more detailed representation of water volume on the ground surface in order to gain a representation of shallow flow paths accurately, despite a grid based representation of topography. Additionally, certain geometry changes and water level assumptions were made to better represent existing surface conditions based on a review of the latest available survey data, and boundary conditions to appropriately interface the flood flows to the receiving watercourse conditions in Parramatta River.

Calibration and validation

For a flood study to produce reliable results, it should be calibrated to observed or existing data, where available. Observed data can be sought from river flow or level gauges that record actual river information while existing data may be sought from historic studies within the catchment of interest.

The flood model adopted for this assessment was developed in 2019 for an earlier phase of the project. Hydrological estimates for Parramatta River were calibrated against the regional Flood Frequency Analysis (FFA) for Marsden Street weir, a river gauging station located where Marsden Street crosses Parramatta River (this is located upstream of the hydraulic model domain). The FFA has been used to predict maximum flows for a range of storm probabilities up to the one per cent AEP. The largest observed flood at Marsden Weir was in April 1988, with a peak flow of 697 cubic metres per second (closely resembling a two per cent AEP event).

Hydrological model parameters were adjusted to achieve the best match to the regional Marsden Street FFA and used as inputs into the hydraulic model.

3.1.3 Flood management objectives

The FMOs define the standard against which the magnitude of impacts arising from the project will be assessed. FMOs cover a range of flood behaviour. The specific objectives applicable to this study area are provided as follows:

- for operational flood levels in events up to the one per cent AEP there should be no increase in flood levels relative to the existing condition (afflux) greater than:
  - 10 millimetres in residential zoned land
  - 20 millimetres in commercial/industrial zoned land
  - 50 millimetres in public land*
- the potential for soil erosion and scouring is minimised for events up to and including a one per cent AEP flood event
- no change in flood hazard category in residential and commercial/industrial zoned land
- no change to the hazard category for events up to and including the one per cent AEP flood event for dedicated evacuation routes.

* Sections 25 and 26 *Local Government Act 1993* classify 'public land' as any land (including a public reserve) vested in or under the control of the council.

These project specific FMOs have been established based on a review of flood criteria adopted in environmental impact statements and conditions of approval for other recent linear infrastructure projects including Parramatta Light Rail Stage 1, Sydney Metro and Inland Rail.

3.2 Groundwater assessment

3.2.1 Desktop review

A desktop study evaluated the existing hydrogeological conditions by identifying the existing geology, aquifers, surface conditions and surficial soils and fill covers. This was supplemented with available borehole data and core log information, vegetation, project details and any other factors considered relevant to identifying potential risks associated with the construction activities and operation of the project.

The desktop review included the following supporting data:

- geological spatial data
- background geotechnical information for the project
- borehole information, including:

- the BoM national dataset of groundwater information available in the form of spatial datasets
  Note: For this assessment purposes, the BoM data has been geoprocessed to only show the borehole locations within a two kilometre buffer of the groundwater study area. Impacts beyond two kilometres are considered unlikely.
- results obtained from the Parramatta Light Rail Stage 2 site investigations undertaken by Coffey in 2019 to provide characterisation of the geology, terrain and subsurface conditions for the project. The site investigations included:
  - obtaining soil samples from 32 land based geotechnical boreholes
  - obtaining sediment samples from four in river geotechnical boreholes (BH07, BH08, BH38 and BH46) located between Camellia and Lidcombe
  - conversion of seven boreholes to groundwater monitoring wells for groundwater gauging, purging and sampling
  - analysis of soil, sediment and groundwater samples for contaminants of potential concern
  - comparing the analytical results to health and environmental screening criteria
  - identifying the potential to disturb acid sulfate soils and areas of salinity
  - assessing potential construction and operation impacts that may result from contaminated land or groundwater, and the potential impacts on soils
  - identifying measures to reduce or minimise identified impacts.

The locations of the monitoring boreholes established by Coffey in 2019 are shown in Figure 4-10 and Figure 4-11 shows those boreholes registered as water works as provided by BoM.

3.2.2 Analytical groundwater modelling

There is limited data available on the water table from the borehole samples taken during the site investigations undertaken by Coffey in 2019. Therefore, an analytical modelling approach was adopted using methods that could determine groundwater seepage from unconfined aquifers into linear excavations with parallel sides. The method is explained in *Dewatering in Foundation Engineering* (Mansur and Kaufman,1962). The extent of the drawdown in surrounding areas was determined using methods explained in *Analysis and Evaluation of Pumping Test Data* (Kruseman G P and de Ridder N A,1994). The results are presented in Section 5.4.

The analytical modelling parameters adopted for this study were based on considerations of core logs and packer test results from the investigation by Coffey in 2019 as well as regional hydraulic properties outlined in *Sydney Metro West, Westmead to the Bays and Sydney CBD, EIS Concept and Stage 1, Technical Paper 7, Hydrogeology* (Jacobs, 2020).

3.3 Water quality assessment

The following methodology has been used to understand the existing (baseline) water quality environment for the project and to assess potential impacts during construction and operation, as well as cumulative water quality impacts. Key steps in the water quality assessment are shown in Figure 3-2.

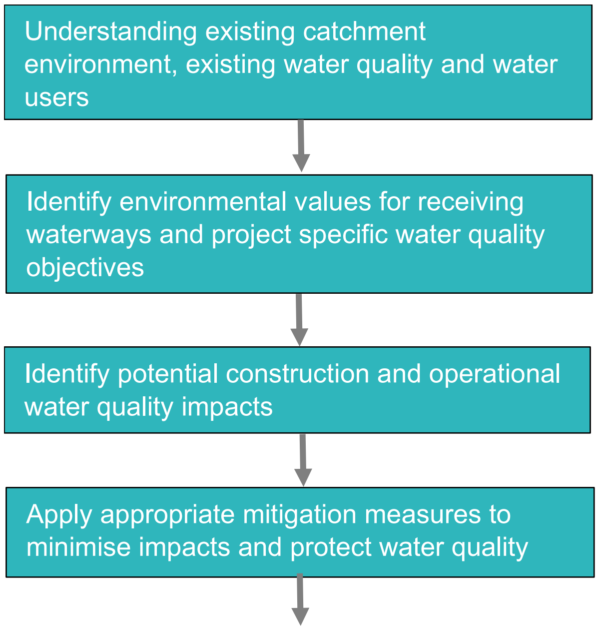

Figure 3-2 Water quality assessment methodology

3.3.1 Existing (baseline) water quality environment

Available water quality studies and assessments were reviewed to understand the baseline surface water quality conditions for the project. An overview of the existing baseline water quality of the study area is provided in Section 4. Existing water quality data for watercourses within the study area was obtained from the City of Parramatta Council and Parramatta Light Rail Stage 1 construction water quality monitoring data. The data is limited and does not include parameters such as heavy metals recoverable hydrocarbons and dioxins. Monitoring frequency, indicators and length of the records vary between the sites; a summary of the data is presented in Table 4-7.

The available data was cross checked with ANZECC (2000) and ANZG (2018) guideline water quality trigger values for slightly disturbed ecosystems in lowland rivers in south-east NSW (refer to Section 4.9.1).

While the guideline trigger values were adopted for this project, site specific water quality trigger values would be considered based on a monitoring program carried out during the pre-construction, construction, and operational phases (refer to Section 8.3).

3.3.2 NSW Water Quality and River Flow Objectives for the Parramatta River catchment

As discussed in Section 2.3.2, the *NSW Water Quality and River Flow Objectives* provide a number of environmental values for the Parramatta River catchment ant its tributary watercourses.

For the Upper Parramatta River, within which the project site is located, the nominated environmental values include aquatic ecosystems, visual amenity, secondary contact recreation, primary contact recreation and aquatic foods (cooked).

Table 3-1 outlines assigned environmental values for watercourses and receiving waters in the study area, where applicable.

Table 3-1 Assigned environmental values for the main watercourses and receiving waters in the study area

Watercourse and/or receiving waters	Environmental objective				
	Aquatic ecosystems	Visual amenity	Primary contact recreation	Secondary contact recreation	Aquatic foods (cooked)
Narawang Wetlands	Yes	Yes			
Duck River	Yes	Yes		Yes	
Haslams Creek	Yes	Yes		Yes	
Subiaco Creek	Yes	Yes			
Vineyard Creek	Yes	Yes			
Parramatta River	Yes	Yes	Yes	Yes	Yes
Charity Creek	Yes	Yes			
Archer Creek	Yes	Yes			

3.3.3 Water quality assessment

Construction

A desktop assessment has been conducted to identify potential sensitive receiving environments, characterise the existing (baseline) environment and identify potential impacts of the project during construction and operation. This has included a review of existing literature on major project assessments and publicly available maps (including geological, topography, drainage, and soil maps).

A qualitative assessment of the potential water quality impacts during the project construction has been carried out. This process has included:

- understanding baseline water quality conditions of the watercourses and catchments relevant to the project and the existing impacts to the surrounding environment. This has been completed through a review of existing water quality data and available water quality literature, reports, and assessments
- reviewing the potential pollutants and impacts to the water quality environment from construction and operational activities
- identifying the key water quality objectives (WQOs) in line with the NSW Water Quality and River Flow Objectives and the ANZG (2018) guidelines (refer to Section 6.1.1)
- identifying appropriate and feasible mitigation measures which can be readily implemented on site to minimise impacts to the water quality environment.

Operation

Water quality modelling using eWater MUSIC was selected for the analysis of pollutant runoff from highly urban catchments and enables the assessment of relative changes in Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP) as a result of the project. The MUSIC modelling was carried out to determine the baseline pollutant loads generated off the local sub-catchments which the project alignment will traverse. These baseline loads were then compared against the relevant ANZECC and ANZG 2018 targets. Additionally, pollutant load reductions for TSS, TN and TP were assessed against reduction targets of the local planning controls outlined in Section 2.5.6.

Once the results of the baseline modelling were identified proposed controls were added to the model to determine how effective proposed controls would be. The proposed controls included Gross Pollutant Traps (GPT) or similar in conjunction with tertiary cartridge filtration devices, as well as a water quality basin, dry bio-filtration basins and swales. Where possible, in areas of greater vegetation, natural water quality controls (i.e. raingardens and basins) have been prioritised over manmade filtration systems. The result of this analysis is presented in Section 6.1.1.

Rainfall inputs

The MUSIC model uses pluviograph data (six-minute time step rainfall data) and user-defined event mean concentrations to estimate pollutant loads. Pluviograph data was obtained in MUSIC from City of Parramatta Council. The data was available for the period 1 January 1967 to 31 December 1976. This is the period that has been selected by City of Parramatta Council in their Music-link data as the period with most reliable data to date. The model was run at six-minute time steps for the available duration.

3.3.4 Consultation

Consultation with City of Parramatta Council, City of Ryde Council, Sydney Olympic Park Authority

A meeting with the City of Parramatta Council was held 13 July 2022 to discuss the FMOs, stormwater/flood management proposals, the project’s operational intent in flood events, water quality objectives and emergency management arrangements for flooding.

Consultation with City of Parramatta Council, City of Ryde Council and Sydney Olympic Park Authority would continue throughout subsequent stages of the project, including discussion on the impacts that the development may have upon existing community emergency management arrangements for flooding.

Consultation with the Department of Planning and Environment and NSW Environment Protection Authority

Meetings with the Department of Planning and Environment and the Environment Protection Authority have taken place to discuss water quality and outline the water quality monitoring program which would include the establishment of baseline water quality conditions.

Consultation with NSW State Emergency Service

A meeting with the NSW SES was held 15 August 2022 to provide an overview of the project, the existing and future flood conditions from the project, the flood management proposals, and the outline strategy for the intended operational response measures in flood events. Preliminary information was provided by SES on emergency management arrangements for flooding along the project alignment.

Consultation with SES will continue throughout the subsequent stages of the project in relation to integrating with existing or future proposed emergency management arrangements.

4 Existing environment

The existing hydrological and hydrogeological regime for groundwater and surface water resources, including reliance by users and other sensitive receptors, is described in this section.

4.1 Catchment and watercourses

The Parramatta River catchment encompasses an area of approximately 252.4 square kilometres and is made up several tributaries and is largely referred to as the Upper and Lower Parramatta River. The project is located within the Upper Parramatta River section where there are a series of weirs that influence the flow of the river. These include Kiosk Weir and Upstream Weir in Parramatta Park and Marsden Weir and Charles Street Weir in the Parramatta CBD. The Parramatta CBD weirs define the tidal boundary with the Lower Parramatta River (refer to Figure 4-1 for geographic context of the project footprint within the Parramatta River catchment).

The headwaters of the Parramatta River are formed by the confluence of Toongabbie Creek and Darling Mills Creek, located in Greater Western Sydney. Other significant tributaries of the Parramatta River downstream include Duck River, Vineyard Creek, Subiaco Creek, Haslams Creek and Archers Creek (refer to Figure 4-2 for watercourses in the vicinity of the project site).

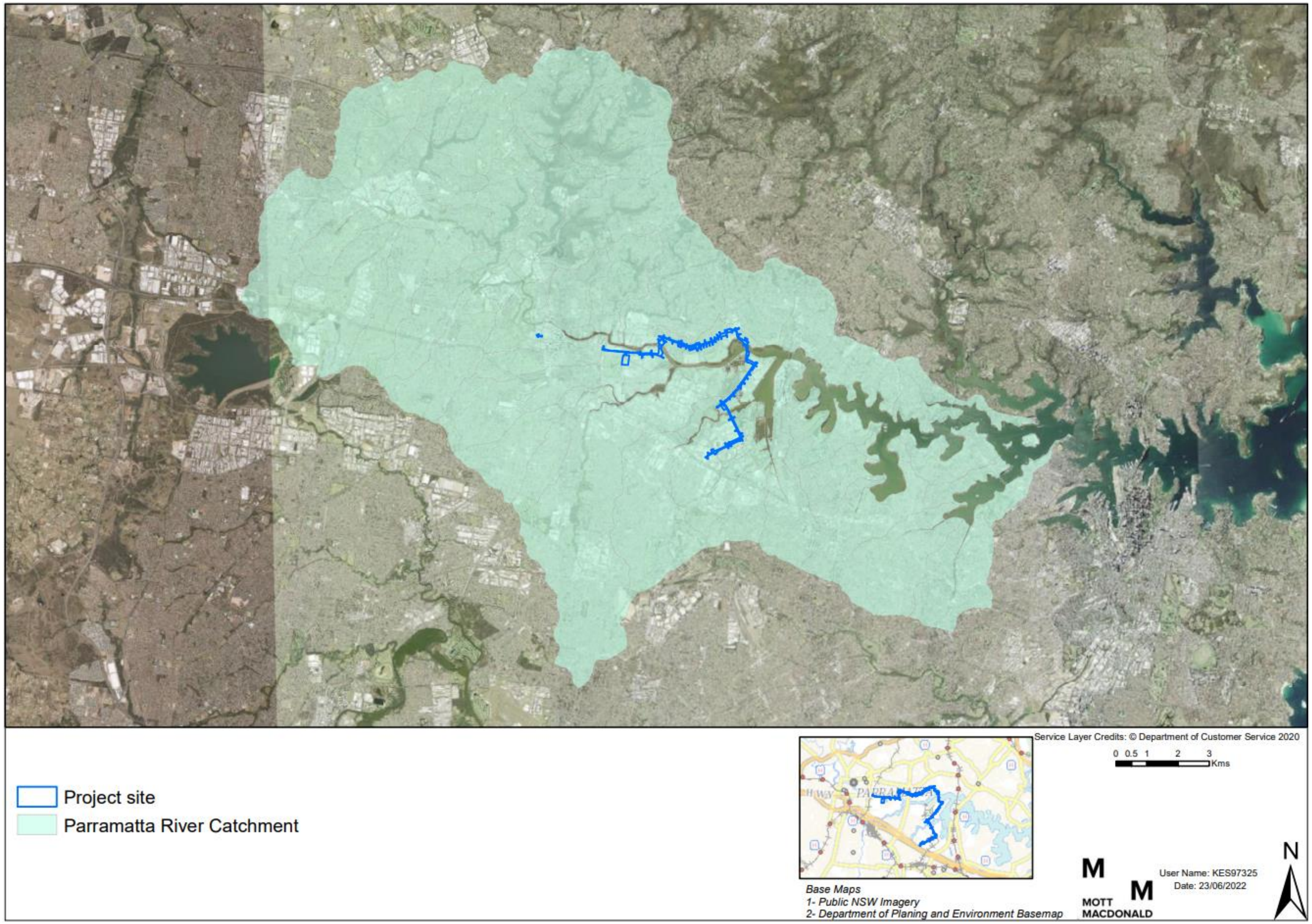

Figure 4-1 Geographic context of the project site within the Parramatta River catchment

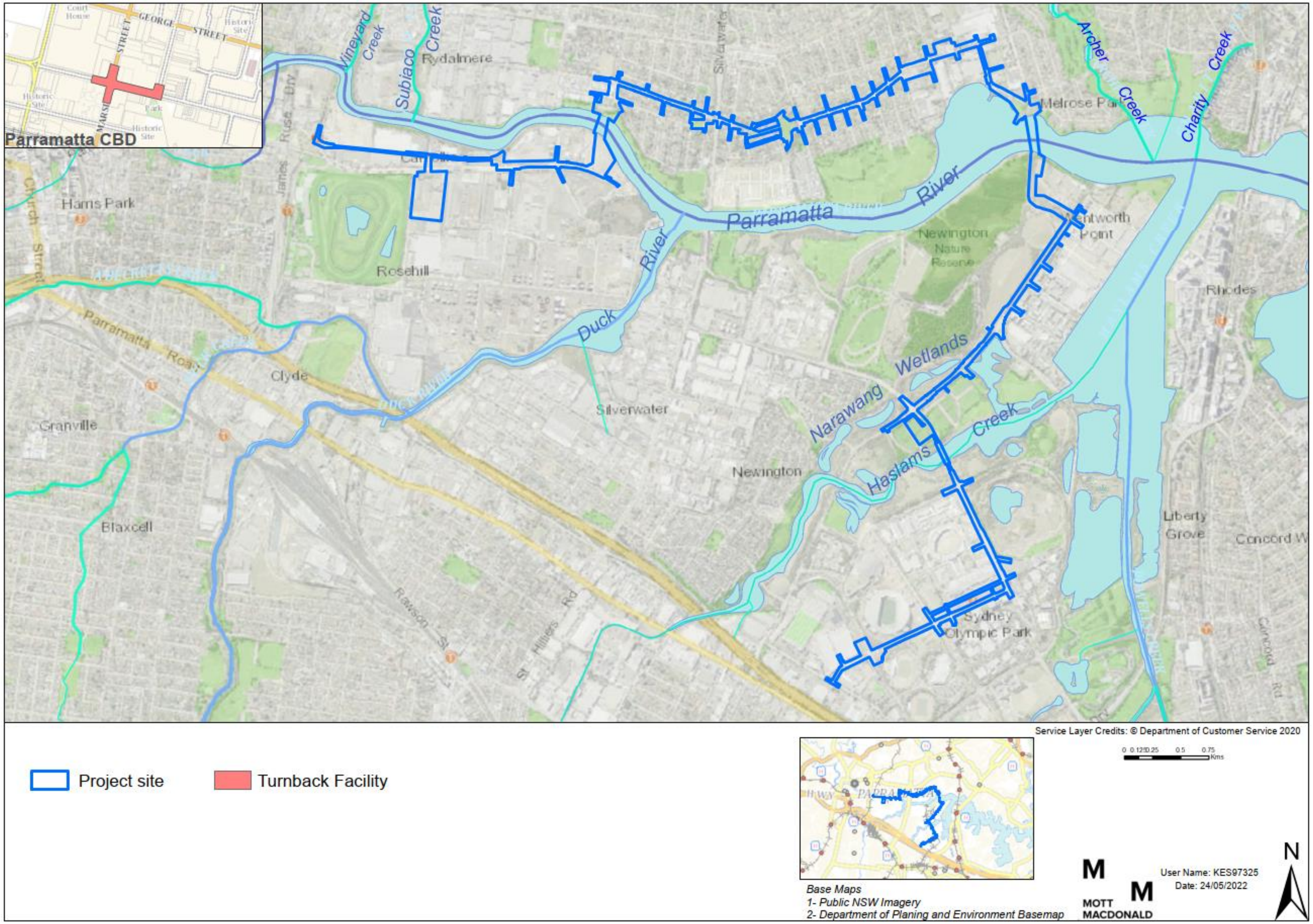

Figure 4-2 Watercourses in the vicinity of the project site

4.1.1 Stream order of the study area

Stream ordering of watercourses was established using the Strahler stream classification system where watercourses are given an 'order' according to the number of additional tributaries associated with each watercourse (Strahler, 1952).

The classification system is illustrated in Figure 4-3. Stream order class 1 begins at the start of new flow paths at the top of a catchment. Where two flow paths of order 1 join, the section downstream of the junction is referred to as a second order stream. Where two second order streams join, the waterway downstream of the junction is referred to as a third order stream. Where a lower order stream (e.g. first order) joins a higher order stream (e.g. third order), the area downstream of the junction will retain the higher number (i.e. it will remain a third order stream).

This system provides a measure of system complexity and is used as an input into assessing hydrological significance and environmental attributes such as potential for fish habitat.

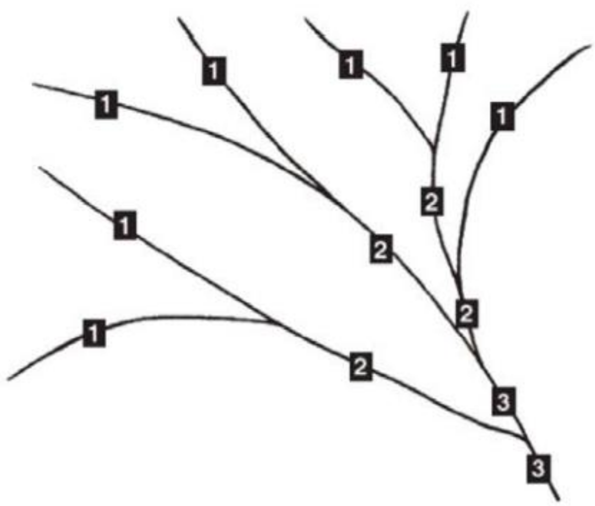

Figure 4-3 Strahler Stream Order Classification System

The stream order and mapping status of the watercourses in the study area are outlined in Table 4-1.

Table 4-1 Key watercourses within the study area and stream order classification

Watercourses	Description	Mapped as key fish habitat?[1]	Waterway class[2]	Habitat for threatened fish species?[3]
Parramatta River	Main tributary of Sydney Harbour (a large fourth order waterway) the river is freshwater upstream of Charles Street weir, downstream it is saline the river would be crossed by the project	Yes	Class 1 (major key fish habitat)	No

Watercourses	Description	Mapped as key fish habitat?[1]	Waterway class[2]	Habitat for threatened fish species?[3]
Duck River	The river is a third order estuarine stream the banks of the channel are densely vegetated by mangroves.	Yes	Class 1 (major key fish habitat) as it is a permanently flowing river.	No
Haslams Creek	Highly modified second order stream within the project site, the creek is estuarine the river would be crossed by the project	Yes	Class 1 (major key fish habitat)	No
Subiaco Creek	Freshwater, second order watercourse	Yes	Class 2 (moderate key fish habitat)	No
Vineyard Creek	Freshwater, second order watercourse	No	Class 2 (moderate key fish habitat)	No

Note 1: Mapped as key fish habitat (NSW Department of Primary Industries, 2013)

Note 2: Waterway classification (Fairfull and Witheridge, 2003)

Note 3: Habitat for threatened aquatic species listed under the NSW *Fisheries Management Act 1994* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

4.1.2 Urban sub-catchment breakdown

The water quality analysis for the existing conditions before the project has identified 20 urban sub-catchments along the project site based on the topography and surface features of the urban environment. The discharge points shown in Figure 4-4 indicate locations where the urban runoff including formal stormwater systems release water to the receiving watercourses. These locations indicate the assessment locations for determination of the baseline water quality pollutant loads for the operational water quality assessment and are possible treatment locations where water quality measures can apply to the urban runoff zone prior to stormwater discharge.

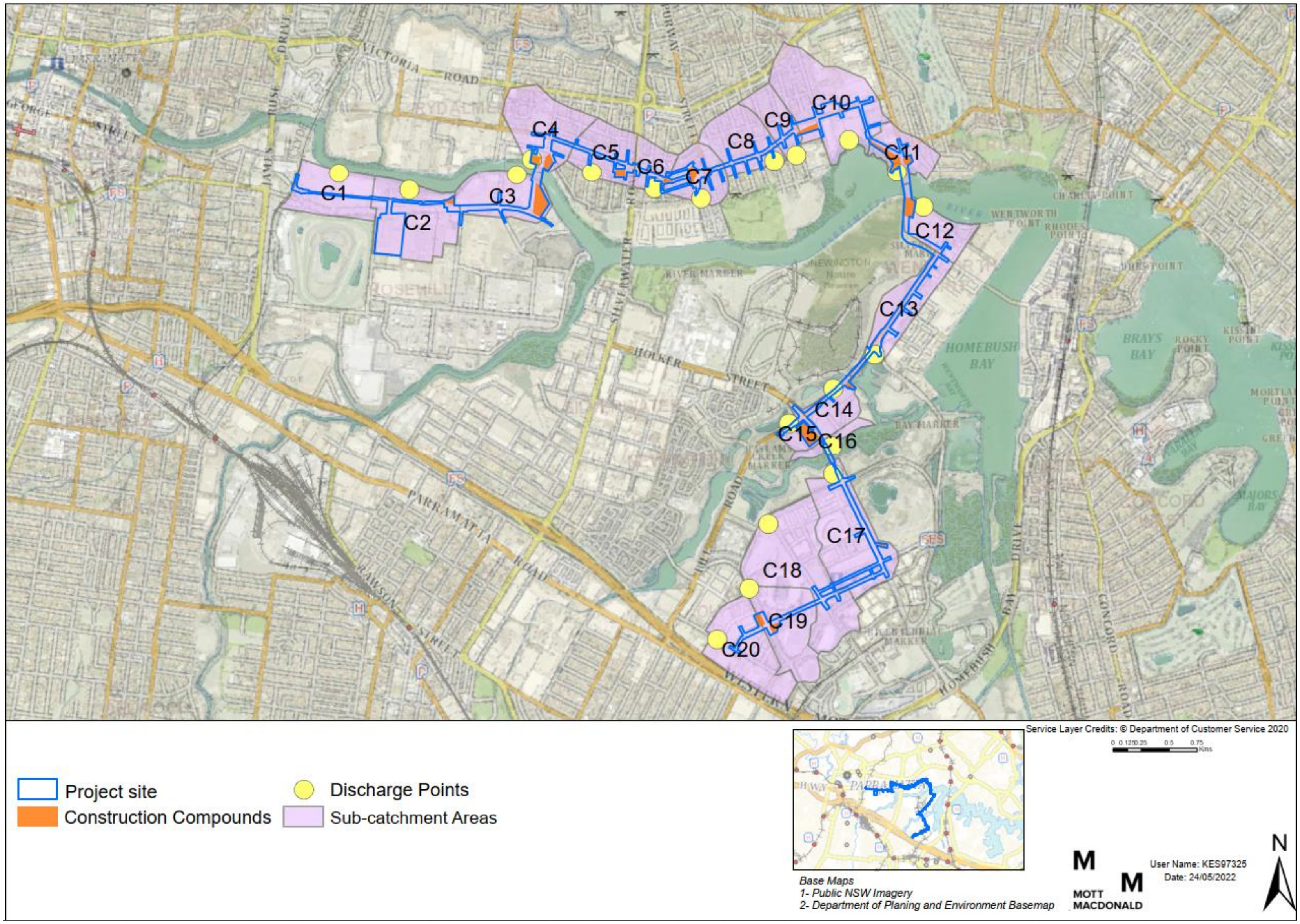

Figure 4-4 Water quality sub-catchment breakdown

The assessment of catchment runoff in the MUSIC model allows comparison of the catchment runoff pollutant loads against the catchment specific WQO trigger values. Sub-catchment outputs from MUSIC were assessed against the aquatic ecosystems objective to identify criteria addressed by the model and identify where modelled pollutant concentrations exceed criteria targets. Sub-catchment boundaries have been drawn based on the best available data at the time, boundaries may be subject to slight changes as new topographical data such as surveys become available.

Of the aquatic ecosystems' criterion, the MUSIC model provides data for two; total phosphorus (TP) and total nitrogen (TN). Mean daily inflow concentrations of phosphorus and nitrogen were extracted from discharge nodes of each sub catchment and assessed against NSW WQO trigger values for TP (30 µg/L) and TN (300 µg/L).

Modelled sub-catchment runoff from six of the 20 sub-catchments achieves the target value for total phosphorus, and four of the 20 achieve the quality target for total nitrogen. C14, C15, C16 and C17 meet quality targets for both TP and TN, while C1 and C13 meet the target for TP alone. The comparison is summarised in Table 4-2. Sub-catchments meeting the trigger threshold for both TP and TN are typically comprised of road/pavement/car park areas and higher proportions of vegetated areas as opposed to areas comprising full urban land use.

Table 4-2 Baseline assessment of WQO trigger thresholds

	Quality Targets		Baseline Values	
Sub-catchment ID	Total Phosphorus (30 µg/L)	Total Nitrogen (300 µg/L)	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)
C1	Achieved	Not achieved	27	332
C2	Not achieved	Not achieved	49	330
C3	Not achieved	Not achieved	41	348
C4	Not achieved	Not achieved	44	389
C5	Not achieved	Not achieved	34	354
C6	Not achieved	Not achieved	34	345
C7	Not achieved	Not achieved	31	383
C8	Not achieved	Not achieved	33	359
C9	Not achieved	Not achieved	34	356
C10	Not achieved	Not achieved	36	421
C11	Not achieved	Not achieved	41	369
C12	Achieved	Not achieved	30	355
C13	Not achieved	Not achieved	37	380
C14	Achieved	Achieved	17	179
C15	Achieved	Achieved	17	156
C16	Achieved	Achieved	15	143
C17	Achieved	Achieved	12	221

Sub-catchment ID	Quality Targets		Baseline Values	
	Total Phosphorus (30 µg/L)	Total Nitrogen (300 µg/L)	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)
C18	Not achieved	Not achieved	40	382
C19	Not achieved	Not achieved	43	374
C20	Not achieved	Not achieved	32	382

4.2 Flooding

Sections of the project site are located on the floodplain of the Parramatta River and are likely to be subject to mainstream and overland flooding. Mainstream flooding results from the Parramatta River and its tributaries, including Haslams Creek and Duck River. Overland flooding results from overflows from stormwater systems which were typically designed and constructed to convey rainfall runoff for frequent storm events.

Existing flood behaviour data for regional modelling documented in the *Lower Parramatta River Floodplain Risk Management Study* (SKM, 2005) is summarised in Table 4-3 for the following locations:

- proposed bridge between Camellia and Rydalmere (western crossing)
- proposed bridge between Melrose Park and Wentworth Point (eastern crossing).

Table 4-3 Flood Behaviour* in the Parramatta River at the two proposed bridge locations

Event	Bridge between Camellia and Rydalmere		Bridge between Melrose Park and Wentworth Point	
	Flood level (metres AHD (mAHD))	Velocity (metres per second (m/s))	Flood level (mAHD)	Velocity (m/s)
One per cent AEP	3.6	1.6	1.42	2
PMF	6	2.5	2.79	2.9

**Lower Parramatta River Floodplain Risk Management Study* (2005), report prepared by SKM for the City of Parramatta Council.

Updated modelling for the project indicates the spatial distribution of floodwater under a range of riverine events including the five per cent AEP, one per cent AEP and PMF, and climate change scenarios for the five per cent AEP and one per cent AEP. Flood map outputs showing flood depth, velocity and hazard predicted for these events under existing conditions is provided in Appendix C1. Specific coastal flood inundation scenarios have not been considered at this stage. The PMF scenario in the Parramatta River uses a one per cent AEP tidal boundary condition (assuming water levels in Sydney Harbour are representative of a one per cent AEP coastal water level, equal to 1.44 metres AHD).

Please note, while the five per cent AEP and one per cent AEP events provide a range of storm rarity for this assessment, other storm AEPs not modelled may have a different hazard profile. This is because flood hazard outputs are a function of water velocity and water depth, rather than simple rarity. Therefore, a storm such as the ten per cent AEP may generate hazards not yet identified by the five per cent or one per cent AEP events. A full range of flood probabilities would be assessed during the next stages of design.

Camellia, Rydalmere to Melrose Park and Hill Road in Sydney Olympic Park experience overland flows in the five per cent and one per cent AEP events and ponding in local road low points. Hill Road in particular is prone to flooding in more frequent storm events, with water depth reaching up to 40 millimetres, an example of which is shown in Figure 4-5. Generally, the flood hazard is low, and is safe for pedestrians and vehicles, however, there are locations along Hill Road that may reach an unsafe level of hazard (unsafe for vehicles, children and the elderly). Local sag points and open spaces on the banks of Parramatta River experience higher hazard that may be considered unsafe.

Figure 4-5 Flooding in Hill Road, April 2015

In the PMF event Camellia and Hill Road are inundated and present a high flooding hazard for people and vehicles. Local roads through Rydalmere to Melrose Park and Sydney Olympic Park, south of Hill Road, experience overland flows and ponding at road low points, but otherwise present a low flood hazard for people and vehicles.

For the one per cent AEP, the inundation extent of the Parramatta River is largely limited to the river itself and open spaces in the adjacent floodplain. For larger events there is further inundation of properties beyond the adjacent floodplains, and large portions of Camellia become inundated.

4.3 Geology

The *Sydney 1:100,000 Geological Series Sheet 9130* (NSW Department of Mineral Resources, 1983) and the *Penrith 1:100,000 Geological Series Sheet 9030* (NSW Department of Mineral Resources, 1991) indicate that the project site is predominantly underlain by Quaternary Alluvium (Qha), Ashfield Shale (Rwa), and Hawkesbury sandstone (Rh). Surface materials consist largely of residual soils and several areas have been landscaped or reclaimed using man made fill or dredged estuarine material.

There are four dykes mapped in close proximity to the project site (two kilometres). The most significant of these intrusions is the Dundas Dyke, which is located in the suburb of Dundas Valley. The Dundas Dyke consists predominantly of basalt, intruding into the surrounding shale. The dykes all trend approximately north-east to south-west.

A description of the regional geological formations is provided in Table 4-4.

Table 4-4 Geological units underlying the project site

Unit	Lithology
Hawkesbury Sandstone (Rh)	Medium to coarse-grained sandstone, very minor shale and laminite lenses
Ashfield Shale (Rwa)	Black to dark-grey shale and laminate
Bringelly Shale (Rwb)	Shale, carbonaceous claystone, laminite, fine to medium-grained sandstone, rare coal
Diatremes (Jv20)	Volcanic breccia, varying amounts of sedimentary breccia and basalt
Quaternary Alluvium (Qha)	Silty to peaty quartz sand, silt and clay. Ferruginous and humic cementation in places. Common shell layers
Man-made fill (Mf)	Dredged estuarine sand and mud, demolition rubble, industrial and household waste
Tertiary Alluvium (Tm)	Sand, clay and peat, variably ferruginous

The surface geology below the project site is shown in Figure 4-6.

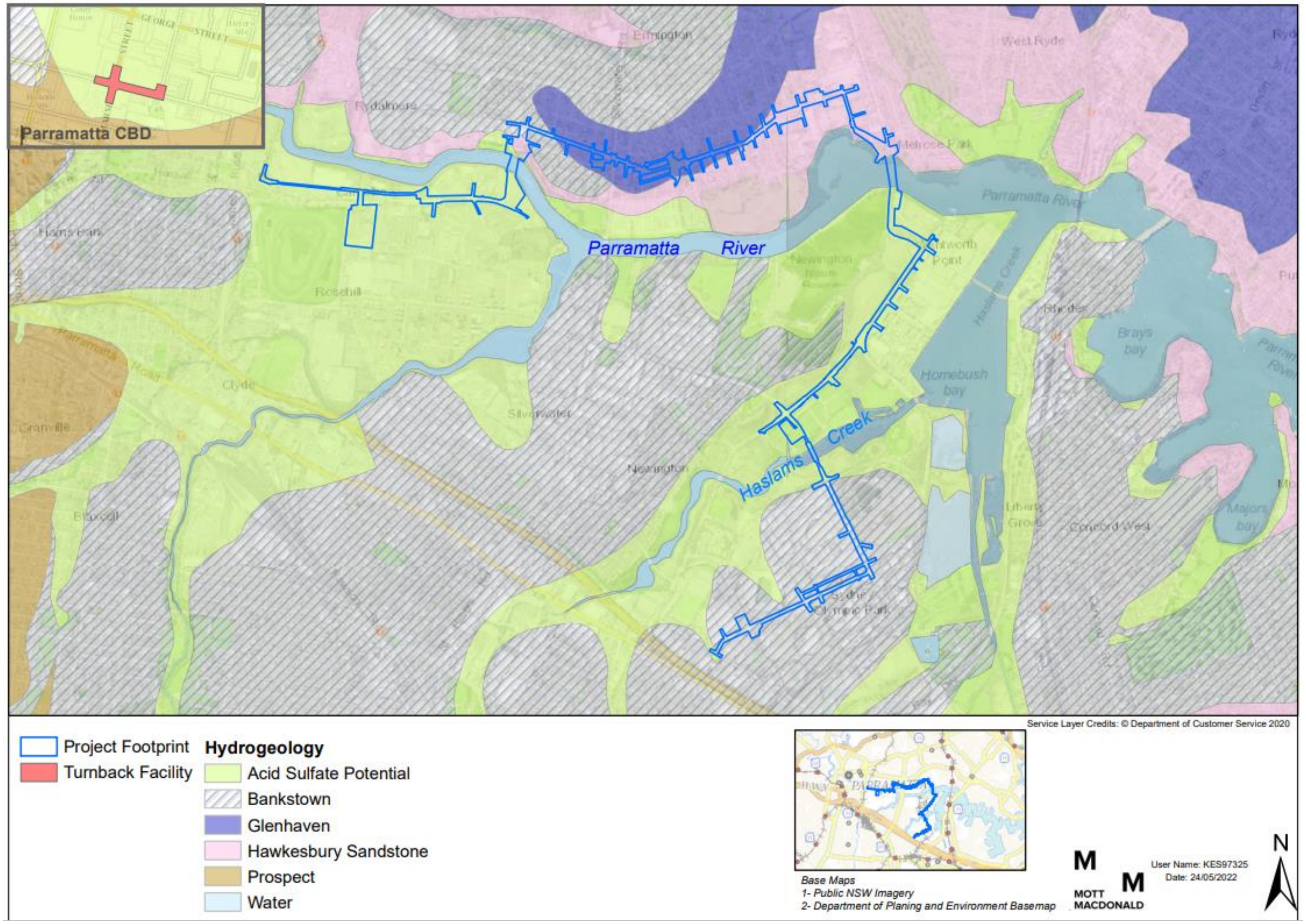

Figure 4-6 Hydrogeology of the study area

South of the Paramatta River, in the suburbs of Camellia, Wentworth Point and Sydney Olympic Park, the project site is situated on alluvial material and/or reclaimed land that has been raised and levelled for industrial developments by filling above the Quaternary alluvial and estuarine deposits. This is particularly noticeable along the eastern end of Grand Avenue at the corner where the proposed alignment turns north to cross the Paramatta River (between Camellia and Rydalmere).

Also, on the southern side of the Parramatta River, between Wentworth Point and Sydney Olympic Park, the alluvium gradually wedges out on each side of Haslams Creek as shown in Figure 4-7.

The Sydney Olympic Park sport facilities are built on reclaimed land below which a few former rehabilitated clay capped waste management / landfill sites are scattered. The fill material in this area lies directly above weathered Ashfield Shale.

Ashfield Shale underlies the surficial soils, alluvium and fill material below the entire project site on the southern side of the Paramatta River.

North of the Paramatta River the disturbed areas of fill materials are found in the vicinity of the proposed bridge crossing at Camellia and similarly at the proposed river crossing from Melrose Park to Wentworth Point. Most of the project site on the north-western side of the project site, (in Rydalmere along South Street) is underlain by residual soils located above the weathered Ashfield Shales which in turn are located above the Hawkesbury Sandstone. The shale layers on this side of the river are relatively thin and perched above the Hawkesbury sandstone in the higher lying areas of Rydalmere. A section of the sandstone (about 100 metres wide) is just north of Rydalmere Wharf.

In Ermington, along Boronia Steet, Hawkesbury Sandstone outcrops occur and extend eastwards along the project site through Melrose Park to within 70 metres of the Paramatta River where it disappears below the alluvium near the proposed river crossing to Wentworth Point.

The Hawkesbury Sandstone is extensive, extending below the Ashfield Sandstone and continues below the entire project site and well beyond the boundaries of the Sydney Metropolitan area. It consists of layers of fine medium and coarse-grained sandstone with very minor shale and laminate lenses.

On both sides of the river, but more dominantly on the southern side of the project site, the material used for fill and industrial reclamation purposes is often found deposited above or mixed with the naturally occurring alluvial material found in the low lying areas and estuarine areas where most of the reclamation has occurred. The content of the fill material is mixed and highly variable. It includes dredged and excavated marine and fluvial sands, saline marine muds, shells, clay, silt, peat and manmade fill (building rubble and other landfill waste material). The material associated with fluvial marine activity is saline with a high iron content, which is typical of Hawkesbury Sandstone and overlying shales.

The underlying Ashfield Shales is composed of black to dark-grey shale, mudstone, laminate and occasional sandstone lenses.

4.4 Soil landscapes

Soil landscapes along the project site (refer to Figure 4-7) include the following formations:

- Camellia: Disturbed terrain.
- Rydalmere and Ermington: Lucas Heights, Blacktown and Glenorie landscapes.
- Melrose Park: Lucas Heights and Glenorie landscapes.
- Wentworth Point: Birrong formation.
- Sydney Olympic Park: Birrong, Ettalong, and Blacktown landscapes.
- Carter Street (Lidcombe): Birrong and Blacktown landscapes.
- Parramatta CBD (location of Macquarie Street turnback facility): Blacktown landscapes.

Soils in these formations are characterised as (Chapman G.A. and Murphy C.L. (1989)) and outlined in Table 4-5.

Table 4-5 Soil formations

Soil formation	Description
Lucas Heights	moderately deep (50-150 cm), hard setting Yellow Podzolic Soils and Yellow Soloths; Yellow Earths on outer edges.
Blacktown	shallow to moderately deep (<100 cm) red and brown podzolic soils on crests, upper slopes and well-drained areas; deep (150-300 cm) yellow podzolic soils and soloths on lower slopes and in areas of poor drainage.
Glenorie	shallow to moderately deep (<100 cm) red podzolic soils on crests; moderately deep (70-150 cm) red and brown podzolic soils on upper slopes; deep (>200 cm) yellow podzolic soils and gleyed podzolic soils along drainage lines
Birrong	shallow to moderately deep (<100 cm) red and brown podzolic soils on crests, upper slopes and well-drained areas; deep (150-300 cm) yellow podzolic soils and soloths on lower slopes and in areas of poor drainage
Ettalong	soils are characterised by deep (>150 cm) organic acid peats, peaty podzols and humus podzols often overlying buried siliceous sands
Disturbed terrain	This represents soils that are variable and cannot fit into any soil landscape classification and therefore details on these soils are not available from Chapman G.A. and Murphy C.L. (1989).

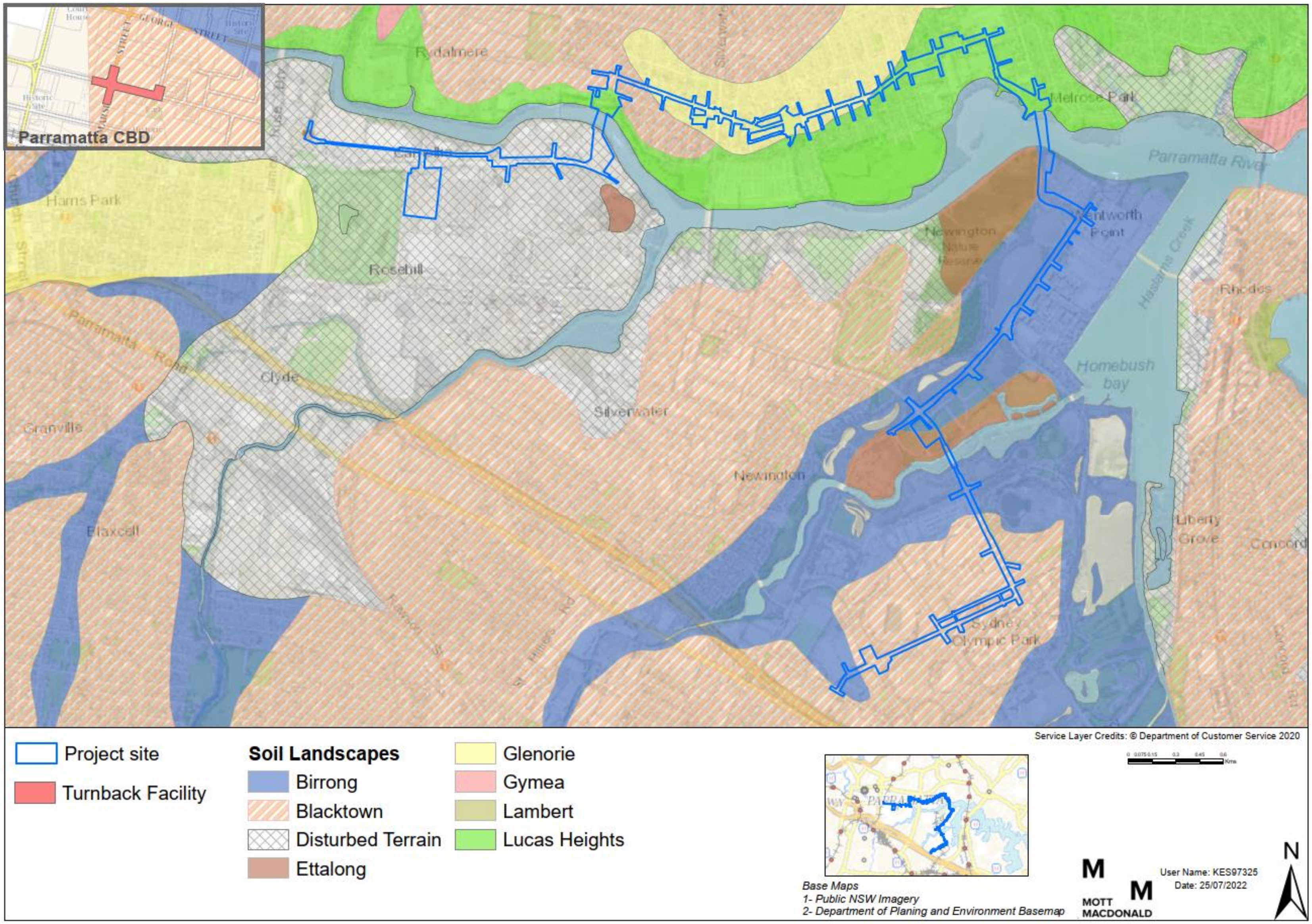

Figure 4-7 Soil landscapes of the study area

4.5 Contamination

The contamination assessment for the EIS is based on a previous desktop assessment site investigations (undertaken by Nation Partners in 2018 and Coffey in 2019, respectively). The results are discussed in Chapter 18 (Soils and contamination) of the EIS.

Due to current and historic industrial activities and land uses in the project site, particularly in the suburbs of Camellia, Wentworth Point and Sydney Olympic Park, there is potential for the presence of contamination in soils with the main contaminations of concern being hexavalent chromium, petroleum hydrocarbons, chlorinated hydrocarbons, and asbestos.

The Coffey investigation also included analysis of groundwater samples from groundwater bores installed along the project site. Refer to Section 4.8 for more information.

A more detailed description of existing areas of contamination concern within the study area is outlined in Chapter 18 (Soils and contamination) of the EIS. The chapter also includes listed contaminated sites located within/close to the project site, and key previous and existing land uses.

4.6 Acid sulfate soils

Acid sulfate soils (ASS) are soils and sediments that contain iron sulfides that when disturbed and exposed to oxygen, generate sulfuric acid and toxic quantities of aluminium and other heavy metals. The sulphuric acid and heavy metals are produced in forms that can be readily released into the environment with potential adverse effects on the natural and built environment, as well as human health. The majority of ASS are formed by natural processes under specific environmental conditions, which generally limits its occurrence to low lying sections of coastal floodplains, rivers and creeks where surface elevations are less than five metres above height datum (AHD).

The Department of Planning and Environment acid sulfate soil risk data and mapping has been reviewed to assess the probability of acid sulfate soils being present.

The high probability ASS areas (refer to Figure 4-8) which would be traversed by the project site are:

- the eastern end of the Camellia peninsula, including the location of the abutment for the bridge over Parramatta River between Rydalmere and Camellia, with high probability of ASS occurrence at two to four metres depth, and within the Parramatta riverbed where ASS probability of occurrence is classified as high
- both the northern and southern ends of the bridge over the Parramatta River between Melrose Park and Wentworth Point, including the northern end of the route in Wentworth Point with high probability of ASS occurrence at zero to one metre depth
- the low lying area within Haslams Creek across Holker Busway in Sydney Olympic Park was classified as high probability of occurrence at zero to one metre depth.

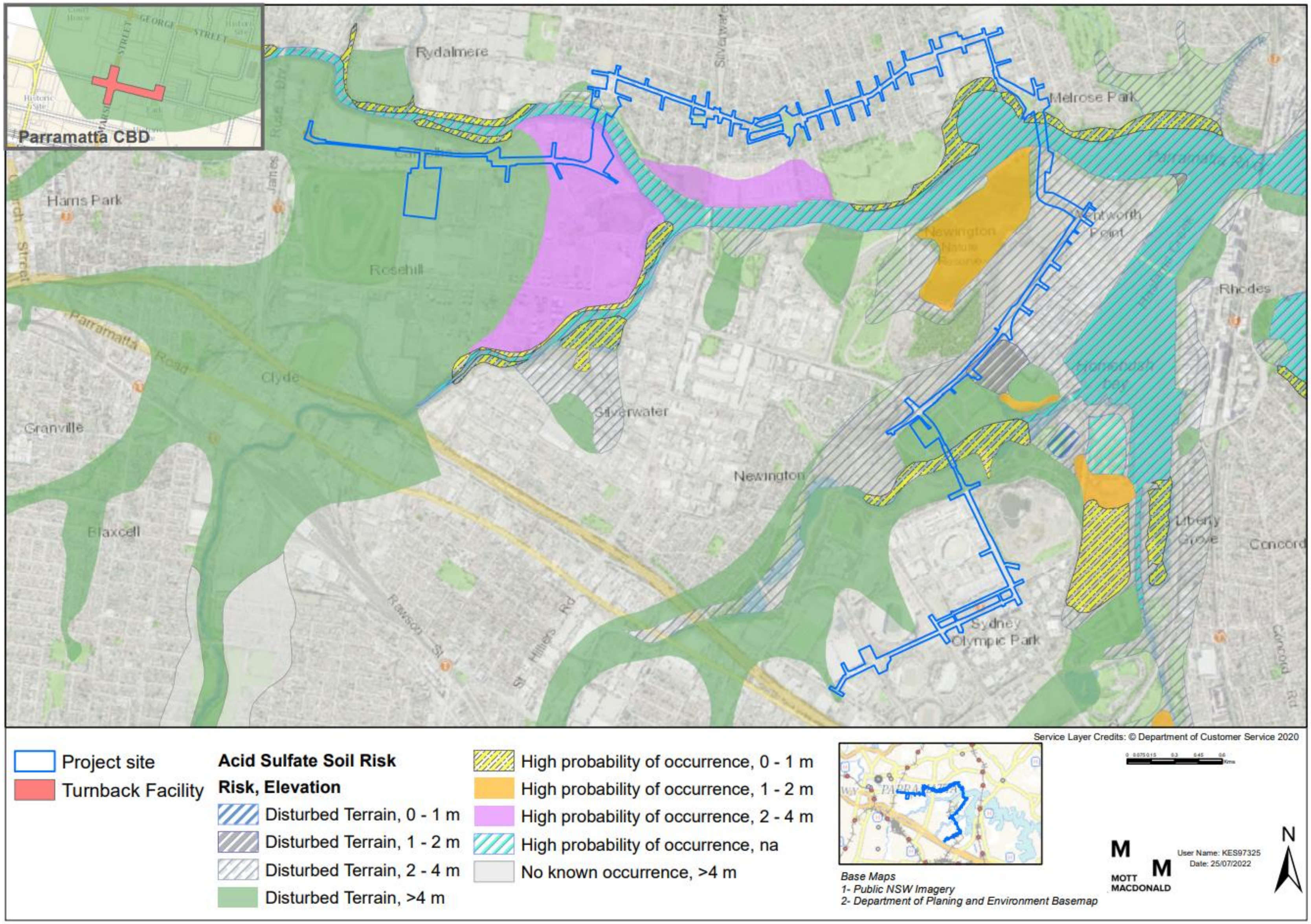

Figure 4-8 Acid Sulfate Soils map

4.7 Soil salinity

Surface water and groundwater can dissolve and mobilise salts and cause their accumulation in other areas. Excessive concentrations of salt can affect plant growth, soil chemistry and cause weakening and degradation of construction materials such as masonry, concrete and bitumen.

The assessment of salinity potential along the project site was carried out using the map of the salinity potential in western Sydney (NSW Department of Infrastructure, Planning and Natural Resources 2002). The project site is generally classified as having moderate salinity potential, with the exception of areas on the northern side of the Parramatta River, which are classified as having low salinity potential (refer to Figure 4-9).

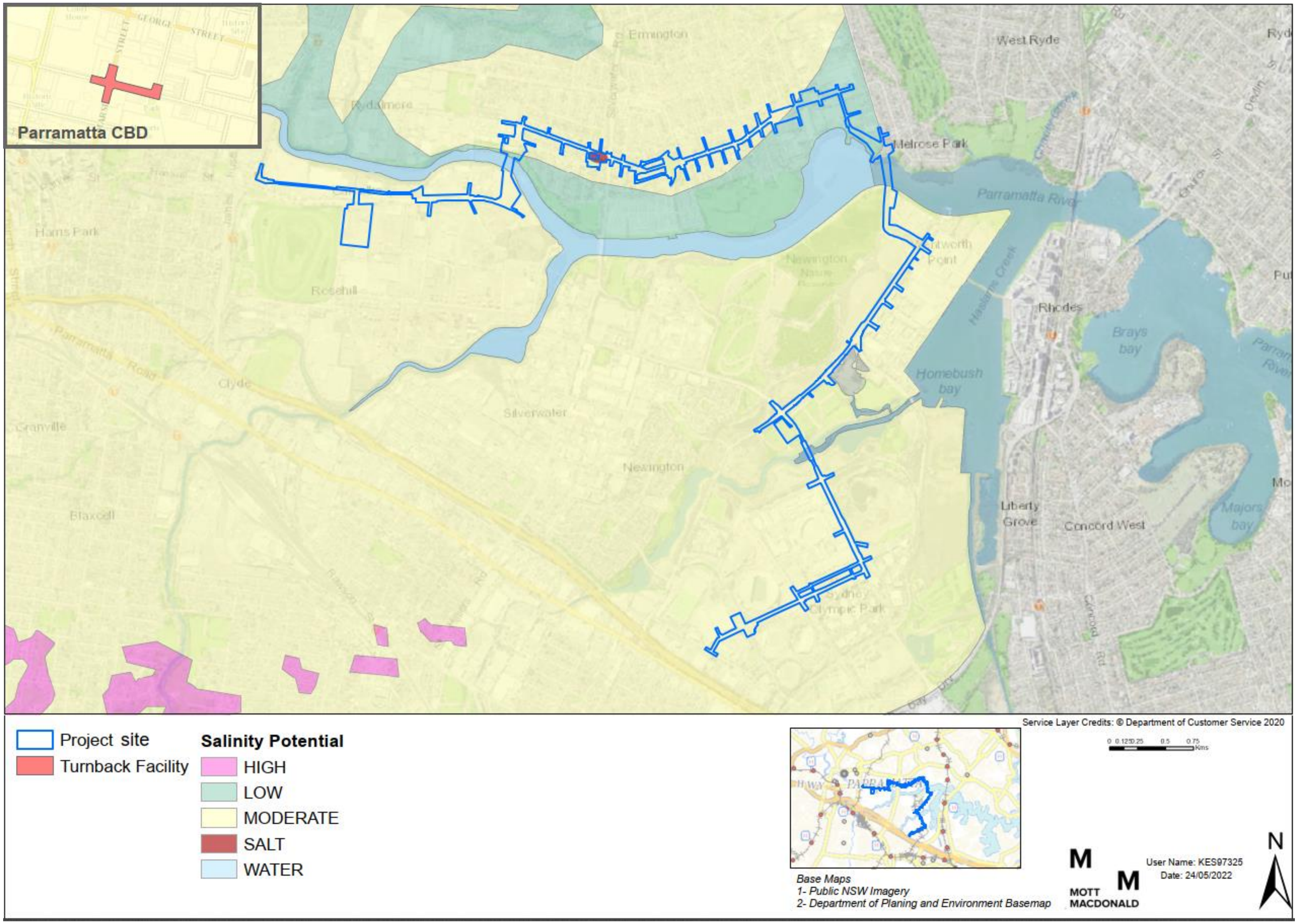

Figure 4-9 Salinity potential

4.8 Groundwater

Existing groundwater quality

Investigations undertaken by Coffey in 2019 included the conversion of seven boreholes to groundwater monitoring wells for groundwater gauging, purging and sampling. Figure 4-10 shows the location of these groundwater wells.

There are no existing boreholes measuring water quality within the footprint of the cutting at Ken Newman Park. However, salinity levels were measured as part of the contamination and geotechnical assessment undertaken by Coffey at groundwater bore BH23. Salinity values (as electrical conductivity) were about 2000 microSiemen per cm in BH23.

Historical investigations in the Camellia peninsula have identified that groundwater is contaminated, with the main contaminants of concern in Camellia being hexavalent chromium, petroleum hydrocarbons and chlorinated hydrocarbons. In Rydalmere, Ermington and Melrose Park the contaminants of concern include copper, nickel and zinc.

Petroleum hydrocarbons and copper, nickel and zinc were detected above the laboratory limit of reporting and/or above the adopted assessment criteria during the investigation undertaken by Coffey. However, these concentrations are considered representative of background concentrations at the sampled locations rather than indicating the presence of gross contamination (refer to EIS Chapter 18 (Soils and contamination) for further information).

In Camellia, the contaminants of concern originate from historic and current industrial activity, including a former Chrome Chemicals facility, Wesco Paints facility, tannery and timber yard. Melrose Park, Wentworth Point and Sydney Olympic Park sources of contamination can be attributed to historic and current commercial and industrial activity and landfilling activities.

These analytes may pose an unacceptable risk to aquatic ecosystems if discharged to receiving waters without appropriate treatment. Heavy metals are considered likely to represent background concentrations rather than specific point sources of contamination in the immediate vicinity of those wells. The source of Total Recoverable Hydrocarbons (TRH) impact is unknown, however may be attributed to natural sources and/or localised contamination.

Piezometer hydrograph and daily rainfall data for each of the monitoring boreholes is provided in Appendix A.

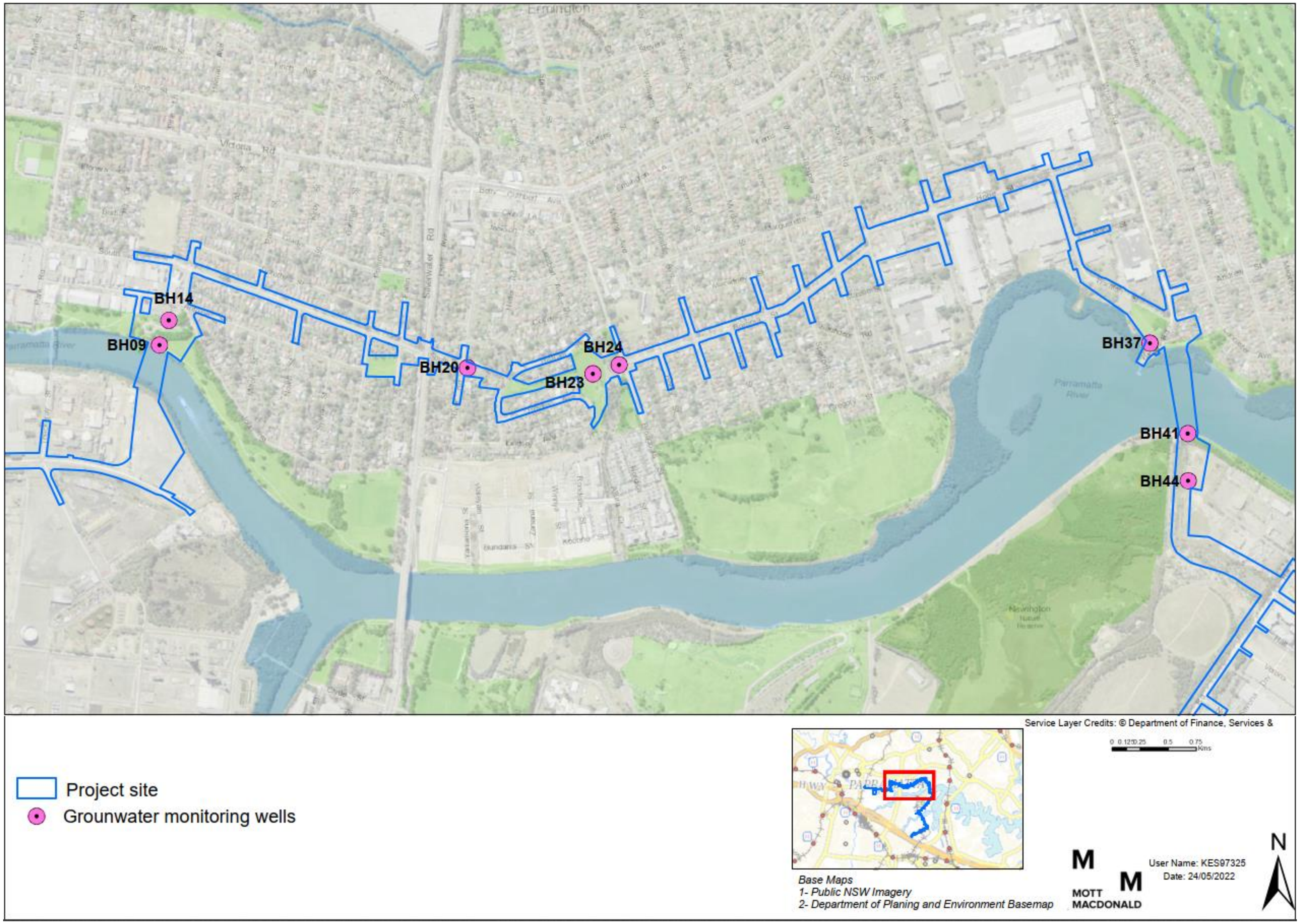

Figure 4-10 Location of monitoring boreholes established during Coffey investigation (2019)

4.8.1 Existing boreholes

A search of the BoM groundwater database identified five licensed water works (boreholes) within two kilometres of the project site (refer to Figure 4-11), which are:

- borehole GW063660, located within the project site and licenced for mining exploration purposes
- boreholes GW024667 and GW200688 which are used for commercial and industrial water use and located more than 800 metres away from the project site
- borehole GW072314 which is used for irrigation and located more than 800 metres away from the project site
- borehole GW107659 which is for commercial and industrial water use and is located in Camellia on rehabilitated ground in an industrial area. It is approximately 100 metres from the project site and 170 metres from the Paramatta River (refer to Figure 4-11). This borehole is 145 metres deep, was established in 2006 and able to pump about three litres per second of saline water (10,000 milligrams per litre) from upper fill and shale aquifer zones and seven litres per second of less saline water (<3000 milligrams per litre) from the deeper sandstone aquifer.

Figure 4-11 Boreholes registered as water works as provided by BoM

4.8.2 Project investigation boreholes

One borehole, BH24, was installed in proximity to the Boronia Street cutting (refer to Figure 4-10), as part of the investigation undertaken by Coffey in 2019. The groundwater level recorded at this location during the Coffey investigation was only 0.6 metres above the floor of the proposed cutting, in the lowest 60 metres portion of the cutting.

A monitoring borehole, BH23 (refer to Figure 4-10), is located downslope, west of the cutting but water levels in that area are well below the floor of the cutting and the alignment.

4.8.3 Groundwater dependent ecosystems

A groundwater dependent ecosystem (GDE) is defined as an ecosystem that has its species composition and natural ecological processes wholly or partially determined by groundwater (Serov et al, 2012). The location of GDEs within the Sydney Basin is mapped by the BoM Atlas of Groundwater Dependent Ecosystems (2017) The review indicated there are no GDEs reliant on the surface expression of groundwater within or near the study area.

There are scattered areas of high potential GDEs (vegetation) reliant on subsurface groundwater within the study area (refer to Figure 4-12.

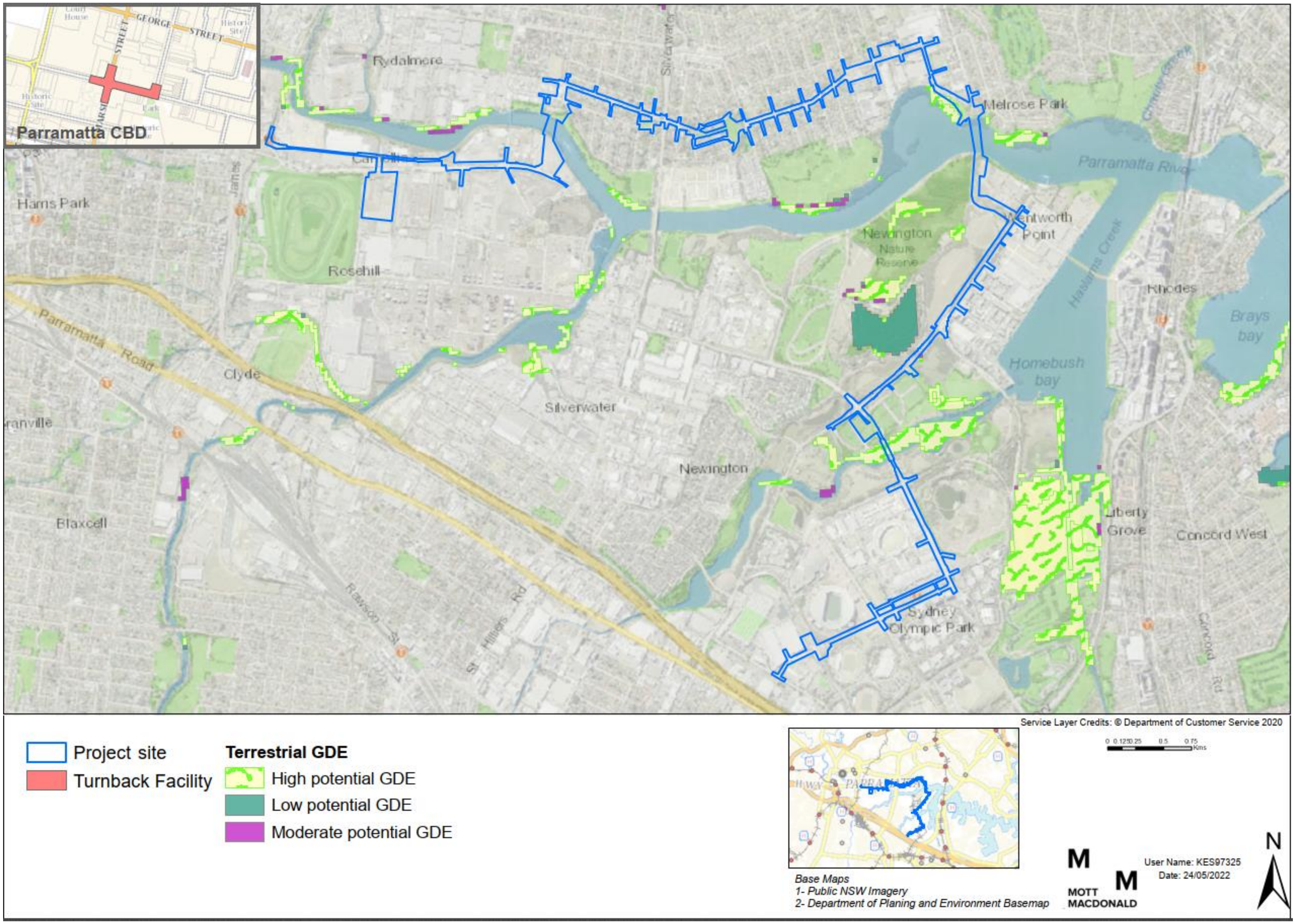

Figure 4-12 Groundwater Dependent Ecosystems (Terrestrial)

4.8.4 Aquifers below the project site

The locations of the aquifers correspond with those of the geological formations described in Section 4.3.

The aquifers below the project site are all unconfined and hydraulically interconnected. The Mittagong Formation (a relatively thin upper layer (mostly consisting of laminites) of the Hawkesbury Formation) separates the sandstone from the shales. Laminates, occasional thin clay lenses and heterogenous bedding planes within the shale and sandstone sediments tend to act as localised aquitards favouring horizontal rather than vertical groundwater movements, but the material is fractured, and some vertical connectivity exists across all aquifer layers below the project site.

The surficial soils, fill material and alluvial material are all primary aquifers exposed to recharge from infiltrated rainfall or hydraulic connectivity to water bodies. A permanent water table exists in low lying estuarine and alluvial sediments alongside water bodies (e.g. Paramatta River).

In higher lying areas further from the permanent waterbodies, the groundwater levels (piezometric surface) in the surficial soil and fill materials tend to fluctuate more. Here the upper layers natural soil covers, and manmade fill exist as perched aquifers or temporary groundwater storage facilities from which water is lost to evaporation, seeps horizontally towards surface drainage areas or percolates downwards into the Ashfield Shales and Hawkesbury Sandstone.

Apart from the upper weathered portion of the Ashfield Shales, the shale and laminate rock mass is dense and largely impermeable, but the material is jointed and fractured providing secondary aquifer storage. The Hawkesbury Sandstone is a primary aquifer with interstitial groundwater storage. The material is, however, compressed and groundwater storage within the fine-grained sandstone is limited.

Although some production boreholes exist in fractured zones, the shales and sandstones are typically low yielding aquifers and poorly exploited throughout the Sydney Metropolitan area. Groundwater within the shales is often saline.

The site investigations undertaken by Coffey in 2019 recorded groundwater levels ranging from 0.54 to 3.34 metres below ground level (refer to Table 4-6).

Table 4-6 Groundwater levels recorded in 2019 investigation

Borehole ID	Suburb	Depth below surface (m*etres below ground level)*
BH09	Rydalmere	0.54
BH14	Rydalmere	1.32
BH20	Ermington	3.34
BH23	Ermington	1.02
BH41	Sydney Olympic Park	1.54
BH44	Sydney Olympic Park	3.01

4.9 Baseline surface water quality

4.9.1 Parramatta River

The Parramatta River Catchment Group is currently working to improve the water quality of Parramatta River. Water quality appears to be improving as a result of these catchment management measures. However, wastewater overflows and stormwater continue to contribute to poor water quality conditions Parramatta River (Parramatta City Council, 2016).

City of Parramatta Council water quality data monitoring

Previous monitoring of the Parramatta River was undertaken by the City of Parramatta Council at the following two locations:

- Site 1 - Parramatta River - upstream of the Duck River confluence.
- Site 2 - Parramatta River - downstream of Duck River in Ermington Bay opposite the Millennium Parklands.

The locations of the monitoring sites are shown in Figure 4-13.

The data supplied by the City of Parramatta Council is limited and does not include parameters such as heavy metals, recoverable hydrocarbons and dioxins. Monitoring frequency, indicators and length of the records vary between the two sites; a summary of the data is presented in Table 4-7. The results of the average recorded values are compared with ANZECC (2000 and ANZG (2018) guideline water quality trigger values for slightly disturbed estuarine ecosystems in south-east NSW.

The available data collected from 2012 to 2016 shows that average values of pH were compliant with the guidelines at both sites. However, average turbidity exceeded the upper limit for trigger values at both sites. Average dissolved oxygen fell just below the lower limit of 80 per cent at both sites. Average Chlorophyll-a median concentrations were elevated, exceeding the recommended limit of four micrograms per litre by more than double the recommended limit at site 2 and more than nine times the recommended limit at site 1. The recorded average electrical conductivity at both sites highly significantly exceeded the upper limit trigger values, indicating the brackish nature of the samples probably due to the sites being located within the upper estuary which is characterised by a mix of freshwater and saline waters.

Table 4-7 Summary of existing water quality data

Parameter (Average)	Trigger Value or Criteria (ANZG 2018)	Site 1- Upstream of Duck River confluence	Site 2 - Ermington Bay
Chlorophyll-a (µg/L)	4	38.2	9.6
Dissolved Oxygen (DO)	80%-110%	76.6	78.9
Turbidity (NTU)	0.5 to 10	23	215.7
pH	7-8.5	7.4	7.5
Conductivity (µS/cm) Comp 25 C	125-1200	26,665.3	34,750.8

Shaded cells indicate exceedance of the ANZECC (2000) and ANZG (2018) applicable guidelines.

Figure 4-13 Existing water quality monitoring sites (source: City of Parramatta Council)

Parramatta Light Rail Stage 1 pre-construction water quality sampling

The construction contractor for Parramatta Light Rail Stage 1 carried out a water quality monitoring program that included a pre-construction water quality screening to determine the water quality in the area. The water quality monitoring was undertaken between June 2019 and May 2020. The pre-construction water quality sampling parameters were compared to ANZECC (2000) trigger values, and a summary of the findings are presented in Table 4-8. A detailed table with the results is provided at Appendix B.

The sampling sites are located at Parramatta River, Clay Cliff Creek, Vineyard Creek, Subiaco Creek, Domain Creek and A'becketts Creek, as shown in Appendix B. Whilst these sampling sites are located upstream of the project site and only cover parts of the western section of the project site (Camellia area), the data is more up-to-date compared to the existing water quality data supplied by City of Parramatta Council and provides additional parameters and evidence on the water quality in the area.

When compared with ANZECC (2000) and ANZG (2018) guidelines, the results show pH, dissolved oxygen, turbidity, aluminium, copper, manganese and iron levels exceeding the water quality trigger values for these parameters, during both wet and dry weather events. Electrical conductivity values are much lower and within the trigger values range, compared to the levels recorded previously by the City of Parramatta Council.

Table 4-8 Pre-construction water quality monitoring results for Parramatta Light Rail Stage 1

Parameter	Pre-construction monitoring compliance with ANZECC (2000) and ANZG (2018) Guidelines (YES/NO)	
	Freshwater sites	Estuarine sites
Turbidity	Yes	No (during wet weather)
pH	No (during wet weather)	No (during wet and dry weather)
Dissolved Oxygen	No (during wet and dry weather)	No (during wet and dry weather)
Electrical conductivity	Yes	Yes
Sulfate	Yes	Yes
Chloride	Yes	No (during wet and dry weather)
Aluminium	No (during wet and dry weather)	No (during wet and dry weather)
Copper	No (during wet and dry weather)	No (during wet and dry weather)
Lead	Yes (except for Clay Cliff Creek)	Yes
Manganese	Yes	No (during wet and dry weather)
Iron	No (during wet and dry weather)	No (during wet and dry weather)
Hydrocarbons	Yes	Yes

Shaded cells indicate exceedance of the ANZECC (2000) and ANZG (2018) applicable guidelines.

4.9.2 Haslams Creek

This creek is a highly modified second order watercourse which drains into the Parramatta River at Homebush Bay. The catchment of Haslams Creek is highly urbanised (including the M4 Motorway) with the upper extents generally concrete lined opened channels and pipes. Haslams Creek is mapped as Key Fish Habitat and is classified as Type 1 (Key Fish Habitat). The upper extent of the creek is generally concrete lined open channels and pipes.

Haslams Creek is located close to the project site where it runs along Hill Road and the Holker Busway in Wentworth Point/Sydney Olympic Park. The project site crosses Haslams Creek via the existing bridge (to which works are proposed as part of the project) on the Holker Busway in Sydney Olympic Park.

Water quality relevant to the ANZECC (2000) and ANZG (2018) guidelines indicate Haslams Creek is characterised by elevated nutrient concentrations and elevated concentrations of faecal coliforms. This indicates the watercourse is generally representative of a heavily urbanised system.

4.9.3 Narawang Wetland

The project site is located adjacent to Narawang Wetlands where it runs along Hill Road and crosses the floodway via the existing bridge (to which works are proposed as part of the project) on Hill Road.

Narawang Wetland forms part of the constructed wetlands within the Millennium Parklands in Sydney Olympic Park. The wetland provides combined functions of flood mitigation, water storage and habitat for the Green and Golden Bell Frog and breeding waterbirds such as the Latham's Snipe.

Narawang Wetland is connected to Nuwi Wetland via a floodway under Hill Road. Nuwi Wetland is open to Haslams Creek and is subject to tidal flushing. The floodway allows flood flows from Haslams Creek to enter Narawang Wetland. One of the key local management challenges within the ponds is the existence of *Gambusia holbrooki* (listed as a 'noxious fish' under the *Fisheries Management Act 1994* (FM Act)*)*, fragmentation, disturbance, edge effects, predation and disturbance by domestic pets and rats and Alligator weed.

Water quality relevant to the ANZECC (2000) and ANZG (2018) guidelines indicate Narawang Wetland is characterised by elevated nutrient concentrations, elevated heavy metal concentrations and high turbidity. This indicates the watercourse is generally in poor condition and is representative of a heavily urbanised system.

4.9.4 Subiaco Creek

The water quality of Subiaco Creek has been measured by Sydney Water on an annual basis since 2006. The data is limited, with ammonia and conductivity the only parameters measured. The conductivity of Subiaco Creek is slightly higher than upstream waterways due to the tidal influences. Median ammonia concentrations of 50 micrograms per litre exceed the recommended guidelines for protection of aquatic ecosystems.

4.9.5 Vineyard Creek

Vineyard Creek is a tributary of the Parramatta River that drains a relatively small (five square kilometres) but highly modified catchment that discharges into the Parramatta River downstream of the Parramatta CBD. Parts of Vineyard Creek and its tributaries have been subjected to substantial modification in stream form through the period of European settlement, but particularly during the period of intense urbanisation since 1970. The catchment is almost fully developed and is composed of low-medium density urban precincts.

Despite compliant pH levels (100 per cent), the water quality of this creek could be considered poor and eutrophied. This is due to the excessive nutrient loads that enter the creek via stormwater and wastewater outlets and runoff. The concentrations of total nitrogen and phosphorus exceed the adopted limits for urban streams at all times for TN and 94 per cent of the time for TP. Ammonia concentrations whilst elevated, comply on occasion (31 per cent) (Jacobs & UNSW, 2016).

4.9.6 Duck River

The Duck River discharges just upstream of the proposed swimming site at Wilsons Park, and it is tidal in its downstream reaches. Several sites have been monitored in the Duck River, including the Botanical Gardens, Mona Bridge, Princess Road West (weir) and the golf course (Wellington Road). Additionally, a water quality monitoring buoy was deployed in the Duck River to measure pH and chlorophyll-a. pH levels were below the adopted limit 97 per cent of the time from the buoy and 92 per cent of the time from other sites. There is no nutrient data for Duck River, however elevated chlorophyll-a concentrations (median 8.8µg/L) infer those nutrient concentrations are also likely to be high. The eutrophied state of Duck River (Parramatta City Council, 2016)) is largely due to the highly industrialised and urbanised catchments surrounding this river. The City of Parramatta Council has identified many sites adjacent to the Parramatta River containing landfill and there are known sites of contamination in close proximity to Duck River (Jacobs & UNSW, 2016).

4.9.7 Archer Creek and Charity Creek

Located approximately 500 metres from the north-eastern section of the project site, Archer Creek flows generally south to the Parramatta River where it joins at Meadowbank Park, Meadowbank.

Archer Creek flows through the Ryde-Parramatta Golf Course before entering Meadowbank Park and the Parramatta River. Charity Creek runs from west of the Main Northern Railway through Meadowbank Park and to the Parramatta River. Meadowbank Park is part of an extensive wetland system bordering the Parramatta River. The mangroves in the wetland system represent a large proportion of mangroves in the Sydney Region (Cardno, 2013). Mangroves provide many benefits to the natural environment. In particular they trap and bind sediments, reducing turbidity, which results in cleaner water. They capture effluents from runoff providing a buffer for nutrients, metals and other toxicants entering coastal waters. Water quality data is limited at this site.

There is insufficient data to assess the site’s suitability for swimming or the ecological health of the site (Jacobs & UNSW, 2016).

4.9.8 Sensitive receiving environments

A sensitive receiving environment is defined as one that has a high conservation or community value, or one that supports ecosystems or human uses of water. These environments are typically sensitive to pollution and degradation of water quality. Sensitive receiving environments include Key Fish Habitat, Nationally Important Wetlands, recreational swimming areas, drinking water catchments, coastal wetlands and areas of known or potential habitats for threatened fish. For the purposes of this assessment, the Parramatta River and the downstream receptors are considered a sensitive receiving environment. The Parramatta River is mapped as Key Fish Habitat and contains disturbed mangrove forests in patches along its banks (refer to Figure 4-14).

Further description of the aquatic receiving environments is provided in Technical Paper 9 (Biodiversity Development Assessment Report).

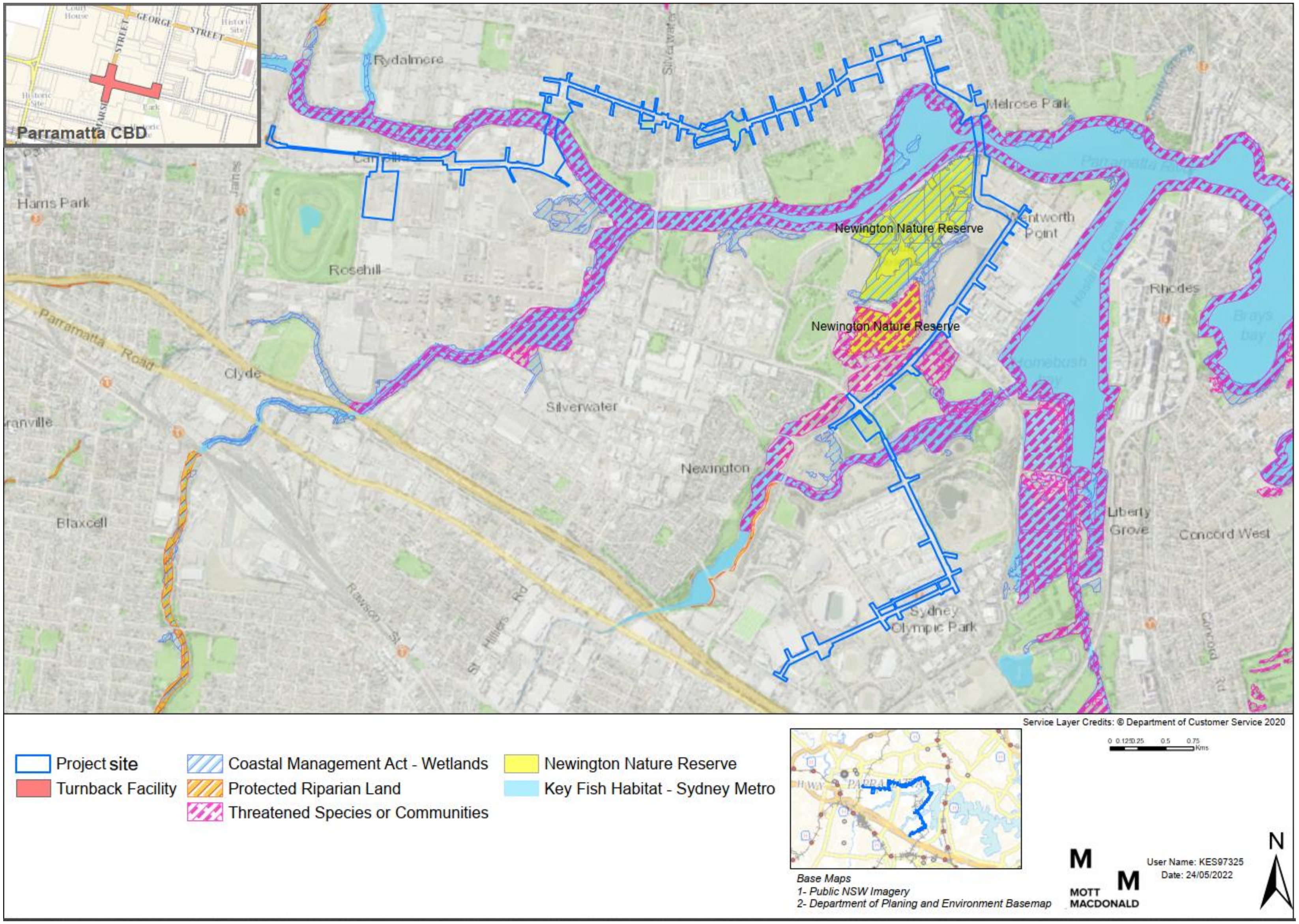

Figure 4-14 Sensitive receiving environments

5 Hydrology and flooding impact assessment

This chapter describes the hydrology and flooding impact of the project on the surrounding environment.

5.1 Flood immunity standards

This section outlines the flood immunity standards for key elements of the project. Flood immunity standards determine particular aspects of the design such as the vertical elevations of rails, stop platforms and critical infrastructure to ensure they are immune to particular storm events to prevent degradation to the service provided. In turn, achieving flood immunity through the design may adversely impact existing flood levels or flows, generating flood impacts. These flood impacts are assessed against the FMOs as outlined in Section 3.1.3.

The flood immunity standards for the project are outlined in Table 5-1.

Table 5-1 Flood immunity standards

Project element	Design standard
Stormwater drainage	Target minimum light rail operability in 0.2 exceedance per year (EY) event including climate change. Designed in line with drainage principles outlined in Table 5-3.
Facilities, including Stops and Electrical, Mechanical and Communications equipment	Located above the 1% AEP flood level including climate change; or designed and rated for immersion or submergence to the extent predicted through flood modelling.
Bridges	**New bridges:** immunity and freeboard designed to current standards and codes, typically 1% AEP including climate change + 500 millimetres freeboard to soffit level, with scour and ultimate limit state requirements to be in accordance with AS 5100 (Bridge Design). **Retained or replaced existing bridges**: immunity would be restricted to the lesser of 1% AEP including climate change + 500 millimetres freeboard and existing performance, which may be less than the current design code requirements. Note: navigational clearance potentially governs design level.
Critical infrastructure	Critical infrastructure would be protected from the PMF, or the 1% AEP flood level including climate change + 500 millimetres (whichever is greater).

In the event that the FMOs are exceeded as a result of providing flood immunity to the project, mitigation measures shall be incorporated into the design to mitigate the severity of flood impacts to a level that meets the FMOs. This could take the shape of additional drainage, transverse culverts, local land grading or detention of stormwater.

5.1.1 Stormwater drainage

Design principles

Drainage infrastructure would be designed:

- to meet the proposed operational requirements of the project
- to avoid or minimise, as part of suite of potential mitigation solutions, the risk of, and adverse impacts from, flooding.

Given the scale of road adjustment associated with the project, significant change to stormwater infrastructure is required. Stormwater design across the project has been divided into three categories as shown in Table 5-2.

Table 5-2 Stormwater design categories

Category	Description
Category S1	Develop design to allow safe conveyance of the 5% AEP storm event within the drainage system, should the network external to the project (upstream and downstream) be upgraded by others to meet the 5% AEP standard. Mitigate against downstream impacts associated with increasing existing hydraulic capacity by constricting pipe and pit capacity where required until upgrade of downstream system by others is carried out
Category S2	Develop design to meet project operational response requirements, minimum operation in 0.2 EY event
Category S3	Maintain operation of existing drainage capacity
All Categories	Develop design to minimise risk and impact from flooding

Drainage design would be developed using the principles shown in Table 5-3.

Table 5-3 Proposed drainage design principles

Test criteria	Design category
Project design clash with existing pits, pipes and other subsurface drainage infrastructure	S1
New drainage is required for operational reasons	S2
Condition assessment identifies defects that require rehabilitation or renewal	S2
Transverse drainage infrastructure where there is no physical clash	S3

5.2 Flood impact assessment

This section documents the potential impacts of the project on existing flooding in the study area. This includes impacts to regional flooding from Parramatta River and local stormwater flooding. Impacts are described relative to either the construction phase (accounting for impacts as a result of construction activities) or the operation phase (accounting for impacts as a result of the operation of the project).

The overall design principle of the project is to use existing roads and finished ground levels where possible. Therefore, the project is not anticipated to significantly alter the existing topography and subsequently, only has minor impacts to existing flood levels, as described further in Section 5.2.2.

Where new impervious surfaces are required, new drainage infrastructure would be required to satisfy the project drainage design principles (Section 5.1.1), with the majority of drainage infrastructure to discharge to existing pit and pipe systems.

5.2.1 Construction impacts

Overview

This section provides a qualitative assessment of flood risk and potential flood impacts associated with construction compounds and construction activities generally within the project site. Flooding during construction activities has the potential to result in delays to construction and damage to plant and materials. It may also pose a safety risk to construction personnel.

In terms of flood impact, construction activities have the potential to change flood behaviour as a result of changes to site topography and installation of temporary buildings and other structures within the floodplain.

Consideration of flood risk and potential flood impact has been carried out for the following:

- construction compounds.
- light rail alignment and road adjustments
- bridge construction and modification.

Potential flood-related impacts during construction may include:

- diversion of existing flood flow routes caused by features within the construction compound (such as spoil stockpiles or barriers). This could result in a loss of flood storage or increased flood risk to adjacent areas.
- an increase in impervious area leading to an increase in runoff volume
- blockage of existing drainage networks through an increase in sediment runoff.

Mitigation measures implemented as part of the Construction Environment Management Plan would ensure that construction activities are compliant with the relevant requirements.

Construction compounds

Table 5-4 summarises both the assessed flood risk and potential flood impacts at each construction compound proposed by the project. A short description of proposed activities at each location is provided for context.

It is acknowledged that the number and location of construction compounds is subject to change in subsequent stages of the design, and re-assessment of flood risk and impact may be required.

Table 5-4 Flood risks and potential impacts - construction compounds

No.	Location	Purpose	Extent of Flood Affectation	Potential flood impacts
1	Grand Avenue (west), Camellia (see Figure 5-1)	Support works along the western section of the project site (including along the former Sandown Line and Grand Avenue) in Camellia.	Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent. Some local ponding of flood water within site compound for the 1% AEP event. Water depths may reach 0.1m in places	Depending on the proposed structures and the storage of materials, plant and equipment on the site, limited obstruction of existing flood volume may occur, causing a redistribution of flow. The redistribution is not expected to have a significant impact on flood level or velocity due to the nature of the existing land use.
2	Grand Avenue (east), Camellia (see Figure 5-1)	Support works for the bridge between Camellia and Rydalmere from the southern side of the Parramatta River.	Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent. Some local ponding of flood water within site compound for the 1% AEP event. Water depths may reach 0.1m in places	Depending on the proposed structures and the storage of materials, plant and equipment on the site, limited obstruction of existing flood volume may occur, causing a redistribution of flow. The redistribution is not expected to have a significant impact on flood level or velocity due to the nature of the existing land use.
3	John Street, Rydalmere (see Figure 5-1)	Support works for the bridge from the northern side of the Parramatta River and works around John Street and South Street, including the John Street stop.	Proposed compound is split into two zones. The western zone is located within Parramatta River 1% AEP flood extent. The southern fringe of the eastern zone is also within Parramatta River 1% AEP flood extent. 1% AEP flood depths exceed 1.5m in places. Proposed compound is entirely inundated by the Parramatta River PMF extent.	Depending on the proposed structures and the storage of materials, plant and equipment on the site obstruction of floodwaters may occur, particularly within the western zone. This has potential to affect private properties on John Street or Antione Street by raising flood levels. Flood impacts in the eastern zones are likely to be negligible. Transport of sediment/materials into Parramatta River due to proximity to river though not expected to adversely affect the capacity of the river due to its overall capacity

No.	Location	Purpose	Extent of Flood Affectation	Potential flood impacts
4	Broadoaks Park, Primrose Avenue, Rydalmere (see Figure 5-1)	Support works along South Street and bridge works at Silverwater Road.	There is an existing 1% AEP flood flow route within Broadoaks Park, flowing from Fallon Road to Primrose Avenue (east to west). Flood depths do not exceed 0.20m.	Depending on the proposed structures and the storage of materials, plant and equipment on the site obstruction of floodwaters may occur. This may impact nearby private properties along South Street, Primrose Avenue or Fallon Street by raising flood levels. The transport of sediment or other materials into local stormwater drainage networks may degrade the networks performance and could cause an increase in flood water levels. The sag locations on Primrose Avenue and Fallon Street would potentially worsen this impact and should be considered when planning and establishing the construction compounds.
5	Ken Newman Park, Hilder Road, Ermington (see Figure 5-1)	Support works east of Silverwater Road, including the River Road stop and works within Ken Newman Park.	The site is not affected by mainstream flooding (lies outside PMF event) and is not affected by major overland flows.	Negligible impact anticipated.
6	Ken Newman Park, Heyson Avenue, Ermington (see Figure 5-1)	Support works within and around Ken Newman Park, including relocation of the water mains, and works along Boronia Street.	The site is not affected by mainstream flooding (lies outside PMF event) and is not affected by major overland flows.	Negligible impact anticipated.
7	Hope Street, Melrose Park (see Figure 5-1)	Support works along Boronia Street and Hope Street and works at the Atkins Road stop.	The site is not affected by mainstream flooding (lies outside PMF event) and is not affected by major overland flows.	Negligible impact anticipated.

No.	Location	Purpose	Extent of Flood Affectation	Potential flood impacts
8	Archer Park/ Waratah Street/ Ermington Boat Ramp/ Wharf Road, Melrose Park (see Figure 5-2)	Support works for the bridge between Melrose Park and Wentworth Point from the northern side of the Parramatta River and works for the Waratah Street stop.	Typically located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent. A small portion of the eastern zone is affected by the one per cent AEP flood.	Negligible impact anticipated on flood behaviour. Transport of sediment/materials into Parramatta River due to proximity to river though not expected to adversely affect the capacity of the river
9	Sanctuary Wentworth Point (see Figure 5-2)	Support works for the bridge from the southern side of the Parramatta River, and for alignment around to and including Footbridge Boulevard stop.	Largely located outside the 1% AEP mainstream flood extent, however, a flow route exists along the western edge of the compound. Flood depths range between 0.5 and 0.6 metres. Flood depths increase significantly in the PMF event for Parramatta River, though still only affects the western edge of the compound.	Negligible impact anticipated on flood behaviour due to nearby land use and open spaces. Transport of sediment/materials into Parramatta River due to proximity to river.
10	Hill Road (at Bennelong Parkway), Wentworth Point (see Figure 5-2)	Support works along Hill Road and the Hill Road stop.	Located outside the 1% AEP mainstream flood extent, but within Haslams Creek PMF extent.	Negligible flood impact anticipated due to location of site compound in large, open space. Proximity of construction activity to Haslams Creek wetlands may result in sediment/materials being washed into the environmentally sensitive areas.
11	Hill Road (north of Holker Busway), Sydney Olympic Park (see Figure 5-2)	Support works along Hill Road including Hill Road bridge construction.	Located outside the 1% AEP mainstream flood extent, but within Haslams Creek PMF extent.	Negligible impact anticipated due to location of site compound in large, open space. Proximity of construction activity to Haslams Creek wetlands may result in sediment/materials being washed into the environmentally sensitive areas.

No.	Location	Purpose	Extent of Flood Affectation	Potential flood impacts
12	Holker Busway, Sydney Olympic Park (see Figure 5-3)	Support works along Hill Road and the Holker Busway, including bridge works and the Holker Street stop. The compound would include a construction workforce parking area for about 200 vehicles.	Located outside the 1% AEP mainstream flood extent, but northern edge within Haslams Creek PMF extent	Negligible impact anticipated due to location of site compound in large, open space. Proximity of construction activity to Haslams Creek wetlands may result in sediment/materials being washed into the environmentally sensitive areas.
13	Australia Avenue, Sydney Olympic Park (see Figure 5-3)	Support works along Australia Avenue and the Jacaranda Square stop.	The site is not affected by mainstream flooding. Overland flow modelling indicates the site may be affected by a PMF event.	Depending on the proposed structures/storage on the site obstruction of floodwaters may occur. Proposed compound located in existing car park so negligible impact expected.
14	Dawn Fraser Avenue, Sydney Olympic Park (see Figure 5-3)	Support works along Dawn Fraser Avenue including the Olympic Boulevard stop.	The site is not affected by mainstream flooding. Overland flow modelling indicates the site may be affected by a PMF event.	Depending on the proposed structures/storage on the site obstruction of floodwaters may occur that may affect private properties on Edwin Flack Avenue.
15	Dawn Fraser Avenue, Sydney Olympic Park (see Figure 5-3)	Support works at and around the Carter Street stop.	The site is not affected by mainstream flooding. Overland flow modelling indicates small areas of the site may be affected by a PMF event.	Negligible impact anticipated on flood behaviour.

Figure 5-1 Construction compound locations – map 1

Figure 5-2 Construction compound locations – map 2

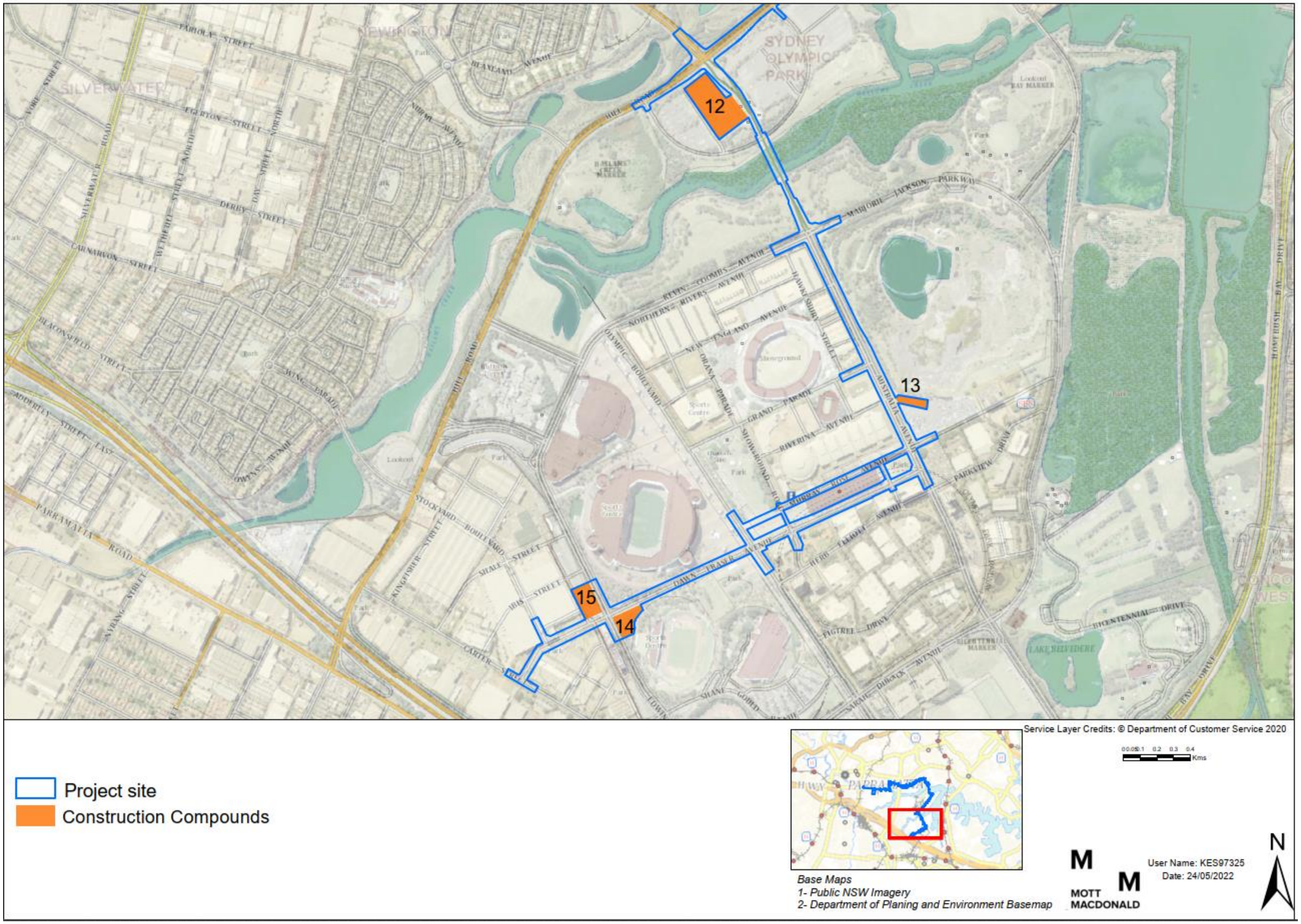

Figure 5-3 Construction compound locations – map 3

Light rail alignment and road adjustments

Potential impacts associated with construction of the light rail and associated road adjustments would include the following:

- Overland flows discharging onto areas of surface works has potential to cause erosion of disturbed surfaces and transport of sediment/materials into waterways.
- Erection of site hoardings or barriers to cordon off construction areas within existing road carriageways may affect local overland flow paths and result in flood impacts within and outside the road corridor.

It would therefore be necessary to plan, implement and maintain drainage measures aimed at managing the overland flow either through or diverting around the construction areas.

Bridge construction and modification

Proposed works and potential construction stage flood impacts at each proposed bridge location are addressed in Table 5-5 for and potential mitigation measures are identified in Section 8.2.

Table 5-5 Flood potential impacts during bridge construction

Bridge	Description	Potential construction stage flood impacts
Proposed bridge between Camellia and Rydalmere	Construction of supporting piers within the Parramatta River would involve temporary access within the river.	Potential impacts include: • obstruction of the waterway by temporary scaffolding/falsework • obstruction of the waterway through temporary access for pier piling works. These could lead to an increase in flood water levels or localised increases in velocity.
Proposed bridge between Wentworth Point and Melrose Park	Construction of supporting piers within the Parramatta River would involve temporary access within the river.	Potential impacts include: • obstruction of the waterway by temporary scaffolding/falsework. • obstruction of the waterway through temporary access for pier piling works. These could lead to an increase in flood water levels or localised increases in velocity.

While the findings of the qualitative assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be undertaken during design development as layouts and staging diagrams are further developed. Construction planning and the layout of construction worksites and compounds would be undertaken with consideration of overland flow paths and flood risk, avoiding flood liable land as far as practicable. Consideration would also need to be given to setting an appropriate hydrologic standard for mitigating the impacts of construction on flood behaviour, taking into account the temporary nature of construction activities and, as such, the likelihood of a flood of a given AEP occurring during the construction period.

Prior to construction a flood and emergency response plan will be prepared. The plan will include measures, process and responsibilities to minimise the potential impacts of construction activities on flood behaviour as far as practicable. It will also include measures to manage flood risks during construction and address flood recovery during construction.

5.2.2 Operational impacts

Overview

This section provides a qualitative assessment of flood risk and potential flood impacts associated with operation of the project.

In terms of flood impact, the project has the potential to:

- increase surface runoff volume and peak flows causing an increase in flood level
- change flood behaviour as a result of changes to site topography or surface finish (such as new hardstand locations at proposed stops)
- increase peak flood levels in Parramatta River caused by a restriction in flow at the new bridges
- increase chance of scouring caused by in-channel structures resulting in erosion riverbed or banks.

Consideration of flood risk and potential flood impact has been carried out for the following:

- flooding from local drainage systems
- light rail alignment and road adjustments (local design surfaces)
- bridge structures.

The impacts assessed through the flood modelling are presented in mapping attached as Appendix 1C including the five per cent AEP, one per cent AEP flood events (with and without climate change).

Flooding from local drainage systems

Many locations along the proposed alignment are subject to flooding caused by stormwater exceeding the capacity of local drainage networks.

Due to the proximity of the proposed alignment to adjacent properties subject to urban overland flow, ground level changes and local drainage system modification required for the project has the potential to cause flood impacts to properties within the extent of these urban overland flows. To achieve operability targets a formal drainage pit and pipe system will be designed to manage overland flows. These drainage systems will typically connect to existing drainage infrastructure networks of City of Parramatta Council or Sydney Olympic Park Authority and potentially be limited by the downstream capacity of these systems.

Key locations experiencing overland flows in excess of the local drainage systems are described below. A preliminary assessment has been undertaken for the EIS noting that detailed survey, drainage system analysis and design grading of interface works with the existing topography would be undertaken during design development. The residual impacts indicated in flood modelling results at these locations can reasonably be expected to be mitigated during design development, to the appropriate flood impact limit stated in the FMOs.

Parramatta CBD

In the Parramatta CBD, the presence of the Macquarie Street turnback facility would have minimal impacts to the flooding regime due to the small footprint of the infrastructure and consistency of finished levels with the existing levels of Macquarie Street.

The Macquarie Street section of the project site's contribution to flood impacts has been assessed as insignificant since there are no proposed structures or fillings which could potentially cause loss of floodplain storage.

Camellia

In Camellia, flooding impacts may occur in the following locations as a result of the operation of the project:

- Along the alignment at Grand Avenue: this is due to the alignment crossing existing flood flow routes from south to north as they travel towards Parramatta River. Any vertical changes to the topography have the potential to create adverse flood impacts as these flow routes become blocked.
- Flood impacts of + 30 millimetres are predicted at the western end of Grand Avenue in commercial land. This would be mitigated during design development when it is expected that as-built drainage details for Parramatta Light Rail Stage 1 are included in the flood modelling. This would enhance the understanding of existing and future flood risk and allow a more suitable mitigation option to be designed if impacts are still prevalent.
- Flood impacts up to + 270 millimetres are predicted at the eastern end of Grand Avenue in commercial land. This is caused by the proposed bridge abutments restricting flow and reducing capacity of the floodplain in this location. Further mitigation measures such as additional cross-culverts through the proposed bridge abutments, or local land reshaping would be considered as part of design development
- Any residual impacts after mitigation are anticipated to be minor only and within the target limits of the FMOs. Further assessment and investigation for piped drainage system capacity to relieve overland flow conditions will be undertaken during detailed design.

Other than these locations, FMOs are met in Camellia with no predicted impact to residential properties or public land.

Rydalmere

In Rydalmere, flooding impacts may occur in the following locations as a result of the operation of the project:

- The project proposes to raise the vertical geometry of the road at John Street, and this has potential to alter or block existing flood flow paths, causing impacts to adjacent properties. A commercial unit at 58 John Street may be impacted by a +30 millimetre increase in water level. Further assessment and investigation for piped drainage system capacity to relieve overland flow conditions would be undertaken during design development, however, it is expected that FMOs would be achieved.
- Mitigation of impacts at South Street / Patricia Street and South Street / Primrose Avenue is expected to achieve the FMOs for residential locations, with no impacts greater than +10 millimetres.
- Any residual impacts after mitigation are anticipated to be within the target limits of the FMOs and further mitigation in Rydalmere is not required.

Ermington

In Ermington, flooding impacts may occur in the following locations as a result of the operation of the project:

- The project may cause some additional ponding of flood water as it crosses Hilder Road and the Sydney Water easement to the west, affecting Residential properties. Mitigation of this ponding to meet the FMOs could be achieved by provision of cross drainage to the rail alignment, discharging to existing overland flow paths. Further assessment of scour protection and flow spreading design to relieve overland flow conditions and residual impacts to adjacent properties would be required through design development.

- The proposed western abutment for the bridge in Ken Newman Park is above the existing surface levels, which may cause flood impacts on the north side of the alignment. To meet the FMOs for residential properties, mitigation of this ponding and redistribution of overland flows has been achieved by including additional cross drainage as part of the design, however, further assessment of scour protection and flow spreading is necessary in future design development.
- Residual flood impacts are predicted in Ken Newman Park, with an increase in water level by up to +40 millimetres as a result of redirected flood waters. As the FMO for Public Land is +50 millimetres, this residual impact is deemed acceptable and has not been mitigated.
- Further assessment and investigation for piped drainage system capacity to relieve overland flow conditions would be undertaken during design development.

Other than these locations, FMOs are met in Ermington with no predicted impact to residential, commercial or public land.

Melrose Park

In Melrose Park, flooding impacts may occur in the following locations as a result of the operation of the project:

- Raised ground levels due to the project at the intersection of Hope Street and Hughes Avenue as well as Hope Street west of Waratah Street may cause adverse flood impacts to residential properties. Mitigation through increasing the capacity of the drainage network and providing new cross drainage would achieve the FMO for no increase greater than +10 millimetres on residential properties. Increased surcharge capacity would also be required at the southern verge to maintain flows in the existing overland flows paths.
- Residual flood impacts greater than +100 millimetres are predicted adjacent to the project at Waratah Street, where flood water ponds against the raised alignment. However, impacts are located entirely within the project site and are not expected to impact commercial or residential properties.
- Further assessment and investigation for piped drainage system capacity to relieve overland flow conditions would be undertaken during design development.

Other than these locations, FMOs are met in Melrose Park.

Wentworth Point

In Wentworth Point, flooding impacts may occur in the following locations as a result of the operation of the project:

- Localised increases in flood levels upstream of the proposed duplication of Hill Road bridge extend beyond the project site. Detailed flow transition structures including scour management at the inlet and beneath the bridge would be considered in design development to mitigate these impacts.
- Residual flood impacts are anticipated in the immediate vicinity of the inlet structure. However, specific mitigation (such as wingwalls or flow control devices) can be used such to reduce any potential flood effects on sensitive communities upstream of the new bridge. These impacts would be further addressed during design development.
- Further assessment and investigation for piped drainage system capacity to relieve overland flow conditions would be undertaken during design development.

The FMOs are met for residential, commercial and public land in Wentworth Point.

Sydney Olympic Park

In Sydney Olympic Park, flooding impacts may occur in the following locations as a result of the operation of the project:

- Changes to the vertical elevation of Dawn Fraser Avenue, in the vicinity of Accor Stadium, would cause the redirection of overland flows around the stadium. Future upgrades to the existing piped drainage system, or further grading changes within the road reserve could serve to mitigate this change in overland flow and reduce flood impacts. Some residual flood impacts are predicted, with an increase in water level of + 25 millimetres adjacent to the alignment. As this is open space in front of the stadium, this increase is not expected to be significant as no properties are impacted.
- Further assessment and investigation for piped drainage system capacity to relieve overland flow conditions would be undertaken during design development.

The FMOs are met for residential, commercial and public land in Sydney Olympic Park. However, Sydney Olympic Park also contains flood sensitive areas and infrastructure including the Narawang Wetland, Brick Pit and a leachate management system. Design development would look to minimise flood impacts to avoid these flood sensitive areas, where possible.

Summary of impacts

Some discrete areas may experience an increase in flood risk as a result of the project as overland flows are affected by the new finished surface levels created by the project alignment causing a redirection of flood flow routes. These would typically occur in locations that experience ponding of flood water under existing conditions, including:

- localised overland flow in Grand Avenue, Camellia
- localised overland flow paths through Rydalmere and Melrose Park:
  - South Street
  - Ken Newman Park
  - Hope Street
- localised overland flow paths in the Sydney Olympic Park roads:
  - Dawn Fraser Avenue
  - Australia Avenue
  - Hill Road

Minimal changes to flow velocities are attributed to the project, with only minor new impervious areas created by the presence of project infrastructure. New impervious surfaces would be provided with drainage infrastructure to satisfy the project drainage design principles (Section 5.1.1), with the majority of drainage infrastructure to discharge to existing pit and pipe systems.

It is not expected that the project would have adverse flooding impacts on any sensitive land use categories, including schools.

Section 8.2 outlines measures to mitigate these localised impacts on overland flows. A Flood Management Strategy would be developed which would set out measures which are aimed at mitigating the impacts of the project on flood behaviour. Further details on the requirements of the Flood Management Strategy, as well as range of measures which would be implemented to mitigate the potential operation related impacts of the project are outlined in Section 8.2.

Some new pit and pipe infrastructure would be required to satisfy the operating requirements for the system during frequent storm events occurring (the target minimum light rail operability is 0.2 EY event including climate change). However, additional runoff capture capacity or alternate capture arrangements are to be considered during further design stages to further reduce impacts. The approach to mitigating features within the design stormwater infrastructure is described in Section 8.2.

Bridge structure impacts

In-stream structures may promote channel scouring resulting in further increase of erosion and impact on mangroves and interference with natural flow regimes. Channel migration may change the position of the low flow path and localised changes to the bed and instream habitat may occur.

The presence of piles, pile caps and piers in the Parramatta River floodplain would reduce the efficiency of the floodplain in conveying flood water downstream. This would result in higher flood levels on the upstream side of the bridge structures. The areas that would be affected would be located to the west of the bridge between Melrose Park and Wentworth Point, as shown in Appendix 1A. The increase in flood levels would be limited to 50 millimetres during the one per cent AEP flood event and would extend into the Newington Nature Reserve.

Bridge construction impacts on flooding are mostly driven by the pile cap structure which is located within the elevations that convey flood water under the bridge structure. Section 8.2 includes measures proposed to mitigate these potential impacts. Change in river flow velocities as a result of the structure are considered minor and localised, with detailed erosion protection measures to be incorporated into the project design, where required. No significant changes to flow would be observed as a result of the project.

5.2.3 Social and economic costs to the community

Based on the assessment of potential flooding impacts outlined in Section 5.2.1 and Section 5.2.2, the potential flooding impacts that are expected to result from the project are generally considered to be minor and localised.

The mitigation measures identified in Section 8.2, reduce flood impacts expected during construction and operation. The associated social and economic costs to the community are negligible.

Further consultation would be undertaken with the NSW State Emergency Service, City of Parramatta Council, and City of Ryde Council as the design progresses to ensure any potential impacts to existing community emergency management arrangements are appropriately mitigated. Further details on the social and economic costs of flood impacts on the community are addressed in Technical Paper 7 (Social Impact Assessment).

5.2.4 Consistency with Council floodplain risk management plans

Relevant plans for the local catchment are described in Section 2.4 and Section 2.5 and includes the City of Parramatta Council’s *Local Floodplain Risk Management Policy (* 2014*)* and the *Lower Parramatta River Floodplain Risk Management Study* (SKM, 2005). The project is considered to be consistent with Council floodplain risk management plans and/or policies, where relevant to the project.

The flood hazard under existing conditions is described in Section 4.2 with some areas identified safe for people and vehicles and others at high levels of hazard due to inundation.

The proposed alignment includes at-grade light rail tracks along the majority of the alignment resulting in minimal changes to the existing hazard categorisation of the floodplain. As a result the flood hazard exposure of the light rail system during operation is consistent with the flood hazard exposure of the current land use, typically pedestrian and vehicle access along local and collector roads. The rail alignment allows for egress routes along the project alignment to higher ground in the event of major and extreme flooding.

The flooding impact assessment describes the impacts of the project on existing flooding conditions and the mitigation of these impacts so as to not worsen the flooded conditions during operation. This includes allowance for flood conveyance through the major Parramatta River floodplain and preservation of overland flow routes and overland flow path capacities. The design alignment following the existing ground levels closely results in the preservation of these localised flow paths. No major filling activities within the floodplain are proposed, with only discrete sections of the alignment raised above the existing ground levels on approach to new structures over existing waterways. This approach maintains the flood storage capacity of the project area where it is within the extents of the floodplain.

5.2.5 Impacts on existing emergency management arrangements

The project is not predicted to alter existing community emergency management arrangements for flooding. The project Operational Environmental Management Plan would include emergency management arrangements to manage flood risks to people and vehicles accessing stops and facilities. Egress arrangements would need consider flood hazard in nearby streets.

5.3 Surface hydrology impact assessment

5.3.1 Construction impacts

Potential hydrology impacts associated with construction of the light rail and associated road adjustments would include the following:

- Potential changes to runoff volumes, local redirection of overland flows and pollutant loadings in surface runoff due to the presence of excavations and temporary construction structures are anticipated to be minor due to the small footprint of disturbed land required for construction, and like-for-like replacement of road pavement with provision for the light rail, resulting in the existing flow regimes being largely maintained. These changes may include temporary reductions in runoff volumes where existing pavements are removed and infiltration to the soil is increased or temporary increases to runoff volumes in the case of working stop platforms comprised of a hardstand pavement.
- Overland flows discharging onto areas of surface works has potential to cause erosion of disturbed surfaces and transport of sediment/materials into waterways.
- Erection of site hoardings or barriers to cordon off construction areas within existing road carriageways may affect local overland flow paths and result in flood impacts within and outside the road corridor.
- Obstruction of flow paths due to the presence of construction works and equipment has the potential to redistribute flood flows, impact downstream properties, and/or mobilise construction equipment or debris. This may result in downstream safety or water quality impacts.
- Construction of the project would not involve the extraction of any water from existing surface water sources. However, the opportunity to re-use site water and harvest rainwater will be explored through construction.

Mitigation measures for localised impacts on surface hydrology during construction are addressed in Section 8.2.

5.3.2 Operational impacts

The vast majority of the project site is within road reserves of existing roads, with the design alignment closely related to the existing surface grading. As a result of this design approach, the disturbance to the surface hydrology within the majority of the project alignment is relatively low as changes to existing surface elevations are minor.

Specific areas where ponding or overland flows are influenced by the project alignment are captured in the flooding assessment in Section 5.2.2. However, no major changes to runoff volumes or typical pollutant profiles of the surface water occurs as the overall dimensions of existing road reserves remains largely unchanged.

Where level changes and new formal drainage features including pits and pipe infrastructure are required, the capture of surface water may increase as there is potential for new drainage infrastructure to be built to a higher standard than is typical for the existing urban drainage networks in the area. Outside of the road reserves, the project site has discrete sections through areas currently comprised of a mix of pavement and vegetated areas at the following locations:

- approaches at the proposed bridge between Melrose Park and Wentworth Point
- approaches at the proposed bridge between Camellia and Rydalmere (including Rydalmere Wharf)
- Ken Newman Park.

In these locations there would be a change in the impervious area which contributes to the volume of runoff generated and the introduction of the light rail vehicles could present changes in terms of new pollutants in the surface water.

Based on MUSIC modelling, the changes in runoff volume for each sub-catchment are presented in Table 5-6, with each sub-catchment location shown in Figure 5-4.

The results identify high percentage reductions in runoff volumes in a number of catchments, these reductions are localised within the relevant catchments. When compared to the broader Parramatta River catchment (252.4 square kilometres) the runoff volumes are negligible and unlikely to result in any noticeable impacts.

Table 5-6 Change in annual runoff volumes by sub-catchment

Sub-catchment	Annual runoff volume (under existing conditions) (ml/yr)	Annual runoff volume (during operation) (ml/yr)	Change (%)	Location
C1	4.72	3.29	- 30.4	Camellia
C2	12.0	8.3	- 30.9	Camellia
C3	21.3	21.3	0	Camellia
C4	16.6	15.1	- 8.7	Rydalmere
C5	12.1	12.1	0	Rydalmere
C6	7.66	7.66	0	Ermington
C7	19.1	15.3	- 19.6	Ermington
C8	10.4	10.4	0	Ermington
C9	7	7	0	Ermington
C10	22.5	16.1	- 28.7	Ermington/Melrose Park
C11	16.7	15.1	- 9.4	Melrose Park
C12	15.5	10.8	- 30	Wentworth Point/Sydney Olympic Park
C13	23.9	23.9	0	Wentworth Point/Sydney Olympic Park
C14	10	7.08	- 29.2	Sydney Olympic Park
C15	8.55	5.96	- 30.3	Sydney Olympic Park
C16	1.48	1.02	- 30.9	Sydney Olympic Park
C17	28.1	23.1	- 17.9	Sydney Olympic Park
C18	7.61	7.61	0	Sydney Olympic Park
C19	9.19	9.19	0	Sydney Olympic Park
C20	5.02	5.02	0	Lidcombe

Shaded cells are catchment areas with decreased annual runoff volume.

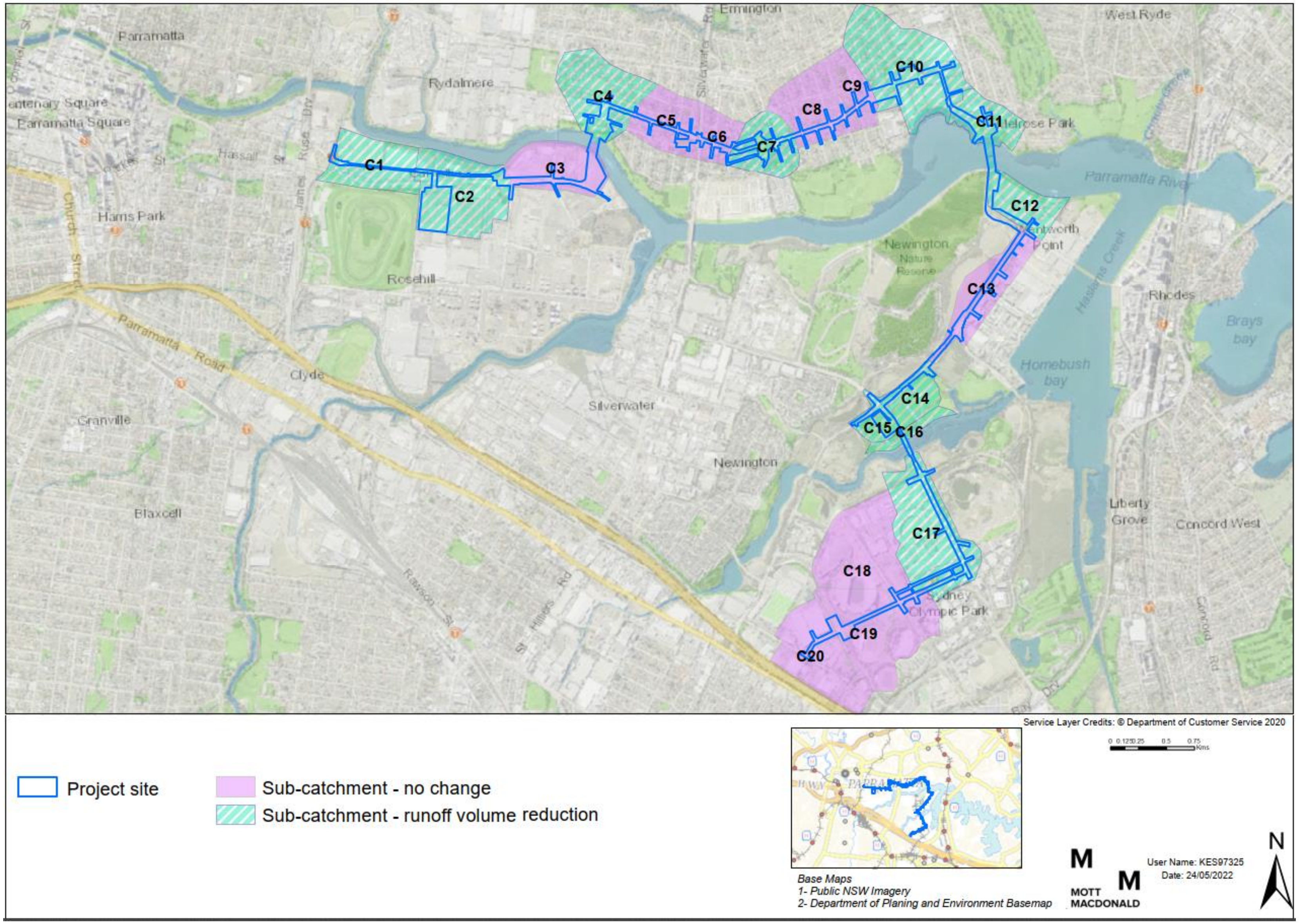

Figure 5-4 Sub-catchment areas with runoff volume reduction

Bridge approaches are features of the project which have the potential to impact on surface water movements adjacent to more sensitive areas including riverbanks and Newington Nature Reserve. Typical impacts include changes to the frequency and level of inundation from flooding as a result of the bridge structures. The relatively short period of inundation from mainstream flood flows triggered by storms in the Parramatta River catchment mean impacts are short term, experienced during the peak of major flood events and are highly localised and would not result in any significant impacts to these areas. The overland flood flow impacts associated with the project are described in Section 5.2.2.

5.4 Groundwater impact assessment

5.4.1 Construction impacts

Impact on groundwater levels, flow and connectivity

As mentioned in Section 4.8, previous groundwater investigations on the project site recorded groundwater levels between 0.54 and 3.34 metres below ground level (refer to Table 4-6). The shallow water levels are mostly encountered in areas adjacent to the Parramatta River, at the proposed road crossing at Boronia Street, and at the proposed new bridge across the low lying part of the Ken Newman Park. Most of the geotechnical boreholes drilled in other parts of the project alignment did not encounter water.

Apart from areas mentioned above, the foundations of the alignment are not likely to be deep enough to intercept the water table as excavations associated with the light rail construction are generally expected to be at a maximum depth of 1.5 metres below ground level (BGL). In some instances it may be necessary to relocate stormwater drains and other utilities. Excavations for this purpose may intercept the water table but are likely to be shallow and of short duration.

At the approaches to the bridge crossings where shallow water tables exist at boreholes immediately adjacent to the Parramatta River (BH09 – 0.54 metres below ground level, BH14 – 1.32 metres below ground level and BH 41 – 1.54 metres below ground level), the alignment would be elevated to meet the height of the proposed bridges. The construction of the approaches to the bridges as well as the installation of piles and bridge foundations would need to be managed to mitigate potential impacts on groundwater quality and seepage towards the estuarine vegetation and aquatic habitats. At these locations minor alterations to shallow, localised groundwater flow patterns would be expected but the overall connectivity between the aquifers and the rivers would not be impacted upon.

There is potential for water levels to rise sufficiently to intercept foundation excavations should high rainfall events or flooding occur during the construction period. A comparison of rainfall to changes in groundwater levels indicated that rainfall events of 60 millimetres could cause groundwater levels in the project site to rise by approximately:

- one metre at BH14 at Rydalmere, in a narrow band of sandstone about 80 metres north of the Rydalmere Wharf and the proposed bridge crossing between Camellia and Rydalmere (refer to graphs in Appendix A)
- 50 centimetres to one metre at BH09 which is located between BH14 and the Parramatta River. In estuarine alluvial material, the response was only 50 centimetres (half a metre). This is possibly due to increased horizontal drainage in the material towards the river
- 50 centimetres (half a metre) in the alluvium at the proposed bridge crossing at Wentworth point in BH44 (southern side of river) and in BH37 (on northern side of the river).

The groundwater levels observed in borehole BH41 change continuously in response to the tidal flux in the Parramatta River (refer to Figure 5-5). This demonstrates there is hydraulic connectivity between the river and parts of the estuarine aquifers close to the river. BH41 is located in Holocene Estuarine Alluvium overlain by fill material.

This tidal flux may impact construction adjacent to Parramatta River, however this flux is likely to be less than water level changes during flood events. Therefore, any measures to accommodate flooding would also account for the tidal flux.

Raised groundwater levels may result in temporary construction delays and necessitate dewatering of excavated areas, should ponded water not soak away rapidly. If polluted, the water would be treated prior to discharge or transferred to a suitable treatment facility for disposal. If necessary, a Trade Waste agreement may be sought from Sydney Water.

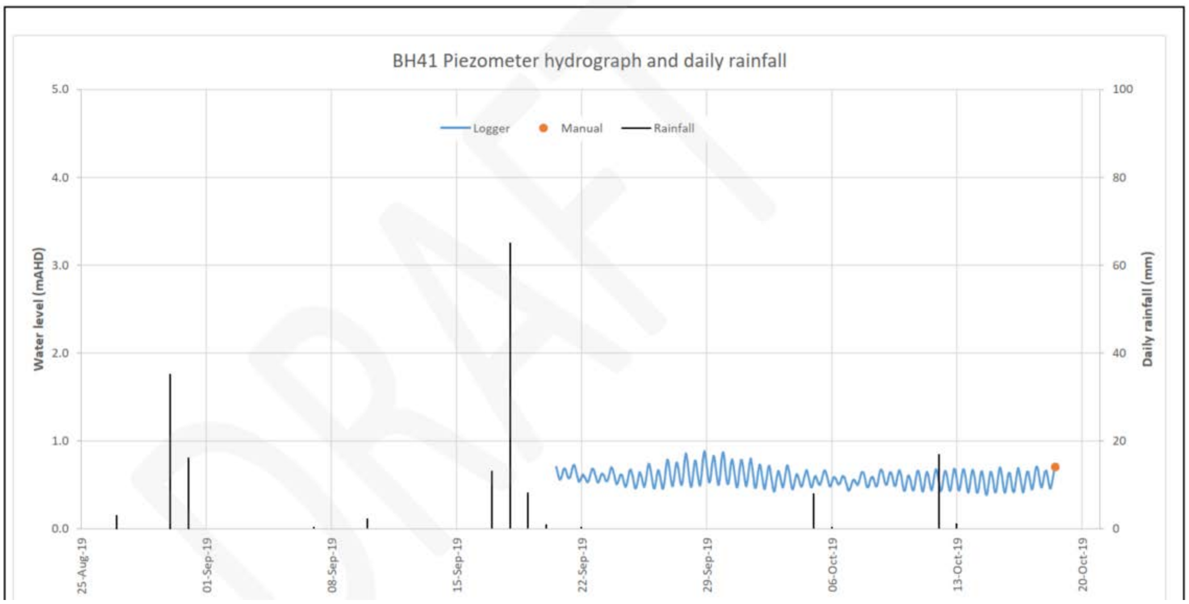

Figure 5-5 Example of groundwater flux in response to tidal flux in the Parramatta River

Surface gradients in the area are generally small (less than two per cent) but some undulating topography exists in the vicinity of Boronia Street in Ermington and a cutting would be needed to reduce the existing street gradient from almost 11 per cent to between five and seven per cent. Part of Ken Newman Park would be raised with fill and the inclusion of a small bridge would be constructed to raise the elevation of the alignment by about five metres before reaching Boronia Street where a cutting approximately 140 metres long and almost three metres deep (inclusive of foundation) would be made into the hill side (refer to Figure 5-6) .

Current groundwater flow in the vicinity of the cutting at Ken Newman Park is inferred to be downslope towards the park which is situated in a localised low lying valley with incised side slopes. The construction of the cutting would cause a localised change in near surface groundwater flow towards the cutting, but the change would be limited to areas close to the cutting (possibly within 40 metres of the cutting). Construction of foundations for the bridge at Ken Newman Park would intercept the water table. The general groundwater levels, flow direction and connectivity should not be affected.

BH24 is located within the lower 60 metres of the 140 metre cutting, which rises towards the east. Boreholes located within the remaining 80 metre section, which is in higher ground, did not incur groundwater. The geology in the cutting consists of fill material overlying shales and sandstones. A conservative value of 0.1 metres per day was adopted to represent the average hydraulic conductivity. The water levels inferred from borehole BH24 were estimated to be between 0.6 metres and 0.7 metres above the floor of the cutting in a 60 metre section along the lower portion of the cutting.

The seepage inflow is estimated to be about 0.35 cubic metres per day. Groundwater drawdown adjacent to the cutting would be about 0.65 metres at the edge of the cutting and negligible at distances of more than 40 metres away from the sides of the cutting.

The analytical modelling was used to predict that a nominal amount of 340 litres per day (>0.01 l/s) would seep into the cutting during the construction stage (for contextual purposes, this quantity is about the same as the amount of domestic water that one person would use in a day in Australia). Most of this seepage water would evaporate or drain downslope towards Ken Newman Park.

Should large rainfall events result in a one metre increase in the groundwater levels surrounding the cutting, the seepage inflow would increase to 1,350 litres per day. Groundwater drawdown on opposite sides of the cutting would extend about 40 to 60 metres away from the cutting depending on climate conditions.

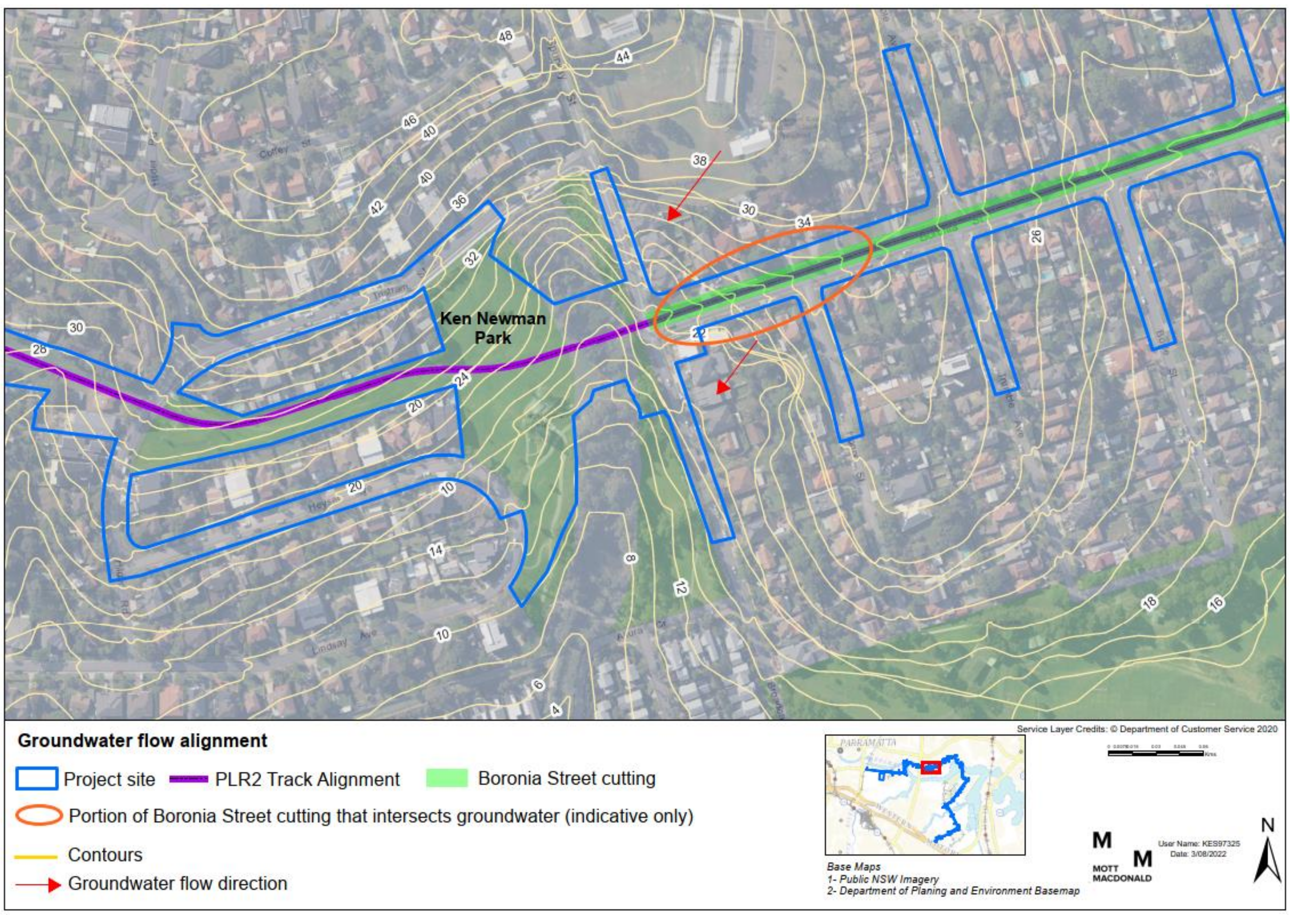

Figure 5-6 Groundwater flow direction at Boronia Street cutting

Groundwater dependent ecosystems (GDE)

As described in Section 5.4.1 the potential for groundwater infiltration during construction is minimal and would likely be associated with piling and the cutting at Boronia Street. Therefore, there would be low potential for drawdown due to infiltration and dewatering and unlikely to be changes in groundwater levels within GDEs.

There are other factors such as changed water quality of groundwater that have potential to affect GDEs in the short term during construction. Areas where this is most likely are where GDEs are within close proximity to the project site. There are four areas that are close to the project site, where it is considered necessary to determine whether there are any risks to shallow groundwater supplies that would impact the water quality to GDEs (referred to as GDE assessment zones). The four GDE assessment zones are shown in Figure 4-12 and potential impacts are discussed below. Areas further away from the alignment are not likely to be affected due to factors such as dilution and vertical percolation.

GDE assessment zone 1 is located in Melrose Park (mangroves) and includes a construction compound which would be elevated slightly above and adjacent to GDEs located in an estuarine environment near to the Parramatta River. The compound would be established in the south eastern corner of the project site. Natural groundwater and surface water drainage would be downslope towards the GDEs. The underlying geology Hawkesbury Sandstone is a low risk groundwater source (refer to Figure 5-7).

The project would not take water from or deliberately add to the underlying groundwater. It would be elevated above the water table and have no impacts on groundwater flow directions.

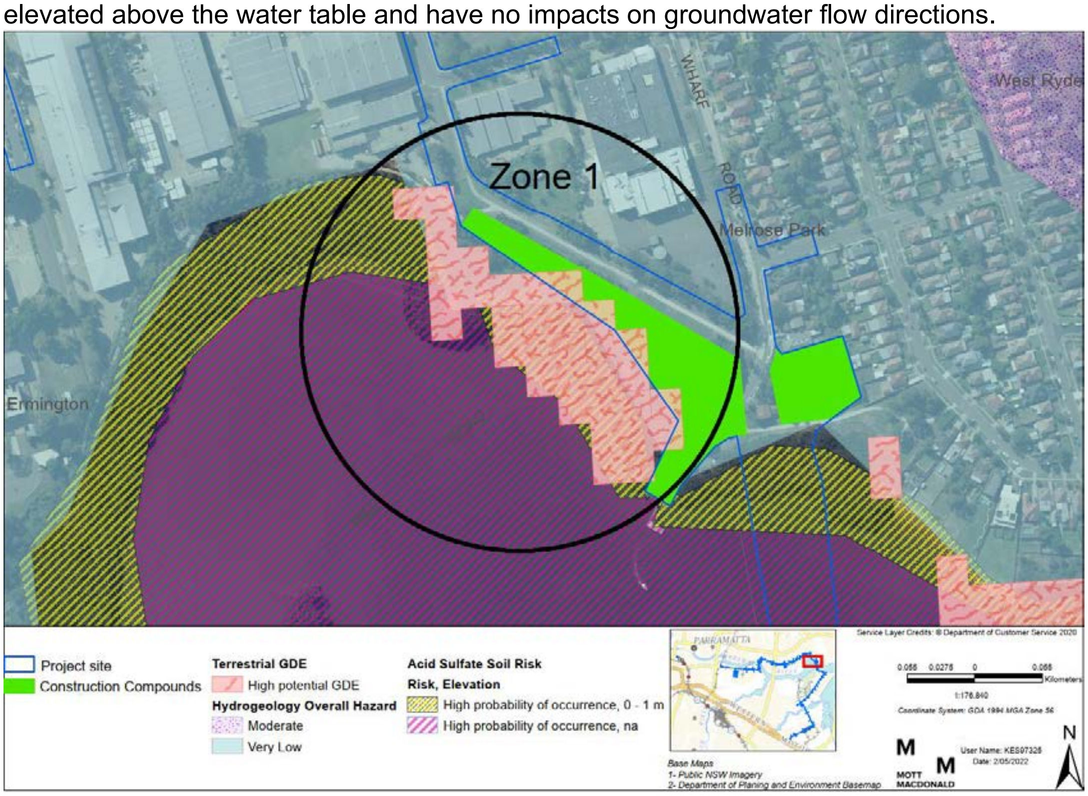

Figure 5-7 GDE assessment zone 1 location

GDE assessment zone 2 is a small area where high potential GDEs exists adjacent to the project site on the eastern side of Hill Road (area of Sydney Turpentine Ironbark Forest and mangroves). The area also overlies potential acid sulfate soils. A small construction compound is proposed south of the GDE. As indicated in Section 5.4.1, construction activities are unlikely to alter the natural height of the water table and groundwater drainage. Therefore, the underlying groundwater contamination risks (from acid sulfate soils) are unlikely to be altered from construction. The overall hydrogeology hazard is moderate (refer to Figure 5-8).

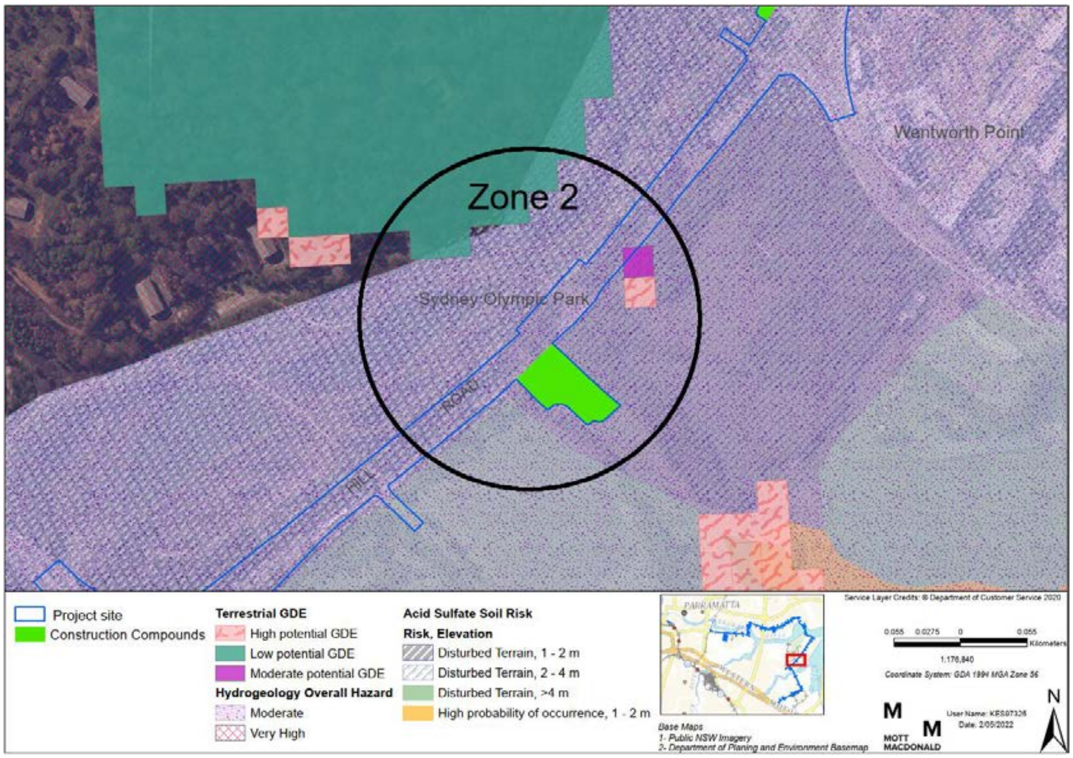

Figure 5-8 GDE assessment zone 2 location

GDE assessment zone 3 consists of sensitive riverine vegetation located along the sides of Haslams Creek adjacent to the Holker Busway. The project site crosses over the creek and damage or removal of some GDEs would be unavoidable (refer to Figure 5-9).

Groundwater and surface water would drain towards the creek and groundwater recharge from the creek would occur whenever the creek floods or water levels in the creek increase to elevations above the water table. The GDEs are sustained by a combination of water sources including rainfall, infiltrated surface runoff, groundwater recharge and water in the creek. Project risks to the GDEs from the water supply perspective would likely be negligible based on the limited changes to water levels during construction and operation.

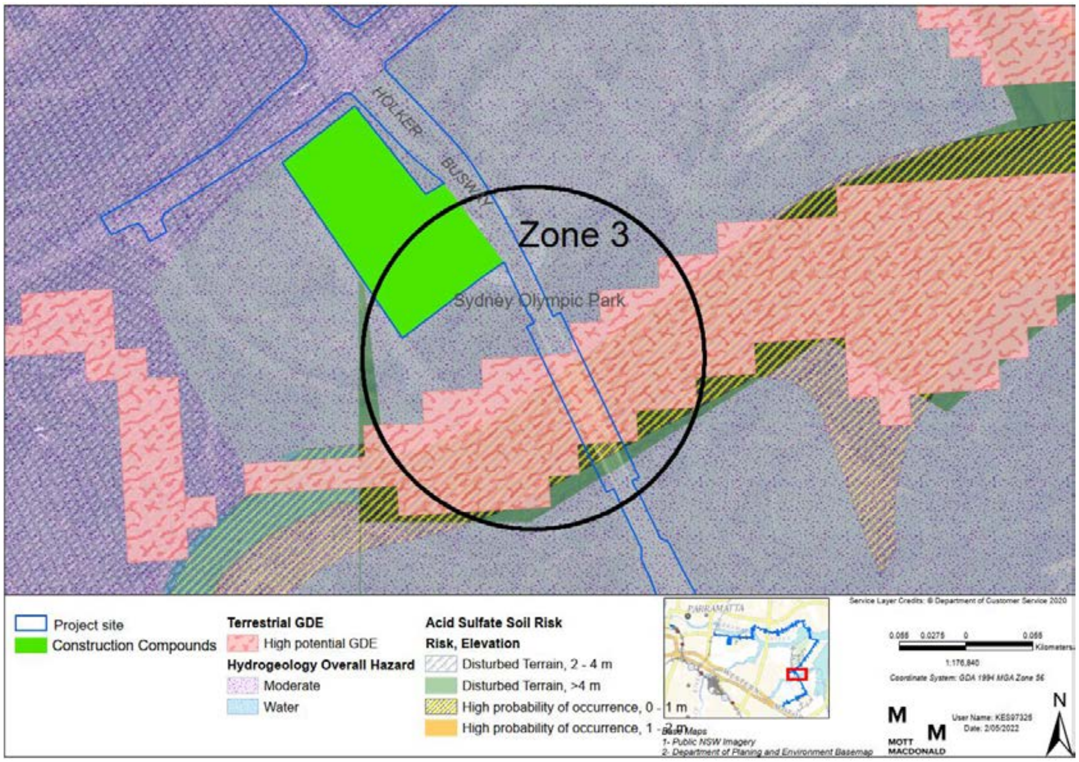

Figure 5-9 GDE assessment zone 3 location

GDE zone 4 is in an area with high and low potential GDEs (mangroves) where there is likely to be acid sulfate soils and salinity hazards (refer to Figure 5-10).

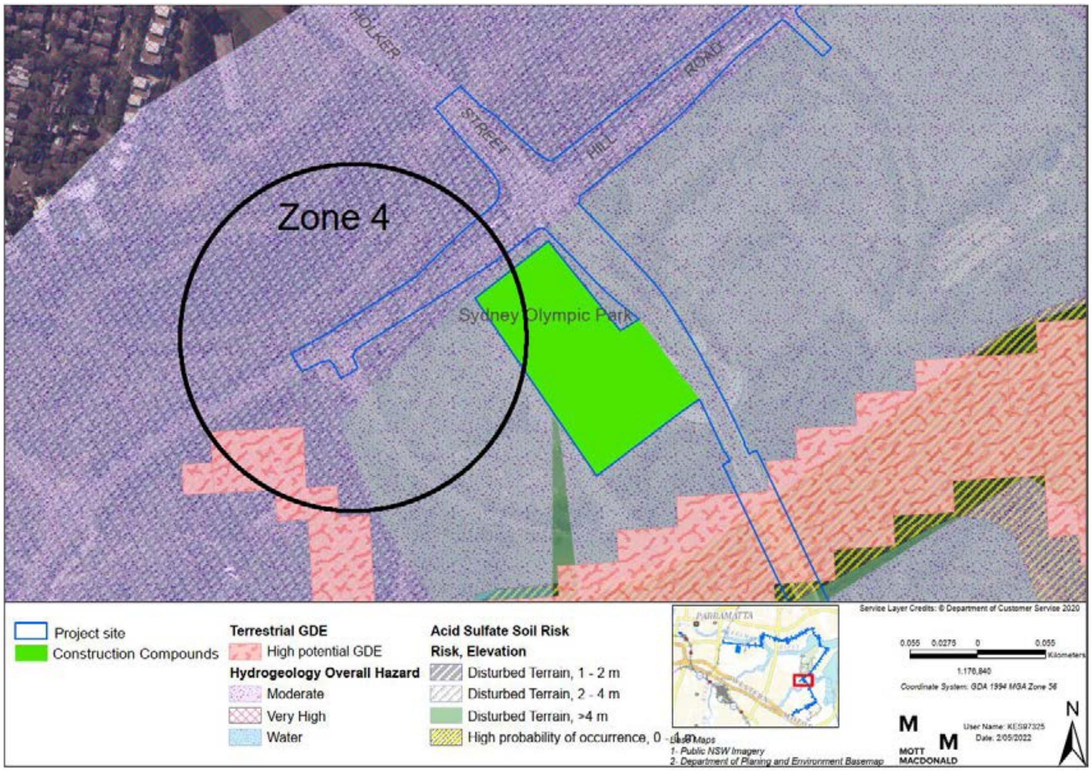

Figure 5-10 GDE assessment zone 4 location

Measures to protect the groundwater quality for GDEs and minimise potential impacts on aquatic ecosystems and riverine vegetation would include managing the storage and spills of hazardous chemicals and minimising the generation of sediment and control of acid sulfate soils. These measures are outlined in the mitigation measures in Table 8-1.

5.4.2 Operational impacts

During operation, the nominal seepage into the Boronia Street cutting would be the only groundwater take. The quantities would be less than three megalitres per annum and no water licence would be required as discussed in Section 2.2.3. Given the nominal seepage, the stormwater drainage system proposed as part of the project is considered to appropriately manage this flow. Therefore, minimal impact to groundwater works, riparian areas or wetlands is expected. Furthermore, there is no requirement for groundwater take to be estimated or considered as part of a water balance. Consequently, this is not anticipated to trigger more than a minimal impact to a key water dependent asset under the NSW Aquifer Interference Policy.

During operation, the project is not expected to impact groundwater salinity levels within the study area provided that concrete and materials for piling and bridge foundations are specified to address underlying water quality expected in a marine estuarine environment.

Maintenance activities would be unlikely to involve ground disturbance activities of sufficient magnitude to increase water infiltration resulting in erosion and off-site transport of saline sediments, particularly with the implementation of standard best-practice erosion and sediment control measures.

Salinity and potential effects on the durability of infrastructure would be considered further as the design progresses.

6 Water quality impact assessment

This chapter describes the construction and operational water quality impacts of the project on the existing environment.

6.1 Construction impacts

Pre-construction activities will generally include the establishment and preparation of construction compounds and work areas, vegetation clearance and trimming, and establishment of environmental controls, temporary roads and pedestrian and cyclists' diversions where required.

Construction activities would be carried out in a highly modified and urban environment. Some construction activities would be carried out within or near waterways, including in river activities associated with bridge construction between Camellia and Rydalmere, Melrose Park and Wentworth Point and adjacent to waterways in Sydney Olympic Park.

Out-of-river construction activities will include the construction of the light rail tracks, light rail stops and retaining walls along sections of the alignment.

Construction of the light rail tracks would generally involve:

- civil works
- removal of existing road pavements
- earthworks (subgrade works for the track slab foundation and compaction)
- drainage construction
- retaining walls
- steel reinforcements and concrete frameworks. Stop and retaining wall construction will likely involve on-site concrete pours, excavation, removal of existing road pavement, and steelwork/framework installation.
- rail installation works and overhead wiring installation.

Construction of the bridges would involve works on the banks of, and within, the Parramatta River. The bridge construction activities likely to have the greatest potential impact on receiving waterways may include:

- establishing temporary work platforms on the northern and southern banks of the Parramatta River to provide access to piers located within the river
- constructing the bridge piers from the temporary work platforms
- constructing bridge abutments on the northern and southern banks of the river using reinforced earth construction on piles
- installing precast bridge segments potentially from temporary work platforms, barges or banks using cranes.

Without mitigation, there is a potential for water quality impacts from all construction sites, in-river and out of river. While it has been noted that the quality of the existing environment is already degraded (refer to Section 4.9), the construction of the project may further degrade water quality if not properly managed.

Key construction activities that have potential to impact water quality in the waterways if not appropriately managed are discussed further in Table 6-1.

Table 6-1 Potential construction impacts on water quality

Construction works	Potential impacts
Bridge construction works	Sources of pollutants that could affect water quality during bridge construction include: • sediments from the riverbed, bank and adjacent areas, including those contaminated by heavy metals, hexavalent chromium, hydrocarbons (including TRH, benzene, toluene, ethyl benzene and xylene (BTEX)), and polycyclic aromatic hydrocarbons (PAH)) from previous industrial activities • exposure of acid sulfate soils and saline soils • chemicals including hydrocarbons and fluids associated with construction processes and machinery • dust and airborne pollutants. Construction would also include vegetation clearing, topsoil stripping, creation of temporary roads, hardstand areas and work set down areas. Pollutants can also enter watercourses from construction machinery and concreting. The construction of bridges and associated activities, such as piling, at Parramatta River and Haslams Creek has the potential to disturb sediments (some of which are contaminated) resulting in potential for mobilisation into the water. In deeper water, the piers would be constructed from barges. Pier construction in shallow water may require the use of temporary work platforms that would also require temporary piers. Pier construction would use driven piles, silt curtains and coffer dams within the area protected by silt curtains to provide a dry working environment and minimise risk of mobilisation of contaminated sediments. This would result in a localised instream barriers causing water to flow under and around the platforms which could result in localised erosion and scour of the riverbank in particular, during flood flows. During further design development modelling would be undertaken to minimise the risk of erosion to nearby riverbanks. The temporary construction barges would be used in deeper water and would have minimal to no impact as the water can readily flow around and under the barges. There are potential impacts from barge anchorage such as sediment disturbance and riverbed alteration; however, they are expected to be negligible. Appropriate construction controls would also be implemented in relation to the bridge works at Hill Road and Holker Busway to minimise the potential for impacts to Haslams Creek and Narawang Wetland. The potential for water quality impacts would be managed by implementing the measures described in Section 8.2.

Construction works	Potential impacts
Concreting activities	Concreting activities can result in concrete dust, slurries or washout water being discharged to downstream watercourses. As a result, the following impacts to water quality may occur: • sedimentation can result in increased turbidity levels, reduced visual amenity and smothering of aquatic ecosystems. Instream structures can lead to scour and deposition of sediments due to changes in flow rates and paths. • concreting and its by-products can result in increased alkalinity and pH which can be harmful to aquatic life. Water from concrete curing can be high in chromium and can accumulate in the gills of fish affecting the health of aquatic organisms.
Construction near waterways	The potential mobilisation of sediments relates principally to construction works immediately adjacent to waterbodies, channels and stormwater drainage. Soil erosion and sedimentation are risks posed to surface water quality throughout the construction phase through increased sediment loads entering downstream environments. Soil erosion could occur due to the effects of wind or surface water flows. Soil erosion could result in movement of sediment which has potential to: • reduce hydraulic capacity due to deposition of material • degrade water quality including lower dissolved oxygen levels, increased nutrients (nitrogen, phosphorus), metals and other pollutants, increased turbidity, and altered pH, leading to increased potential for bioaccumulation of heavy metals in aquatic species • increased sedimentation, smothering aquatic life and affecting aquatic ecosystems.
Earthworks	The project would require earthwork activities which could expose the ground/soils at light rail stop sites and along the project site. Similarly to bridge construction, earthwork activities may lead to mobilisation of sediment and the potential for increased erosion within and around waterways and slopes.
Stockpiling and spoil handling	The construction of the project would generate spoil and other waste, including vegetation, general construction and demolition waste, and potentially excess spoil from excavations and earthworks, which would be temporarily stored in stockpiles. Through sediment movement, stockpiling of materials poses a risk to the water quality of receiving environments. This can impact the receiving aquatic environment through increased biological oxygen demand which may in turn decrease available dissolved oxygen, reduce visibility and light penetration and change the pH of receiving waterways. Spoil and other wastes would be minimised and reused where possible.

Construction works	Potential impacts
Potential for spills and litter	Accidental spills or leaks of hydrocarbons (e.g., oils, fuels, grease etc.) could occur from the use, maintenance or re-fuelling of construction plant and equipment at construction sites, or from vehicle/truck incidents travelling to and from construction sites. These contaminants, along with rubbish and building materials from construction sites, could increase the alkalinity and pH of downstream waterways which can be harmful to aquatic life. Construction activities, including in river and out of river activities, could introduce additional materials to local drainage lines and receiving waterways, particularly during high rainfall events. Contaminants could include those from construction materials including rubbish, fuel and chemicals from accidental spills during refuelling, and dust, litter and other building materials (such as concrete dust and concrete solids from bridge construction).
Disturbance of acid sulfate and contaminated land	High risk acid sulfate soils (refer to Section 4.6) and contaminated soil and groundwater (refer to Section 4.8) are present along the alignment. Construction activities such as excavation, land clearing and drainage pose a risk to water quality when the activity is carried out in areas of actual or potential acid sulfate soil, and in contaminated areas. During construction, there is the potential for contaminated sediments to enter waterways from surface runoff or via the local stormwater network, impacting aquatic ecosystems.
Construction compounds	Most construction activity is contained within existing road reserves, with additional areas required for bridge and bridge approach construction, and construction compounds. Construction compound areas are typically on higher ground within the context of the local topography. This is to improve the access and functionality of the construction site during periods of inclement weather, but also serves to reduce the incidence of impacts to surface water flow and mitigate risks should a spill occur within the compound site.

6.1.1 Surface water quality

Impacts against the NSW water quality objectives

As outlined in Table 6-1, there are a number of potential pollutants associated with construction activities that may affect the performance of the project from either the mobilisation of existing contamination or from leaks and spills due to construction activities. Each pollutant has the potential to impact the water quality and subsequently the water quality objectives and environmental values (aquatic ecosystems, visual amenity, primary and secondary contact recreation, and aquatic foods (cooked)) of watercourses downstream of the proposal.

As per the overview of the existing baseline water quality of the study area (provided in Section 4), the baseline water quality is degraded and currently not achieving the WQOs, particularly for parameters such as pH, dissolved oxygen, turbidity, aluminium, copper, manganese and iron levels which monitoring during Parramatta Light Rail Stage 1 showed exceeded ANZECC (2000) and ANZG (2018) trigger values during both wet and dry weather events.

Aquatic ecosystems could be impacted by degrading water quality from the mobilisation of sediments and accidental spills and leaks into receiving waterways. The activities associated with in-river construction have the potential to increase phosphorus, nitrogen and turbidity levels, alters pH levels, and reduce dissolved oxygen levels.

Visual amenity could be affected by the mobilisation of sediment and release of contaminations (including gross pollutants (heavy metals, hydrocarbons and volatile organic compounds (VOCs and concrete solids)), potentially impacting natural visual clarity and colour of the water. Primary and secondary contact recreation and aquatic foods (cooked) which look at maintaining or improving water quality for activities such as swimming, boating and production of aquatic foods for human consumption have the potential to be impacted by similar pollution pathways and contaminants. The Department of Primary Industries website indicates that *'Recreational fishing in the Harbour has not been banned, but fishers are urged to follow dietary advice on the consumption of seafood from the Sydney Harbour, Parramatta River and other connected tidal waterways. Fishers can also continue to practise catch and release.'*

Appropriate mitigation measures would be implemented to manage the potential impact of construction on the water quality of water courses within this project area, to achieve NSW Water Quality Objectives, and to reduce the impact to aquatic ecology. These mitigation measures are outlined in Section 8.2.

A water quality monitoring program would be developed as part of the project soil and water management plan prior to construction commencing (refer to Section 8.3). This would include targeted monitoring of receiving waters and shallow groundwater to validate baseline water quality conditions. Monitoring would occur at all waterbodies with the potential to be impacted, and all discharge water would be monitored to confirm compliance with the project-specific criteria. The ongoing monitoring will be undertaken to contribute towards achievement of the ANZECC (2000) and ANZG (2018) guideline water quality trigger values.

Out of river construction sites would implement erosion and sediment controls, in accordance with erosion and sediment (ERSED) risk management and controls to ensure out of river construction sites will have limited point source discharge to receiving waterways or stormwater systems during construction. Site specific measures will minimise the potential for construction sites impacting the water quality of nearby waterbodies. Therefore, the waterbodies achievement of the NSW Water Quality and River Flow Objectives are unlikely to be influenced.

Where contaminated water is encountered, whether known or unknown, at out of river construction sites, it would be managed in accordance with the following hierarchy of treatment methods, where reasonable and feasible:

- treatment on site and reuse within the project site (for example for dust suppression)
- treatment on site and discharge to surrounding environment
- treatment on site and discharge to sewer under a trade waste agreement
- treatment on site and disposal to an appropriately licenced liquid waste facility.

Any discharge would be managed in accordance with Transport for NSW *Water Discharge and Reuse Guideline DMS-SD-02*4 (2019).

The preferred methods to manage contamination would be confirmed following further geotechnical and contamination investigations and would be defined in the waste and resource management plan.

6.1.2 Groundwater quality

Acid sulfate soils may be encountered during excavation for track infrastructure and utility works and piling for bridge piers. This may make soils unsuitable for re-use as fill and may affect landscaping. Additionally, dewatering for piling or excavation near the Parramatta River could result in the localised drawdown of the groundwater table, which could temporarily expose potential acid sulfate soils to air.

As discussed in Section 5.4.1, the Boronia Street cutting may intercept the water table and whilst the cutting is located along the boundary of the zone of moderate salinity potential (refer to Figure 4-9), the volumes of water (inflow) are unlikely to have higher salinity than the natural seepage into Ken Newman Park. During rainfall events, storm water would dilute the seepage.

Due to the presence of shallow contaminated groundwater near the Parramatta River, extraction of groundwater during excavation could result in contamination of the receiving surface waterways if the groundwater is not treated adequately prior to discharging into surface waterways. There is also the potential for construction workers to either ingest or have contact with contaminated groundwater during excavation activities. If encountered at out of river construction sites, groundwater would be managed in accordance with the treatment hierarchy outlined above in Section 6.1.1.

In addition, there is potential for increased contaminants migration into surrounding areas via leaching, overland flow and/or subsurface flow or dust, with the potential to impact on receiving environments, nearby watercourses and the surrounding community.

There is a minor risk that accidental chemical spills from refuelling could enter shallow aquifers. Any spills of this nature have the potential to seep into shallow groundwater.

Appropriate mitigation measures would be implemented to manage the potential impact of the construction activities on groundwater quality and are provided in Section 8.2.

6.2 Operational impacts

The operational phase of the project has the potential to impact and degrade the water quality of receiving waterways through the discharge of polluted water flows or airborne contaminants (e.g. particulate matter).

6.2.1 Surface water quality

Increases in impervious surfaces could result in the build-up of contaminants in dry weather, which during rainfall events, could be transported to surrounding watercourses as stormwater and wastewater. The main pollutants relating to surface runoff include:

- sediments from the impervious surfaces from atmospheric deposition
- small amounts of heavy metals attached to particles washed off the impervious surfaces (i.e. from wheel/rail contact and braking)
- small amounts of oil and grease and other hydrocarbon products (i.e. from wheel/rail contact and braking)
- litter from the rail corridor including wind-blown litter from the road corridor or deposited by light rail users
- nutrients such as nitrogen and phosphorus (organic compounds) from biological matter and from natural atmospheric deposition of fine soil particles.

The emphasis in stormwater quality management for surface runoff includes managing the export of suspended solids and associated contaminants – namely heavy metals, nutrients, hydrocarbons and organic compounds. Pollutants such as nutrients, heavy metals and hydrocarbons are usually attached to fine sediments. Trapping suspended solids is, therefore, the primary focus of the water quality management strategy for the operational phase of the project.

Erosion and sedimentation

During operation, there remains the potential for erosion in recently disturbed areas. This risk would be higher during initial periods of landscaping and re-establishment of vegetation, particularly where soft landscaping is proposed, including open areas at some stops, adjacent to disturbed areas and in areas where topsoil is settling, and vegetation is establishing. Some light rail stops would undergo landscaping which presents the greatest risk of sediment loads entering waterways through the stormwater system. Soil stabilisation work may be required at these stops following construction activities and severe storms, to prevent further erosion, topsoil loss or soil mitigation.

Measures to manage erosion would be included in the Operational Environmental Management Plan/System. Further details on impacts from soil erosion and sediment migration during operation and management measures are discussed in the EIS Chapter 18 (Soils and contamination).

Emissions from light rail vehicles

During operation, light rail vehicles would likely produce minimal pollutants and chemicals, however very small amounts of metals, oils, grease and particulates may be generated such as during braking. There is also potential for stormwater runoff from the light rail corridor to produce some sediment, nutrients bound to sediment, and domestic litter/rubbish from customers.

The light rail vehicles would spray small quantities of sand on the rails ahead of the main traction units to increase friction and improve the contact in wet conditions if required. In some circumstances, the application of sand to the rails may lead to generation of small amounts of material that might be carried in suspension should the activity coincide with or follow heavy rain. The resultant impact on water quality and drainage systems is not expected to be significant given the small quantities.

The Camellia maintenance and stabling facility is a facility constructed for Parramatta Light Rail Stage 1 operation. The impacts associated with modifications needed for the project are not considerably increased compared to those for Stage 1 operations.

Overall, the project is anticipated to contribute to a reduction in contaminant sources from current road operations (brake dust, motor oil etc. from buses and light motor vehicles) through the anticipated reduction in light motor vehicle traffic.

Proposed treatment prior to stormwater discharge

MUSIC modelling outlined in Section 3.3.3 has been carried out to propose and assess controls for relevant water sub-catchments across the project site (refer to Figure 5-4 for locations). The water quality devices have been designed to treat the first flush which is equivalent to the three month average recurrence interval, this is to ensure the initial surface runoff which has a high pollutant concentration from the rainfall event is treated. The selected configuration of mitigation measures is presented in Table 6-2.

The results indicates that by utilising the proposed controls, the local planning controls for water quality outlined in Section 2.5.7 can be achieved, and the reductions in pollutant loads would assist in contributing to each sub-catchment meeting the relevant WQOs. While the treatment train proposed may not bring the regional catchment back within the WQO trigger thresholds, a reduction in the pollutants reaching the downstream receiving system relative to the existing conditions contribute to achieving these targets into the future.

Table 6-2 Potential treatment types prior to stormwater discharge per sub-catchment

Sub-catchment	Treatment type	Reduction rates (%)			
		Gross pollutants	TSS	TP	TN
C1	Raingarden	100	95.6	81.7	61.6
C2	Raingarden	100	95.8	81.7	61.7
C3	• 2 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	97.7	69.6	60
C4	Bioretention	100	95.6	76.2	61.1
C5	• 5 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	98.7	69.9	60.5
C6	• 2 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	98.7	69.9	60.5
C7	• Swale • Raingarden	100	99.4	93.7	59.6
C8	• 2 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	98.7	69.9	60.5
C9	• 1 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	98.6	69.8	60.4
C10	Raingarden	100	95.5	81.8	60.9
C11	Bioretention	100	95.1	76.6	61.2

Sub-catchment	Treatment type	Reduction rates (%)			
		Gross pollutants	TSS	TP	TN
C12	Raingarden	100	95.5	82.6	61.3
C13	• 2 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	98.2	69.4	60
C14	Raingarden	100	95.3	82	60.8
C15	Raingarden	100	95.4	82.1	61.2
C16	Raingarden	100	95.5	82.4	61.9
C17	• 1 x gully pit insert / basket type GPT Raingarden	100	98.8	85.7	61.9
C18	• 1 x gully pit insert / basket type GPT stormwater quality treatment and filtration device	100	98.7	69.7	60.4
C19	• 1 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	98.5	69.7	60.3
C20	• 1 x gully pit insert / basket type GPT • stormwater quality treatment and filtration device	100	98.7	69.8	60.5

6.2.2 Groundwater quality

There is not anticipated to be an ongoing risk to groundwater quality once the project is operational. This is due to the fact that maintenance activities associated with operation of the project would be unlikely to be of sufficient depth to encounter groundwater. The potential for leaks and spills during maintenance activities would be minimised through the implementation of standard operating procedures.

7 Cumulative impacts

Cumulative impacts result from the successive, incremental, or combined effects of an activity or project when added to other past, current, planned, or reasonably anticipated future impacts.

The extent to which another development or activity could interact with the construction and/or operation of the project would be dependent on its scale, location and/or timing of construction. Generally, the largest adverse cumulative impacts would be expected to occur in situations where multiple long-duration construction activities are undertaken close to and over a similar timescale as the construction activities for the project.

Key developments in the study area are shown in Figure 7-1, however, of those shown, it is considered the following have the potential to result in cumulative hydrology, flooding and water quality impacts:

- Parramatta Light Rail Stage 1
- Sydney Metro West - Westmead, Parramatta & Sydney Olympic Park
- Draft Camellia-Rosehill Precinct (Place Strategy)
- Camellia waste facility
- Melrose Park - North planning proposal
- Holdmark Planning Proposal (Melrose Park Southern Precinct)
- 659 and 661 Victoria Road, Melrose Park - Sekisui House Australia Pty Ltd
- ‘Sanctuary’, 14-16 Hill Road, Wentworth Point - Sekisui House Australia Pty Ltd
- Sydney Olympic Park new high school
- Block D, 37-39 Hill Road, Wentworth Point
- Sydney Olympic Park - Open Water Surf Facility - (URBN SURF Sydney)
- ‘Antara’, 1 & 2 Murray Rose Avenue - Sydney Olympic Park
- Mixed Use Development – Sites 2A and 2B Sydney Olympic Park
- Sydney Olympic Park Sydney Metro West Station – Over & Adjacent Station Development
- Carter Street Precinct (Phase 3 and 4) - Lidcombe
- ‘Vivacity’, 5 Uhrig Road - Lidcombe.

These developments are being carried out by other parties and would require separate approval. Transport for NSW would endeavour to coordinate mitigation and management activities where possible to minimise cumulative impacts.

The potential for cumulative hydrology, flooding and water quality impacts as a result of these projects is described in further detail in this chapter.

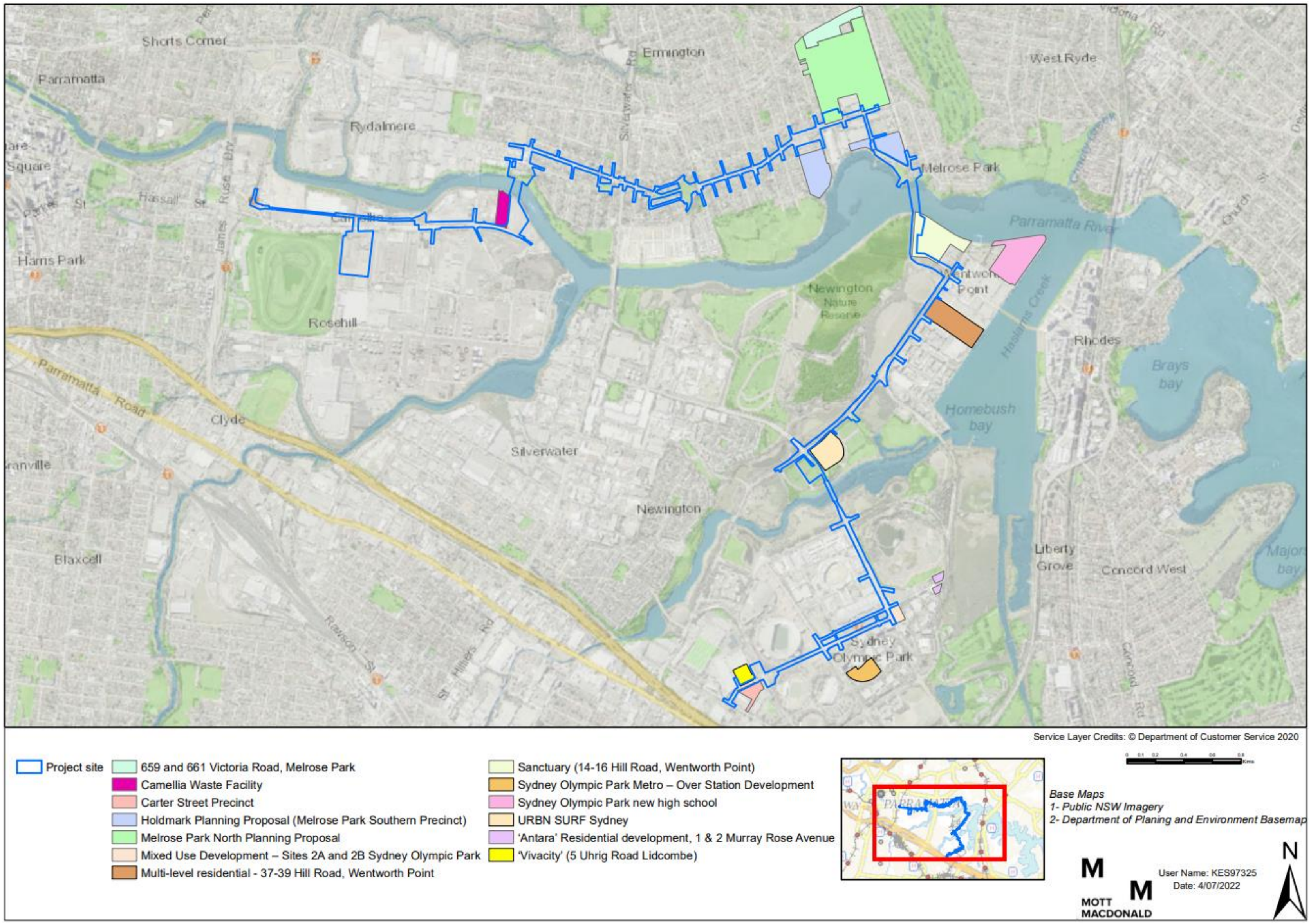

Figure 7-1 Key developments in the study area

7.1 Cumulative impacts – flooding and hydrology

Table 7-1 outlines other development projects in the vicinity of the Parramatta Light Rail Stage 2 project and how they may interact or interface with the project. Only developments that interact with the project site or, have potential to generate significant cumulative flood impacts are listed.

Table 7-1 Cumulative impacts – Flooding and hydrology

Project name	Description	Cumulative impact assessment
Parramatta Light Rail Stage 1	• The Parramatta Light Rail Stage 1 will connect Westmead to Carlingford via the Parramatta CBD and Camellia with a two-way track spanning 13 kilometres. The route will link Parramatta's CBD and railway station to the Westmead Health Precinct. Interaction with the project: • Part of the current project scope includes modifications to the Parramatta Light Rail Stage 1 stabling and maintenance facility at Camellia.	• The Parramatta Light Rail Stage 1 works include surface changes to establish the light rail alignment and stabling and maintenance facility in Camellia adjacent to Grand Avenue. This initial stage of the light rail system would result in minimal changes to flooding behaviour due to the alignment predominantly following existing roads and existing road grades. • There is the potential for cumulative local impacts from Stage 2 to be observed in the Grand Avenue location where localised ponding and overland flows are influenced by the stabling and maintenance facility and local alignment. • Refer to Appendix D for cumulative impact flood maps. For Parramatta Light Rail Stage 1 they show broadly similar flood impacts (in terms of magnitude and location) to those predicted by Parramatta Light Rail Stage 2.

Project name	Description	Cumulative impact assessment
Sydney Metro West Westmead, Parramatta & Sydney Olympic Park	Consists of the construction of a new 24 kilometre metro line and metro stations at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock and The Bays. Interaction with the project: • The Clyde stabling and maintenance facility would be located approximately 800 metres south of the project site at Camellia on Colquhoun Street. • The Parramatta Sydney Metro West Station site is located on the north-eastern boundary of the project site bounded by George, Macquarie, Church and Smith streets. • The Sydney Olympic Park Sydney Metro West Station site would connect to the project site along Dawn Fraser Avenue and would provide interchange with the light rail and buses. • Indicative station construction works at Parramatta is expected to commence in early 2025 and be completed by 2027. • Indicative station construction at Sydney Olympic Park is expected to commence by late 2024 and be completed by late 2027. • Clyde stabling and maintenance facility construction works are expected to commence in early 2025 and completed by early 2028.	• The main alignment for Sydney Metro West is underground, and only the discrete station/facilities have been considered in this report. • The Parramatta Station site involves new structures over the station which would potentially impact floodplain storage and conveyance due to some overland flow within the Parramatta CBD road reserves. • The Clyde stabling and maintenance facility includes filling within the floodplain and affects the conveyance and storage of Duck Creek and Duck River upstream of the confluence with Parramatta River. The extent of anticipated impacts from the stabling and maintenance site are limited to Duck River with minimal cumulative impact due to the distance between sites and the diminished flood impacts from the metro site as observed further downstream in Duck River. • The Sydney Olympic Park Station site is located near the top of the catchment and with replacement of existing urban developments, minimal changes in impervious site coverage occur, resulting in little change to runoff characteristics. Refer to Appendix D for cumulative impact flood maps for the Lower Parramatta River highlighting: • generally similar impacts to those predicted for Parramatta Light Rail Stage 2 in Sydney Olympic Park as a result of cumulative development • separated flood impact areas within Duck Creek and Duck River (from Parramatta River floodplain) as a result of Clyde stabling facility with no cumulative effects observed.

Project name	Description	Cumulative impact assessment
Draft Camellia-Rosehill Precinct (Place Strategy)	The masterplan includes three sub precincts and covers approximately 320 hectares across Camellia, Rosehill, and a portion of Clyde. It presents a 20-year vision for the area. The draft place strategy was exhibited for public comment from 17 December 2021 to 4 March 2022. Currently there is no specific indication of timing however the draft strategy lists a proposed staging of the developments in the precinct. Interaction with the project: • The site interacts with the project along Grand Avenue and the proposed stop ‘Sandown Boulevard’. • The development also interacts with the project site parallel to Parramatta River as it extends to the proposed John Street stop.	• The draft strategy for this precinct includes a strategic direction to maintain floodplain storage and conveyance through the development of the precinct. • Ensure no net loss of flood storage due to cut and fill or loss of flood conveyance or significant diversion of flood flows or significant changes to hydraulic flood hazard conditions that impact on private property or impact on safe access or on evacuation routes. • The principles of maintaining flood conveyance and no net lost storage limits the potential impacts of any development triggered by implementation of the Camellia-Rosehill Precinct strategy. As such no flow barriers or development ‘parcels’ have been applied in the modelling to ensure consistency with the place strategy principles. • Residual flood impacts are anticipated to be local, with potential impacts to overland flows and ponded floodwater in Grand Avenue.
Viva Energy Clyde Western Area remediation project	• The development is part of the large Clyde Terminal and is located in the south-western part of the site. Stage 1 remediation works were completed between October 2020 and February 2021. Stage 2 and the final Stage 3 were expected to commence late 2021 and early 2022. However, a construction program for the final works is yet to be confirmed. Interaction with the project: • The northern boundary of the site directly interacts with the project site corridor along Grand Avenue (including a section of Durham Street) as it extends across the Parramatta River to John Street.	• The works proposed for the remediation limit filling to locations outside the 1% AEP flood extent, largely mitigating flood impacts from the development. • Residual flood impacts are anticipated to be local, with potential impacts to overland flows. • Refer to Appendix D for cumulative impact flood maps for the Lower Parramatta River that highlights separated flood impact areas within Camellia (from Parramatta River floodplain) as a result of local development, with no cumulative effects observed.

Project name	Description	Cumulative impact assessment
Camellia waste facility	• Located at 37 Grand Avenue Camellia and consists of construction of a Materials Recycling Facility (MRF). The construction of the MRF comprises of three stages: • Stage 1 preloading of the site works commenced July 2019 and were completed in January 2020. • Stage 1A works which includes those works not originally anticipated to be undertaken under the approved Stage 1, which were approved in January 2020 and completed in July 2020. • Stage 2 construction works, and an estimated completion date are not yet confirmed. Interaction with the project: • The site interacts with the project on the southern boundary along Grand Avenue and the eastern boundary of the footprint as it runs across Parramatta River to the project site adjacent to South Street.	• The proposed works for the facility limit filling to locations outside the 1% AEP flood extent, largely mitigating flood impacts from the development. • Refer to Appendix D for cumulative impact flood maps for the Lower Parramatta River indicating local cumulative flood impact areas within Camellia (from Parramatta River floodplain) as a result of local development, concentrated around the perimeter of the assumed structure at the facility. • This conservative assumption for proposed development demonstrates a worst-case situation without mitigation measures employed. The assumed development footprint for waste facility would worsen flooding north of the alignment, reducing the flood impacts experienced under the Parramatta Light Rail Stage 2 alone south of Grand Avenue. Refinement of the facility's flood impacts is anticipated during further design development of the facility and as described in this report, further flood mitigation for the approach embankment for the bridge between Camellia and Rydalmere is also anticipated during design development • Residual flood impacts are therefore anticipated to be local, with potential impacts to overland flows.

<table>
<tr><th>Project name</th><th>Description</th><th>Cumulative impact assessment</th></tr>
<tr><td>Melrose Park - North planning proposal</td><td>The proposal applies to the Northern Precinct of the Melrose Park Urban Renewal Precinct.
This proposal seeks to rezone the land to facilitate the urban renewal of the precinct. The development will include residential buildings, a new school and commercial premises.
A development application for the proposal including tree removal, remediation, and bulk earthworks was lodged in December 2021 and is currently awaiting further information.

The overall development is determined to be delivered in multiple stages over a 12–15-year period.

Interaction with the project:
The southern boundary of the site is located along the project site on Hope Street. The site will interact with the project site along Hope Street, Hughes Avenue and Wharf Road.</td><td>Exhibited documents indicate the site is located outside the Parramatta River floodplain, however potential impacts to overland flow in the vicinity of Hope Street remain. The development application documentation is stated to follow the planning proposal, including further detail on the management of overland flows.
A qualitative assessment indicates that the cumulative flood impacts would be similar to those experienced by the project alone.</td></tr>
</table>

Project name	Description	Cumulative impact assessment
Holdmark Planning Proposal (Melrose Park Southern Precinct)	This proposal seeks to amend planning controls that apply to the subject site and intends to redevelop the site from IN1 General Industrial to R4 High Density Residential and RE1 Public Recreation. The development will include residential buildings and non-residential open space. Exhibition of the proposal's draft Site-Specific Development Control Plan and draft Planning Agreement concluded on 21/09/2022. Interaction with the project: • The site will interact with the project site along Hope Street, Hughes Avenue, Wharf Road, Waratah Street and Mary Street.	• The subject land for the planning proposal is subject to inundation from the Parramatta River floodplain, however with mitigation measures applied to minimise Parramatta River floodplain impacts, potential impacts to overland flow in the vicinity of Waratah Street remain. Refer to Appendix D for cumulative impact flood maps for the Lower Parramatta River indicating: • local flood impact areas within the immediate surrounds of the planning proposal assumed structures • cumulative flood impacts may be experienced in Waratah Street as a result of the built form at the planning proposal site. The final site layout has been conservatively assumed. • These flood impacts are likely to be mitigated through the design development of any potential structure on the planning proposal site, limiting any ground level structures from influencing overland flows.
'Sanctuary' (14-16 Hill Road, Wentworth Point) Sekisui House Australia Pty Ltd	The urban renewal/residential development consists of staged phases and includes sub-precincts 2 to 6. The development of sub-precincts 2-6 were lodged in July 2021 and are currently under assessment. Interaction with the project: • The Sanctuary site intersects with the project site corridor on the lot adjacent to the corner of Wattlebird Road and Lapwing Street as it connects to Ferry Wharf Circuit along Louise Sauvage Pathway.	• The works proposed for the development limit filling to locations outside the 1% AEP Parramatta River flood extent, largely mitigating flood impacts from the development. • Residual flood impacts are anticipated to be local, with potential impacts to overland flows. • Cumulative flood impact assessment indicates that the combined flood impacts are significant, but mainly attributed to the conservative representation of potential development at 'Sanctuary' blocking overland flow paths. The project flood impacts are minor and only apparent at the immediate area adjacent the light rail alignment.

Project name	Description	Cumulative impact assessment
Sydney Olympic Park new high school	The site comprises part of an area of land owned by Transport for NSW and forms part of the Wentworth Point Planned Precinct. This proposal is currently under assessment with main construction works likely to be completed by late 2023 and operational by early 2024. Interaction with the project: • The site will be located east of the project site and have frontage along Burroway Road.	• The works proposed for the facility limit filling to locations outside the 1% AEP Parramatta River flood extent, largely mitigating flood impacts from the development. • Residual flood impacts are anticipated to be local, with potential impacts to overland flows. • Cumulative flood impact assessment indicates that the combined flood impacts are significant, but mainly attributed to the conservative representation of potential development at the high school blocking overland flow paths. The project flood impacts are minor and only apparent at the immediate area adjacent the rail alignment.
Block D, 37-39 Hill Road, Wentworth Point	Demolition of existing buildings and construction of multi-level residential flat building. Construction works are currently underway. The development is scheduled to be complete by June 2023. Interaction with the project: • The site is located to the east of the project site along Hill Road.	• The works proposed for the facility limit filling to locations outside the 1% AEP Parramatta River flood extent, largely mitigating flood impacts from the development. • Residual flood impacts are anticipated to be local, with potential impacts to overland flows. • Cumulative flood impact assessment indicates that the combined flood impacts are significant, but mainly attributed to the conservative representation of potential development at the residential site blocking overland flow paths. The project flood impacts are minor and only apparent at the immediate area adjacent the rail alignment.

Project name	Description	Cumulative impact assessment
Sydney Olympic Park - Open Water Surf Facility (URBN SURF Sydney)	• Located at Pod B5 car park, Hill Road, Sydney Olympic Park. • The development incorporates a 1-2 storey building on the south-western corner of the site. Entry to the facility will be located immediately adjacent to the bus stop within the Holker Busway (which will interact with the project corridor). Construction works began early 2022 and are scheduled to be completed by early 2023. Interaction with the project: • The site is located east of the project site along Hill Road and north to the project site along Holker Busway.	• The works proposed for the facility limit filling to locations outside the 1% AEP Parramatta River flood extent, largely mitigating flood impacts from the development. • Residual flood impacts are anticipated to be local, with potential impacts to overland flows. • Refer to Appendix D for mapping of the Lower Parramatta River indicating local flood impact areas within the immediate surrounds of the URBN SURF assumed structures. • Cumulative flood impacts experienced north of Hill Road result from a conservatively estimated built form at the facility. These flood impacts are likely to be mitigated through the design development of any potential structure on the planning proposal site, limiting any ground level structures from influencing overland flows.
Mixed Use Development – Sites 2A and 2B Sydney Olympic Park	• Located at 2A and 2B Australia Avenue, Sydney Olympic Park. This development proposes the construction of two towers for serviced apartments and commercial use. Currently under assessment after being exhibited between December 2021 and January 2022. Interaction with the project: • The site will be located along the eastern boundary of the project site on Australia Avenue.	• The development site is located near the top of the catchment and with replacement of existing car parks, minimal changes in impervious site coverage occurs resulting in little change to runoff characteristics. • Refer to Appendix D for mapping of the Lower Parramatta River indicating local flood impact areas within the immediate surrounds of the mixed use development assumed structures. • Cumulative flood impacts experienced west of Australia Avenue result from a conservatively estimated built form at the facility. These flood impacts are likely to be mitigated through the design development of any potential structure on the planning proposal site, limiting any ground level structures from influencing overland flows.

<table>
<tr><th>Project name</th><th>Description</th><th>Cumulative impact assessment</th></tr>
<tr><td>Carter Street Precinct (Phase 3 and 4)

Lidcombe</td><td>The mixed-use residential development within the Carter Street Precinct (52 ha) is known as the Broader Meriton Land.

The site is rezoned from industrial zone to allow for high-density mixed-use development, including up to 5,500 dwellings, a new village centre, a site for a new primary school and new public open space. The proposal is to be delivered in four phases. Phases 1 and 2 are completed. Phases 3 and 4 are currently under construction. Phase 3 construction is expected to be completed within a 36-month period.

Interaction with the project:
• Phase 3 (4-8 Uhrig Street) of the development is located at the intersection of Uhrig Road and Grazer Street. The site interacts with the project site located along Uhrig Road where it connects to Dawn Fraser.
• Phase 4 (11A and 13 Carter Street) of the development is located directly adjacent to Phase 3 at the intersection of Carter Street and Uhrig Road.
• The site interacts with the southern boundary of the project site at this junction.</td><td>• The development site is located near the top of the catchment and with the replacement of existing car parks, minimal changes in impervious site coverage occurs resulting in little change to runoff characteristics.
• Cumulative flood impact assessment indicates that the combined flood impacts are similar to those experienced in the Parramatta Light Rail Stage 2 only impact assessment, with some additional overland flow flooding to the north of Dawn Fraser Avenue.
• Refer to Appendix D for mapping of the Lower Parramatta River indicating local flood impact areas within the immediate surrounds of the Carter Street precinct assumed structures.
• These flood impacts are likely to be mitigated through the design development of any modifications to the formal drainage system in the vicinity of the Carter Street precinct.</td></tr>
</table>

Project name	Description	Cumulative impact assessment
‘Vivacity’ (5 Uhrig Rd, Lidcombe)	• The site is located at the intersection of Uhrig Rd and Stockyard Boulevard. The mixed use residential and commercial development. Stage one of the development was completed in March 2020. Confirmation on construction works for Stage two is not available however the anticipated completion date for Stage two is 2024. Interaction with the project: • The site will interact with the northern boundary of project site along Uhrig Road.	• The development site is located near the top of the catchment and with replacement of existing buildings, minimal changes in impervious site coverage occurs resulting in little change to runoff characteristics. • Cumulative flood impact assessment indicates that the combined flood impacts are similar to those experienced in the Parramatta Light Rail Stage 2 only impact assessment, with some additional overland flow flooding to the north of Dawn Fraser Avenue. • Refer to Appendix D for mapping of the Lower Parramatta River indicating local flood impact areas within the immediate surrounds of the ‘Vivacity’ assumed structures. • These flood impacts are likely to be mitigated through the design development of any modifications to the formal drainage system in the vicinity of the ‘Vivacity’ site.

7.2 Cumulative impacts – water quality

Whilst the quality of the existing water is currently documented as being degraded (refer to Section 4), the construction of the project, along with other developments occurring simultaneously close to the project may potentially further degrade water quality resulting in a cumulative increase of water quality pollutants, sediment loads and litter due to vegetation removal, excavation and equipment haulage. However, provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers would be minimal.

Some of the listed key developments in the area are already in progress but are yet to reach complete development. Others are still in the planning phase and their pace of development is uncertain at this stage. Any surface water and groundwater impacts of the project are therefore likely to be negligible over the long-term in the broader area.

Cumulative contamination and soil impacts may result from the disturbance of soils, including contaminated soil, and discharge of contaminated groundwater from other developments undertaken simultaneously to the project. This could result in the erosion and transport of soils and contaminated sediments into surface water bodies.

The environmental assessments prepared for Sydney Metro West and for other projects occurring near key areas of environmental concern in Camellia and Sydney Olympic Park included assessment of contamination and provided management measures. These projects are not expected to generate significant new contamination during construction. However, they are all likely to encounter and disturb existing contamination from past land uses that would require investigation, management and/or remediation.

The potential for cumulative impacts due to erosion and sedimentation would be managed by implementing standard erosion and sedimentation control measures. As such, it is not expected that the project would have a substantial cumulative impact on erosion and sedimentation.

Provided that projects constructed concurrently with the project are completed in accordance with the conditions of approval and any environment protection licence conditions, cumulative contamination and soils impacts are expected to be minimal.

There is unlikely to be a cumulative impact to groundwater as a result of the project as the excavations required for the light rail alignment and foundations, are not likely to be deep enough to intercept the shallow groundwater table, except in rainfall events or flooding. Foundations/piling for the bridges and excavation for the Boronia Street cutting are the only construction activities likely to intercept groundwater. However, they will not impact groundwater flow.

The potential cumulative construction impacts associated with the project and the identified key developments would be further considered as the design and construction planning is developed. Transport for NSW would coordinate activities with the proponents of these other developments to minimise potential cumulative impacts.

8 Recommended management and mitigation

8.1 Approach to management and mitigation

8.1.1 Water quality

A construction soil and water management plan would be prepared as part of the CEMP and implemented during construction. The plan would detail processes, responsibilities and measures to manage potential soil and water quality impacts during construction. The plan would be prepared in accordance with relevant guidelines and standards, including *Managing Urban Stormwater – Soils and Construction*, Volume 1 (Landcom, 2004) (referred to as the 'Blue Book'), *IECA's Best Practice Erosion and Sediment Control – for building and construction sites (2008)* and *Sydney Olympic Park Authority Policy - Stormwater Management and Water Sensitive Urban Design* (Sydney Olympic Park Authority, 2016) (in relation to Sydney Olympic Park). The development of mitigation measures in the plan would be guided by the Blue Book to determine the magnitude of rainfall events to which the capacity of the construction mitigation measures should be designed. Further information, including an outline of the plan, is provided in the EIS Chapter 23 (Approach to environmental management and mitigation).

The effectiveness of the mitigation measures would be monitored by developing and implementing a water monitoring program, described further in Section 8.3.

During operation, water quality would be protected through implementation of a range of water quality treatment measures that would reduce pollutant loads leaving the project site, contribute to working towards achieving the NSW water quality objectives, and protect nearby sensitive receiving environments. Potential measures treatment measures would be confirmed during ongoing design development.

Other mitigation measures proposed to minimise potential water quality impacts are listed in Table 8-1.

8.1.2 Groundwater

A dewatering management strategy would be developed to ensure groundwater is appropriately managed when intersected during construction. The strategy would include:

- reviewing existing groundwater conditions to provide adequate background information
- identifying proposed management options, including treatment on-site, discharge to surface water, infiltration, reinjection, disposal to the wastewater network and disposal at a waste facility
- assessing the feasibility of each proposed option, considering site-specific constraints, details of when each option is appropriate and any associated environmental impacts
- developing procedures to limit exposure of receptors (for example, use of personal protective equipment requirements for construction workers)
- identifying requirements of relevant regulatory authorities in relation to each management option
- confirming the measures to be implemented to manage groundwater during dewatering activities.

8.1.3 Works in the Parramatta River

Bridge construction works in the Parramatta River have the potential to cause water quality impacts, affect flooding regimes, and result in changes to hydrological processes. These potential impacts would primarily be associated with the clearing of vegetation, potential temporary work platforms and construction of bridge piers.

A construction riverine protection management plan would be developed and implemented prior to construction commencing. The plan would detail the measures to manage potential changes to hydrodynamic processes within the Parramatta River and to ensure appropriate mitigation measures are implemented to minimise erosion, scour and destabilisation of the riverbanks.

8.1.4 Minimising the potential for flooding impacts

Ongoing design development would be undertaken to minimise the localised flooding impacts as far as practicable. This would consider the design of bridges to minimise flow disruption, and the capacity of proposed and existing stormwater drainage systems. It will also consider flood sensitive areas in Sydney Olympic Park, including the Narawang Wetland, Brick Pit and leachate management system.

The location and layout of construction work sites and compounds would be prepared with consideration of overland flow paths, avoiding flood liable land and minimising changes to flow paths where practicable to minimise impacts.

The presence of temporary structures and work areas within and next to the Parramatta River and other watercourses in the study area, could pose an environmental and safety risk in the event of a flood event. Floodwaters could mobilise pollutants and construction materials from these areas. A construction flood emergency response plan would be prepared that sets out measures which are aimed at mitigating the risks in the event of a flood occurring during construction.

8.2 Mitigation measures

Mitigation measures have been identified to manage both construction and operation site specific impacts and these measures are presented in Table 8-1.

Table 8-1 Summary of potential impacts and management measures

Reference	Impact	Mitigation measure	Applicable location(s)	Phase
HF1	Flood protection	A flood management strategy will be prepared, building on the results of the assessment presented in this technical paper, to inform further design development and demonstrate how: • the project will achieve the Flood Management Objectives and Flood Immunity Standards • the risk of flooding to the project will be minimised • the potential impacts of the project on flood behaviour (under pre-project conditions) would be managed such that flooding characteristics will not be adversely impacted. The flood management strategy will • confirm the project's level of flood immunity • confirm the impacts of the project on flood behaviour in accordance with the NSW Floodplain Development Manual (DIPNR, 2005) • identify design responses and management measures to minimise: – flooding impacts above the one per cent AEP by adopting climate change adaptation measures – flooding impacts to flood sensitive areas and infrastructure within Sydney Olympic Park, including the Narawang Wetland, the Brick Pit and the existing leachate system – potential impacts to the flood capacity and potential for scour as a result of the bridge piers. The strategy will be prepared by a suitably qualified and experienced specialist in consultation with City of Parramatta Council, City of Ryde Council, Sydney Olympic Park Authority, NSW State Emergency Service and the Department of Planning and Environment.	All precincts and facilities	Design

Reference	Impact	Mitigation measure	Applicable location(s)	Phase
HF2	Residual impacts and flood protection	Drainage and flood management infrastructure will be designed with regard to relevant drainage design requirements and guidelines, including the *Development Engineering Design Guidelines* (City of Parramatta Council, 2018) and *Sydney Olympic Park Authority Policy - Stormwater Management and Water Sensitive Urban Design* (Sydney Olympic Park Authority, 2016).		
HF3	Residual impacts and flood protection	Ongoing consultation will occur with the NSW State Emergency Service and relevant councils in relation to potential impacts to existing community emergency management arrangements for flooding.	Camellia stabling and maintenance facility, Rydalmere Wharf, Sydney Olympic Park Station, Sanctuary Wentworth Point development site.	Design, pre-construction and operation
HF4	Flooding behaviour impacts	Hydrodynamic modelling will be undertaken to inform the final bridge construction methodology to minimise the risk of riverbank destabilisation or additional flooding to nearby areas. The modelling will also identify if additional measures, such as scour protection are required	Bridge crossings	Pre-construction
HF5	Flood protection	Construction planning and the layout of construction worksites and compounds will be undertaken with consideration of overland flow paths and flood risk, avoiding flood liable land as far as practicable.	Project wide	Pre-construction
HF6	Flood protection	A flood and emergency response plan will be prepared and implemented. The plan will include measures, process and responsibilities to minimise the potential impacts of construction activities on flood behaviour as far as practicable. It will also include measures to manage flood risks during construction and address flood recovery during construction.	Project wide	Pre-construction Construction
WQ1	Water quality	The location and specification of water quality treatment measures will be considered in the drainage design (at each design phase) with reference to the NSW and project-specific water quality objectives and existing water quality.	Project wide	Design

Reference	Impact	Mitigation measure	Applicable location(s)	Phase
WQ2	Water quality	Consultation with NSW EPA, City of Parramatta Council and Sydney Olympic Park Authority will be undertaken during the development of the water quality monitoring program.	Project wide	Pre-construction
WQ3	Water quality	A soil and water management plan will be prepared as part of the CEMP to minimise potential for pollutants to enter surface and groundwater. Specific measures will be identified in consultation with relevant government agencies and will be consistent with the principles and practices detailed in Landcom's (2004) *Managing Urban Stormwater: Soils and Construction, IECA's Best Practice Erosion and Sediment Control – for building and construction sites.* and *Sydney Olympic Park Authority Policy - Stormwater Management and Water Sensitive Urban Design (Sydney Olympic Park Authority, 2016)* (in relation to Sydney Olympic Park). The objectives and strategies of the soil and water management plan will include the following: • minimise the extent and duration of exposed surfaces (particularly those works that have the greatest potential to disturb soils that are contaminated or have a high erosion and runoff hazard) • develop and implement adequate water quality control measures prior to the carrying out of significant earthwork or bridge construction activities • identification of specific areas that present a higher risk of impacting the receiving waters during bridge construction activities, along with specific controls to reduce the risk of these impacts occurring • earthwork activities will implement erosion and sediment control measures, in accordance with *Transport for NSW Water Discharge and Reuse Guideline* and ERSED risk management and controls	Project wide	Construction

Reference	Impact	Mitigation measure	Applicable location(s)	Phase
		• minimise and manage impacts on water quality and downstream receiving environments during instream activities. Where piling, concreting, earthworks, scour protection or other works are required within or adjacent to a waterway, a silt barrier such as a boom, bund or curtain will be installed either downstream of the work site and/or around the piles themselves prior to the commencement of works. • for activities located on land affected by the 5% AEP flood (such as bridge support construction or works within the waterway itself), flood response measures will be necessary, such as active monitoring of weather forecasts and appropriate action for flooding (such as removing equipment or closing activity locations) • areas of potential contamination concern will be identified and works in these areas managed to minimise disturbance • develop procedures for the assessment, handling and stockpiling of potentially contaminated materials, in accordance with OEH's *Waste Classification Guidelines* (2016) • confirm the proposed water quality controls (such as sediment fences and bunding of chemical storage areas) for out of river and in-river construction sites are appropriately implemented prior to surface water discharging into creeks and waterways • release of contaminated sediments will be prevented by implementing sediment control measures		

Reference	Impact	Mitigation measure	Applicable location(s)	Phase
		• soils excavated or exposed from potential acid sulfate soils areas will be subject to the provisions of an acid sulfate soil management plan developed in accordance with the *Acid Sulfate Soils Assessment Guidelines* (ASSMAC, 1998). Once acid sulfate soils have been treated, depending on the results of testing, they could either be reused on site, or disposed of at an appropriate facility.		
WQ4	Water quality	Storage and containment systems for the stockpiling of contaminated material during construction will be designed to be impervious to the materials stored, resistant to fire (where required), covered to prevent contact with rainfall, and managed and maintained to prevent any release of liquids and contaminated run-off to stormwater drains, waters and land.	Project wide	Construction
WQ5	Water quality monitoring	A surface water and groundwater monitoring program will be developed as part of the soil and water management plan prior to construction commencing to monitor compliance with the water quality objectives. The monitoring will enable potential impacts on surface and groundwater to be identified, controlled and reported. Targeted verification monitoring of receiving waters and shallow groundwater prior to construction will be undertaken to confirm baseline water quality conditions. The monitoring program will be developed in consultation with the NSW EPA, City of Parramatta Council and the Sydney Olympic Park Authority. Further details of the water quality monitoring program are outlined in Section 8.3.	Estuarine aquifers at bridge between Camellia and Rydalmere and bridge between Melrose Park and Wentworth Point; locations of GDEs, construction areas near the water works at Wentworth Point, the cutting at Boronia Street and monitoring sites established for geotechnical purposes.	Construction

Reference	Impact	Mitigation measure	Applicable location(s)	Phase
WQ6	Water quality	Discharge to surface water will be undertaken in accordance with Transport for NSW Water *Discharge and Reuse Guideline DMS-SD-024* (2019c), and project specific objectives.	Project wide	Construction
WQ7	Water quality	Measures including soil stabilisation work to manage erosion following construction activities at light rail stops and newly landscaped areas will be included in the Operational Environmental Management Plan.	Project wide	Operation
GW1	Groundwater	Design and construction planning will seek to minimise impacts on and from groundwater by: • avoiding the need to extract groundwater • minimising groundwater inflows and volumes into excavations • considering the potential effects of salinity on the durability of new infrastructure, such as bridge piers.	Project wide	Design
GW3	Groundwater	A dewatering management strategy will be prepared as part of the CEMP and implemented during construction. The plan will detail measures for the appropriate management of extracted groundwater.	Project wide	Pre-construction Construction
GW5	Groundwater	Excavation techniques will be adopted to minimise impacts on aquifers in line with defined minimal impact aquifer interference activities outlined in the *NSW Aquifer Interference Policy.*	Where any excavation is likely to encounter aquifers	Construction
GW6	Existing boreholes	Further investigations and consultation with the owner of groundwater borehole GW107659 will be undertaken to identify the potential to affect existing water extraction and to identify appropriate management measures in accordance with *NSW Aquifer Interference Policy*.	Borehole GW107659	Design

Reference	Impact	Mitigation measure	Applicable location(s)	Phase
GW7	Existing boreholes	Further investigations and consultation with the owner of groundwater borehole GW063660 will be undertaken to identify if the bore can be decommissioned. Any decommissioning required will be undertaken in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Uniform Drillers Licensing Committee, 2012).	Borehole GW063660	Construction
General1	Emergency management arrangements	The project Operations Management Plan/System must include emergency management arrangements to manage flood risks to people and vehicles accessing stops and facilities. Egress arrangements will need consider flood hazard in nearby streets.	All precincts and facilities	Operation
General2	Work within watercourses	Works within or near watercourses will be undertaken with consideration of the Guidelines for watercourse crossings on waterfront land (DPI, 2012) and Guidelines for controlled activities on waterfront land – Riparian corridors (NRAR, 2018).	Water crossings	Construction

HF: Hydrology and Flooding, **SWQ:** Surface Water Quality, **GW:** Groundwater

8.3 Water quality monitoring

A water quality monitoring program (mitigation measure WQ5) will be developed as part of the soil and water management plan to determine the effectiveness of the project-specific mitigation measures. The monitoring program will be designed to validate baseline water quality conditions and to confirm project-specific water quality criteria. The monitoring program will be designed in accordance with the National Water Quality Management Strategy (and associated guidelines such as the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*) and the *NSW Water Quality and River Flow Objectives*. Given the present degraded state of surface waters in the study area, the primary objective of the program will be to demonstrate the project will work towards achieving the NSW water quality objectives.

Note: The following water quality monitoring program scope is indicative only and will be subject to refinement following the issue of the project’s conditions of approval.

8.3.1 Water quality monitoring phasing

The water quality monitoring will be undertaken during the following two stages:

- pre-construction phase (baseline validation) where screening, including cross-checking the existing water quality against ANZECC (2000) and ANZG (2018) guideline values, is undertaken to determine where the NSW Water Quality Objectives are being achieved in the existing environment
- construction phase to assess for impacts to receiving water quality with temporal reference to the upstream control sites.

8.3.2 Water quality monitoring frequency

The number of sampling events required is generally determined by the variability of the water quality data; however, an indicative monitoring regime will require the following frequency:

- pre-construction sampling - includes four wet weather (weather permitting) and four dry weather events
- construction phase
  - dry weather – quarterly
    - wet weather – during rainfall events exceeding 20 millimetres
    - incident investigation - in response to any discharge, in-stream works, incident or complaint observed to result in impact to water quality
    - construction site dewatering and discharge monitoring – prior to any discharge of construction water from site.

8.3.3 Water quality monitoring sites

The water quality monitoring will involve the collection of surface and groundwater samples at selected locations within the project site, especially where worksites are in close proximity to watercourses or receiving water bodies. This will include Parramatta River, Subiaco Creek, Duck River, Vineyard Creek, Haslams Creek and Narawang Wetland. Within each watercourse, sites will be selected based on the following indicative criteria:

- the monitoring should be undertaken as close as possible to the proposed discharge points of the project site to the receiving waters
- the sampling locations should be representative of where the site discharge mixes with the receiving waters.

In relation to works in and adjacent to watercourses and receiving water bodies in Sydney Olympic Park the monitoring program would be confirmed in consultation with the Sydney Olympic Park Authority.

8.3.4 Water quality monitoring parameters

A minimum of two rounds of water quality testing will be undertaken as part of the monitoring program. The indicative parameters that will be tested, both in the field and laboratory is outlined in Table 8-2.

Table 8-2 Indicative water quality monitoring parameters

Method	Parameter
Field water quality probing	• Flow • pH • Temperature • Electrical conductivity • Dissolved oxygen • Redox potential • NTU • Oil and grease • Salinity
Laboratory sampling	• TSS • Salinity (EC) • pH • Sulfate • Chloride • heavy metals (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, zinc) • major cations (sodium, potassium, calcium and magnesium) • major anions (chloride, sulfate and bicarbonate) • Total Phosphorus • Total Nitrogen • Hydrocarbons (TPH, TRH) • Chlorophyll-a
Additional information collection	• preceding rainfall • river / creek water level • tidal sequence in tidal reaches • visual observations for litter, debris, oil, grease and large pollutants summary of relevant construction activities and discharges observations of other non-construction contributors to variations in water quality (e.g. stormwater) • groundwater levels • recharge rates • photos • other activities in the area with the potential to affect water quality

8.4 Residual impacts

Localised changes in the surface runoff of stormwater are likely in the vicinity of the project, where changes are made to the existing topography. Mitigation of the changes to runoff are anticipated once the surface water reaches the nearest capture location of the stormwater network by means of the mitigation measures discussed in Section 8.2.

In addition, application of appropriate design standards and industry best practice, as well as mitigation measures throughout the life of the construction and operation of the project, will minimise impacts to the receiving waterbodies around this project.

In terms of residual operation impacts, negligible increases to flood depths along key access routes are predicted in both the one per cent AEP and PMF events, though some of these areas are already predicted to be substantially flooded under existing conditions.

9 Conclusion

A hydrology, flooding and water quality assessment was carried out for the project.

The project site is located in a highly urbanised environment that has been substantially altered from its natural state and water quality is typical of that for urban catchments in Sydney.

Sections of the project site are located on the floodplain of the Parramatta River and are likely to be subject to mainstream flooding from Parramatta River and its tributaries and overland flooding from stormwater overflows.

Construction activities have the potential to:

- adversely impact surface water and groundwater through release of sediment, disturbance of contaminated or acid sulfate soils, pollutants such as fuels, oils or other chemical spills or leaks from use of plant and equipment, hazardous materials, and/or construction materials from the construction site
- changed flood behaviour as a result of changes to site topography, drainage controls and installation of temporary buildings and other structures within the floodplain.

Consideration of flood risk and potential flood impact has been carried out for the following:

- construction compounds
- light rail alignment and road adjustments
- bridge construction and modification.

Potential impacts of the construction activities on surface hydrology includes potential changes to runoff volumes, local redirection of overland flows and pollutant loadings in surface runoff. Changes in runoff volumes are anticipated to be minor, including temporary reductions in runoff volumes where existing pavements are removed and infiltration to the soil is increased, and temporary increases in runoff volumes in the case of working stop platforms comprised of a hardstand pavement.

During operation the majority of the project site is on existing roads, with the design alignment closely related to the existing surface grading. Outside of the road reserves, the project site has discrete sections that are a mix of pavement and vegetated areas. In these locations there is a change to the volume of runoff generated and the introduction of the light rail vehicles present changes in terms of new potential pollutants in the surface water.

The excavations needed to accommodate the light rail alignment and foundations, are not likely to be deep enough to intercept the shallow groundwater table, except in rainfall events or flooding. Foundations/piling for the bridges and excavation of the cutting at Ken Newman Park are the only construction activities likely to intercept groundwater. However, they would not impact groundwater flow.

During operation increased impervious areas may result in increased flood levels. The two new bridges across Parramatta River have increases in flood levels at properties which are already impacted by flooding, including foreshore properties on the Parramatta River near the Wentworth Point structure and immediately to the west of the Camellia structure.

In-stream structures may promote channel scouring resulting in further erosion and mangrove loss. Channel migration may change the position of the low flow path and localised changes to the bed and instream habitat may occur. Drainage system upgrades and additions alter the existing runoff flow distribution, generally increasing the capacity of the local storm water system and reducing potential impacts to adjacent properties during flood events. Proposed stops may alter localised flood behaviour by introducing increased hardstand areas and flow path obstructions.

The proposed bridge constructions have the potential to disturb sediments (and thereby impact water quality) either in situ through piling or on the bank (depending on proposed method of construction). The possible construction of temporary work platforms also have the potential to create instream barriers, impact mangroves, increase erosion and interfere with natural flow regimes.

The potential for cumulative impacts with other projects were identified and considered to be low provided the standard mitigation measures to manage erosion and sedimentation and contamination of soil and groundwater are implemented.

There are a number of mitigation measures proposed to minimise impacts associated with construction and operation of the project. These include measures to guide future design stages to minimise flood impacts and preparation of various management plans during construction to manage ground and surface water quality, including establishing a water quality monitoring program.

The proposed mitigation measures are considered to appropriately minimise the project’s anticipated impacts. The remaining residual impacts would consist of localised changes in the surface runoff of stormwater where changes are made to the existing topography. During operation there would be negligible increases to flood depths along key access routes, though some of these areas are already predicted to be substantially flooded under existing conditions.

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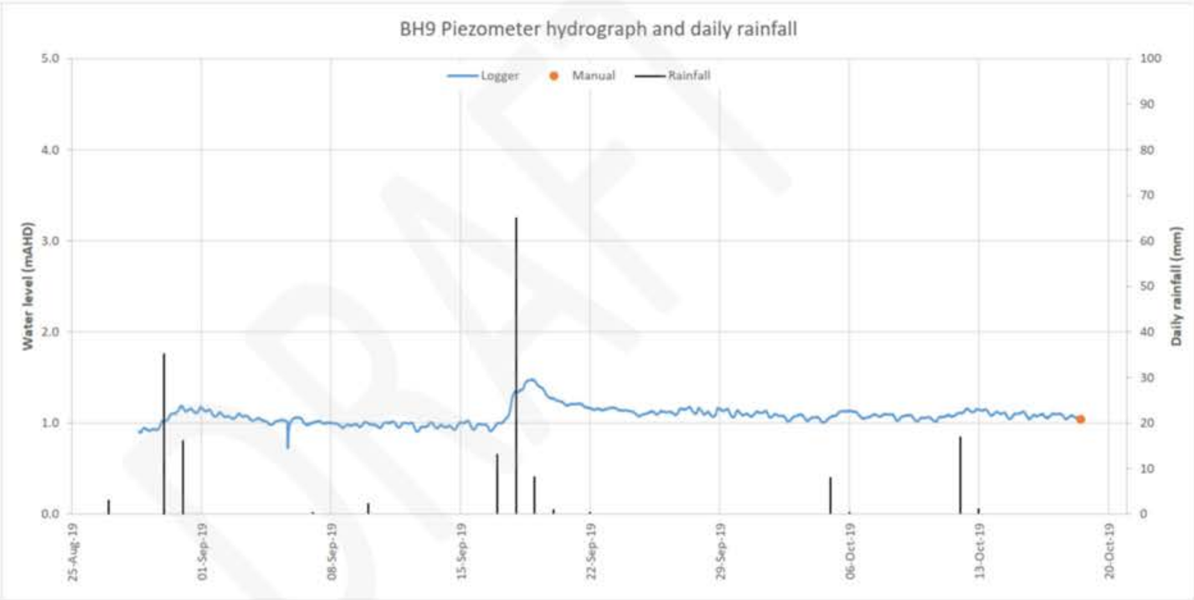
11 Appendices

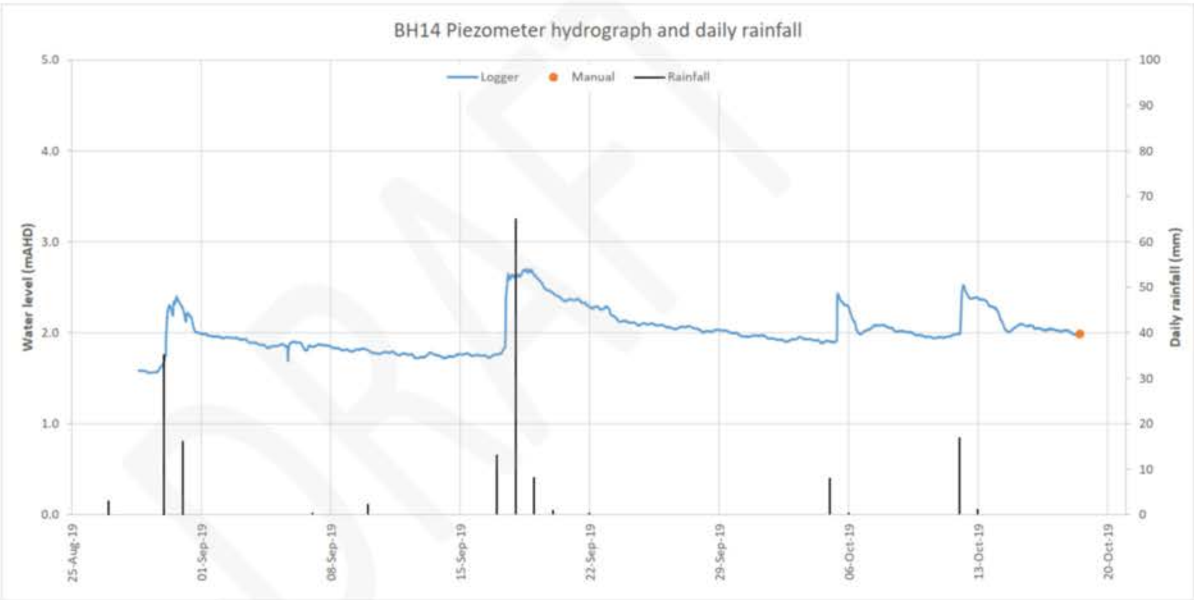
Should you have any difficulty in reviewing the content of the appendices, please contact the Project for assistance by email: ParramattaLightRail@transport.nsw.gov.au or calling the 24 hour community information line on 1800 139 389

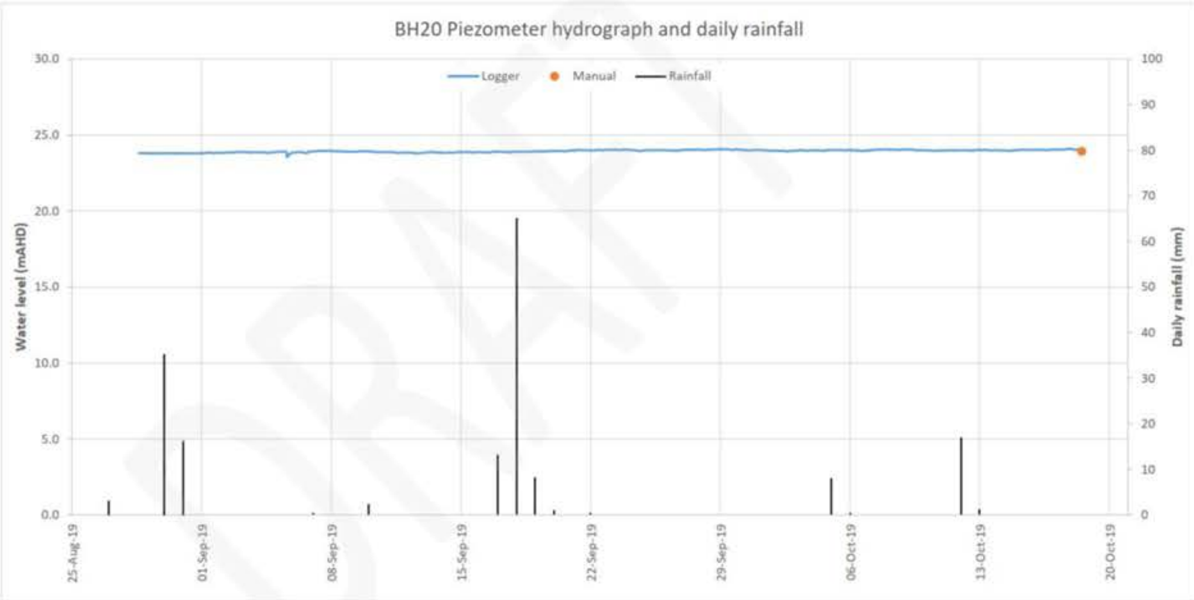
Appendix A Selected borehole monitoring results

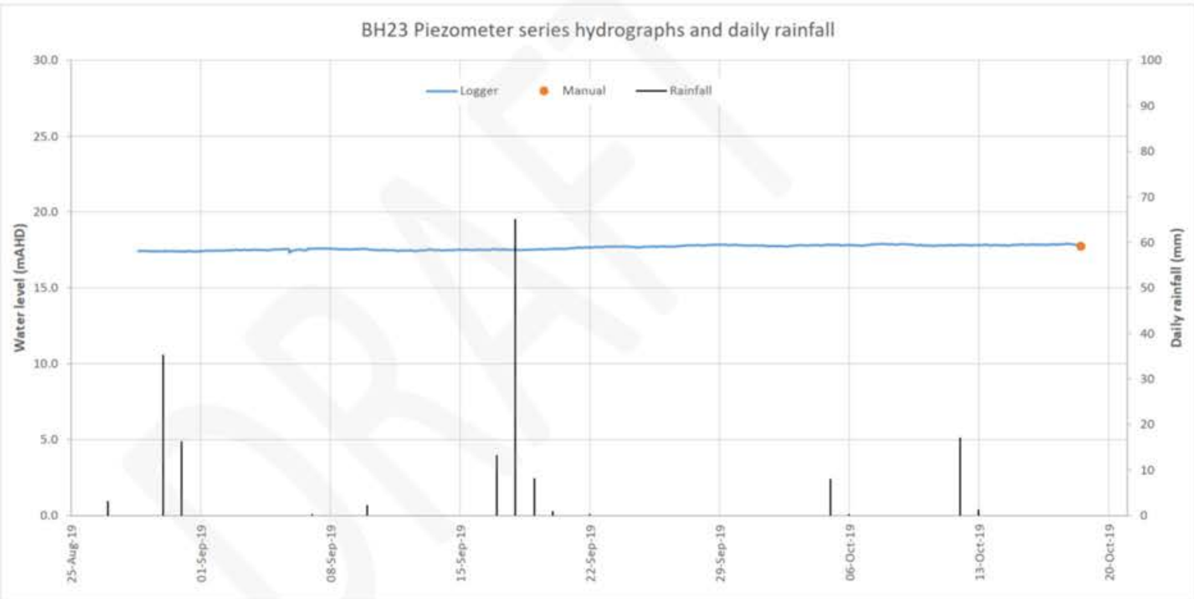
Appendix A - Selected borehole monitoring results

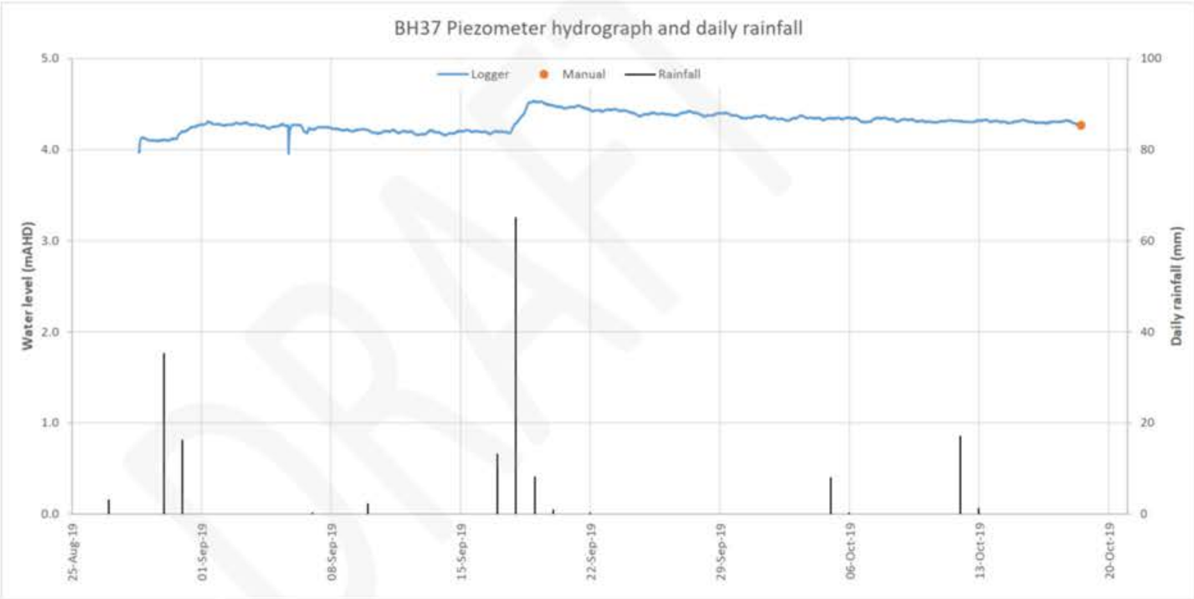
(Source: Geotechnical Interpretative Report, Coffey, 19 October 2019)






BH20 Piezometer hydrograph and daily rainfall
Logger
Manual
Rainfall
Water level (mAHD)
Daily rainfall (mm)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
100
90
80
70
60
50
40
30
20
10
0
25-Aug-19
01-Sep-19
08-Sep-19
15-Sep-19
22-Sep-19
29-Sep-19
06-Oct-19
13-Oct-19
20-Oct-19


BH23 Piezometer series hydrographs and daily rainfall
Logger
Manual
Rainfall
Water level (mAHD)
Daily rainfall (mm)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
100
90
80
70
60
50
40
30
20
10
0
25-Aug-19
01-Sep-19
08-Sep-19
15-Sep-19
22-Sep-19
29-Sep-19
06-Oct-19
13-Oct-19
20-Oct-19



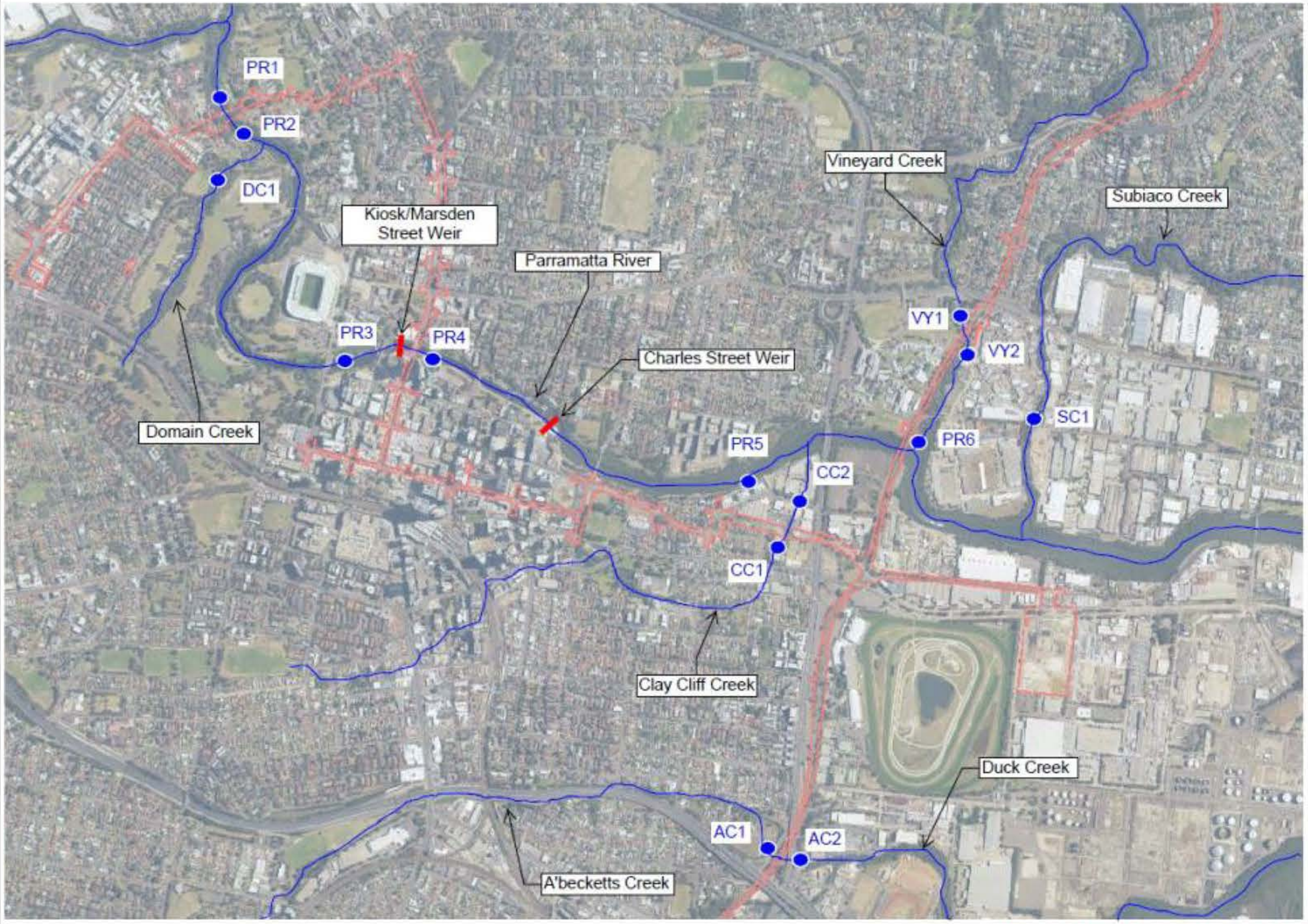
BH37 Piezometer hydrograph and daily rainfall
Logger
Manual
Rainfall
Water level (mAHD)
Daily rainfall (mm)
5.0
4.0
3.0
2.0
1.0
0.0
100
80
60
40
20
0
25-Aug-19
01-Sep-19
08-Sep-19
15-Sep-19
22-Sep-19
29-Sep-19
06-Oct-19
13-Oct-19
20-Oct-19

Appendix B Pre-construction water quality monitoring results for Parramatta Light Rail Stage 1

Appendix B - Pre-construction water quality monitoring results for Parramatta Light Rail Stage 1

	Onsite							laboratory																
Location	Water Type	Rain event (mm)	Temp (C)	pH	Dissolved Oxygen (%)	Conductivity (uS/cm)	Turbidity (NTU)	pH	Conductivity (uS/cm)	Turbidity (NTU)	Chloride (mg/L) LOR: 1	Chloride (mg/L) LOR: 0.1	Sulfate (mg/L) LOR: 1	Sulfate (mg/L) LOR: 0.1	Total Al (mg/L)	Total Cu (mg/L)	Total Pb (mg/L)	Total Mn (mg/L)	Total Fe (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	1,2-Dichloroethane-D4	Toluene-D8	4-Bromofluorobenzene
Parramatta River (PR1, PR2, PR3, PR4 and PR5)	Fresh	44.0	17.9	7.7	173.8	7522.6	30.8	6.9	12714.2	11.5	4234.9	5170.8	642.7	797.7	6.5	4.9	0.1	2.4	14.7	11.9	0.1	108.6	108.5	105.3
Domain Creek (DC1 - Upstream of Mouth)	Fresh	48.0		7.5	157.8	298.3	112.8	6.9	347.4	12.6	48.8	77.3	37.5	35.2	0.3	0.01	0.04	0.05	0.9	3.0	0.7			
Clay Cliff Creek (CC1)	Fresh	48.7	20.2	8.1	314.6	424.0	40.6	7.4	3163.0	24.8	939.7	1036.6	165.5	183.7	0.6	0.01	0.05	0.02	0.6	7.3	0.1	104.9	107.5	104.4
Subiaco Creek (SC1 - Upstream of Mouth)	Fresh	48.0	17.5	7.6	114.4	13479.9	23.0	7.0	15077.2	10.4	5199.6	6217.1	809.7	1116.6	0.4	0.04	0.02	0.04	0.5	5.1	0.1			
A 'Becketts Creek (Upstream)	Fresh		18.8	8.0	201.8	3.7	32.0	8.2	7330	6.2	2130.0	2040.0	317.0	275.0	0.1	0.04	<0.001	0.07	0.3					
Clay Cliff Creek (CC2)	Potentially Saline	20.2	21.9	8.0	107.1	24.4	13.9	8.1	25900	6.8	8580.0	9120.0	1380.0	1310.0	0.1	0.01	<.001	0.06	0.2			119	114	107
Vineyard Creek (VY1 and VY2)	Potentially Saline	44.0	17.8	7.7	133.6	1959.4	30.5	7.3	616.3	10.4	105.5	100.0	45.5	36.9	0.2	0.01	0.02	0.02	0.7	13.2	0.1			

Shaded cells indicate exceedance of the ANZECC (2000) and ANZG (2018) applicable guidelines.
Water quality monitoring was undertaken between June 2019 and May 2020.



Legend

- Project boundary (April 2020)
- Waterways
- Monitoring locations

Notes:
Charles Street weird separates upstream Parramatta River and downstream Parramatta river. Upstream is fresh water and downstream is saline when it hasn't rained in a while.

PLR1 _ CPB-Downer _ DRG _ DWG _ LOT No. _ DRG No. _ REV

Ref No.	Completion rec.	Work package	Description	Designed	Verified	Approved
Ref No.	Comp. rec.	Package	not provided	dd/mm/yy	dd/mm/yy	dd/mm/yy

Scale 1: 13,177

0 353 707 Meters

Coordinate System: GDA 1994 MGA Zone 56 - Height Datum: AHD

This map is a user generated static output from CPB Contractors Web GIS Viewer and is for reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable.

This drawing is confidential and shall only be used for the purpose of this project. The signing of this title block confirms the design and drafting of this project have been prepared and checked in accordance with the ISO 9001-2000 quality assurance.

Date Printed: 4-May-2020

Drawing Colour Coded - Print All Copies in Colour

Drawn by:	not provided
Designed by:	not provided
Dwg check by:	not provided
Des check by:	not provided
Approved by:	not provided

Parrmatta Light Rail - PLR1
Custom Extent

FILE No: n/a
SHEET No: n/a
STATUS: verified
DRG No: DRG No.
EDMS No: n/a

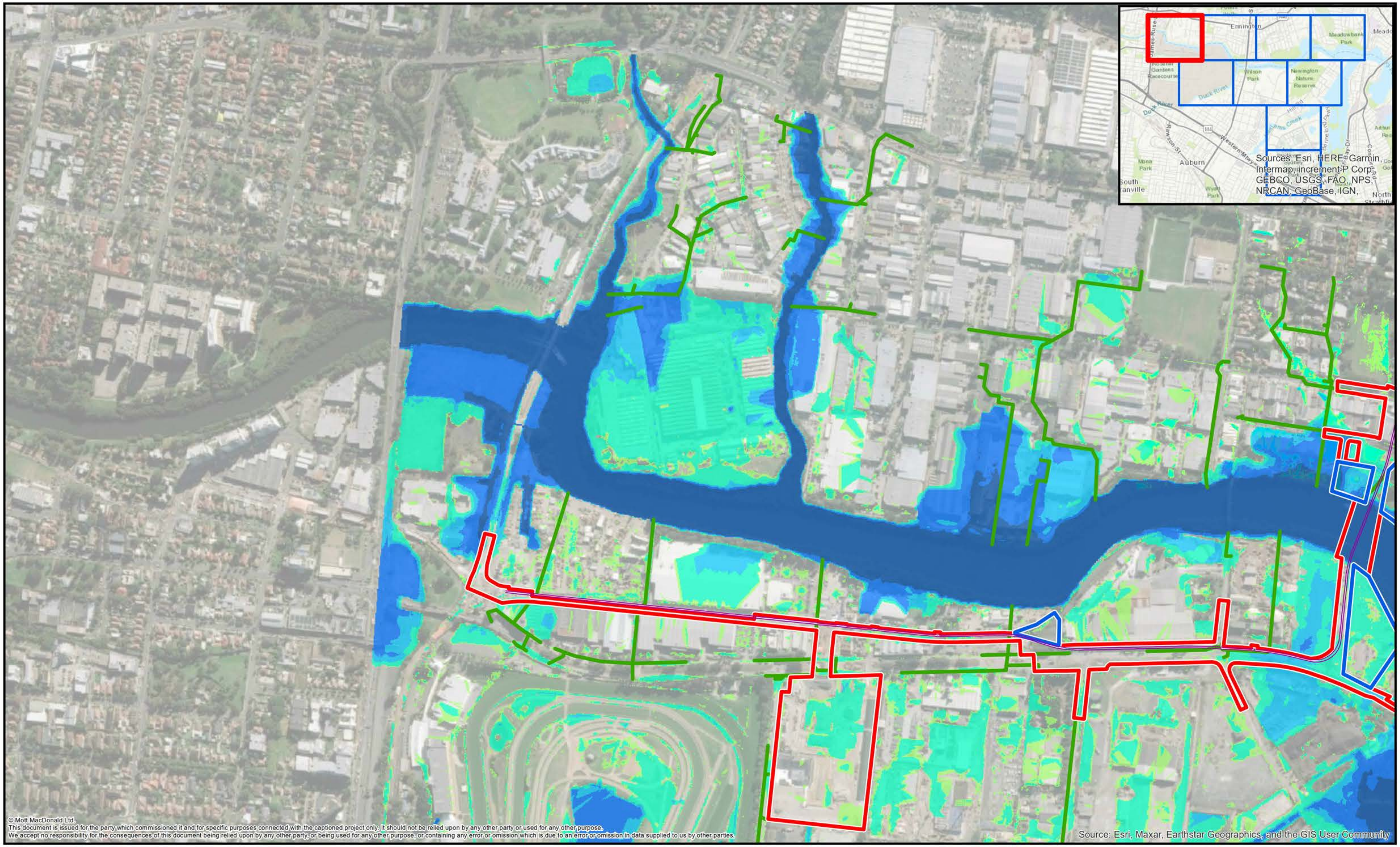
Appendix C Flood Modelling Figures - Flood Level Difference

Appendix C1 - Flood Modelling Figures - Existing Conditions

Appendix C2 - Flood Modelling Figures - Design Conditions

Appendix C3 - Flood Modelling Figures - Flood Level Difference

Appendix C1 - Flood Modelling Figures - Existing Conditions



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

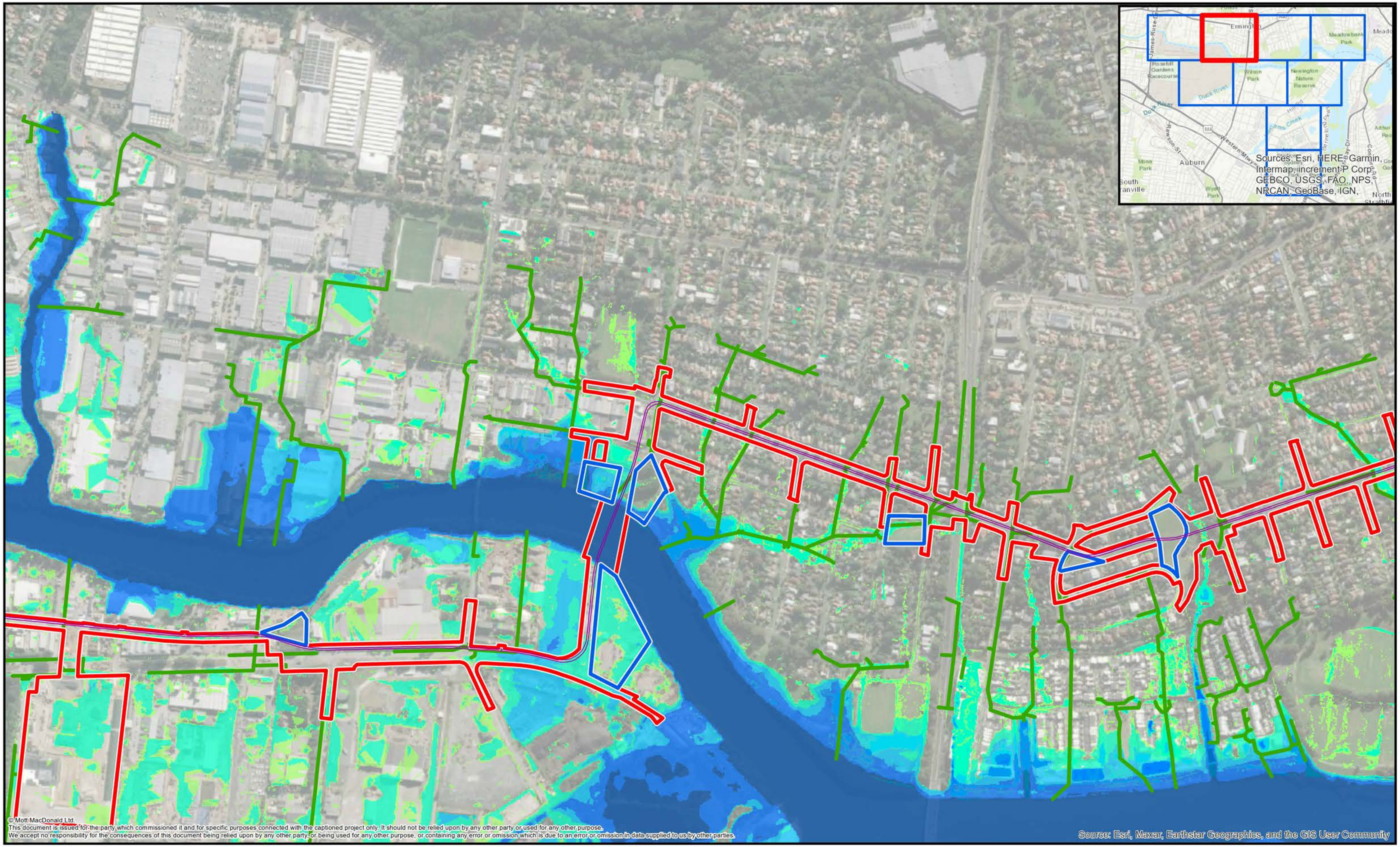
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

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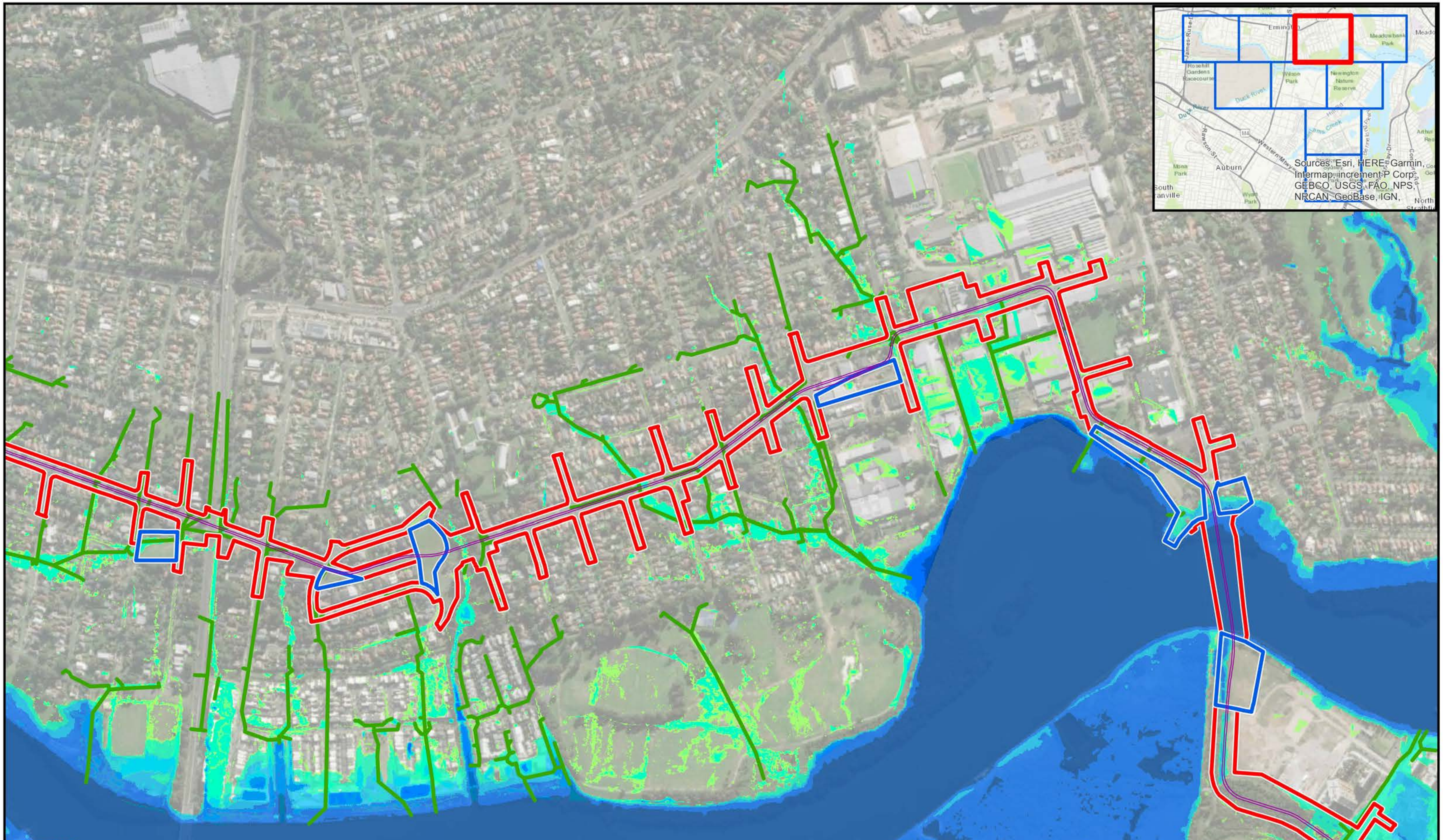

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

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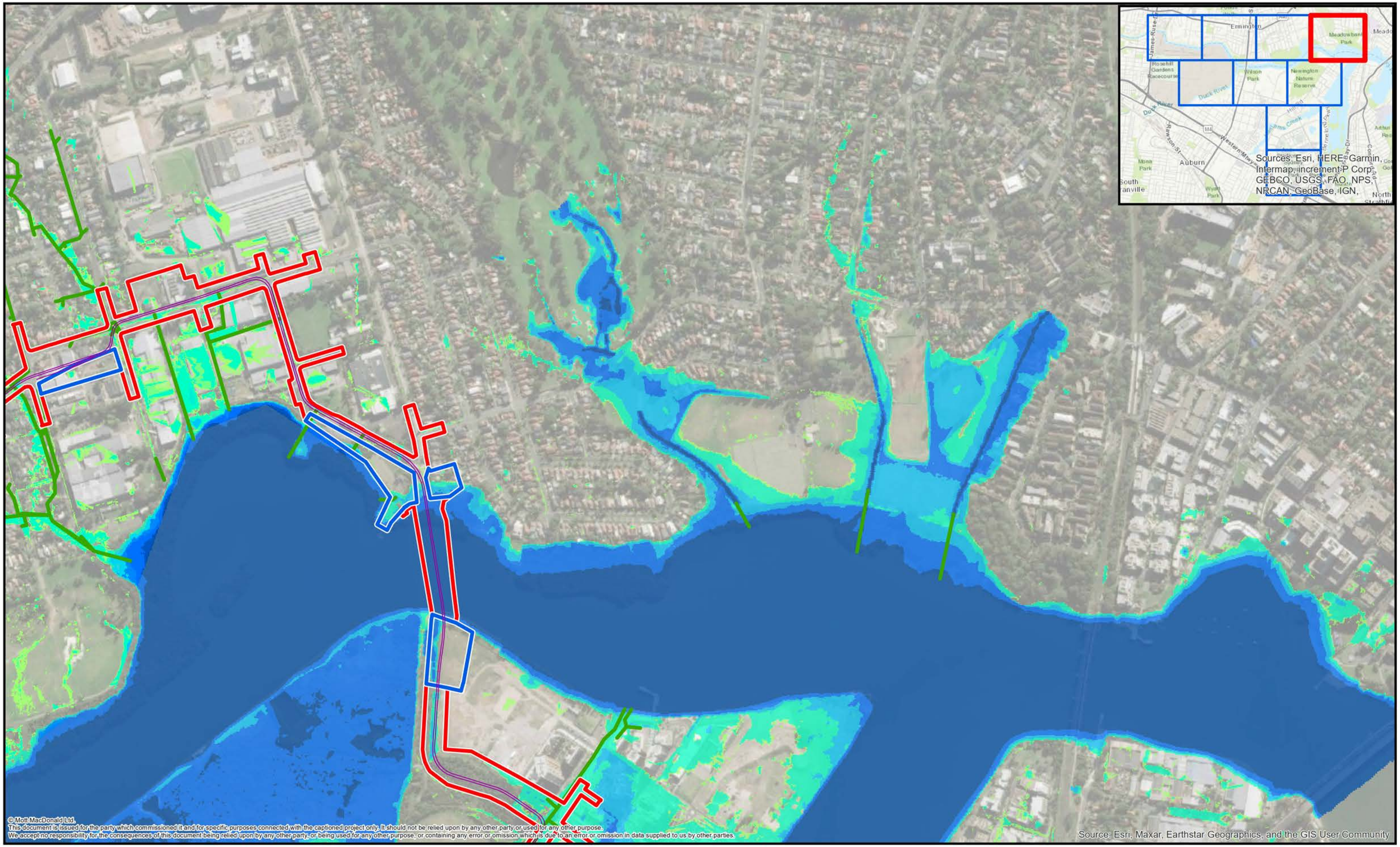

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

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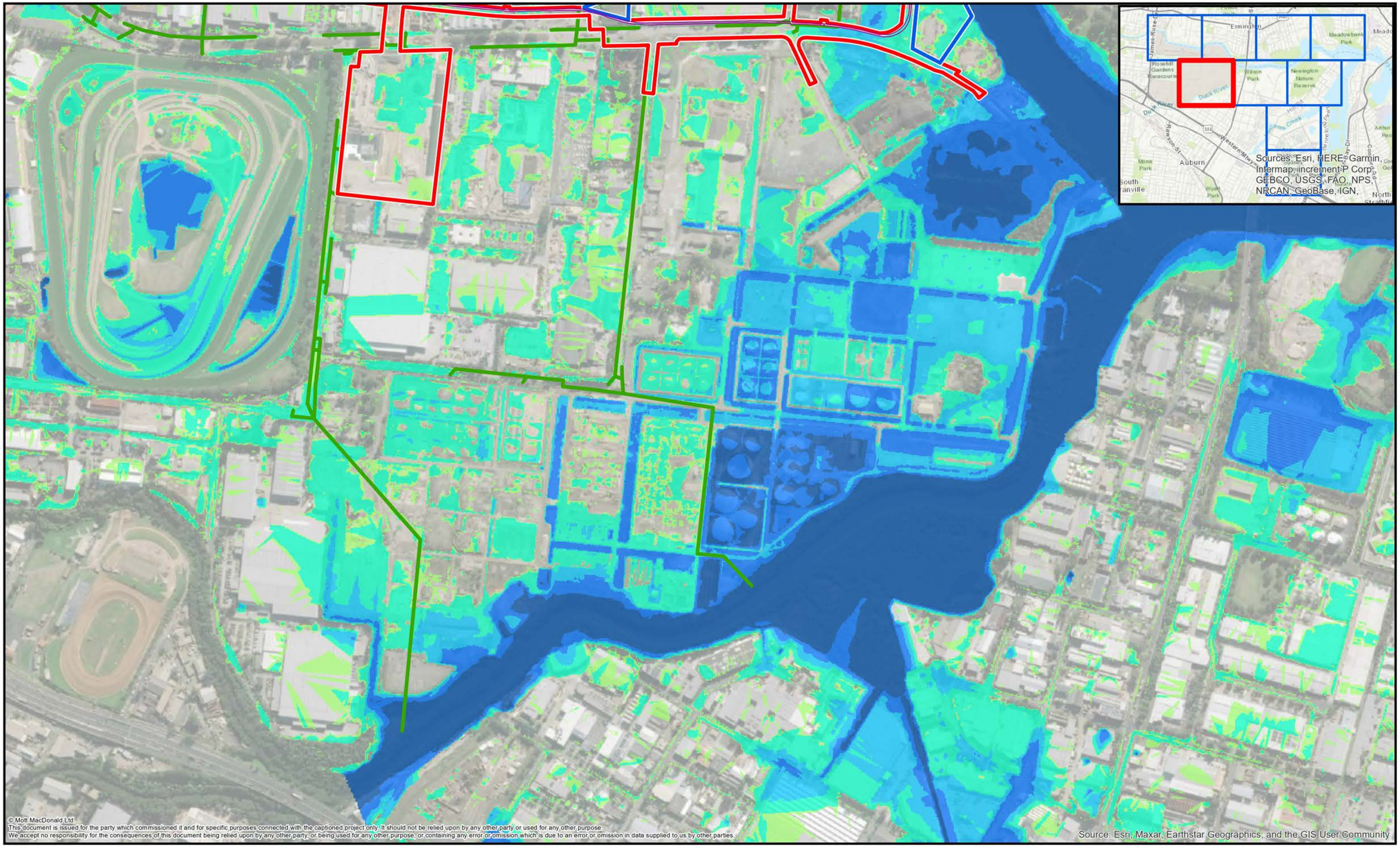


Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

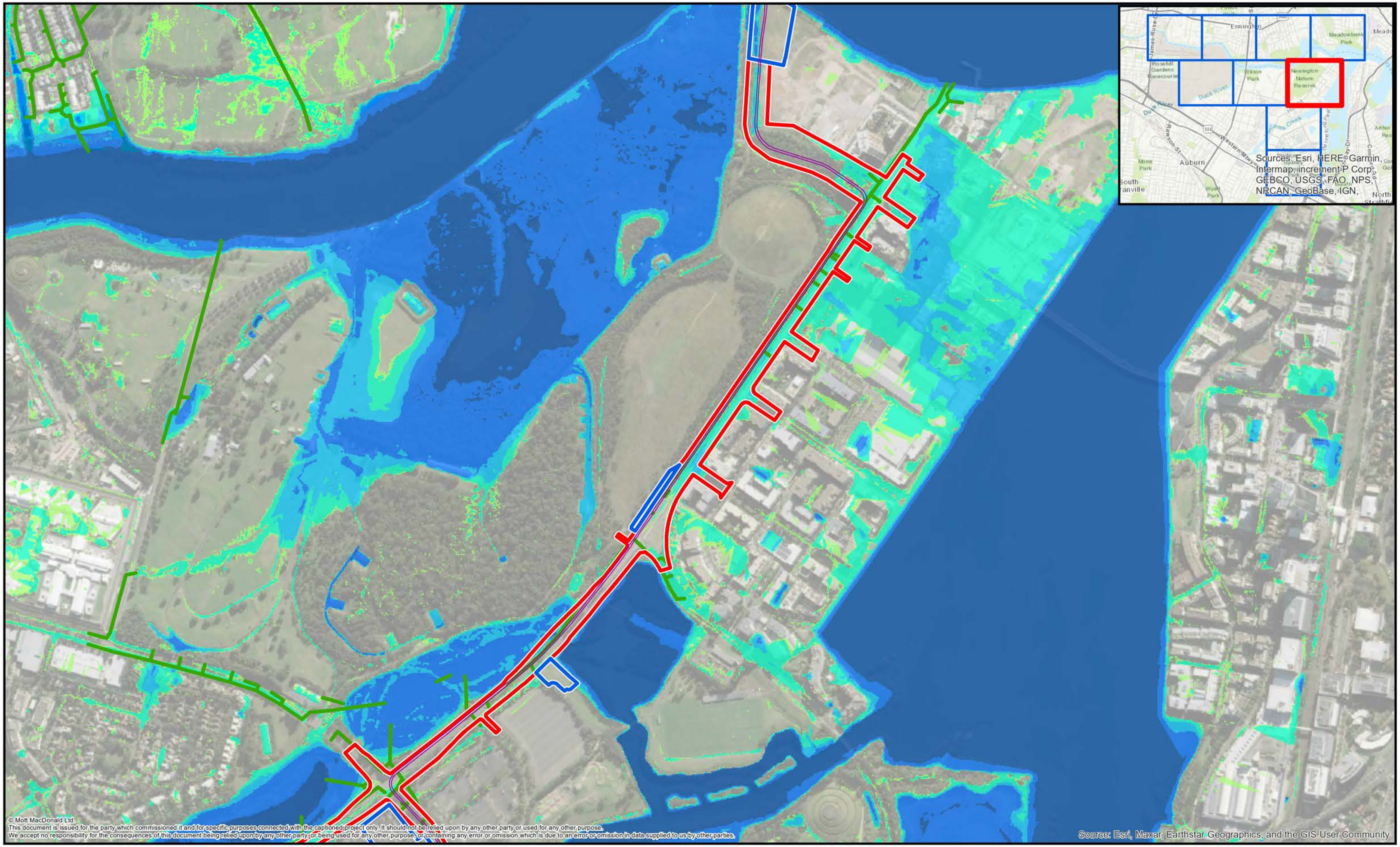
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

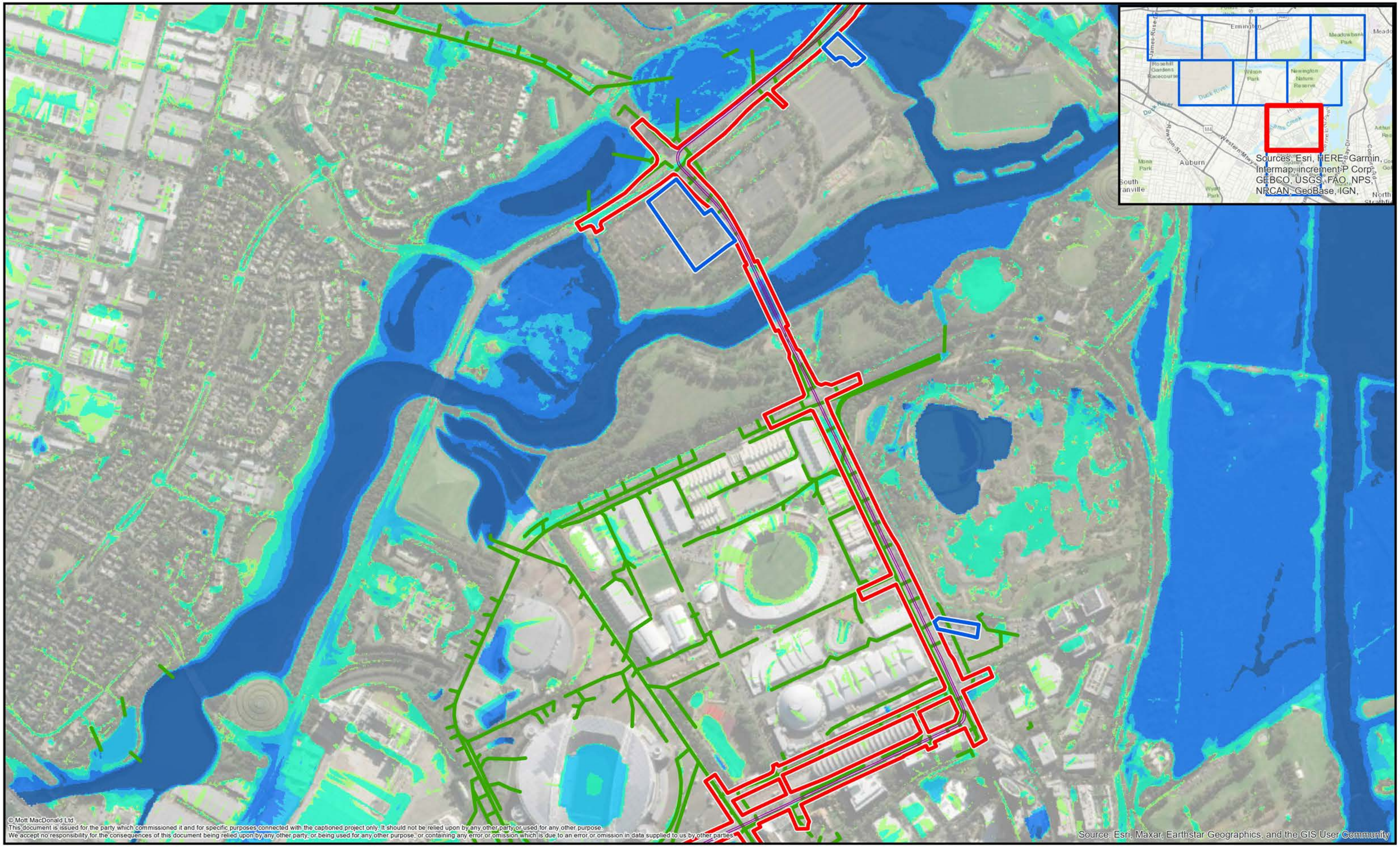
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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- >2

Title

Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

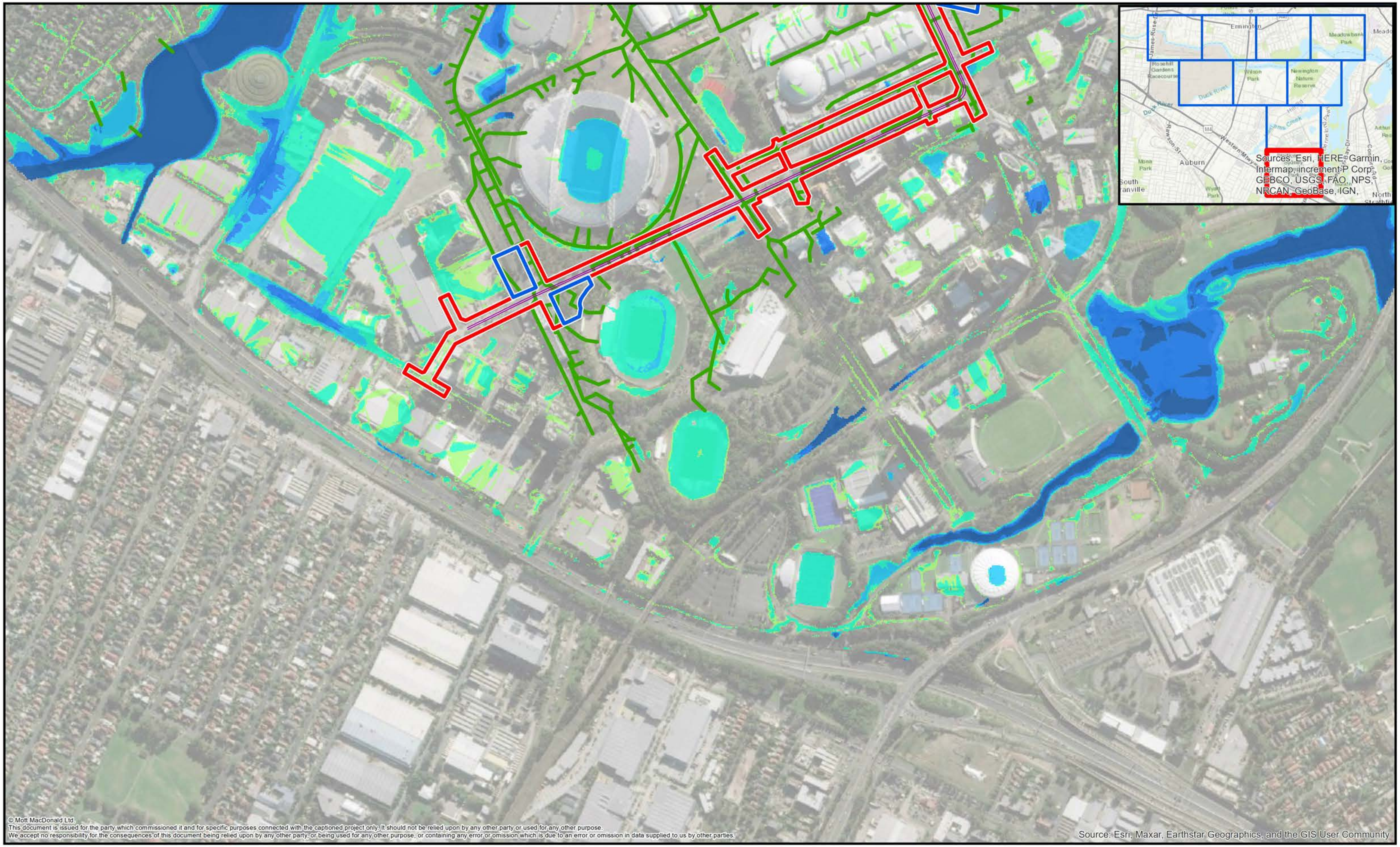
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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Existing Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

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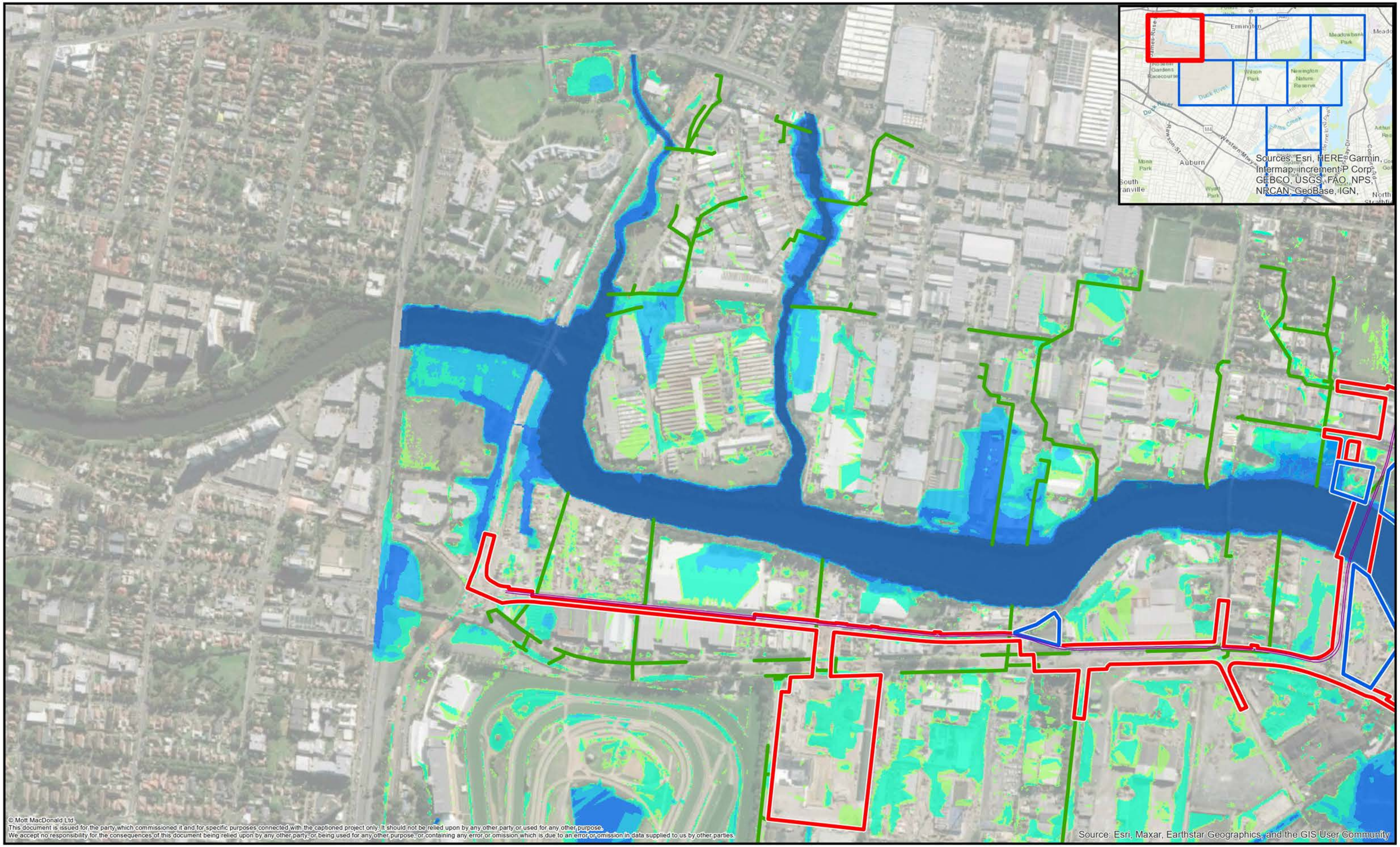

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
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Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

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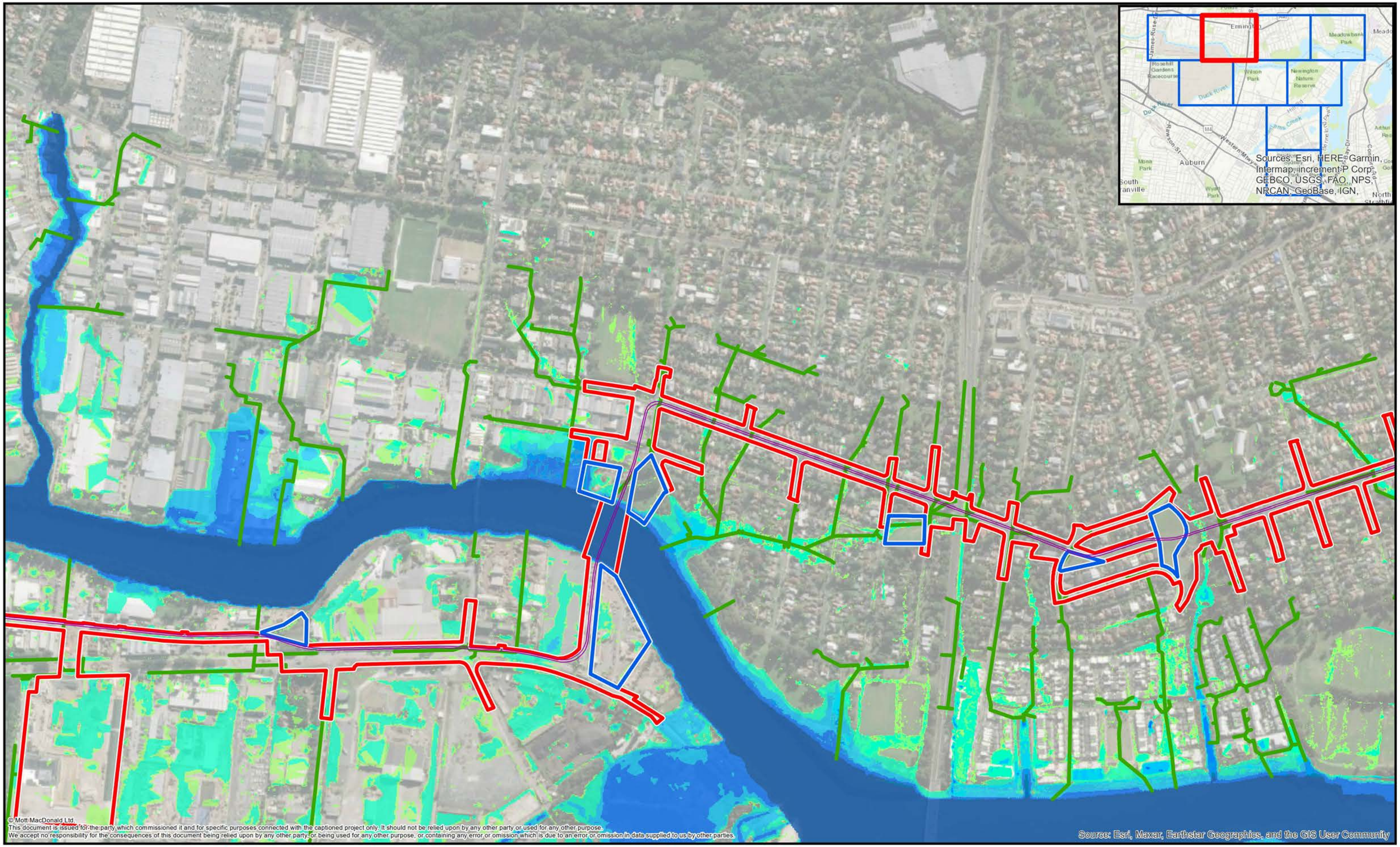

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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Title

Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

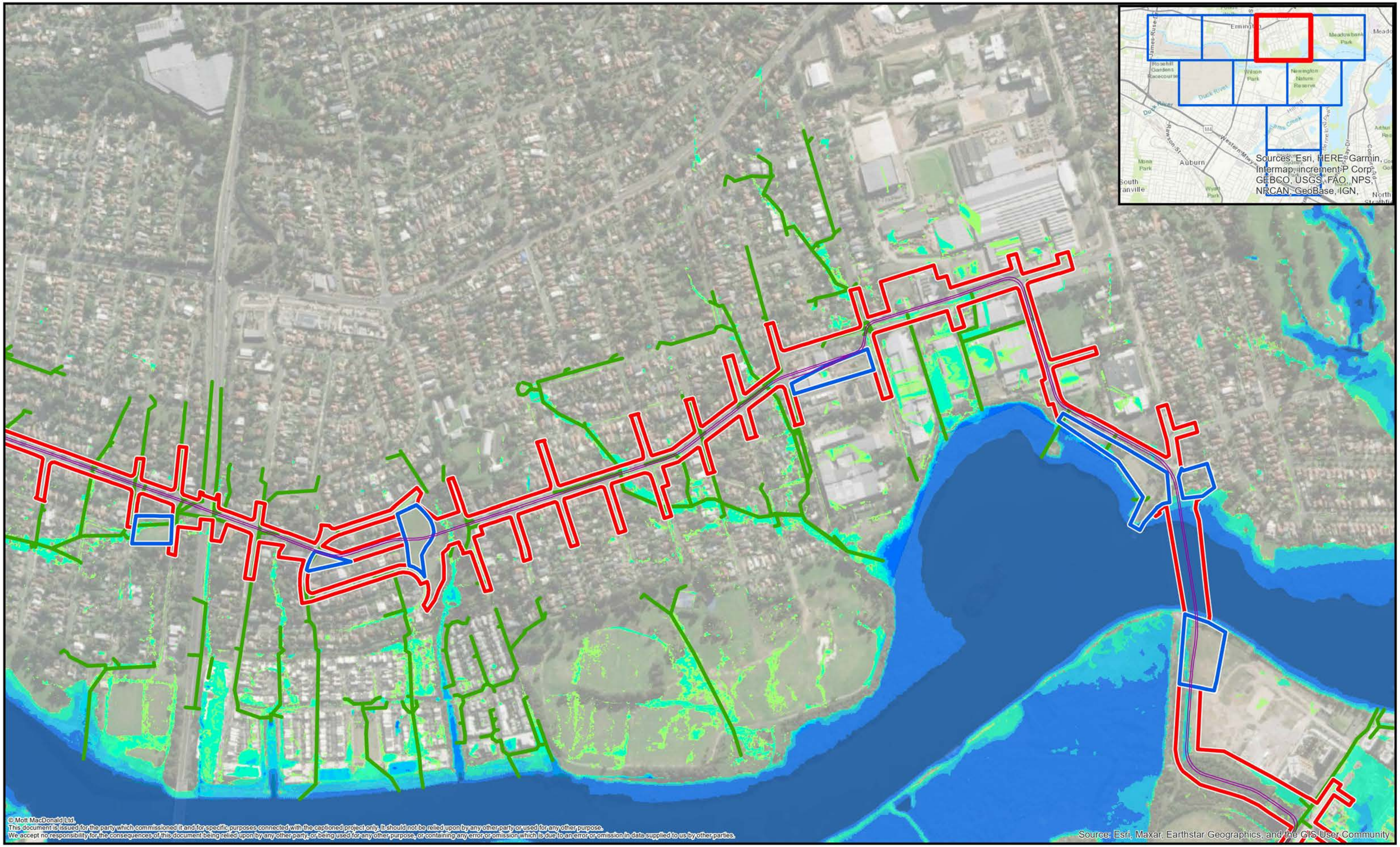
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions 1% AEP Flood Depth

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1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

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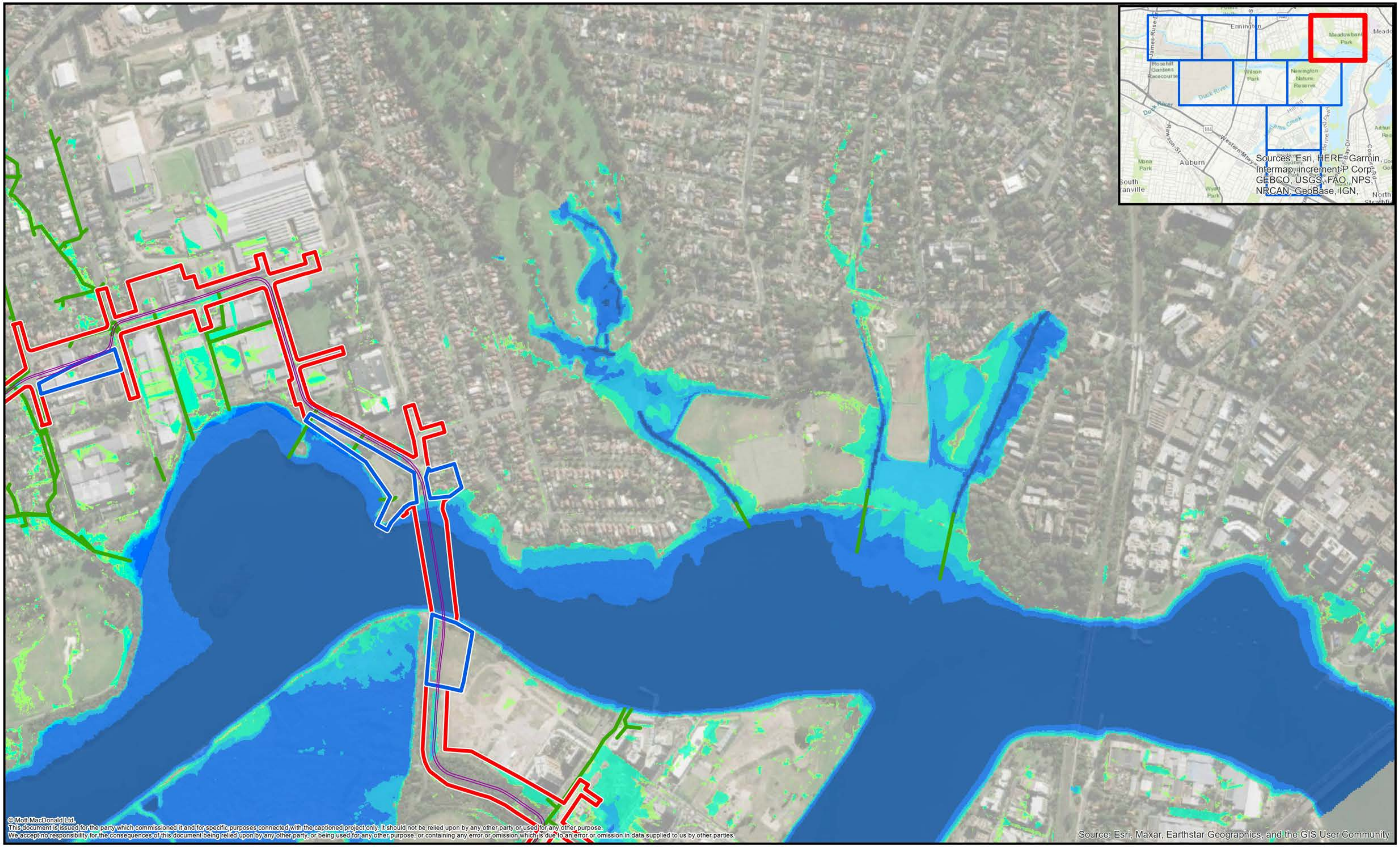

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
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Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

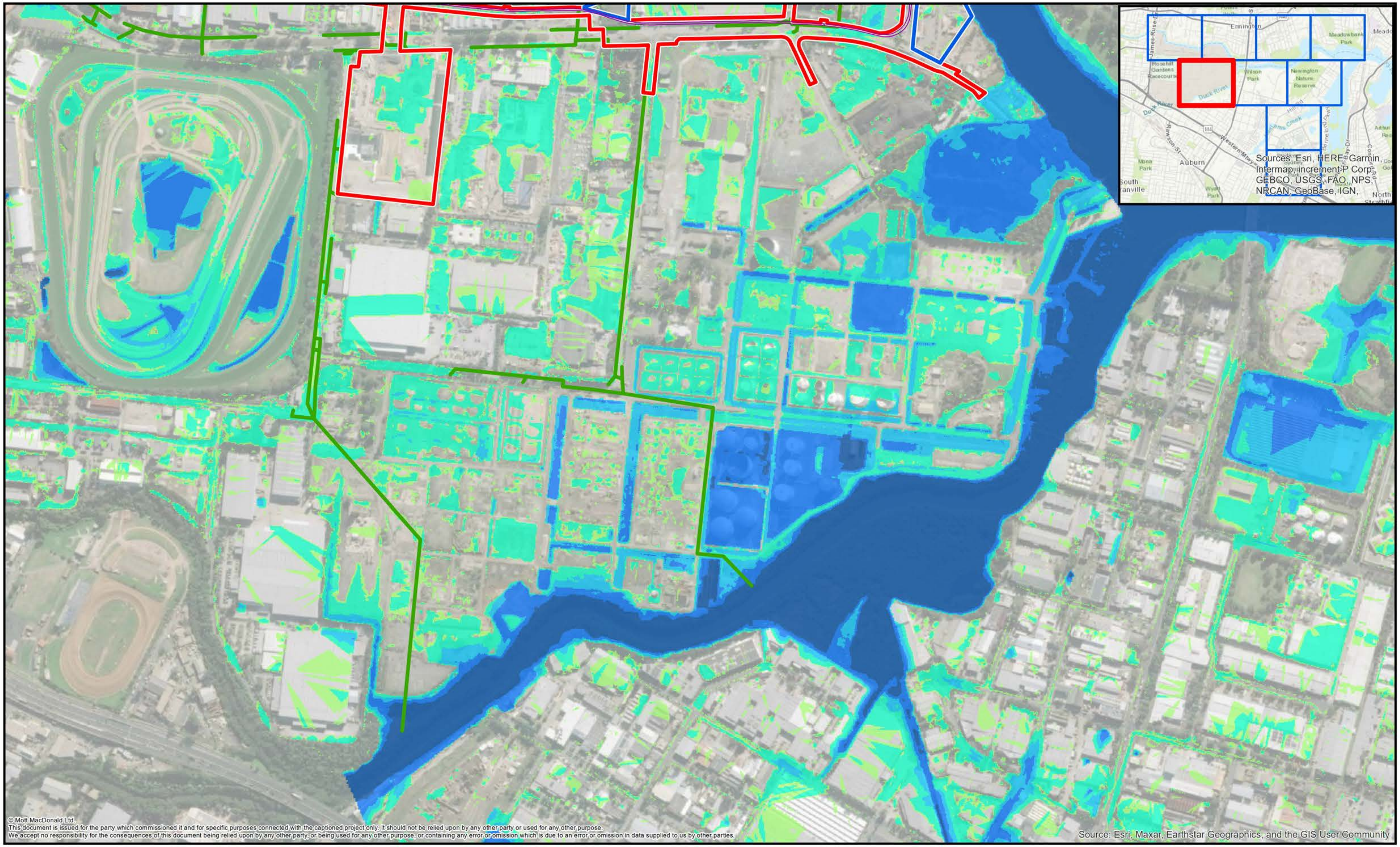
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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Title

Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

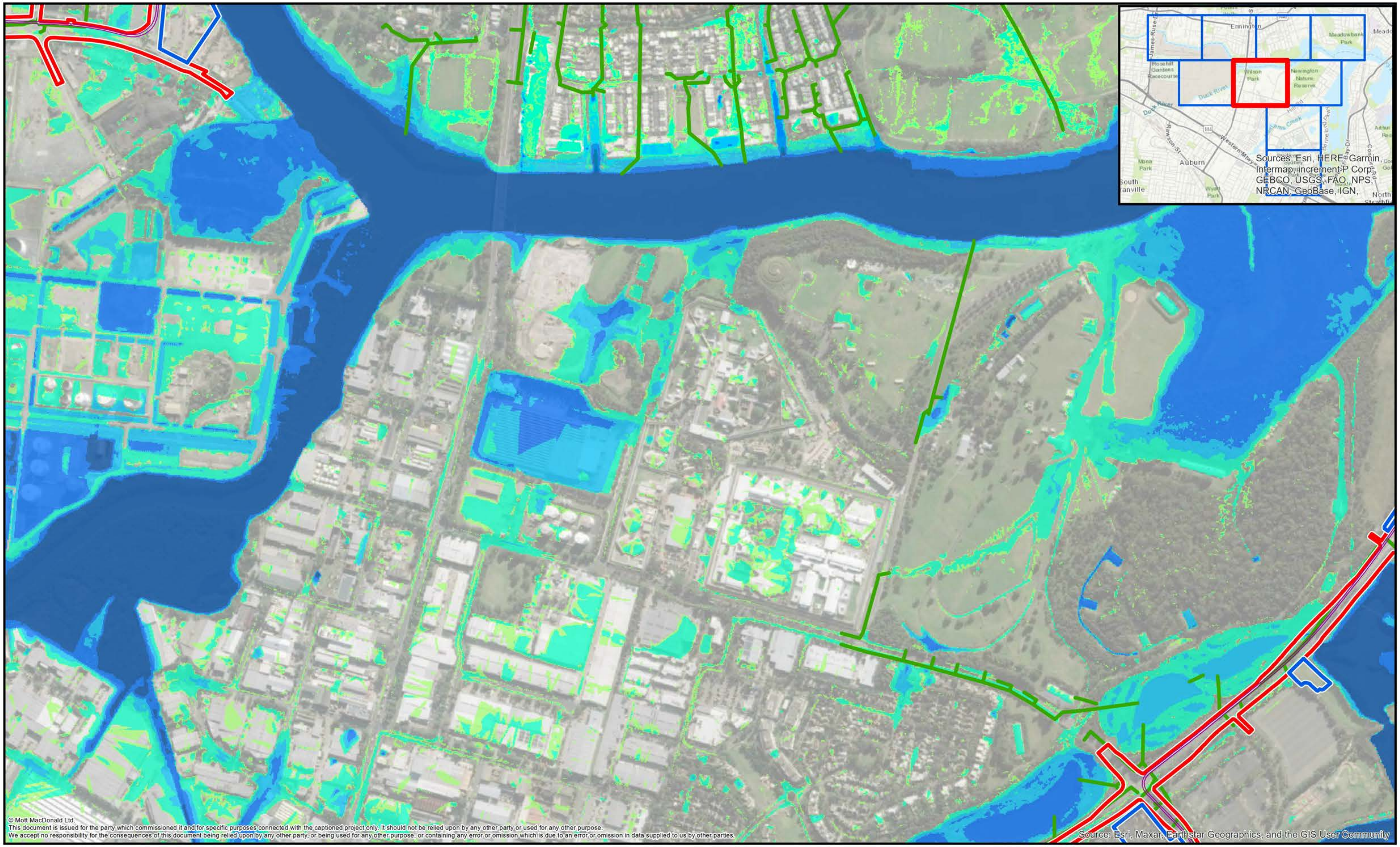
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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Title

Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

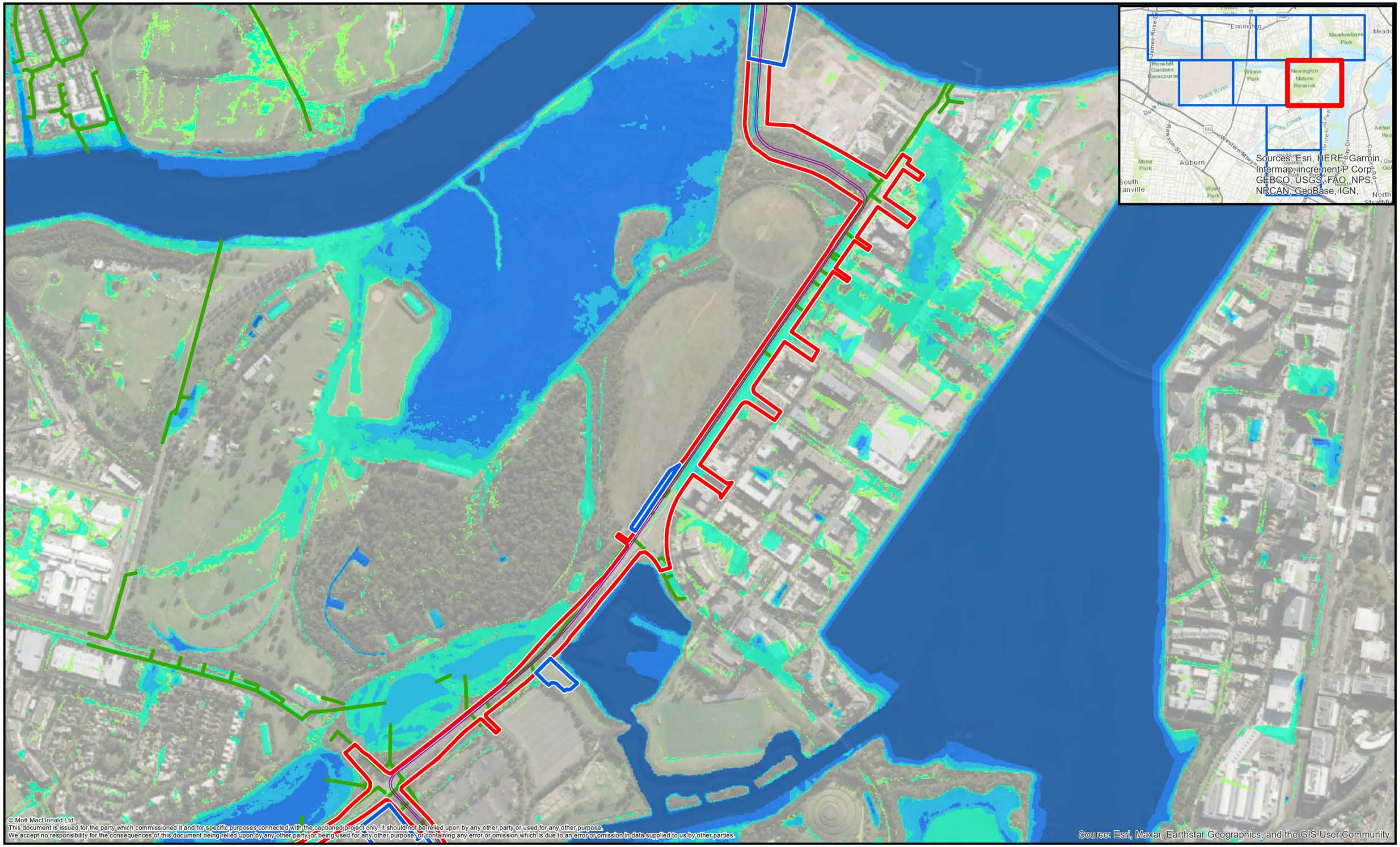
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

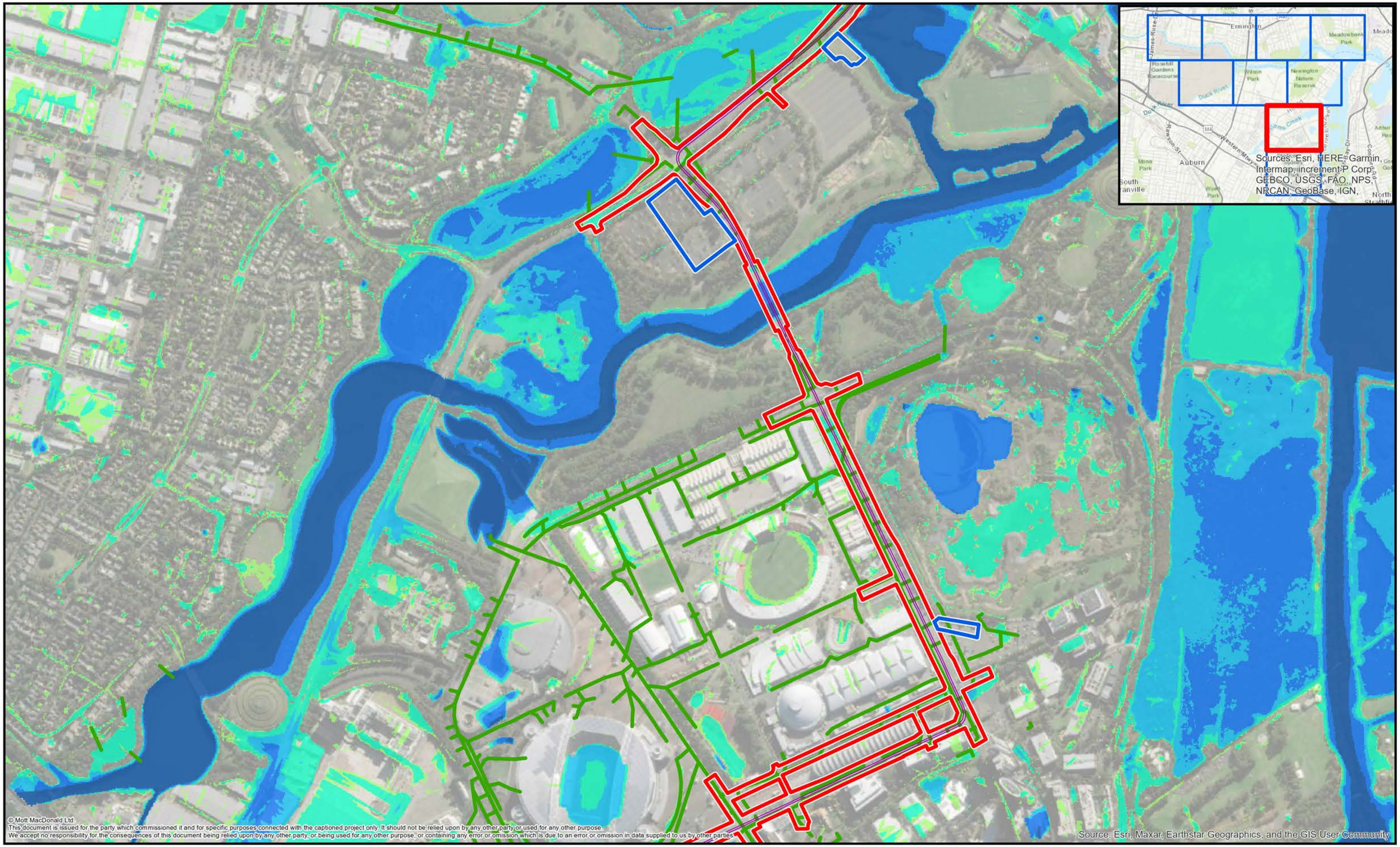
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
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Title

Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

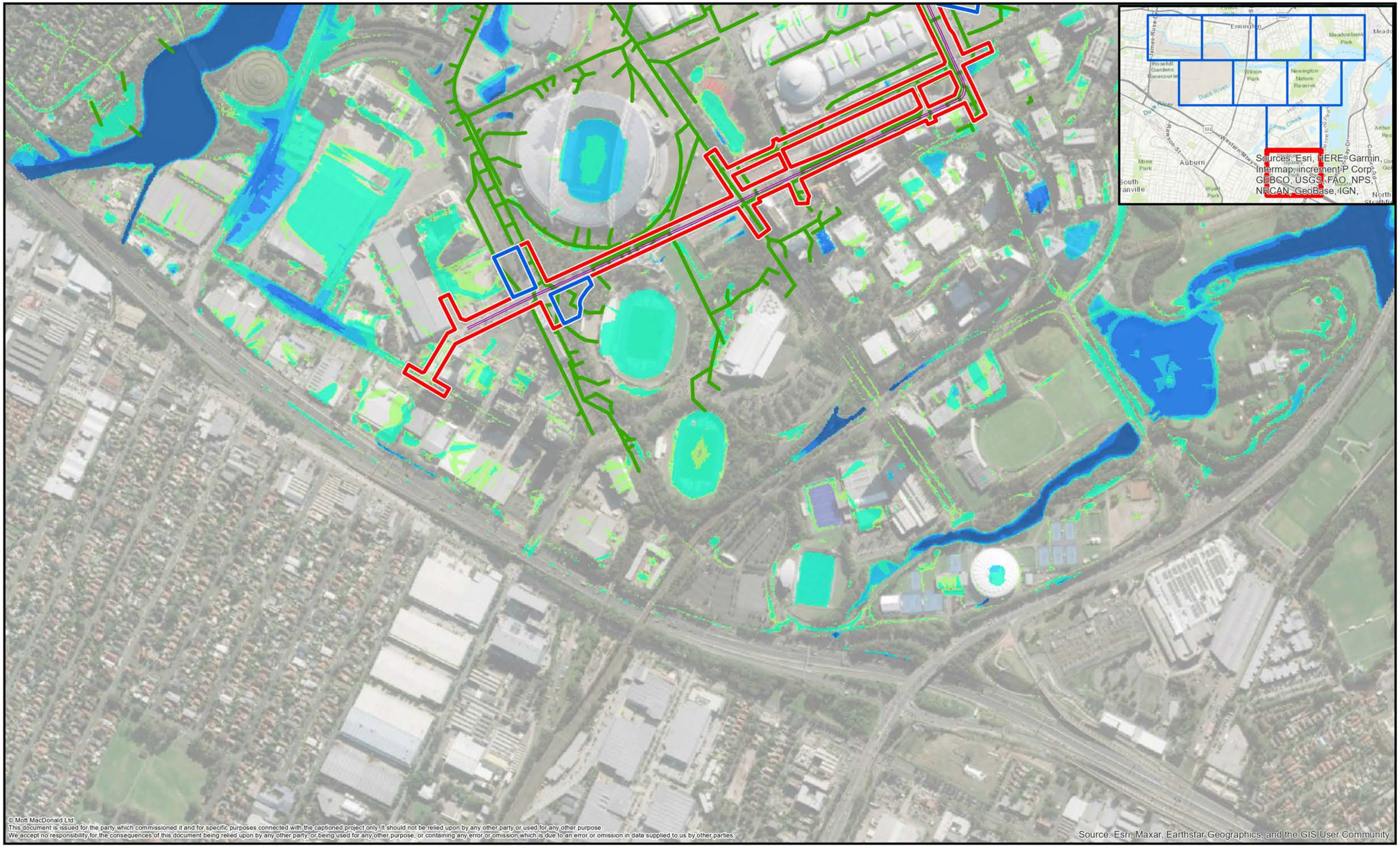
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
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Title

Existing Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

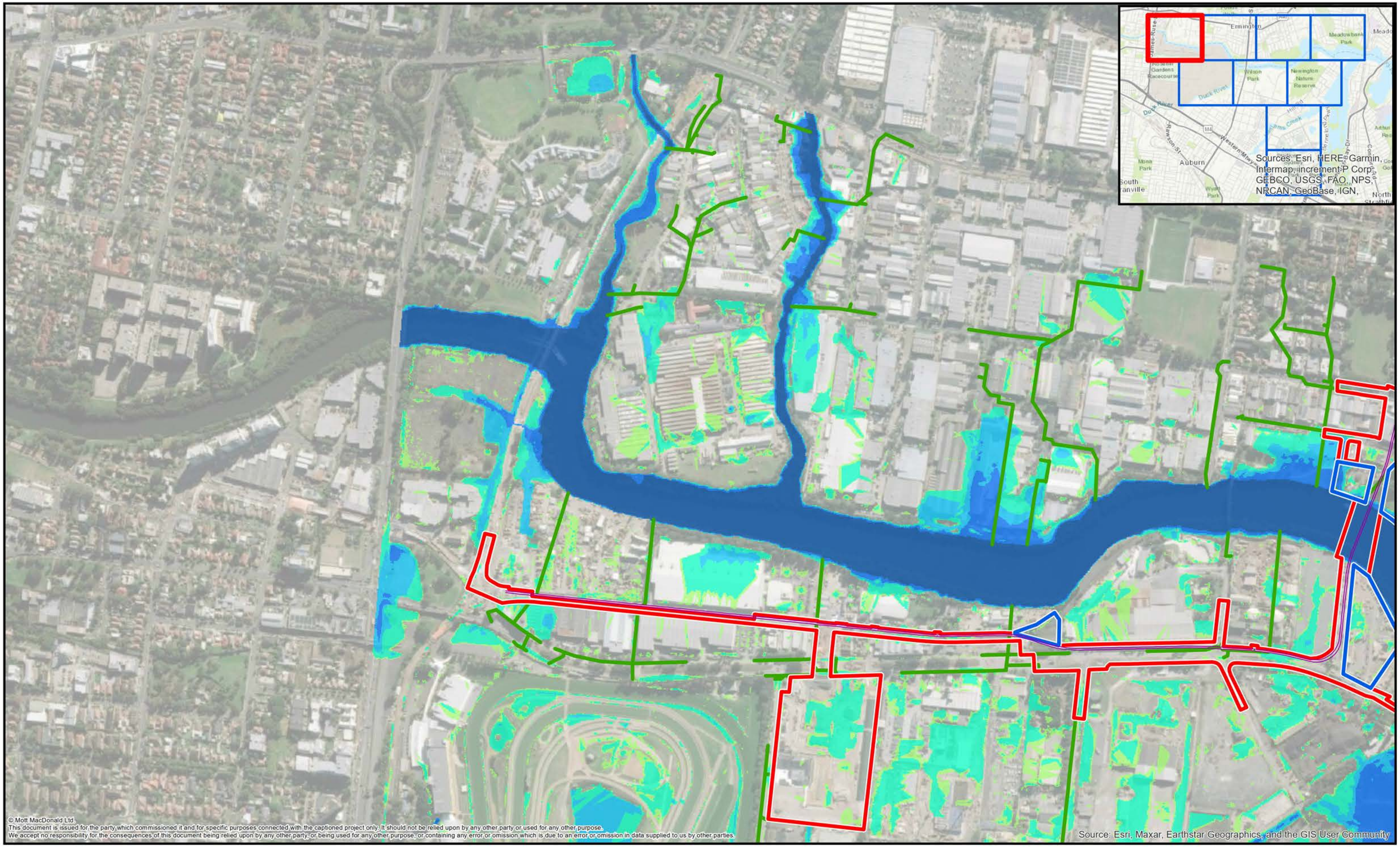
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

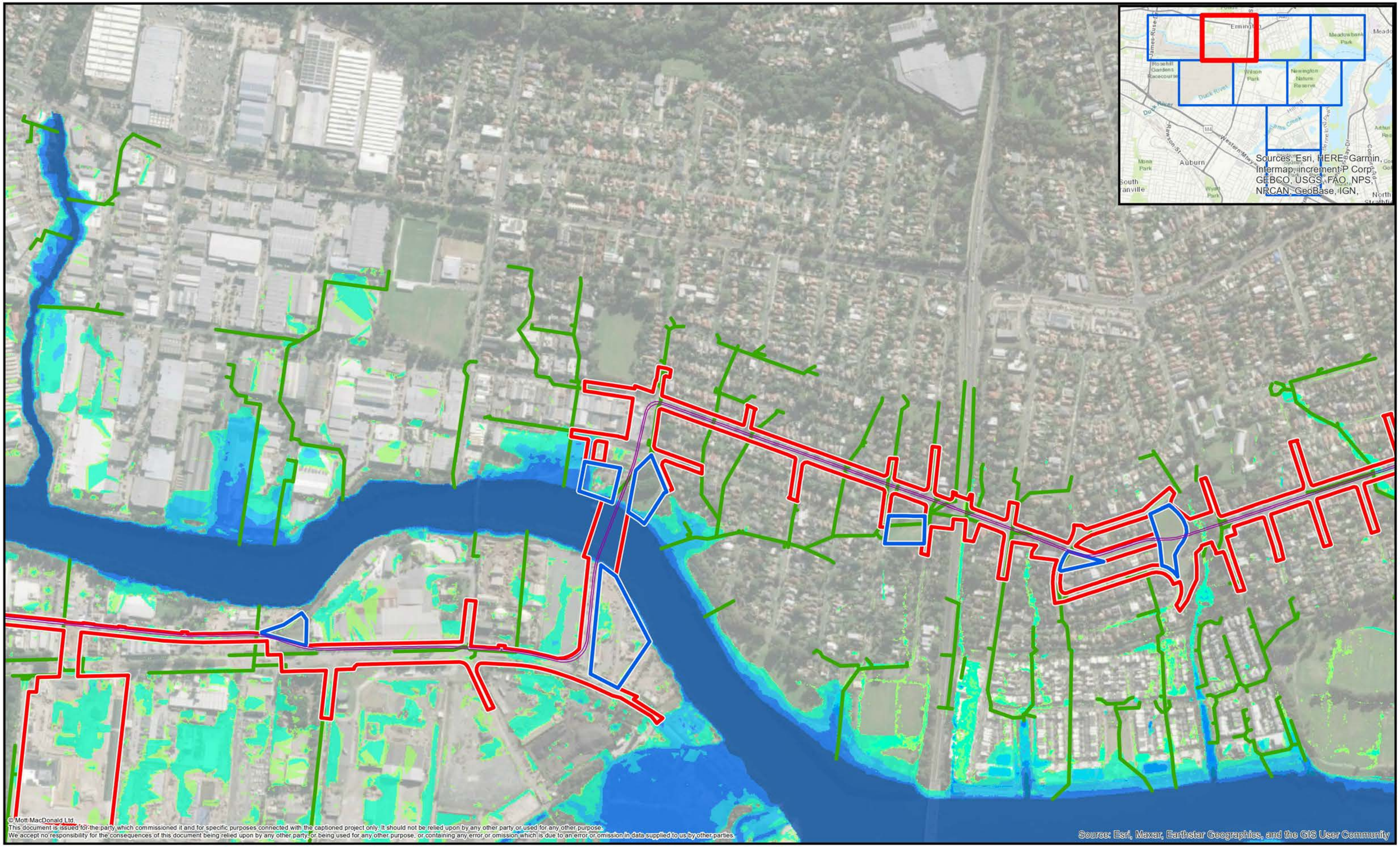
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

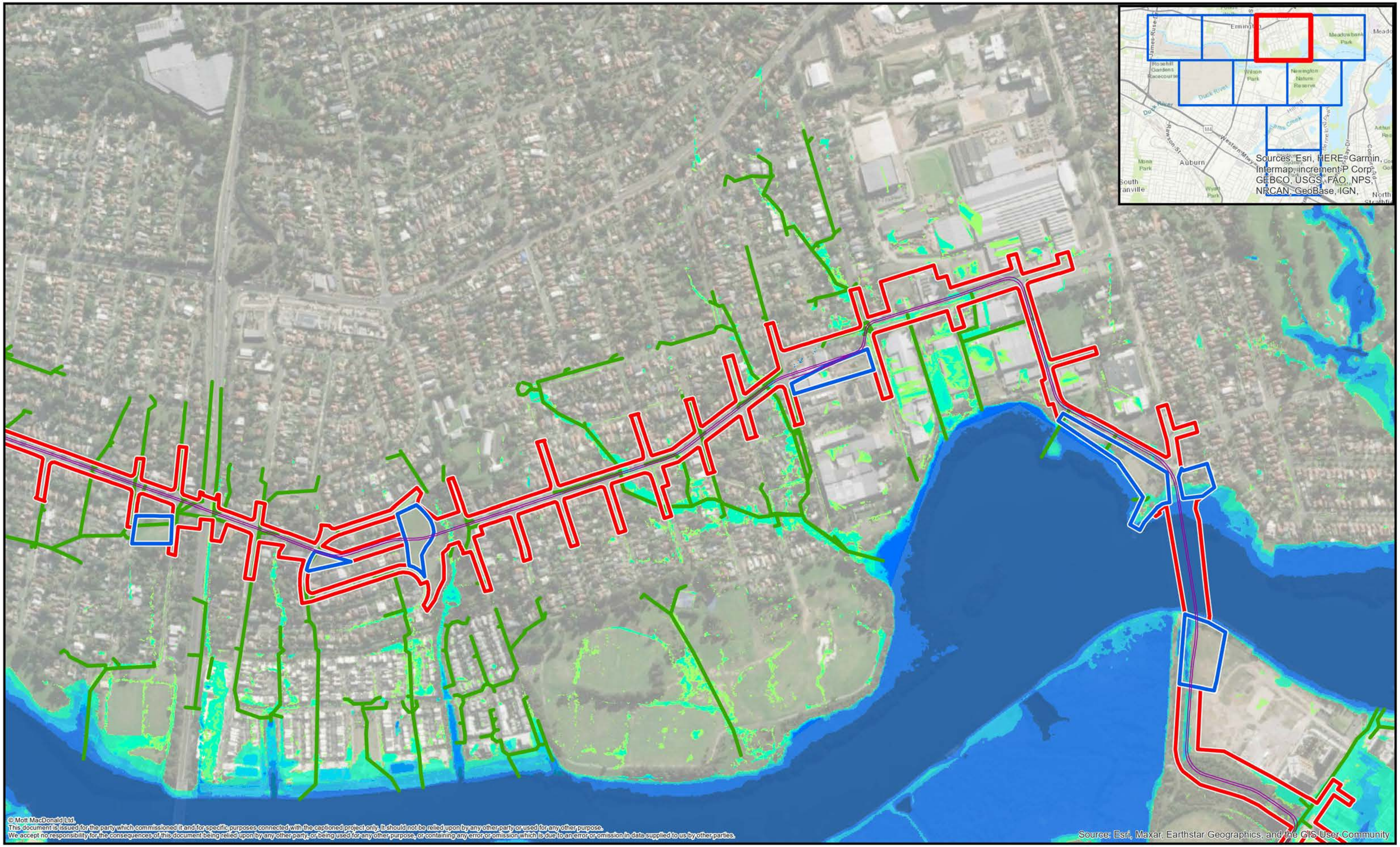
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

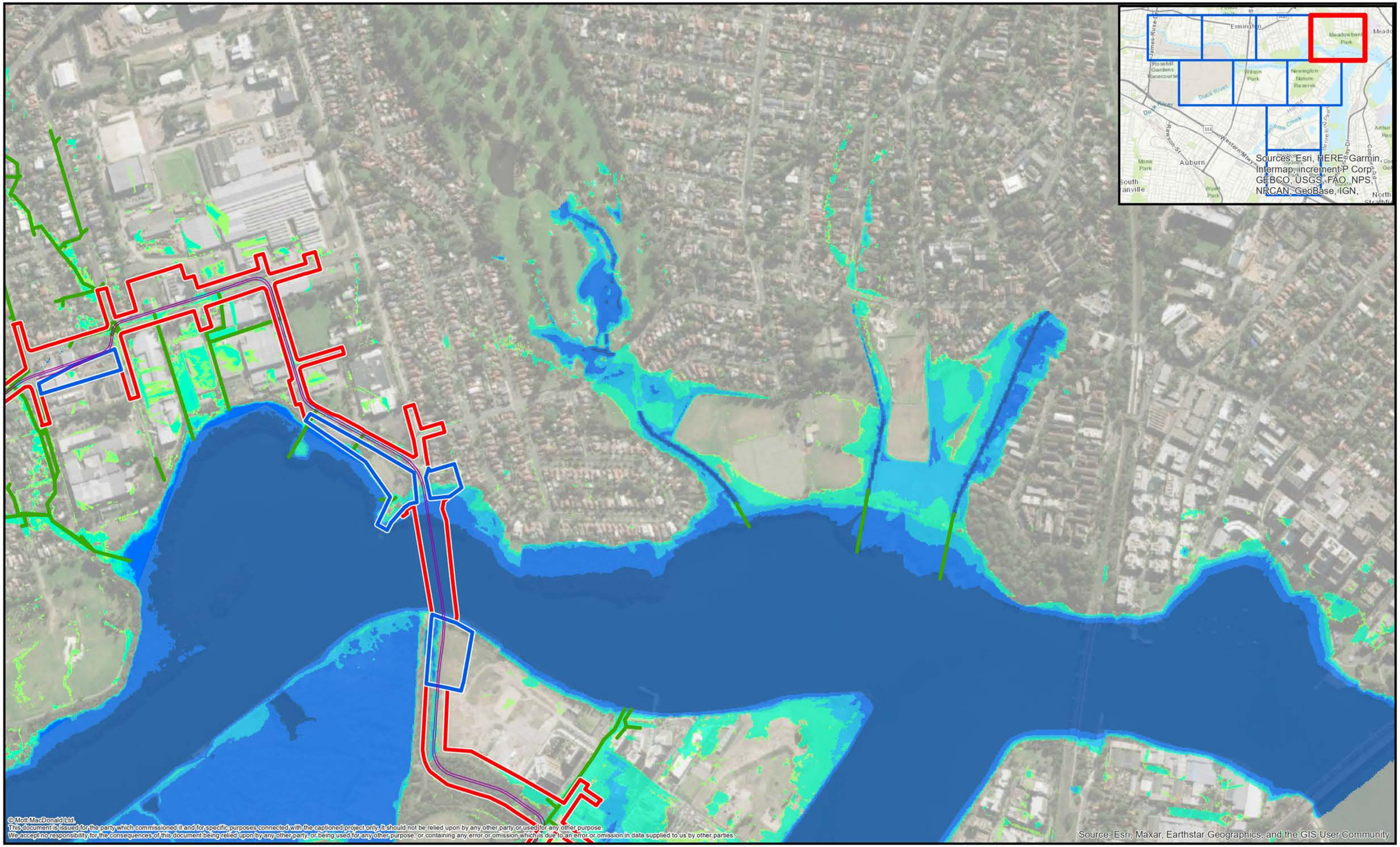
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

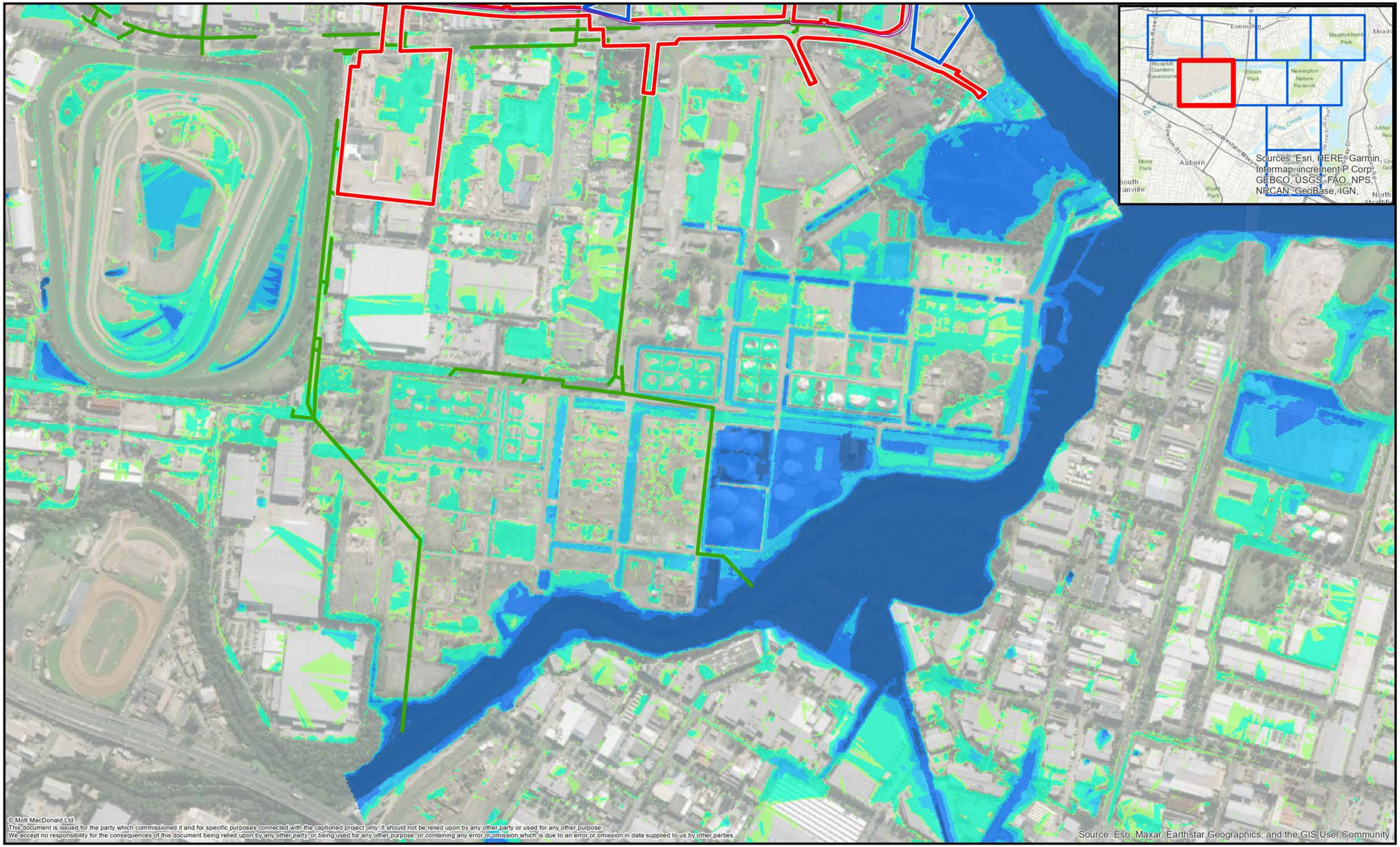
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

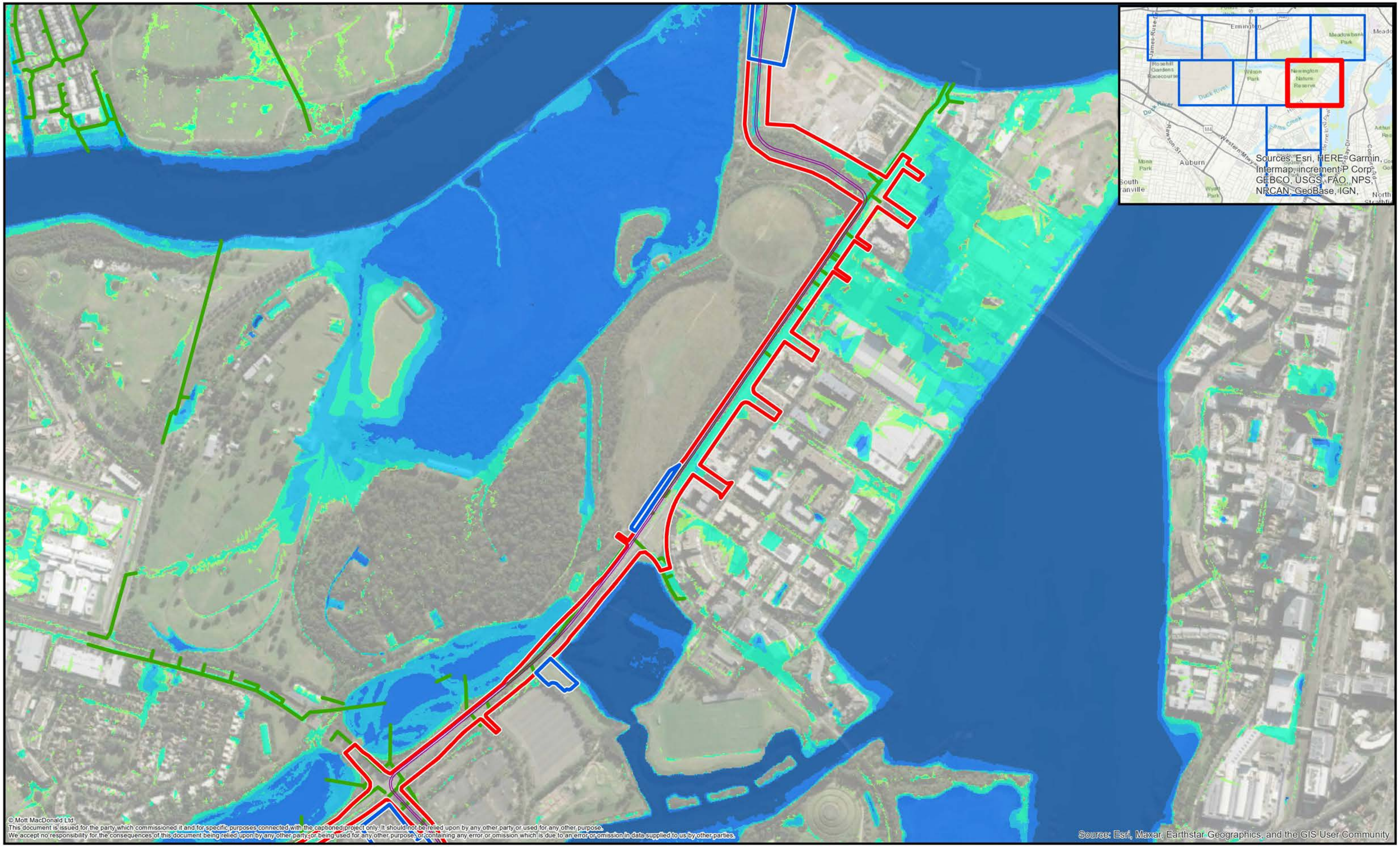
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

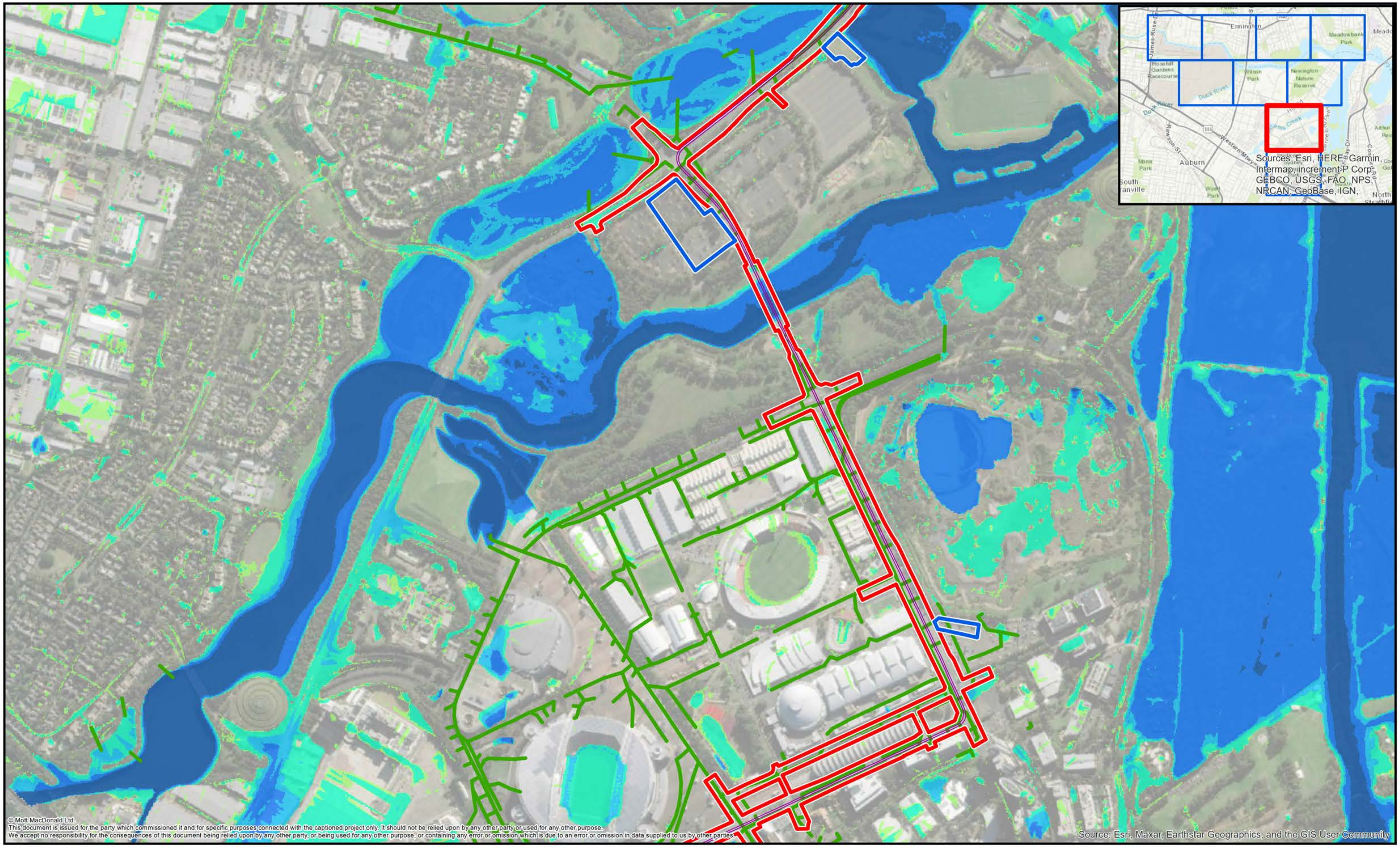
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
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Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

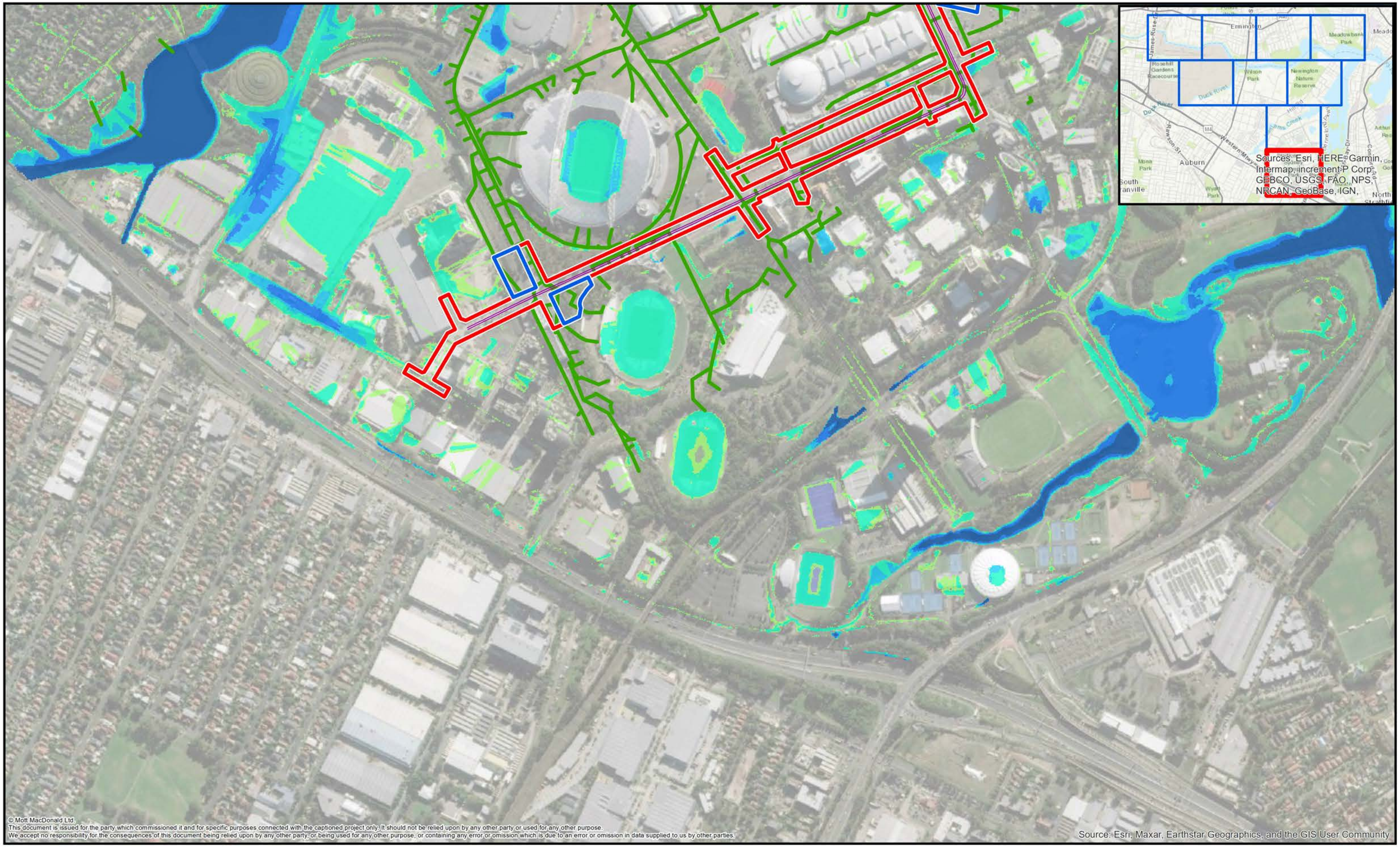
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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Title

Existing Conditions 5% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

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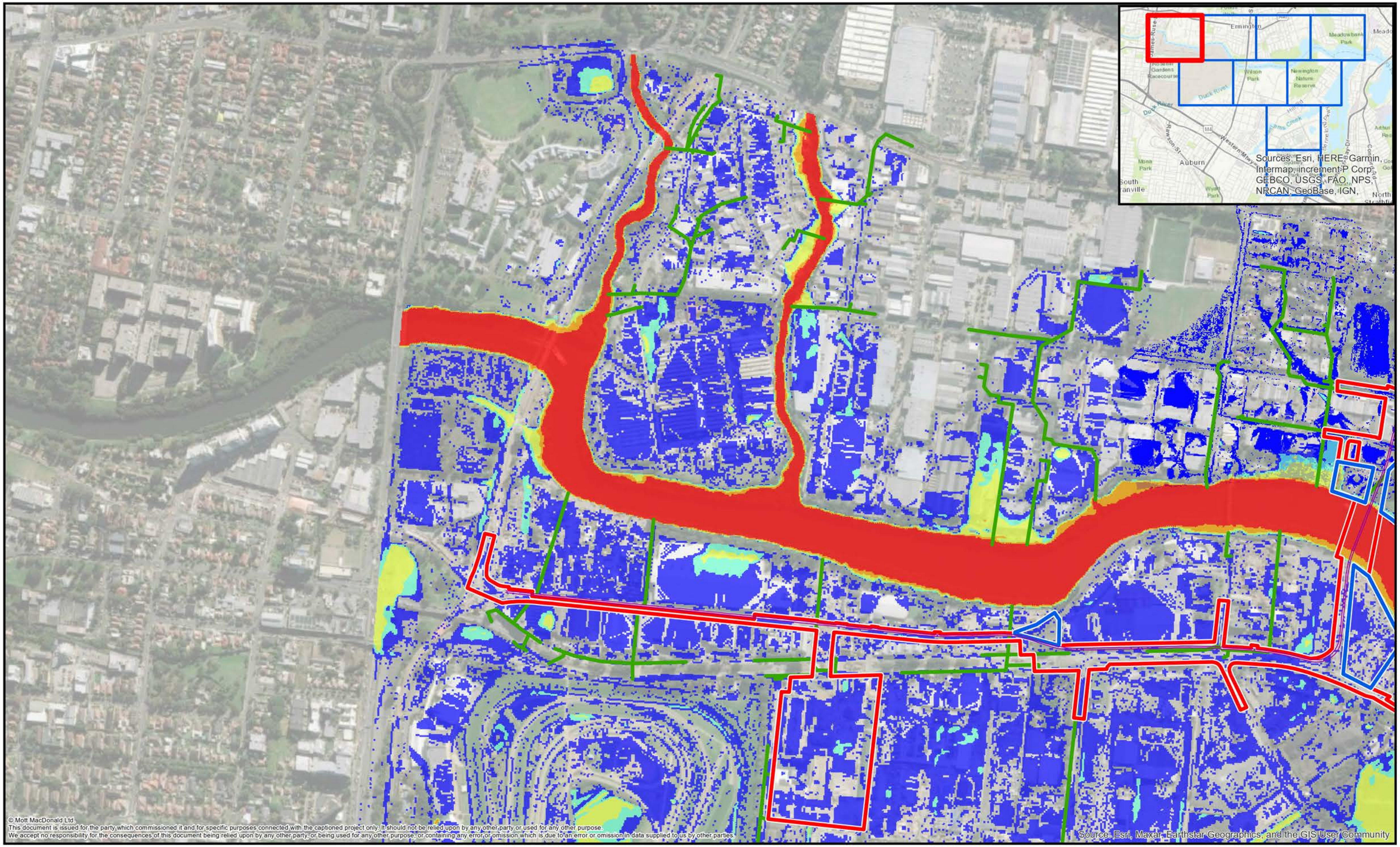


Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

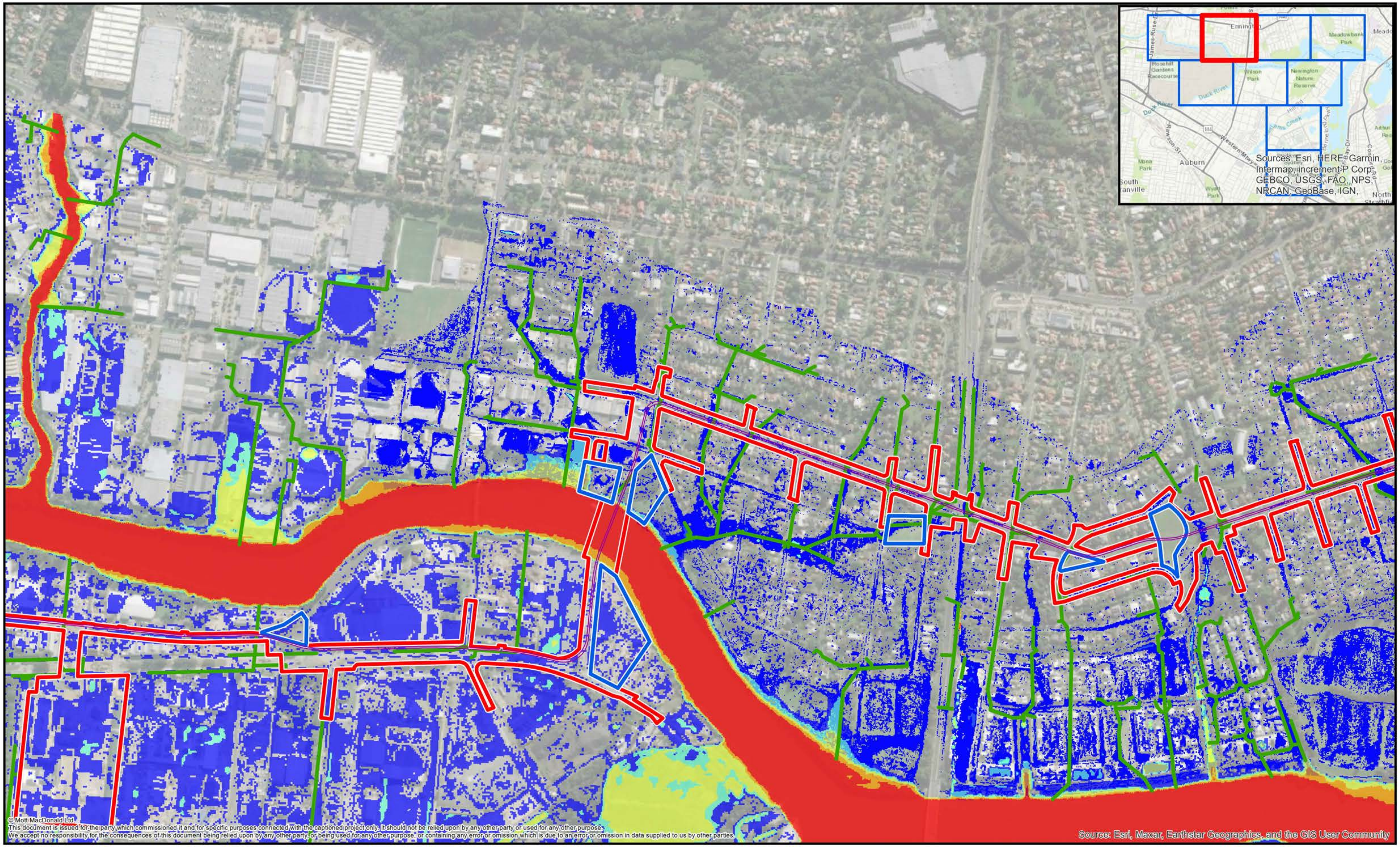
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

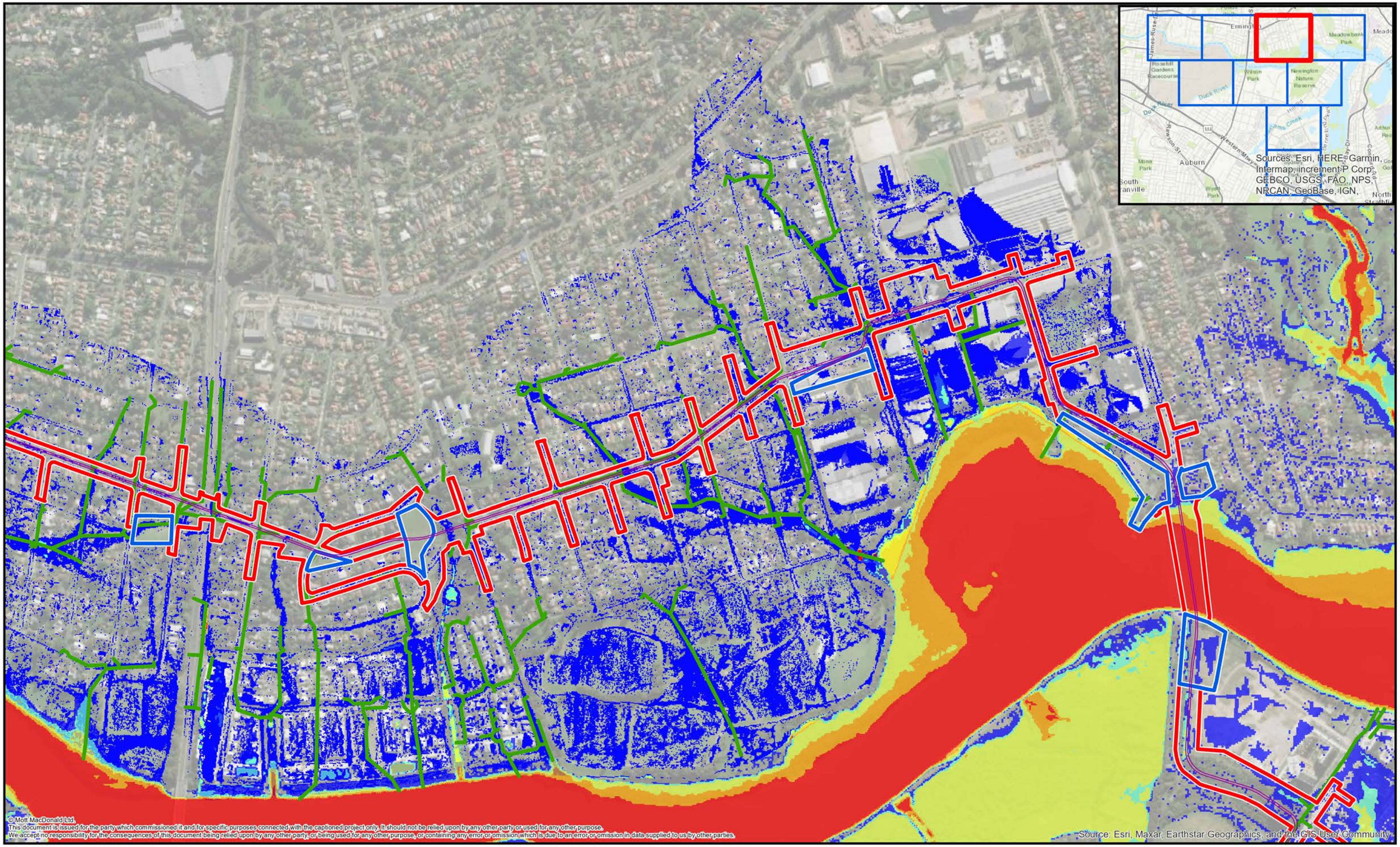
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

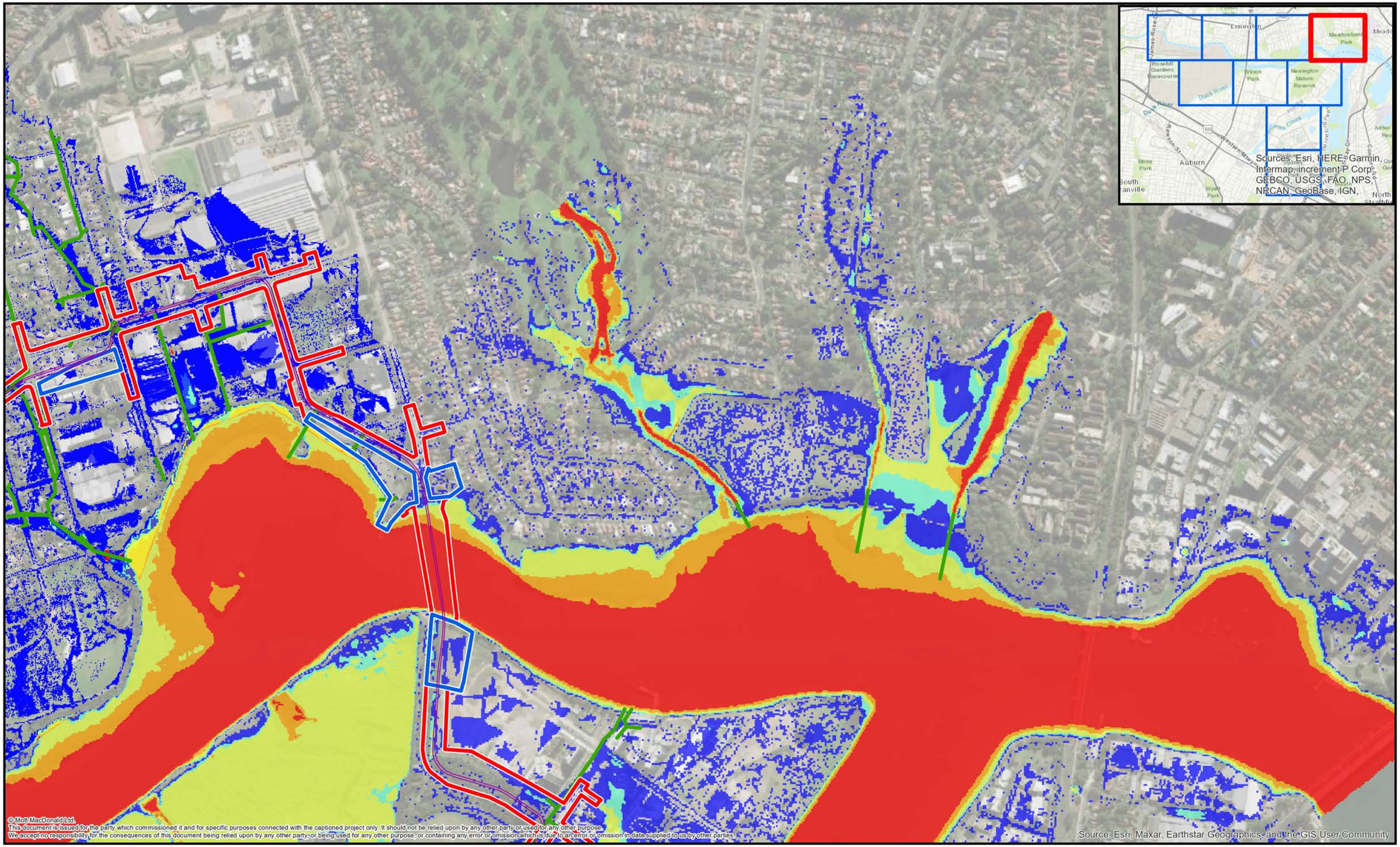
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

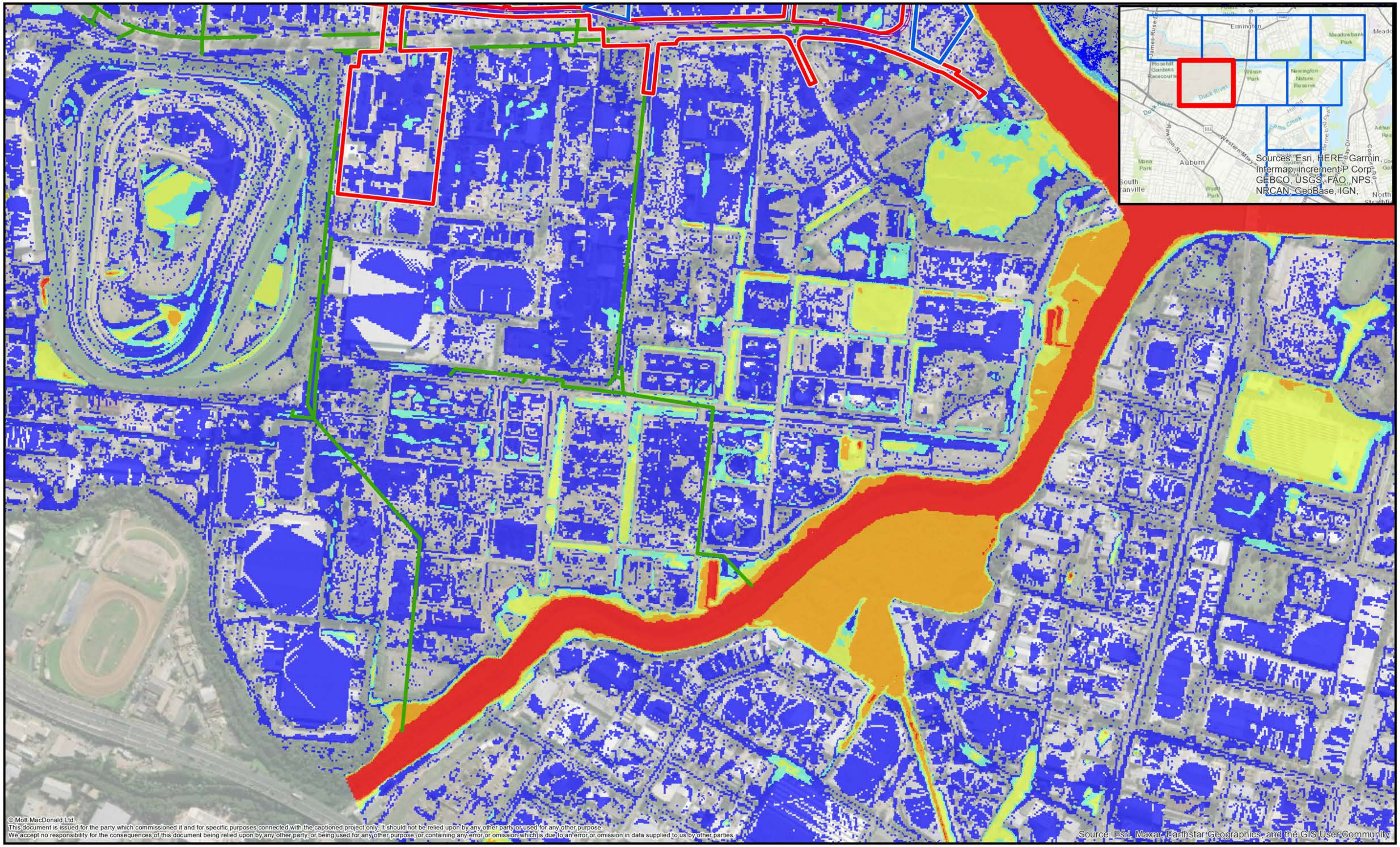
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

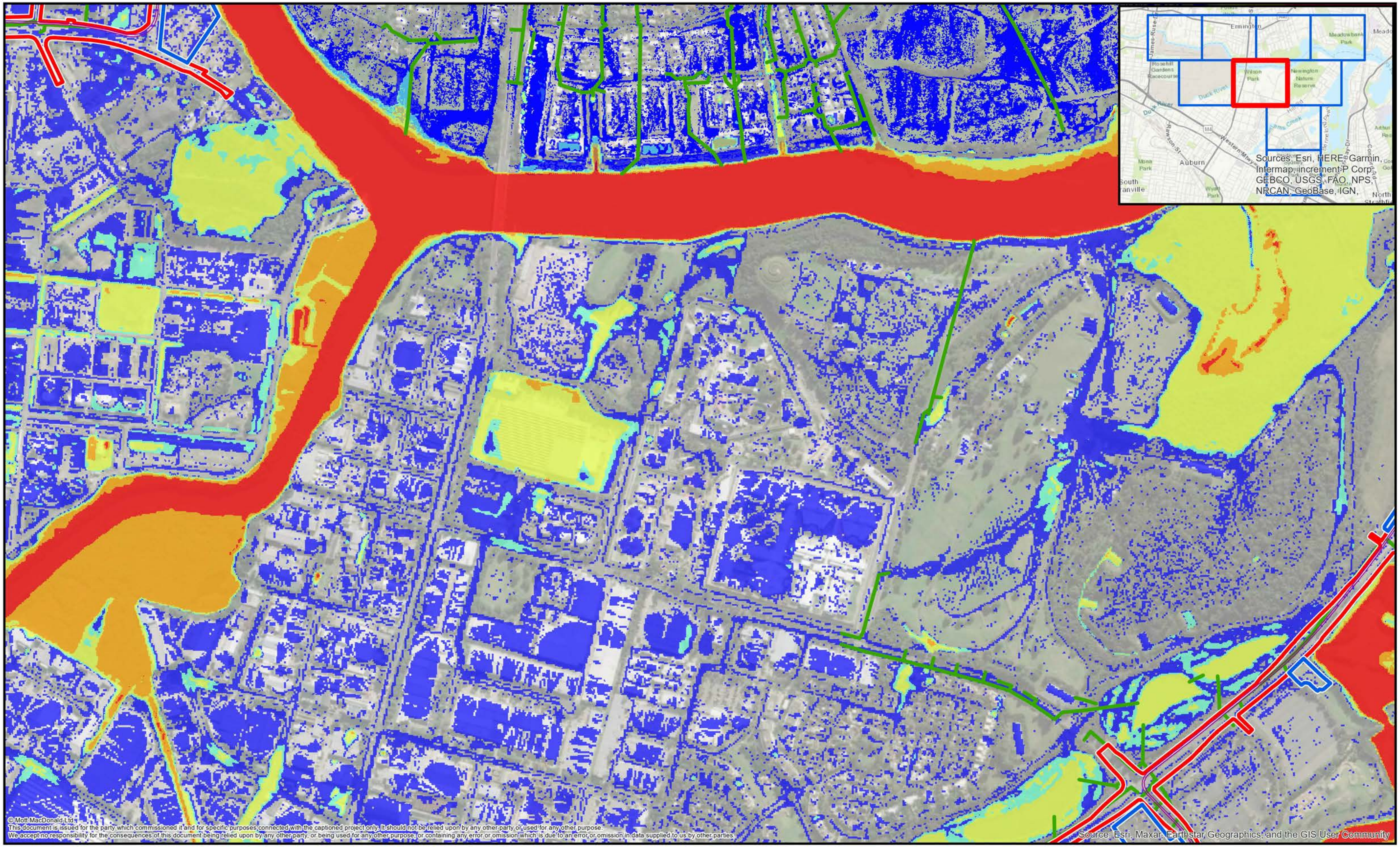
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

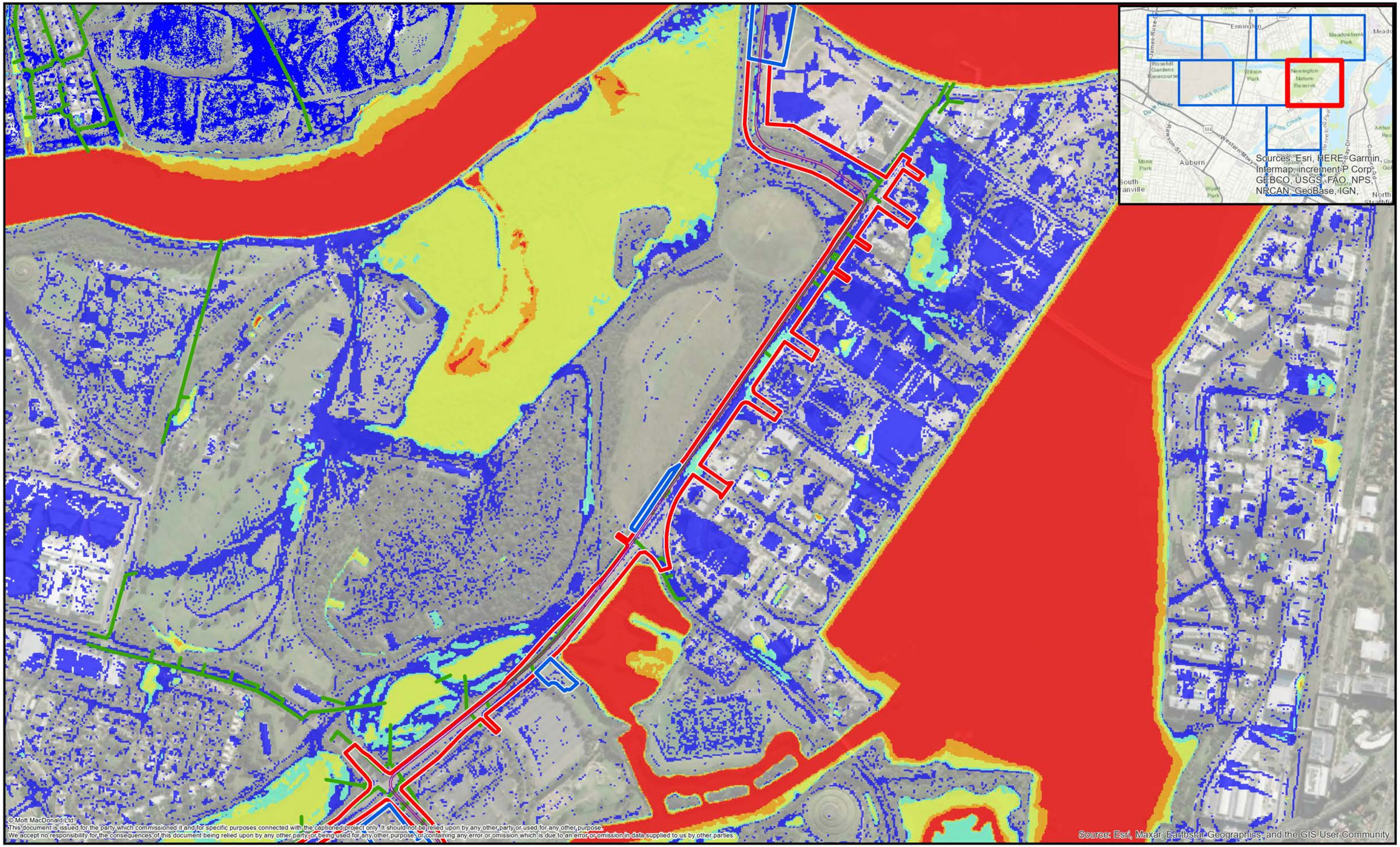
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

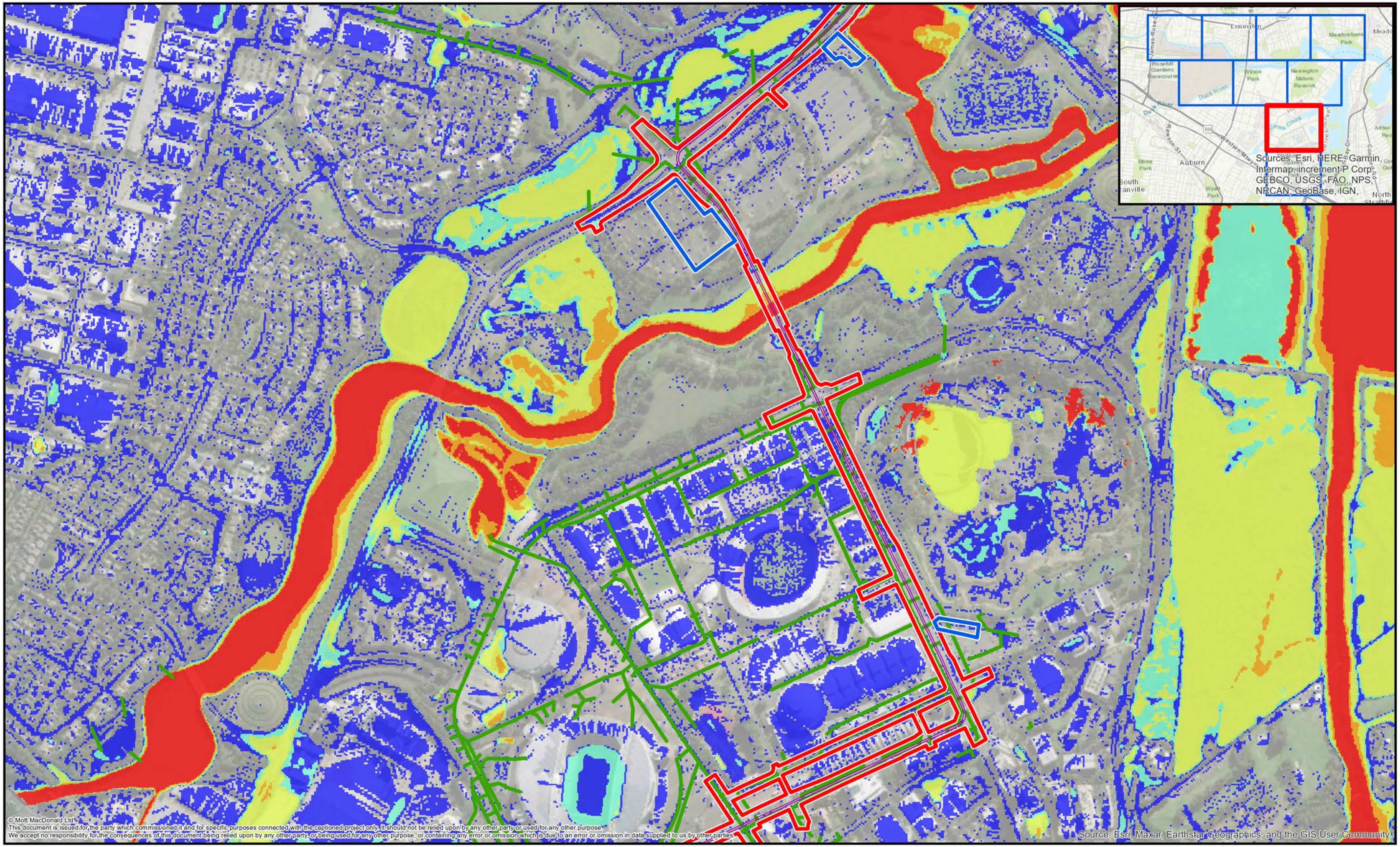
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 7 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Flood Hazard (ZAEM1)

H1

H2

H3

H4

H5

H6

Title

Existing Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

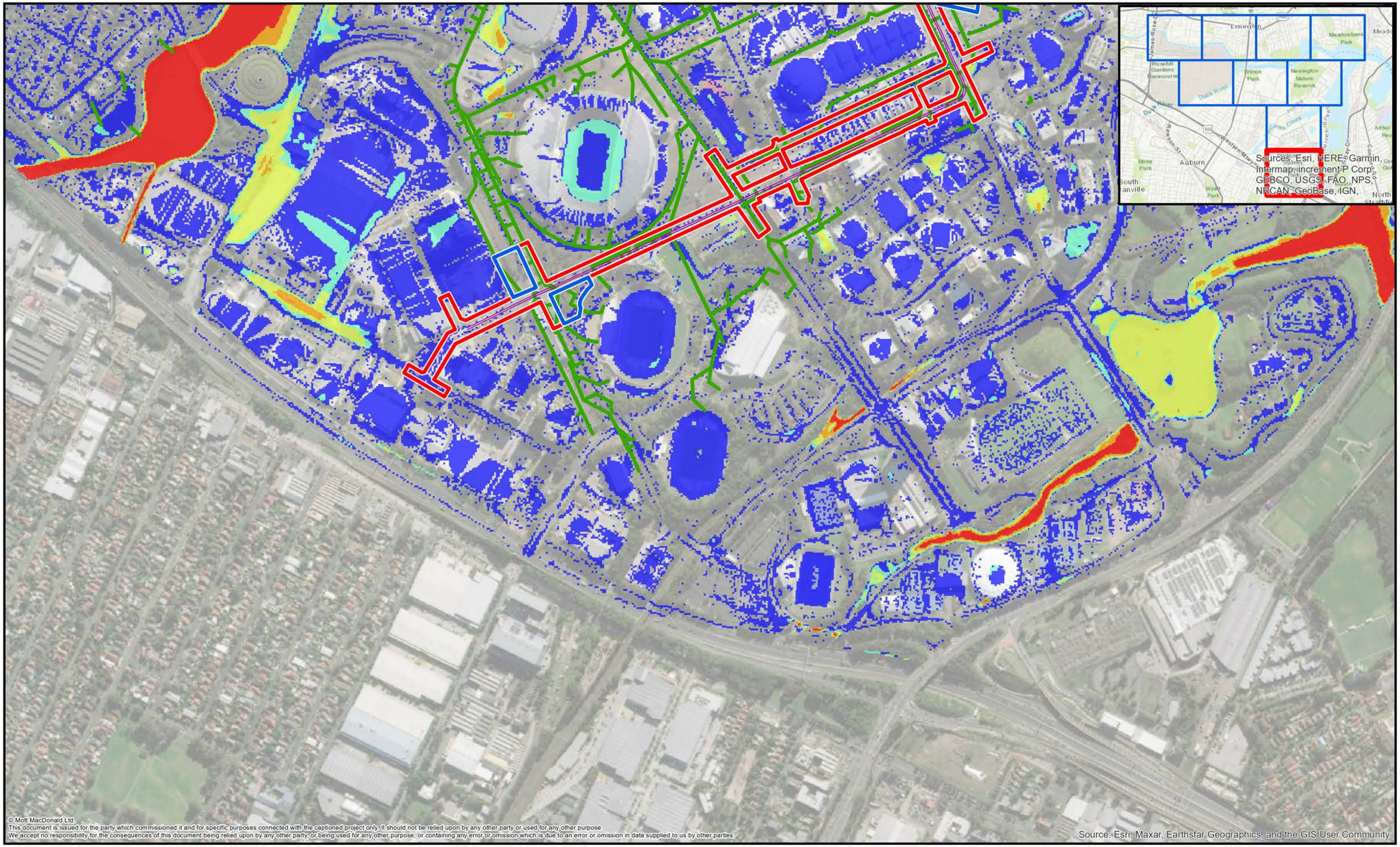
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
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Existing Conditions 5% AEP Flood Hazard

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1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

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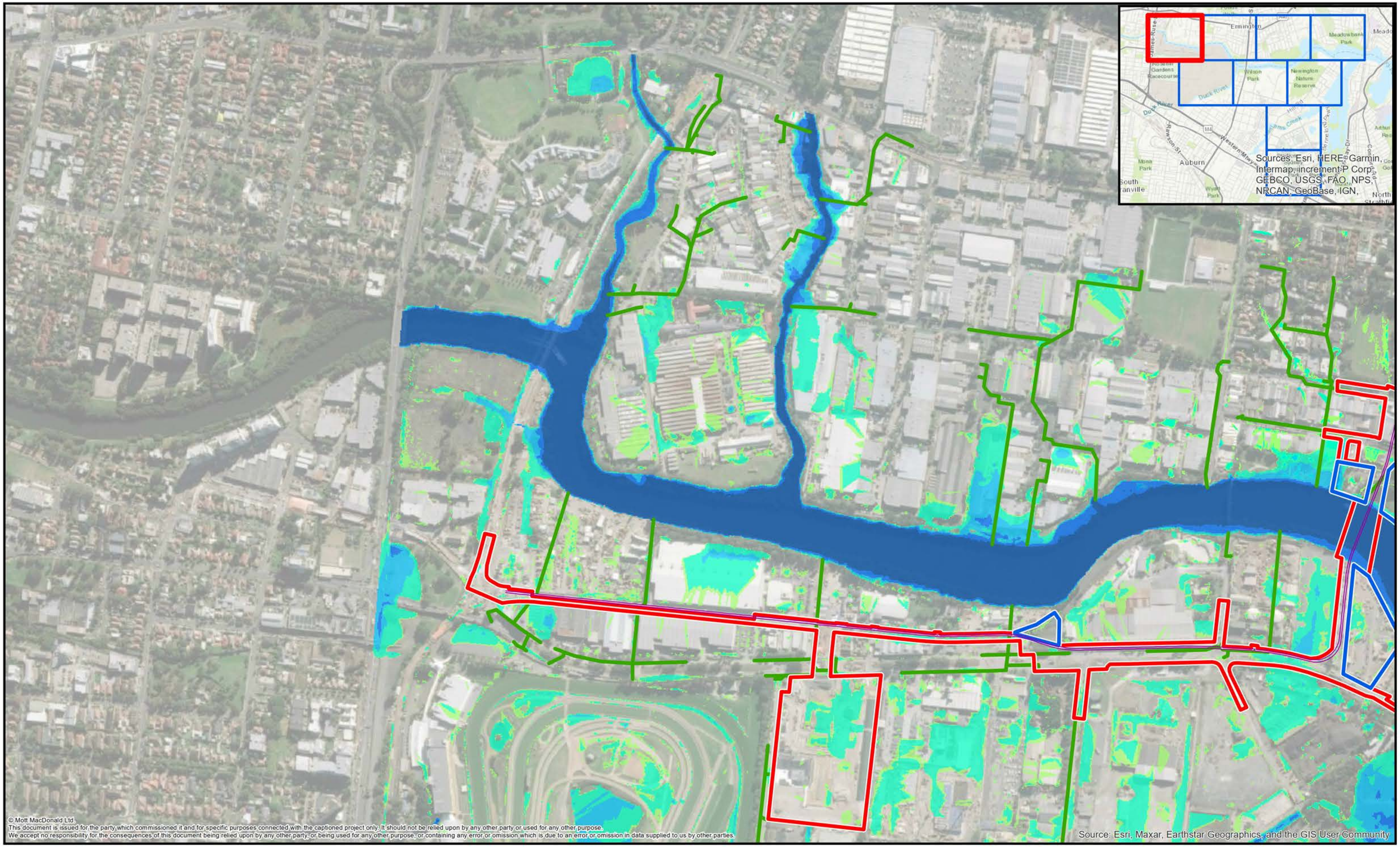

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 1 of 9

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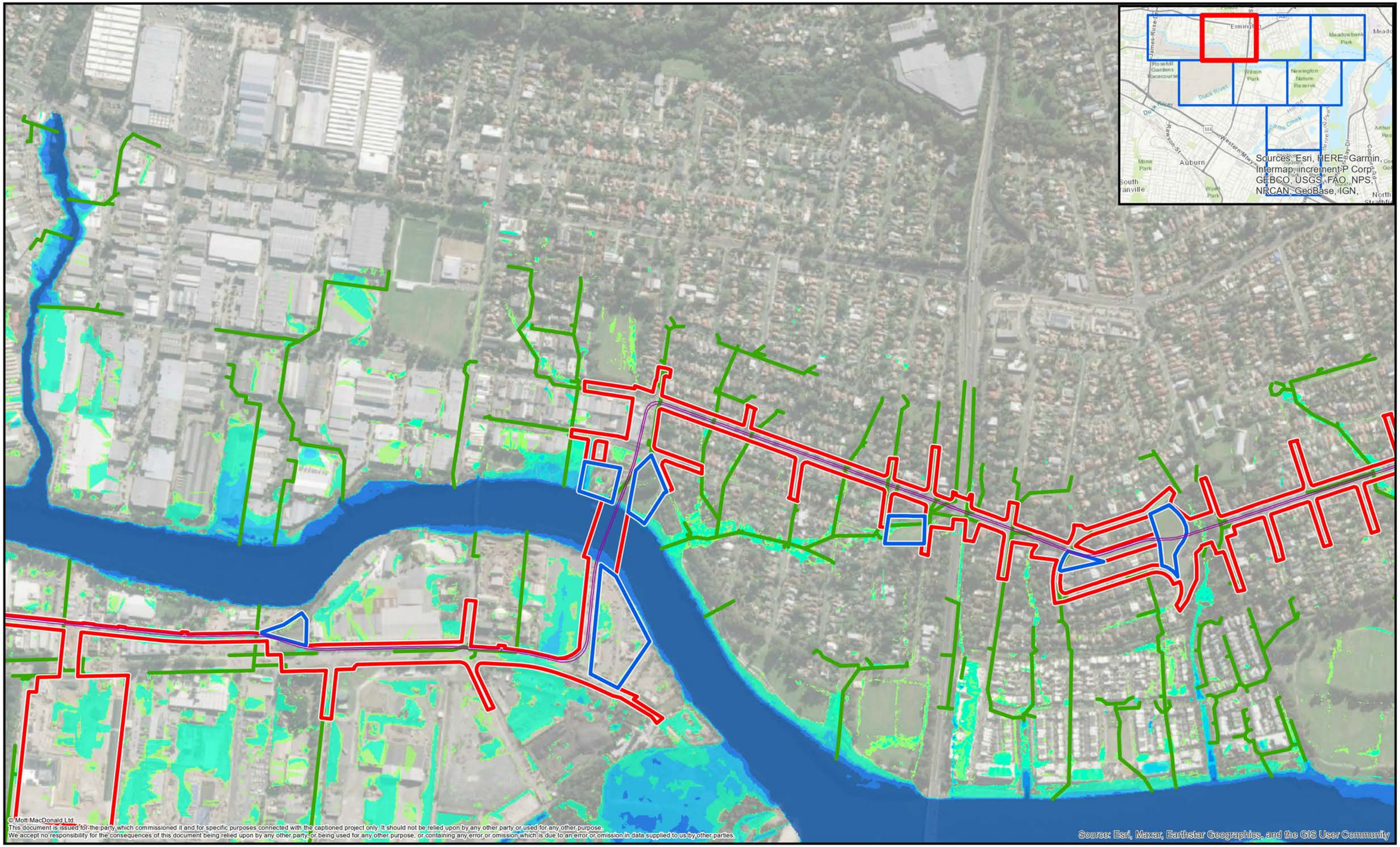

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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- 1 - 2
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Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

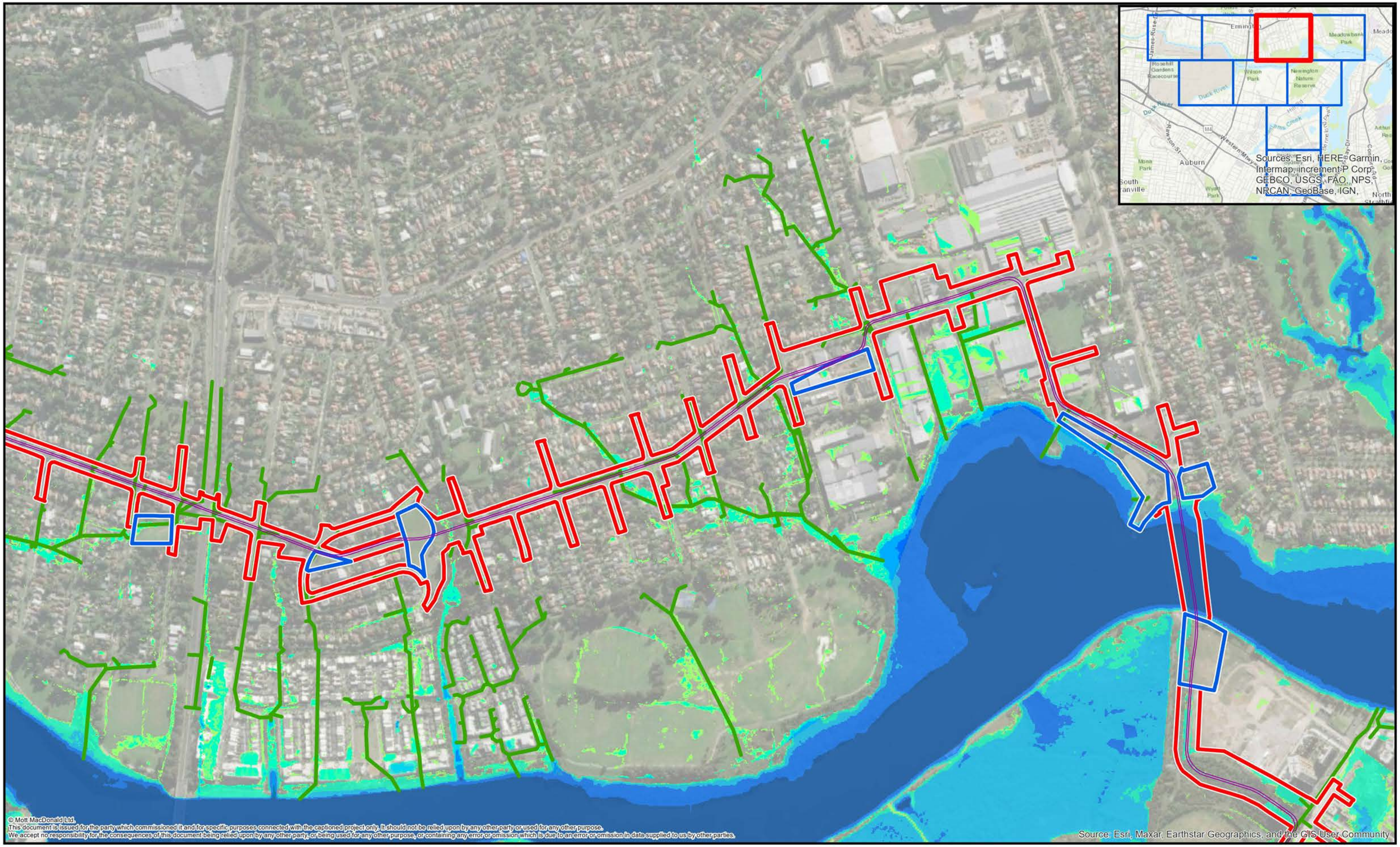
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

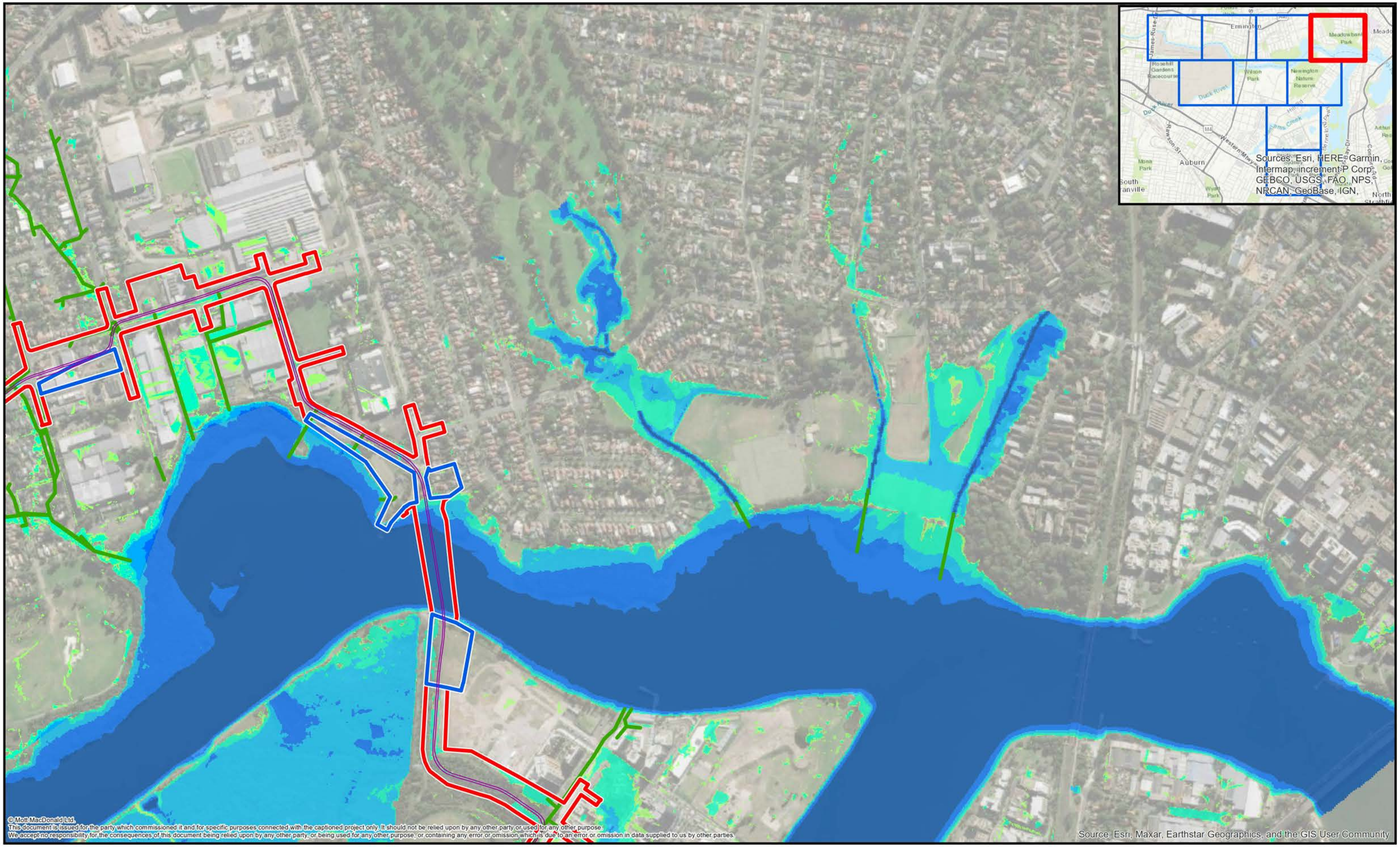
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

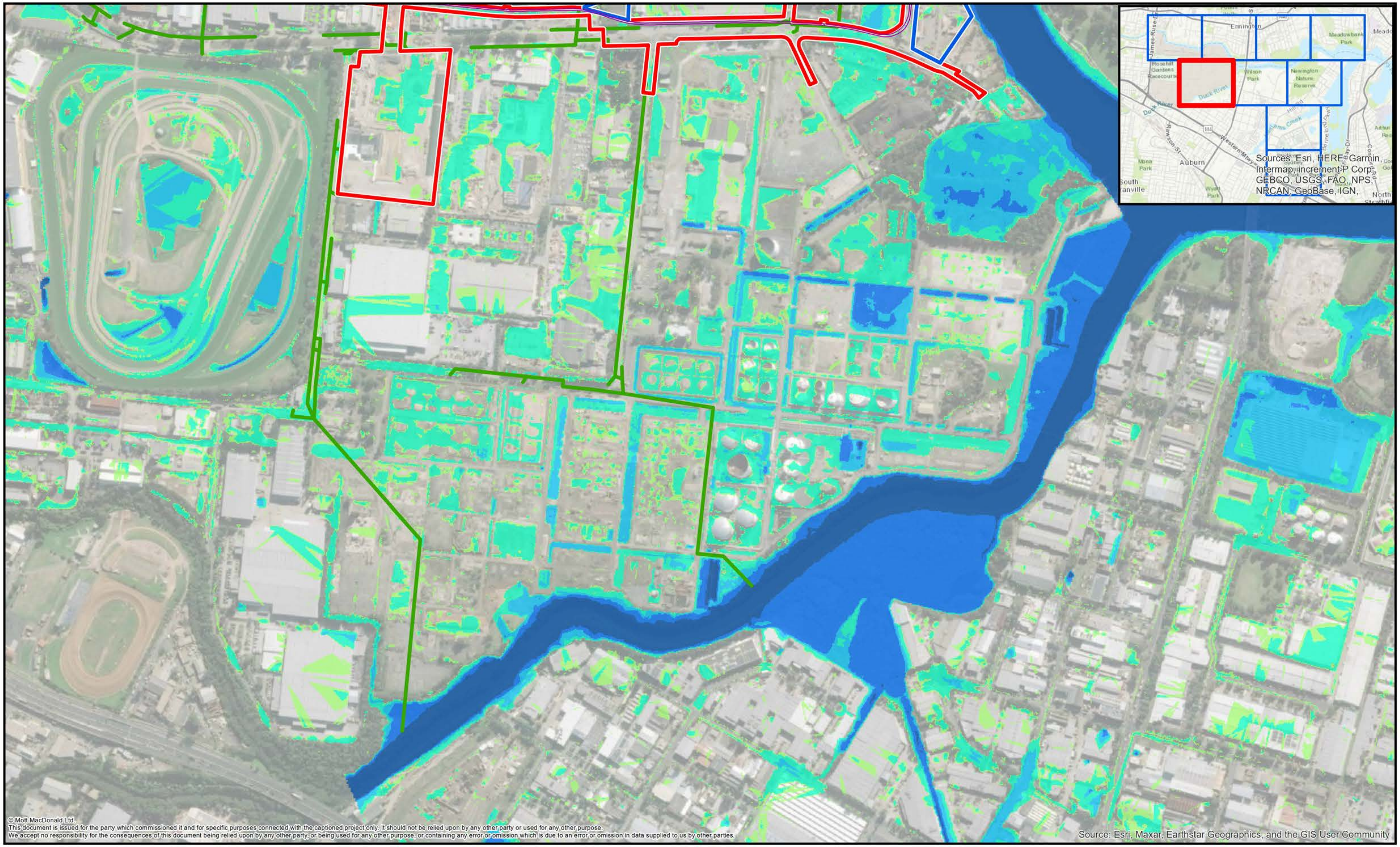
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

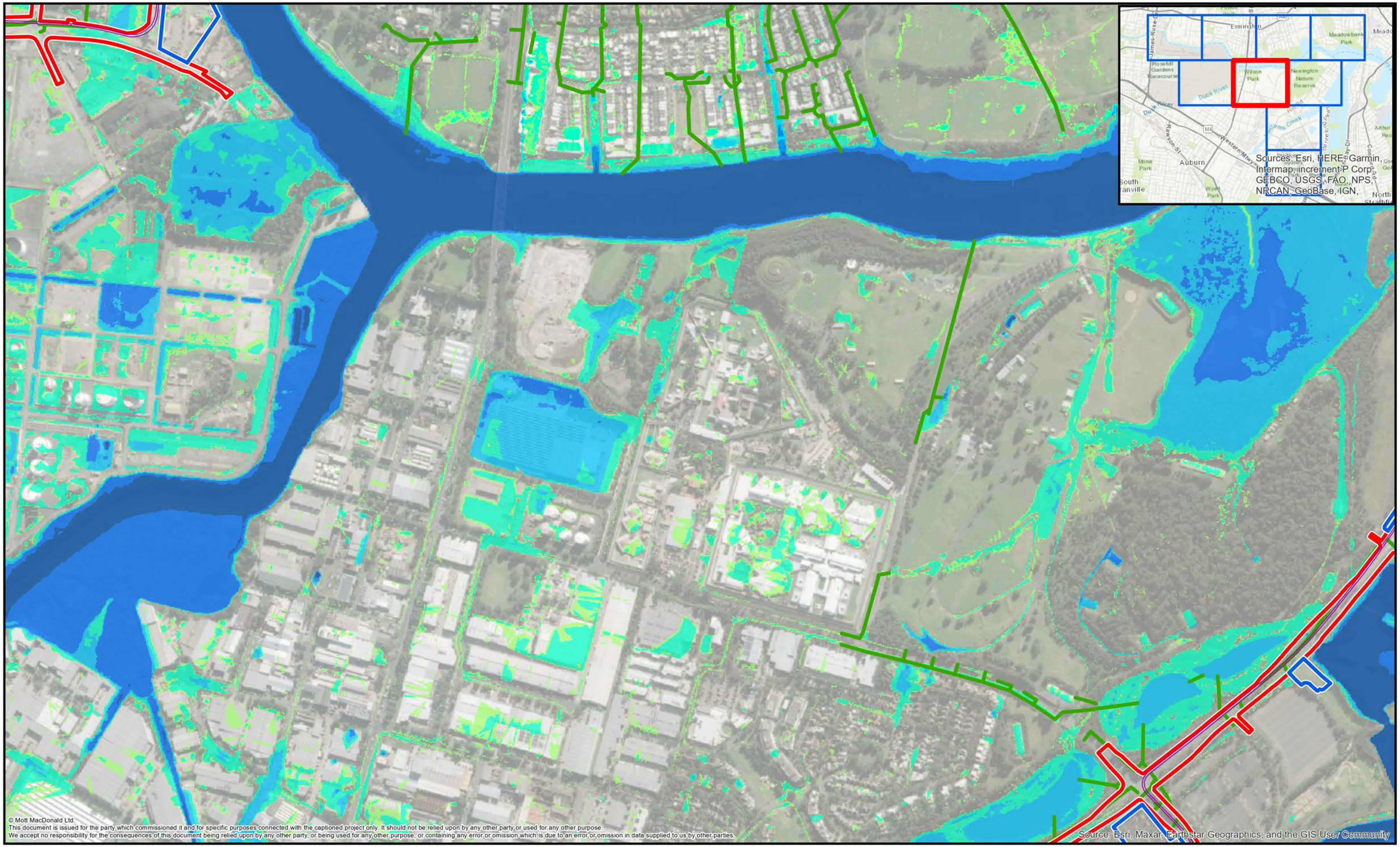
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

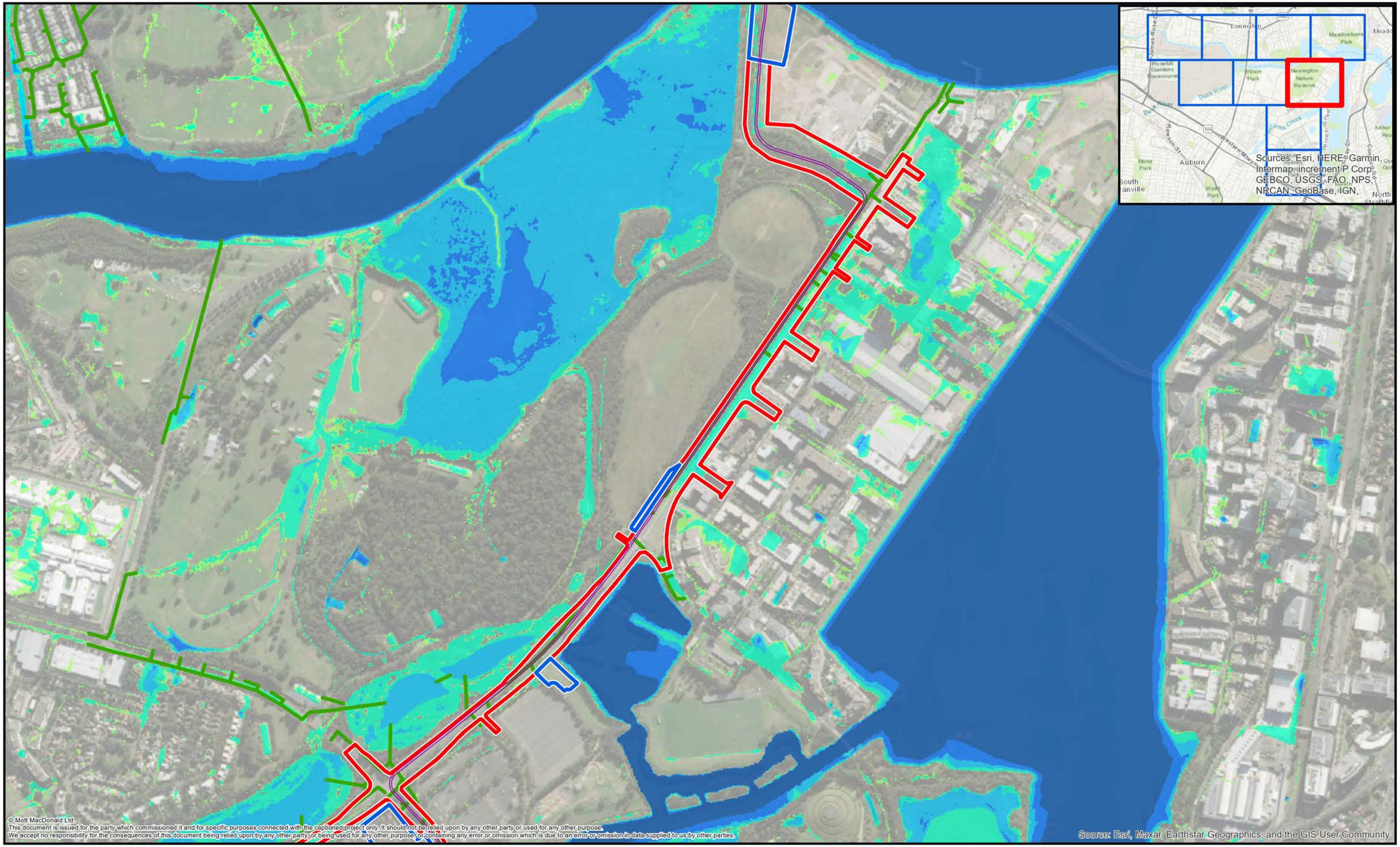
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

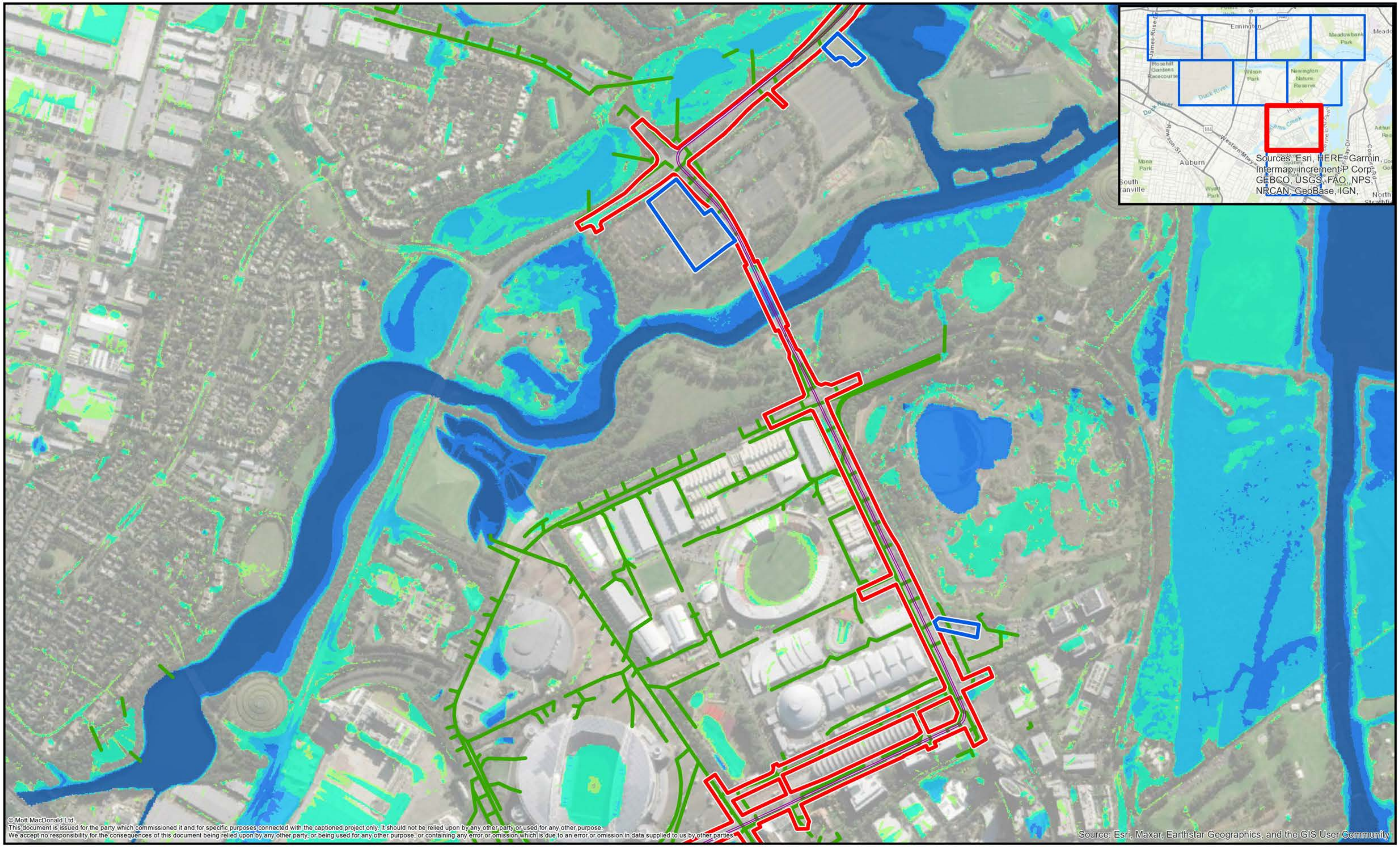
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

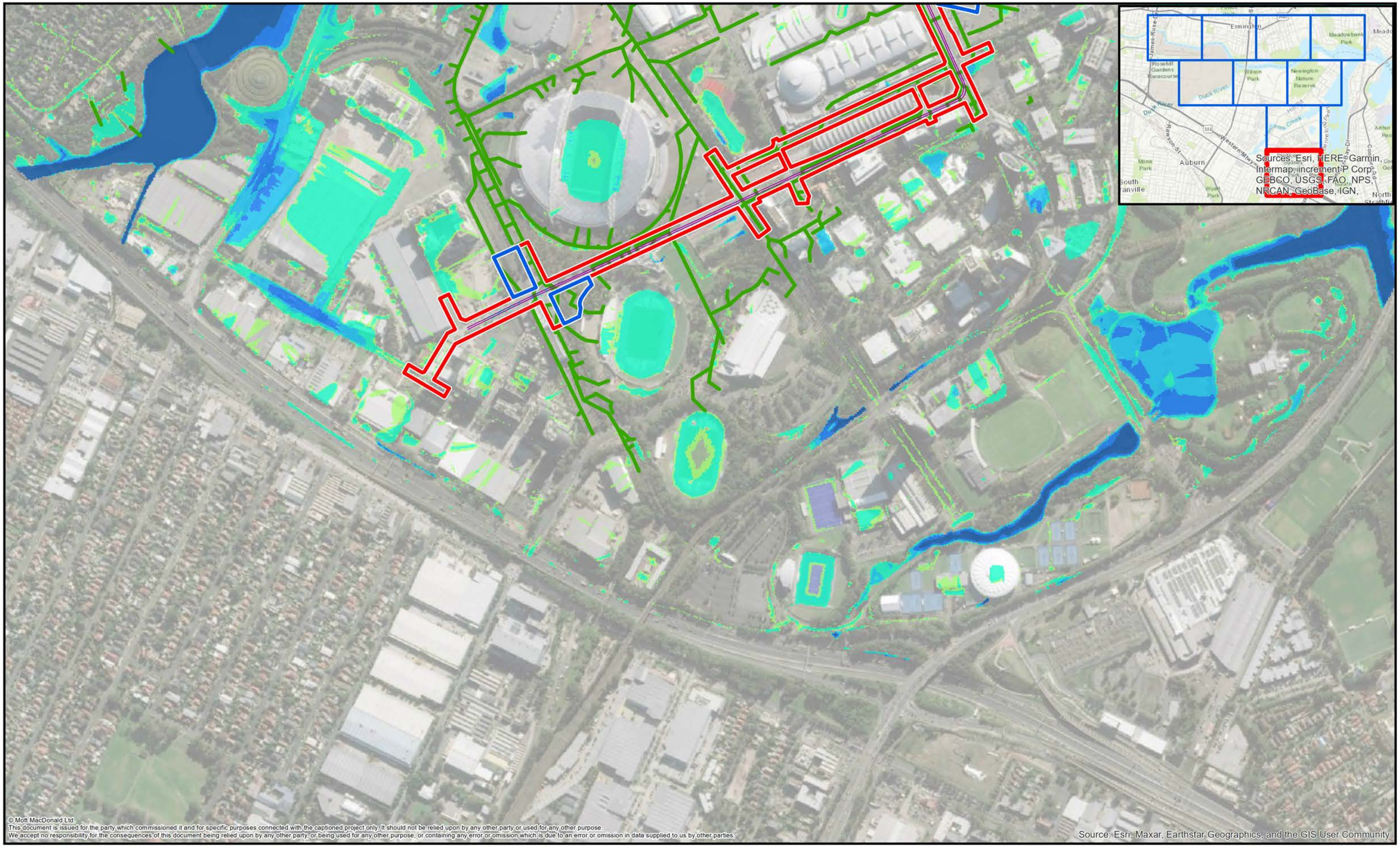
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

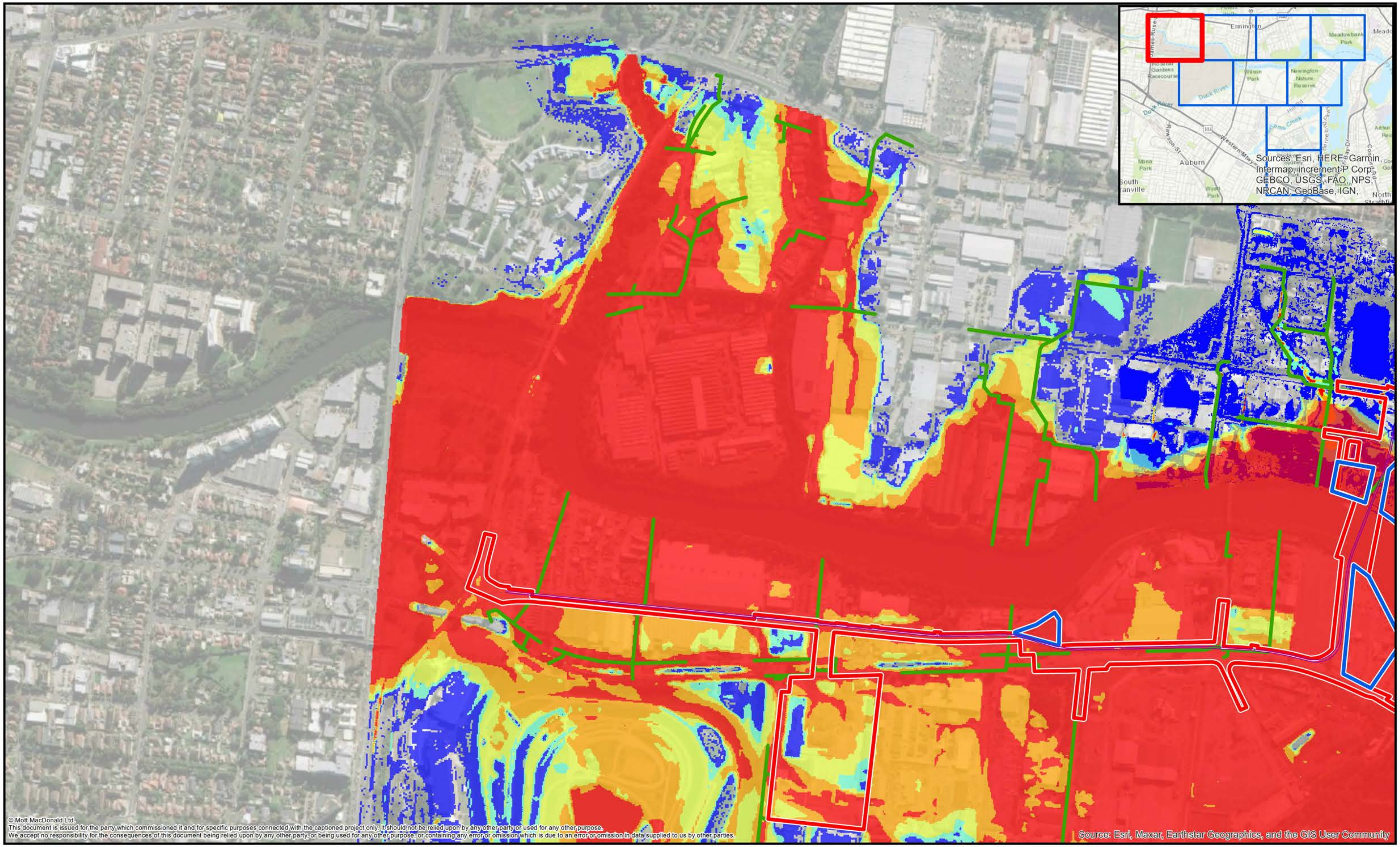
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

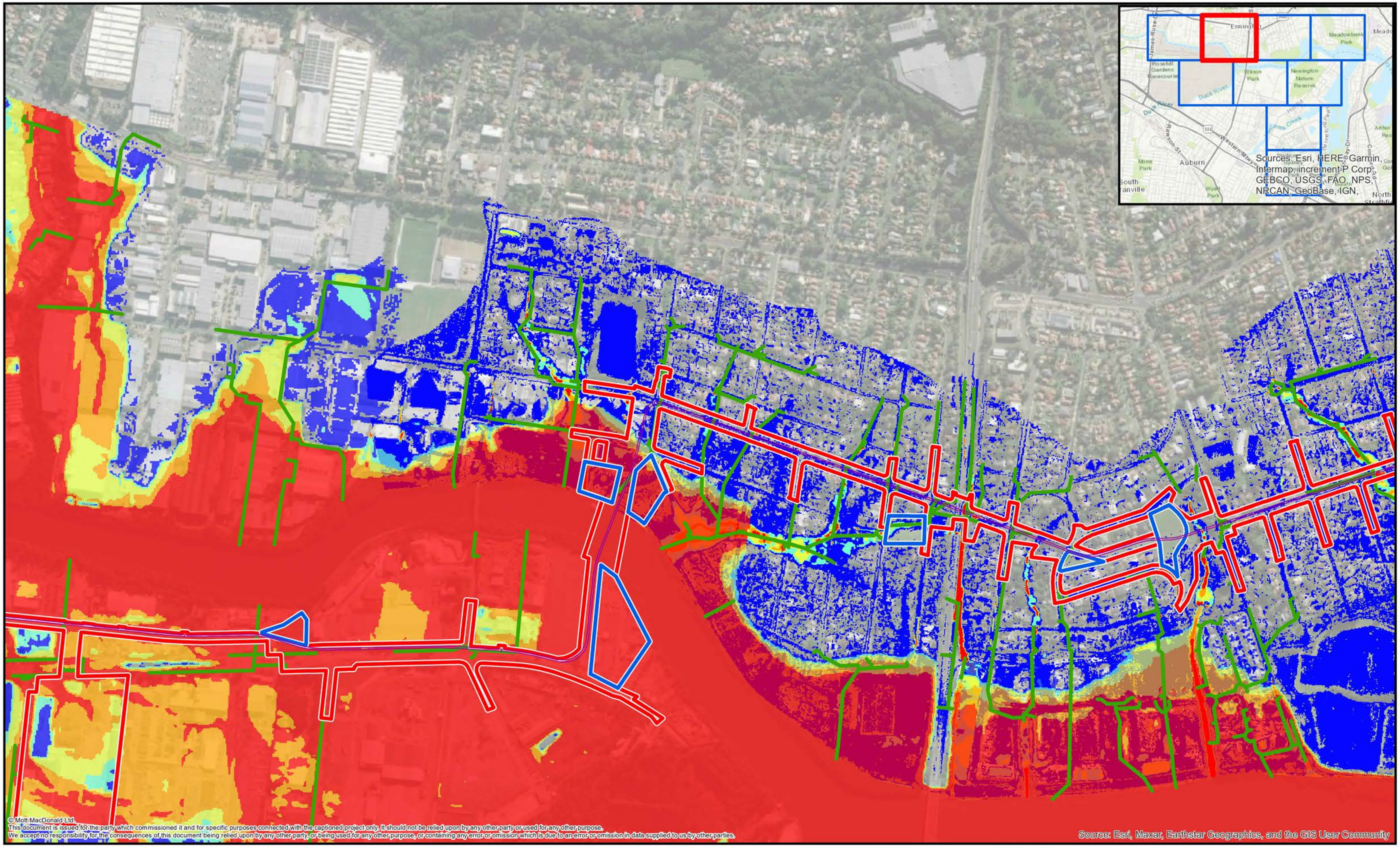
Scale at A3

M M MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

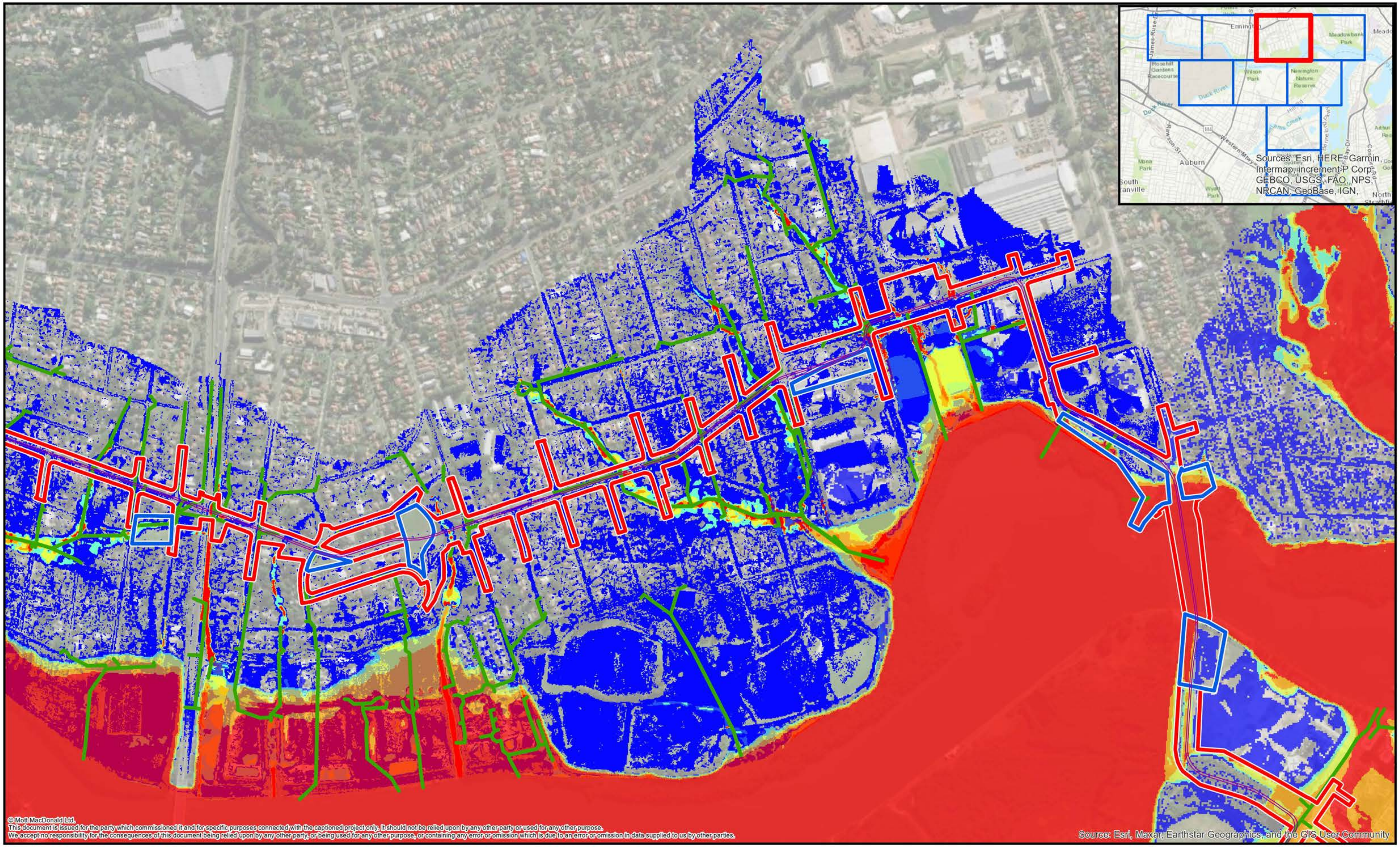
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Flood Hazard (ZAEM1)

H1

H2

H3

H4

H5

H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

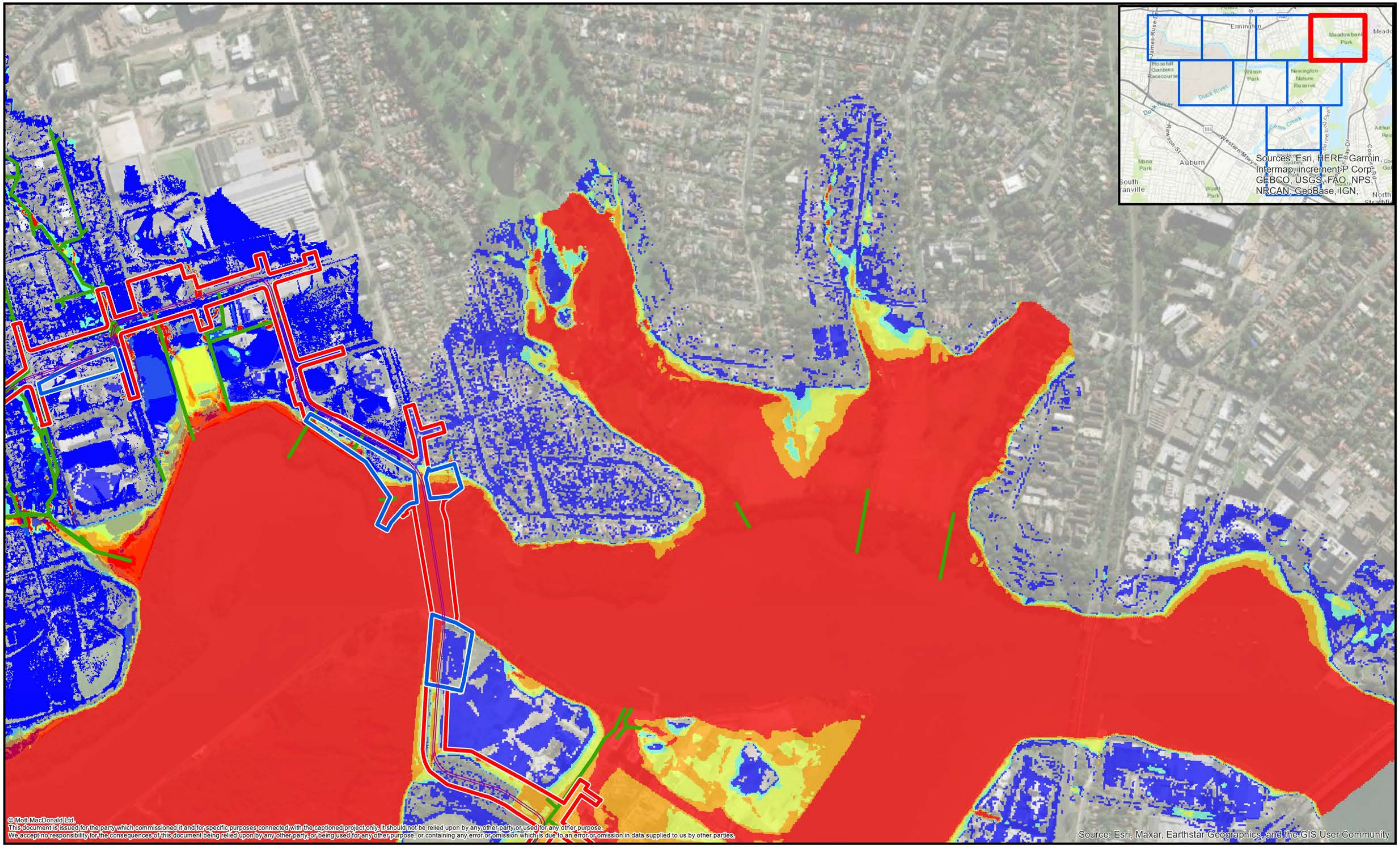
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

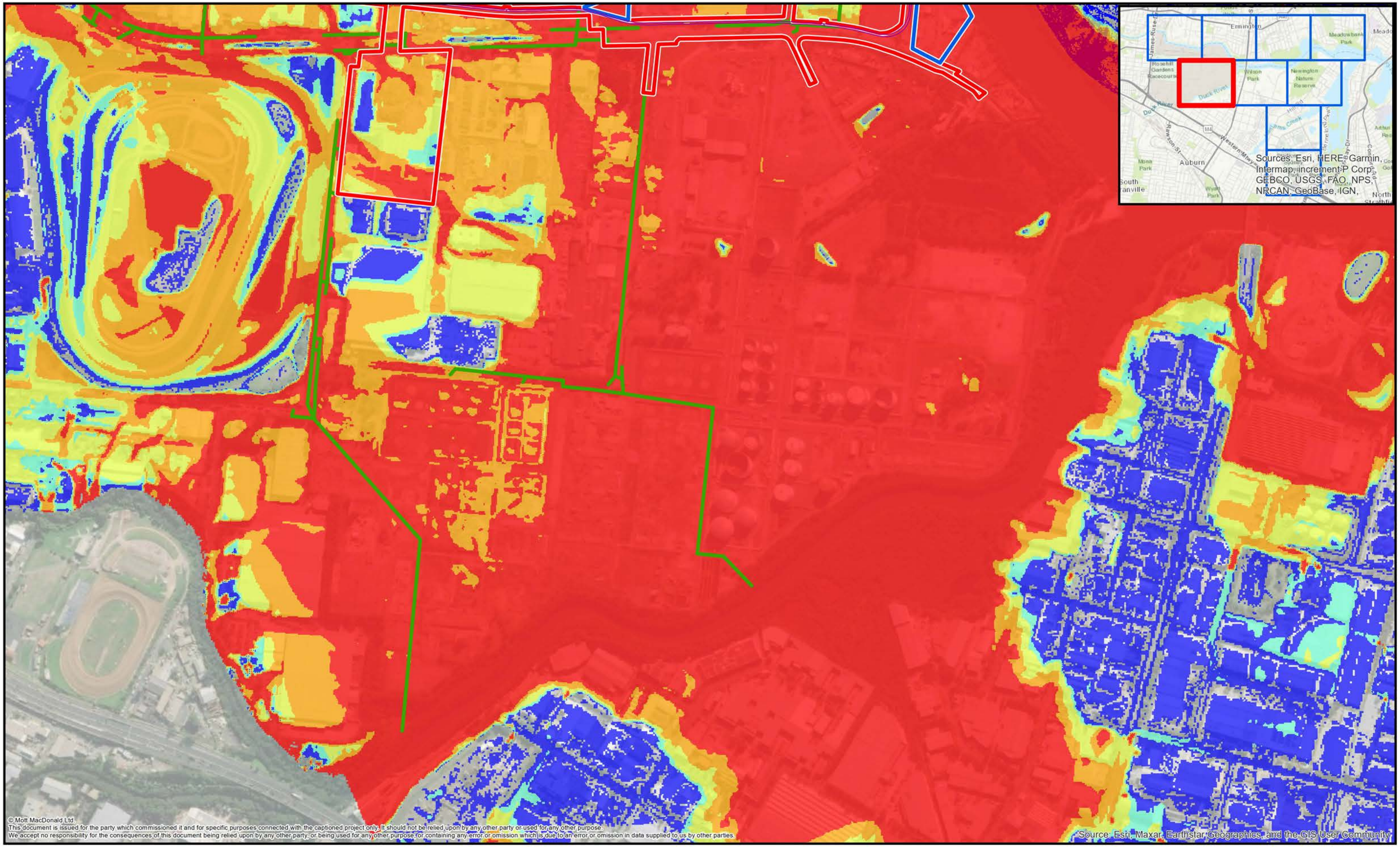
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

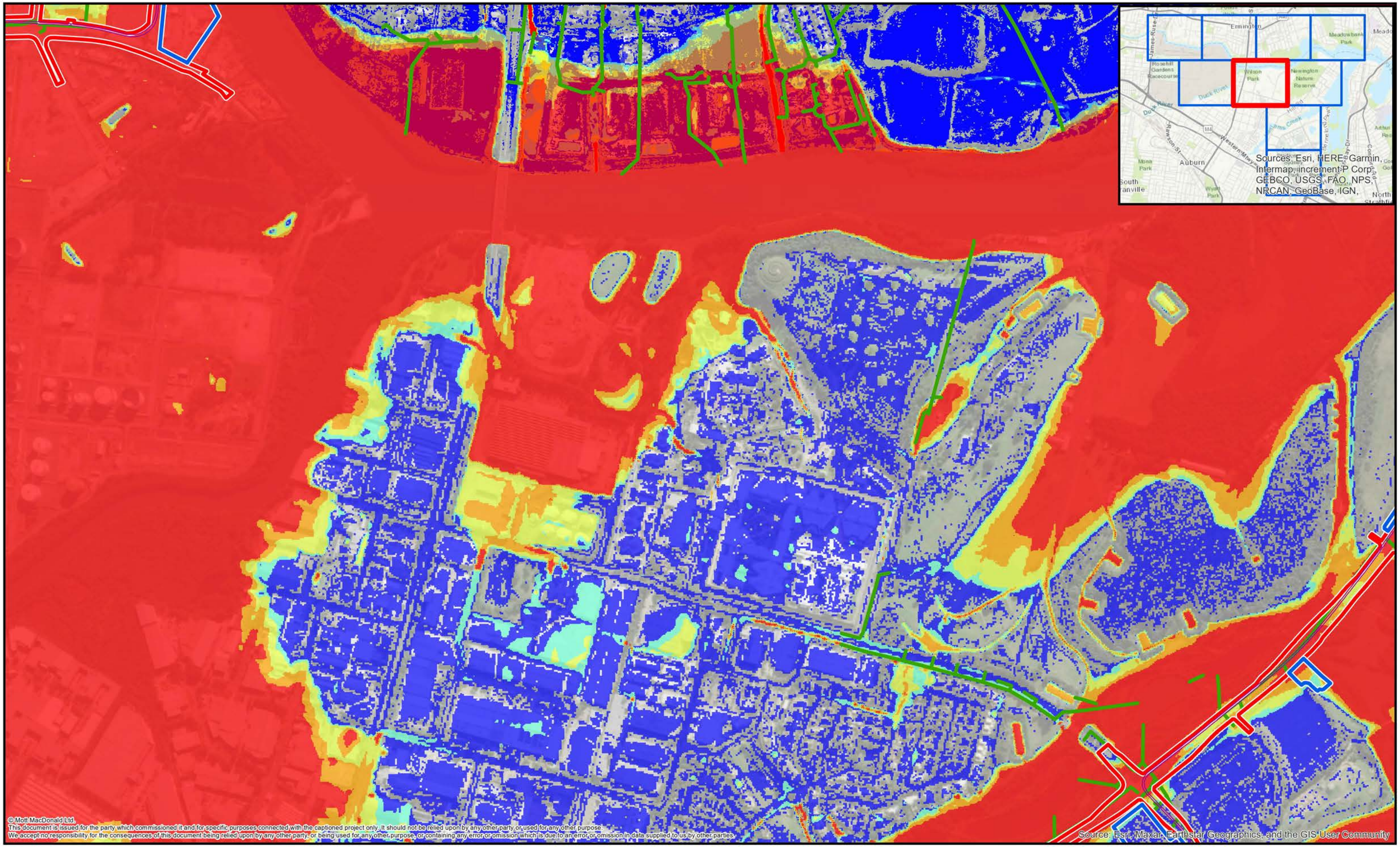
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

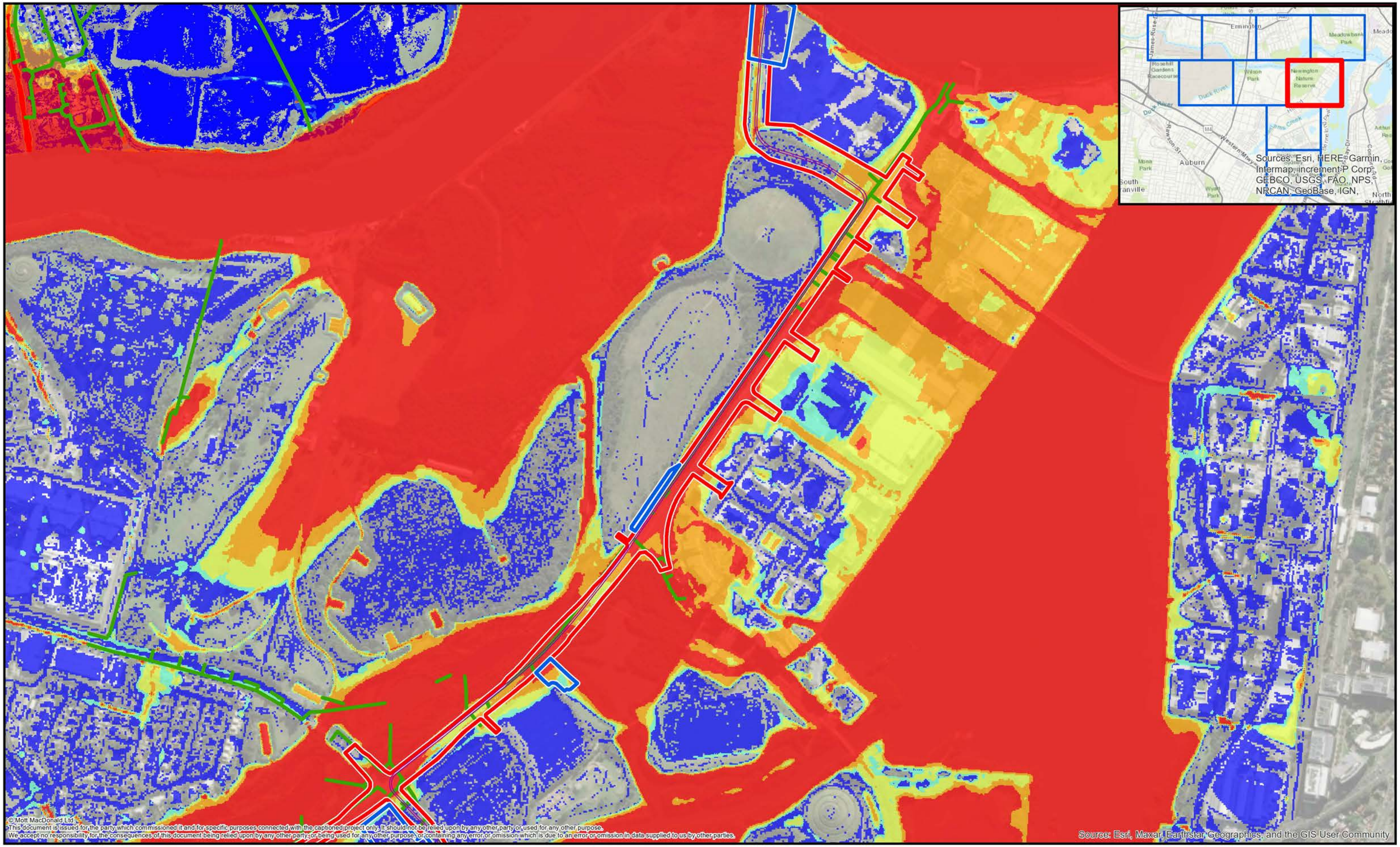
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

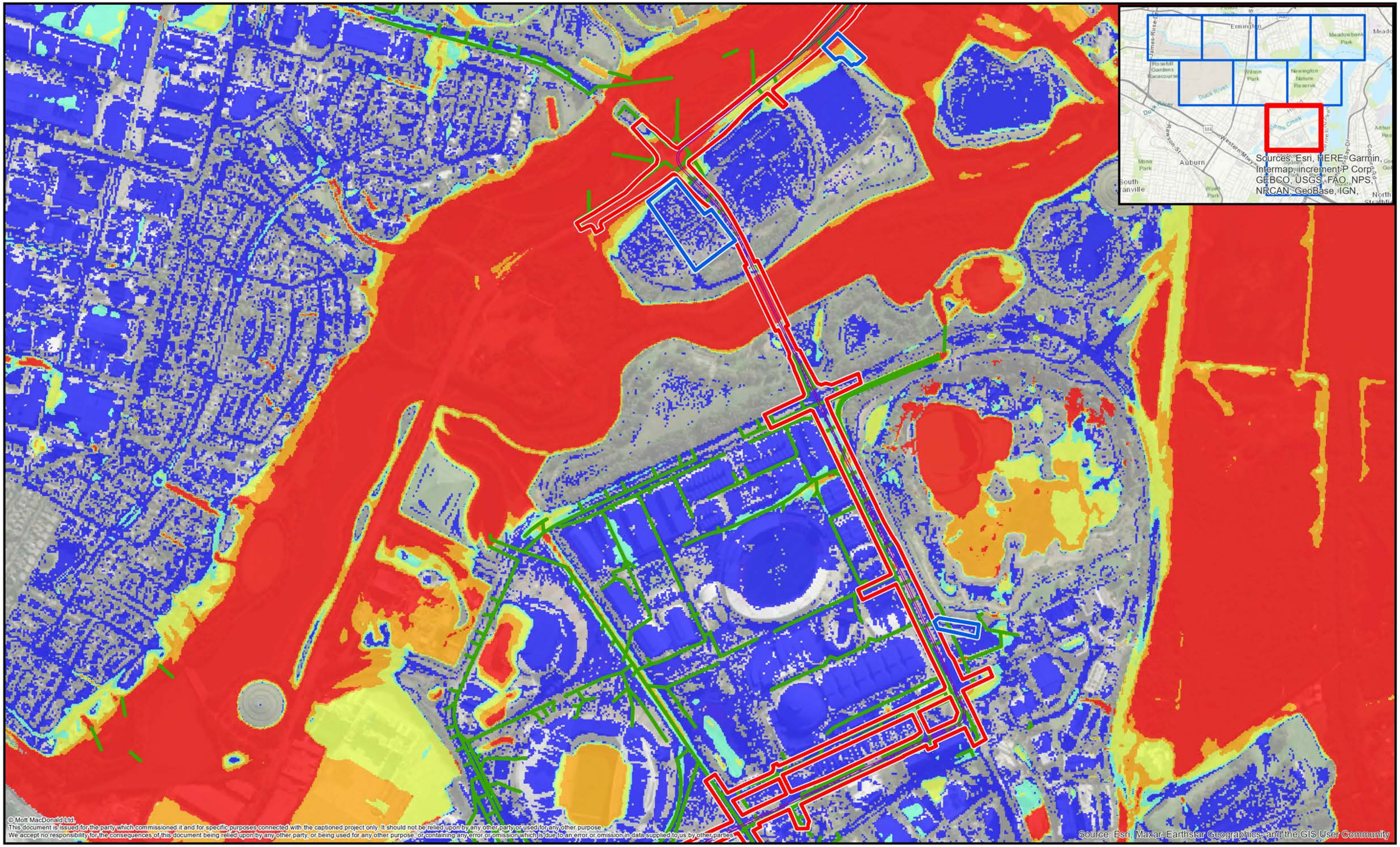
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

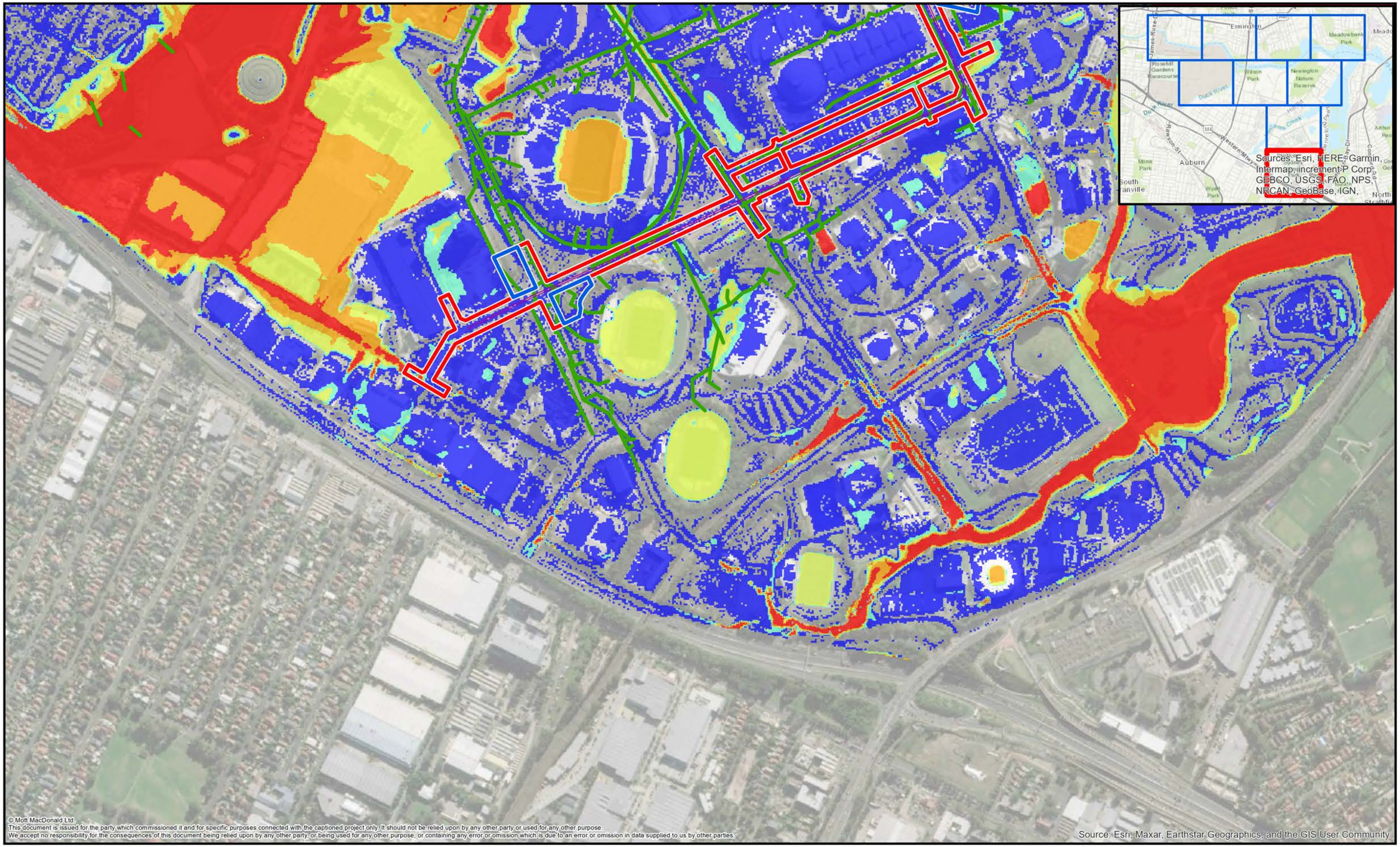
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

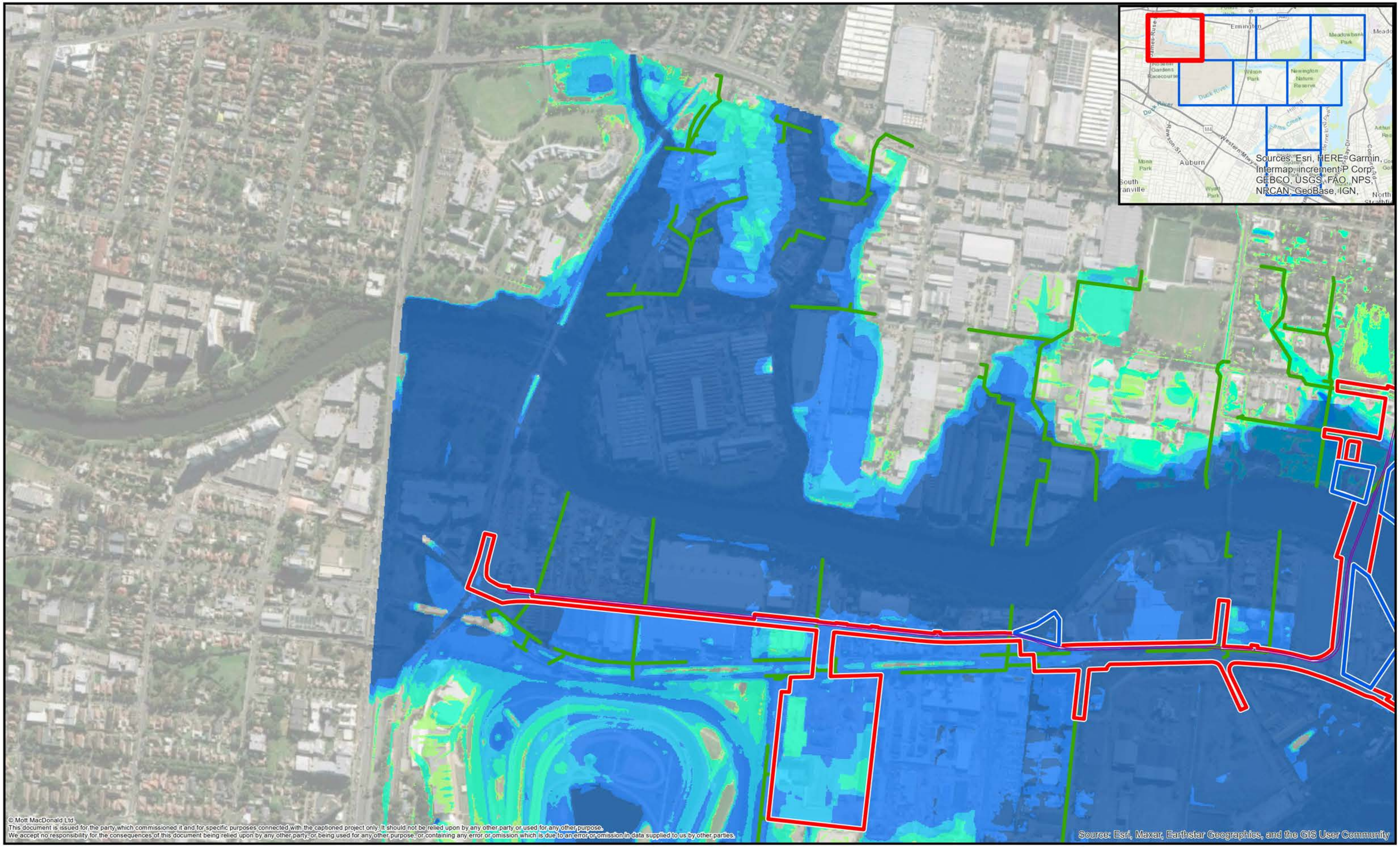
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

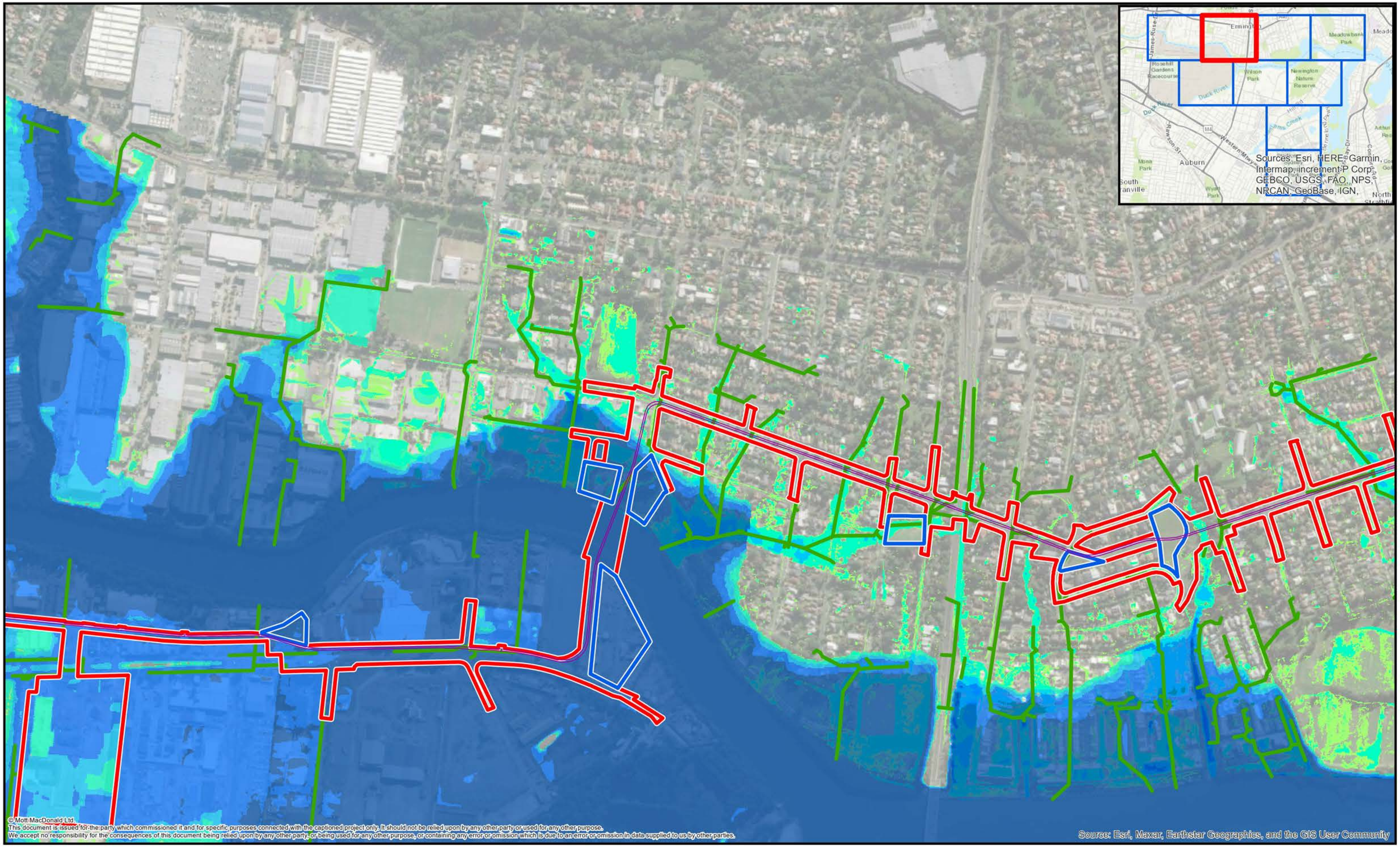
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

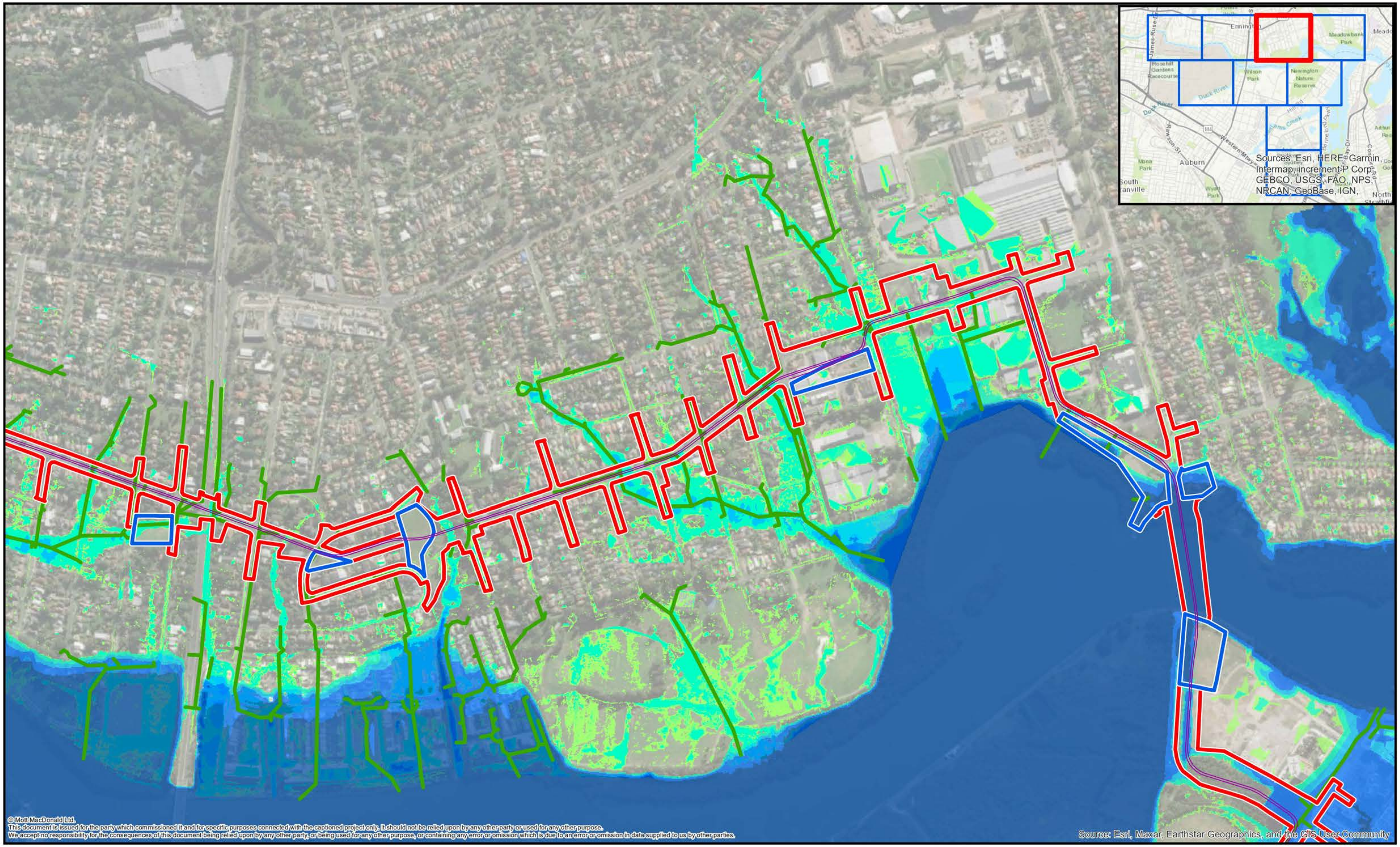
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

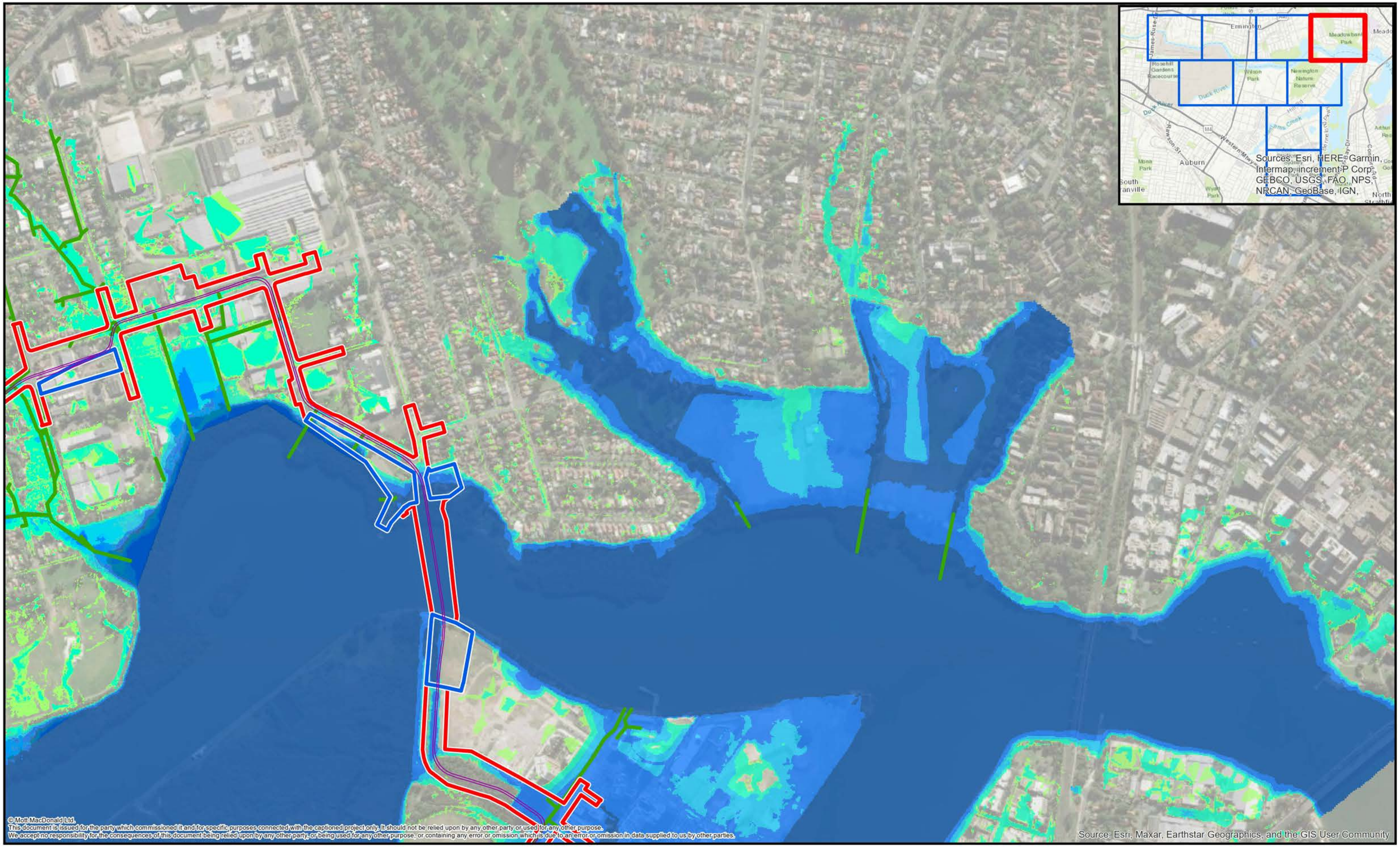
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

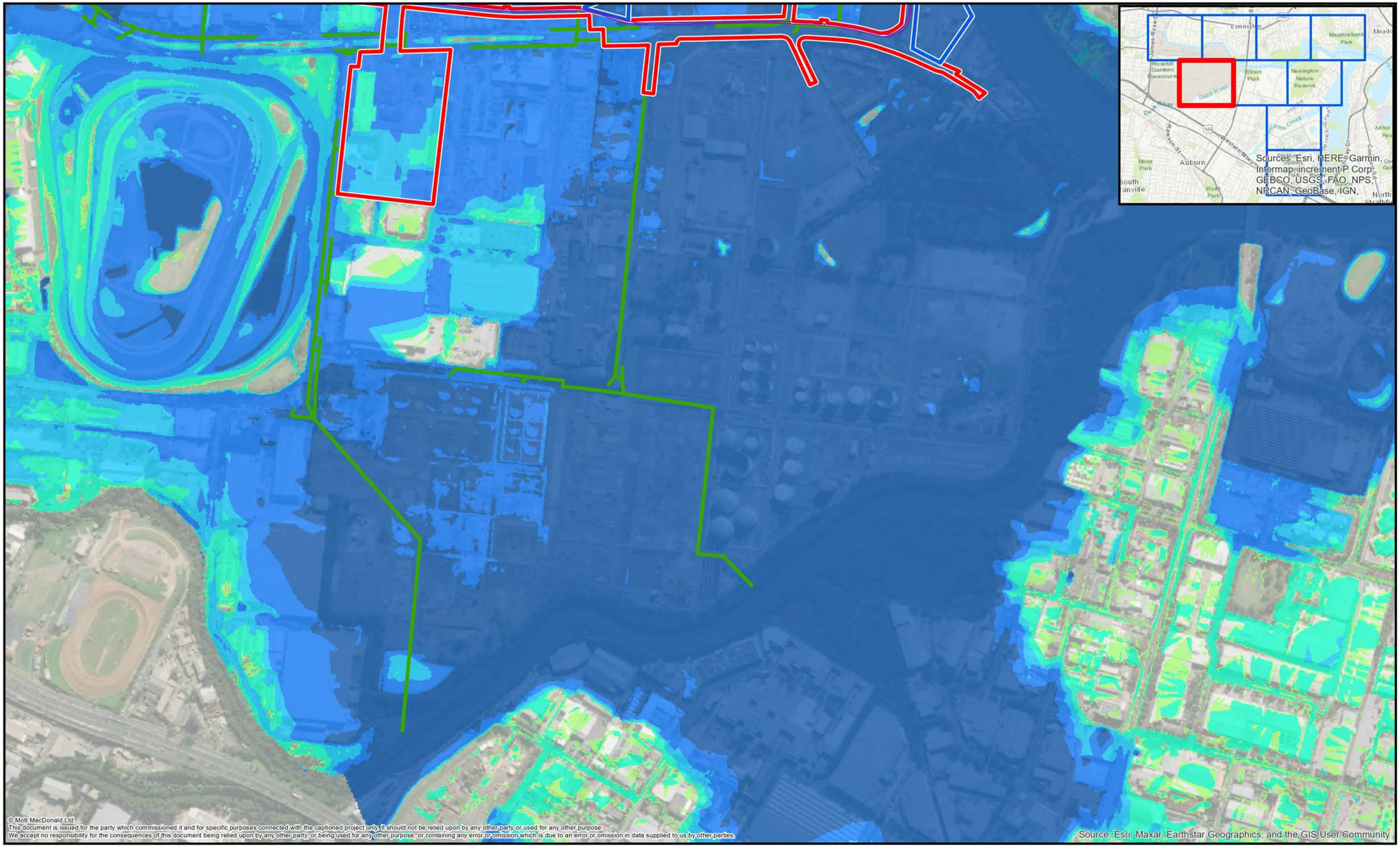
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

M M MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

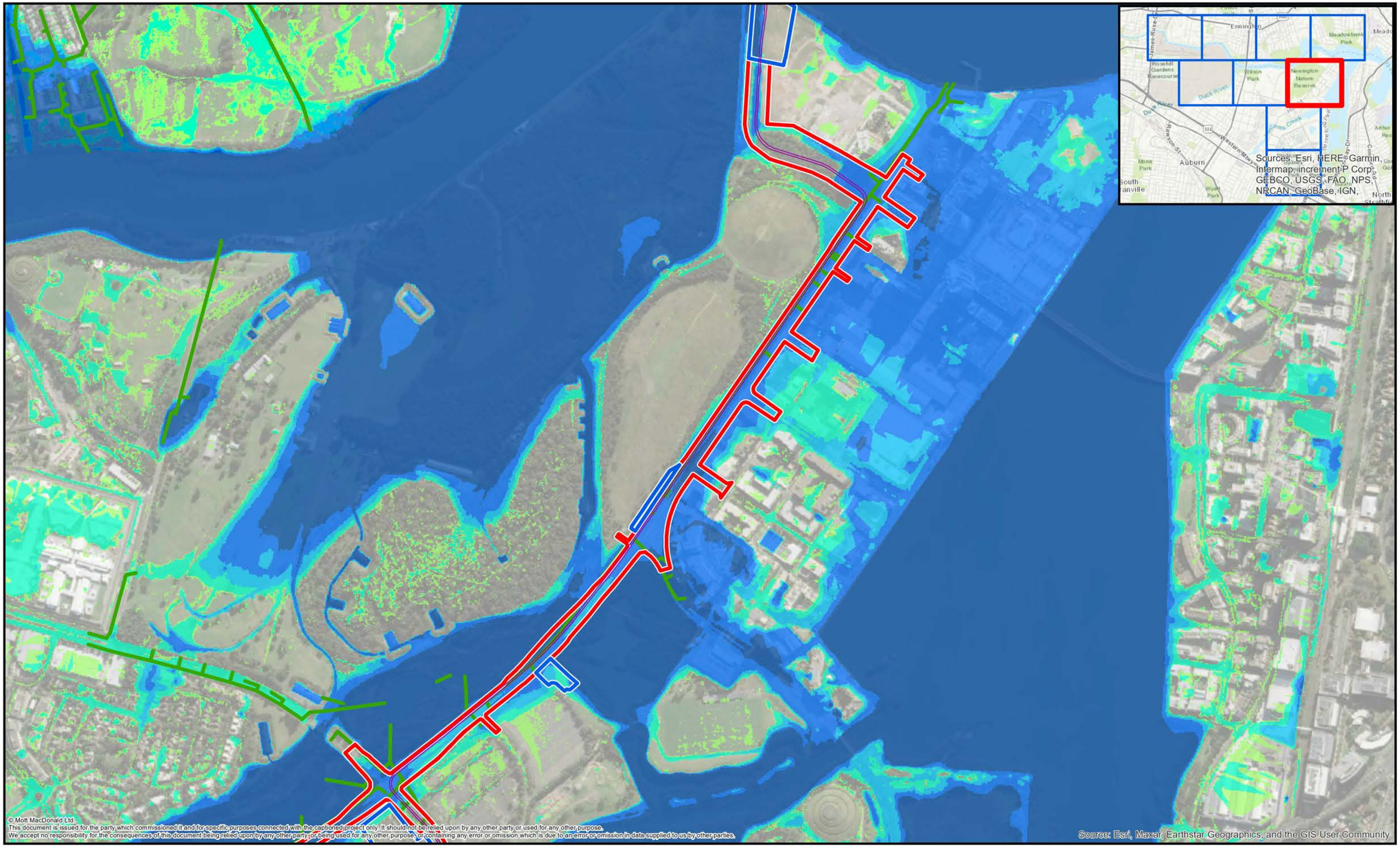
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

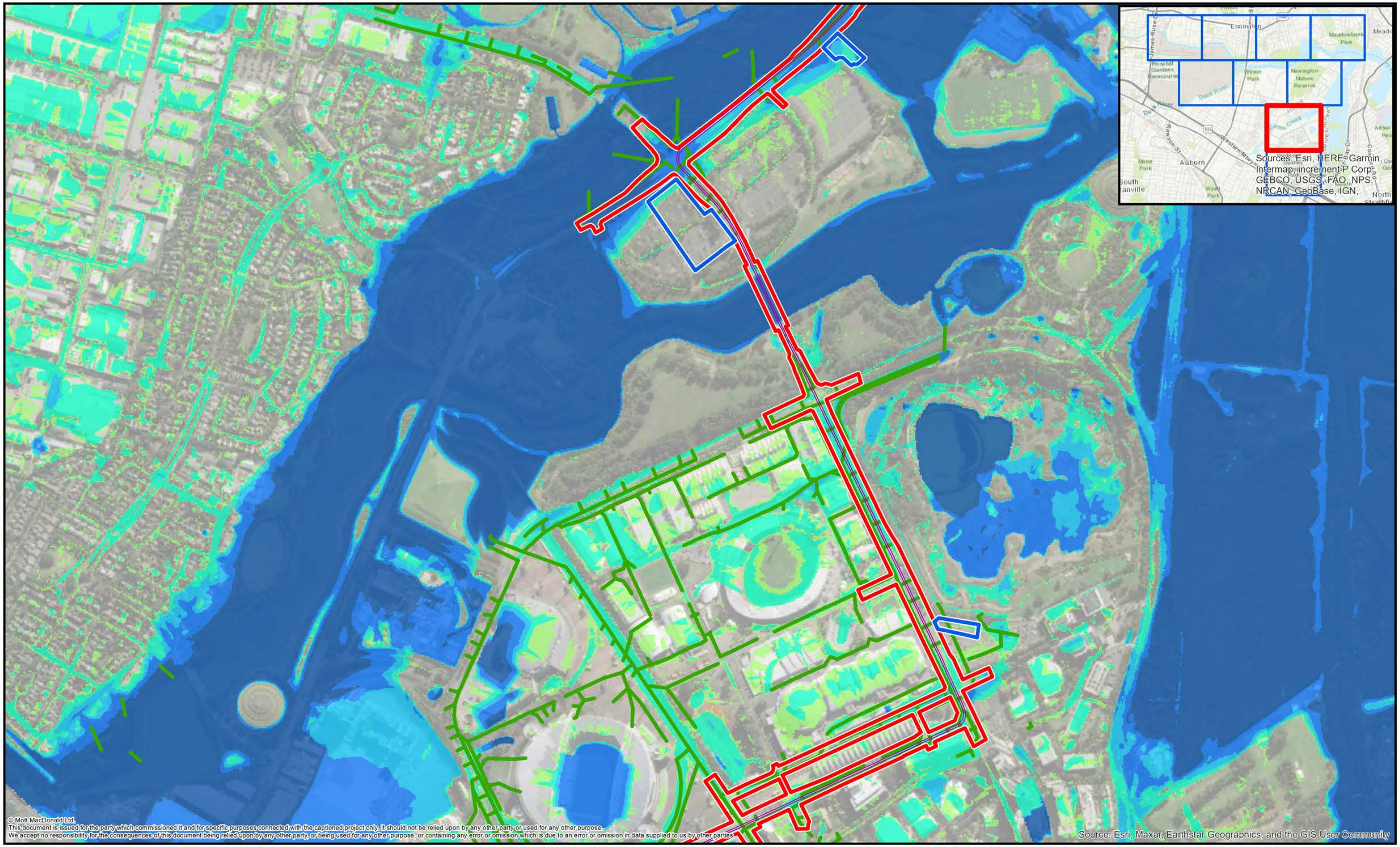
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

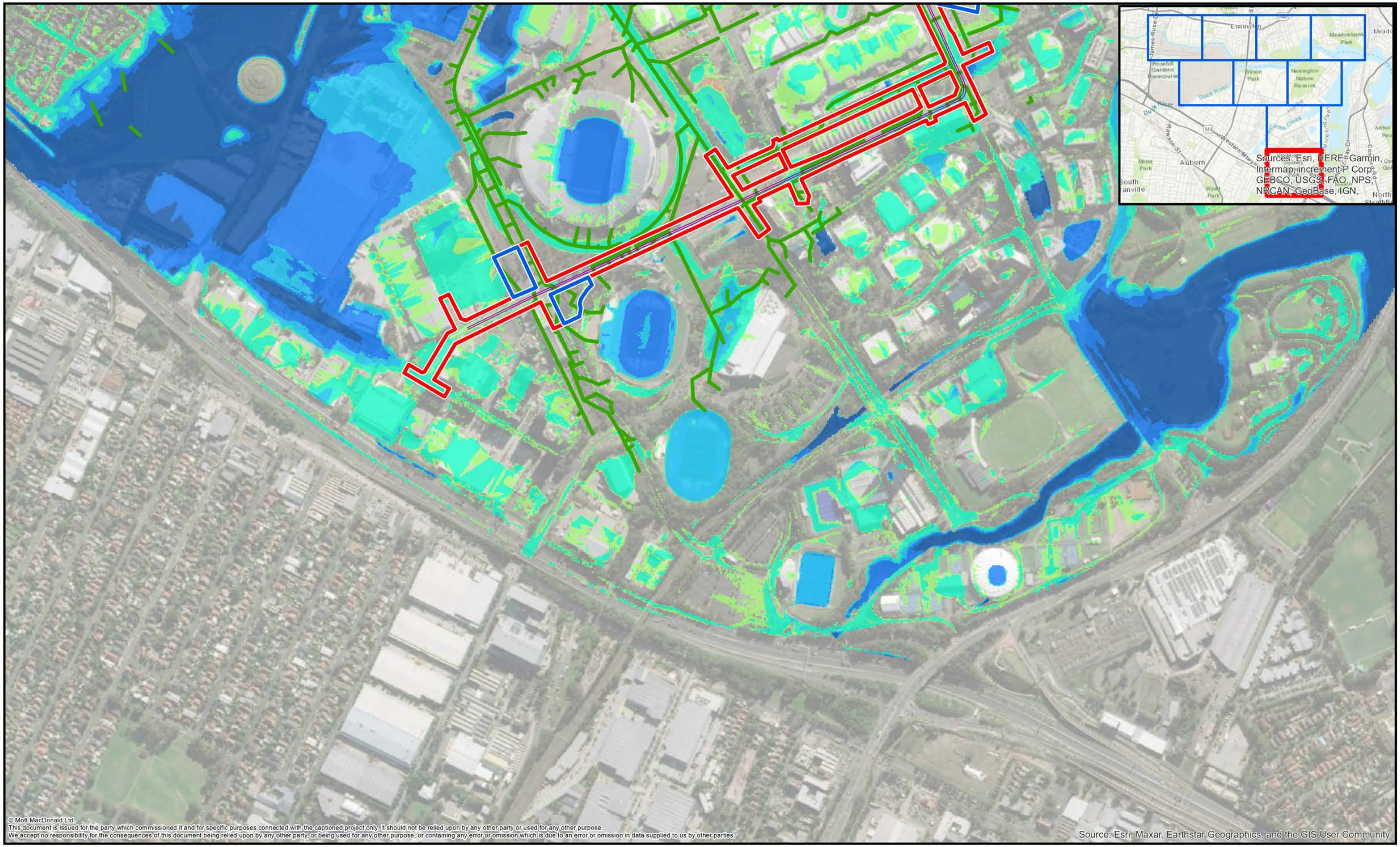
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Existing Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

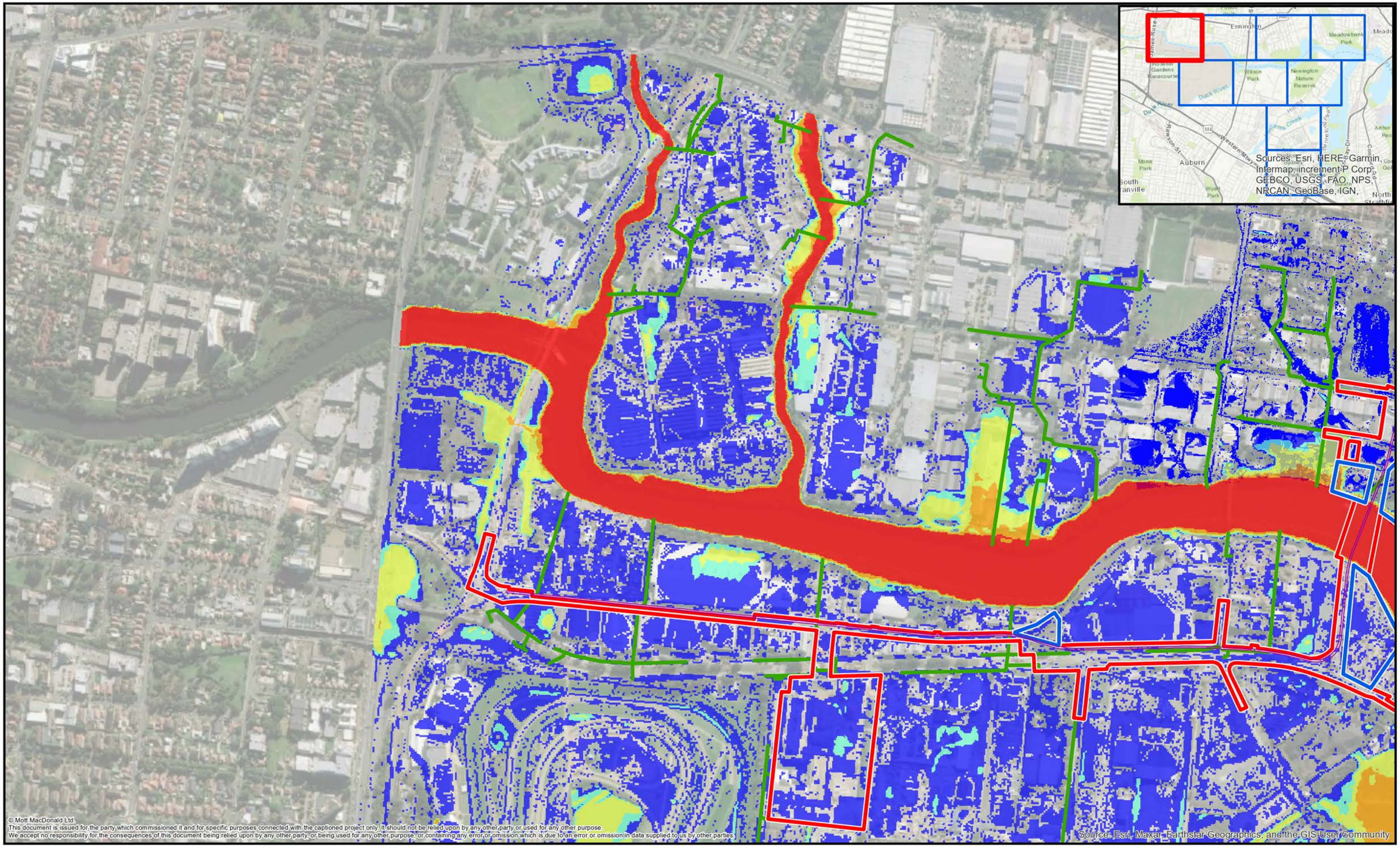
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

Project Alignment
Construction Compounds
Project Site
Stormwater Pipes

Flood Hazard (ZAEM1)

H1
H2
H3
H4
H5
H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

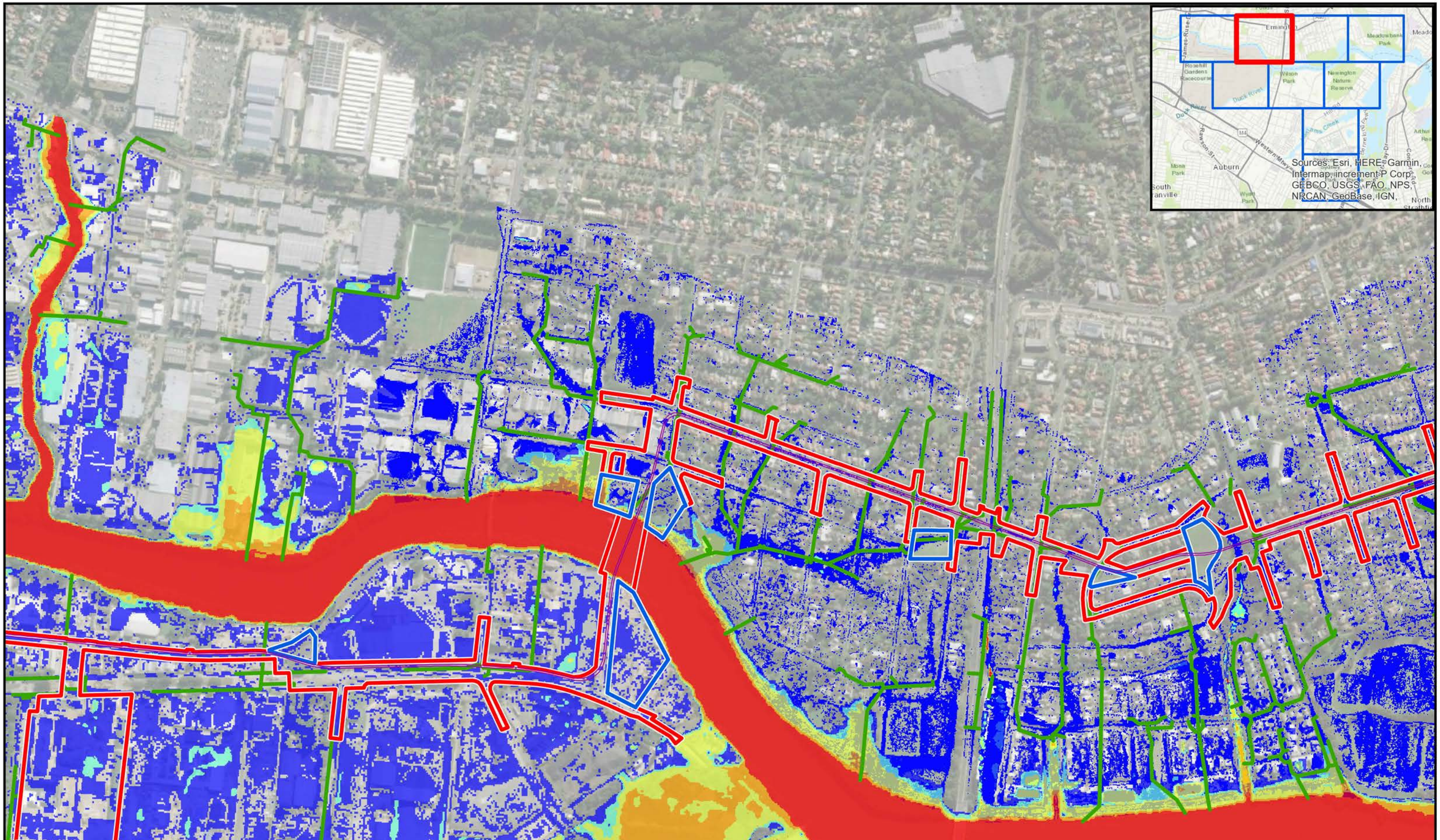
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

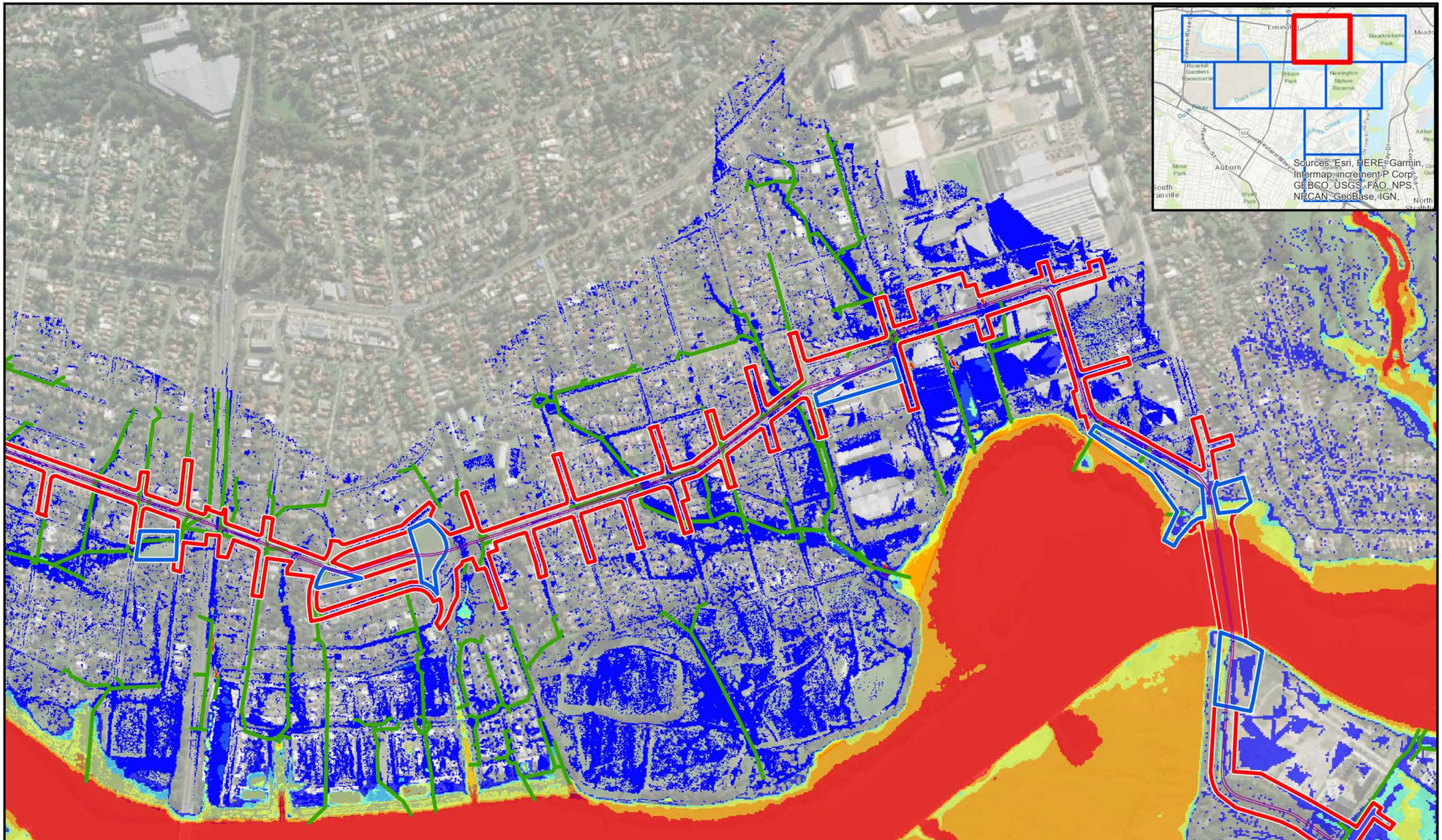
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

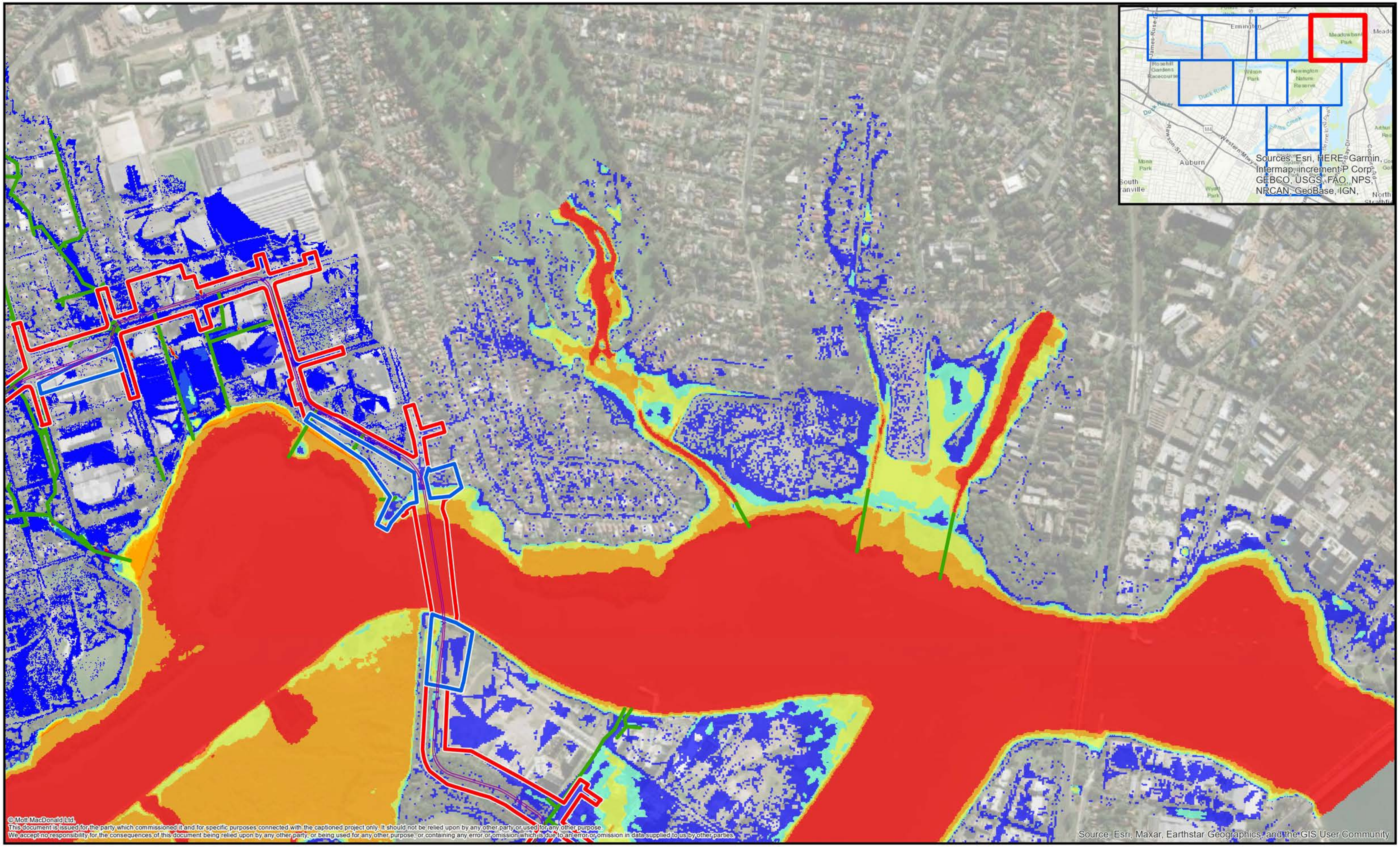
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

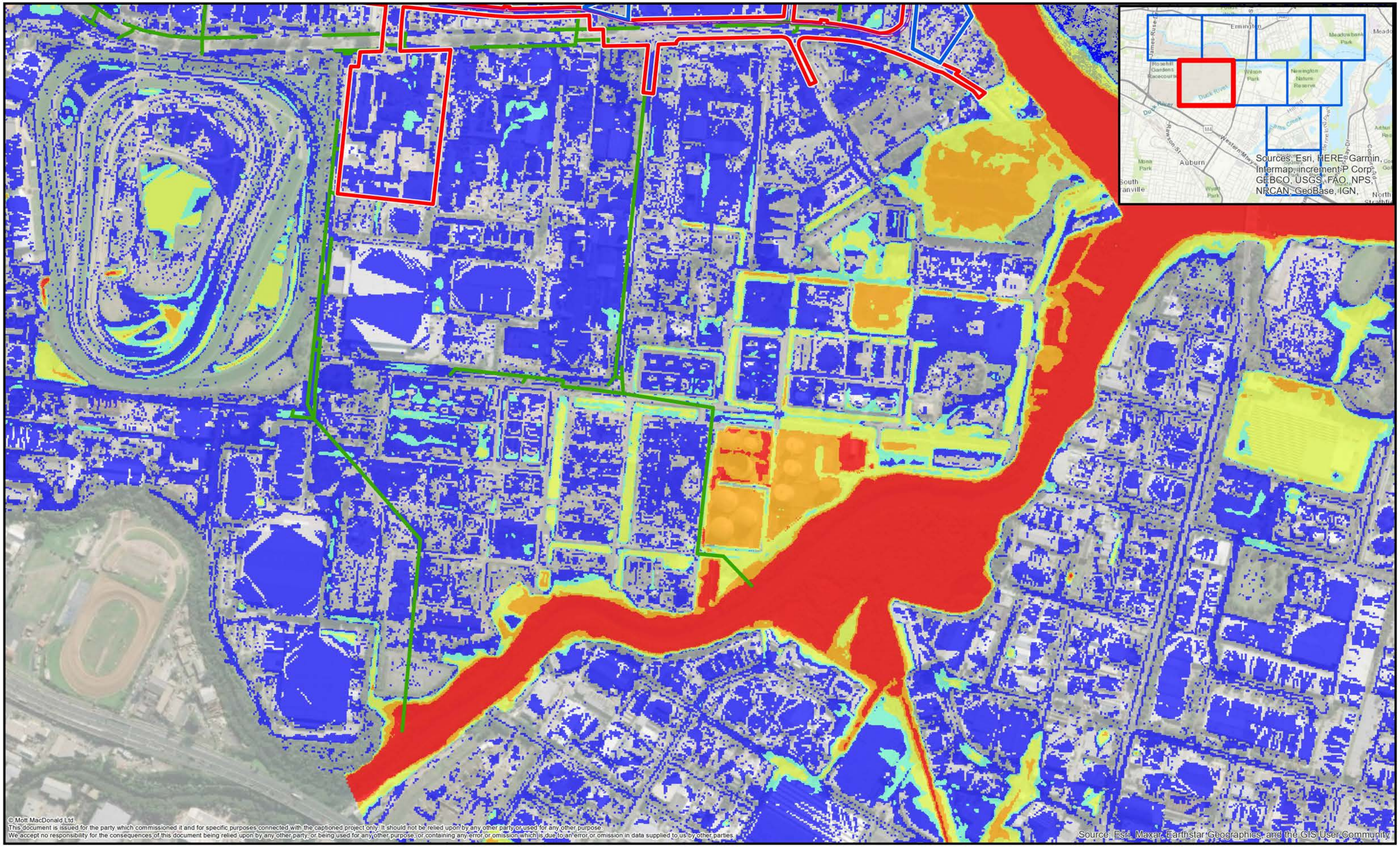
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

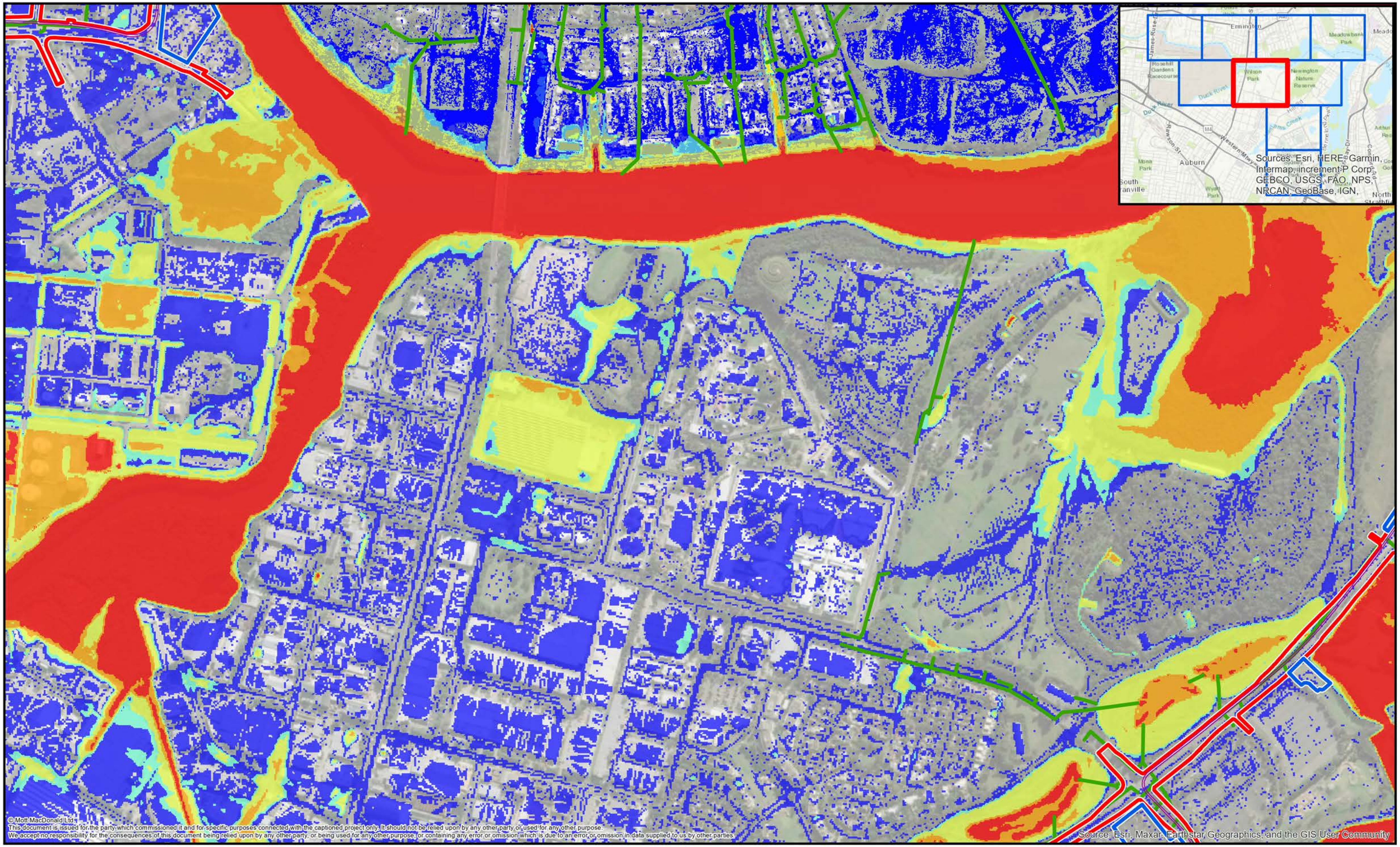
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes
- **Flood Hazard (ZAEM1)**
  - H1
  - H2
  - H3
  - H4
  - H5
  - H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

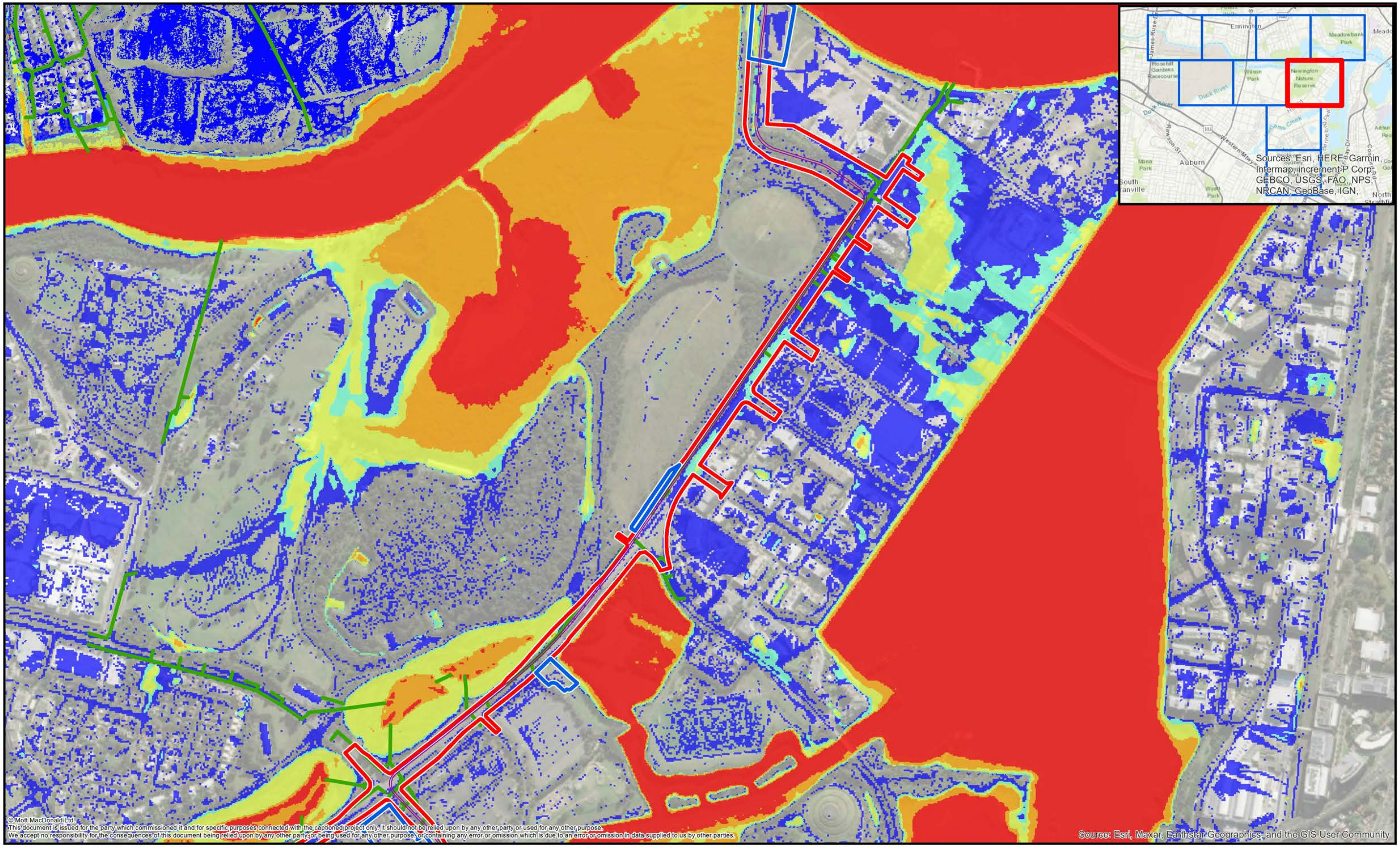
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

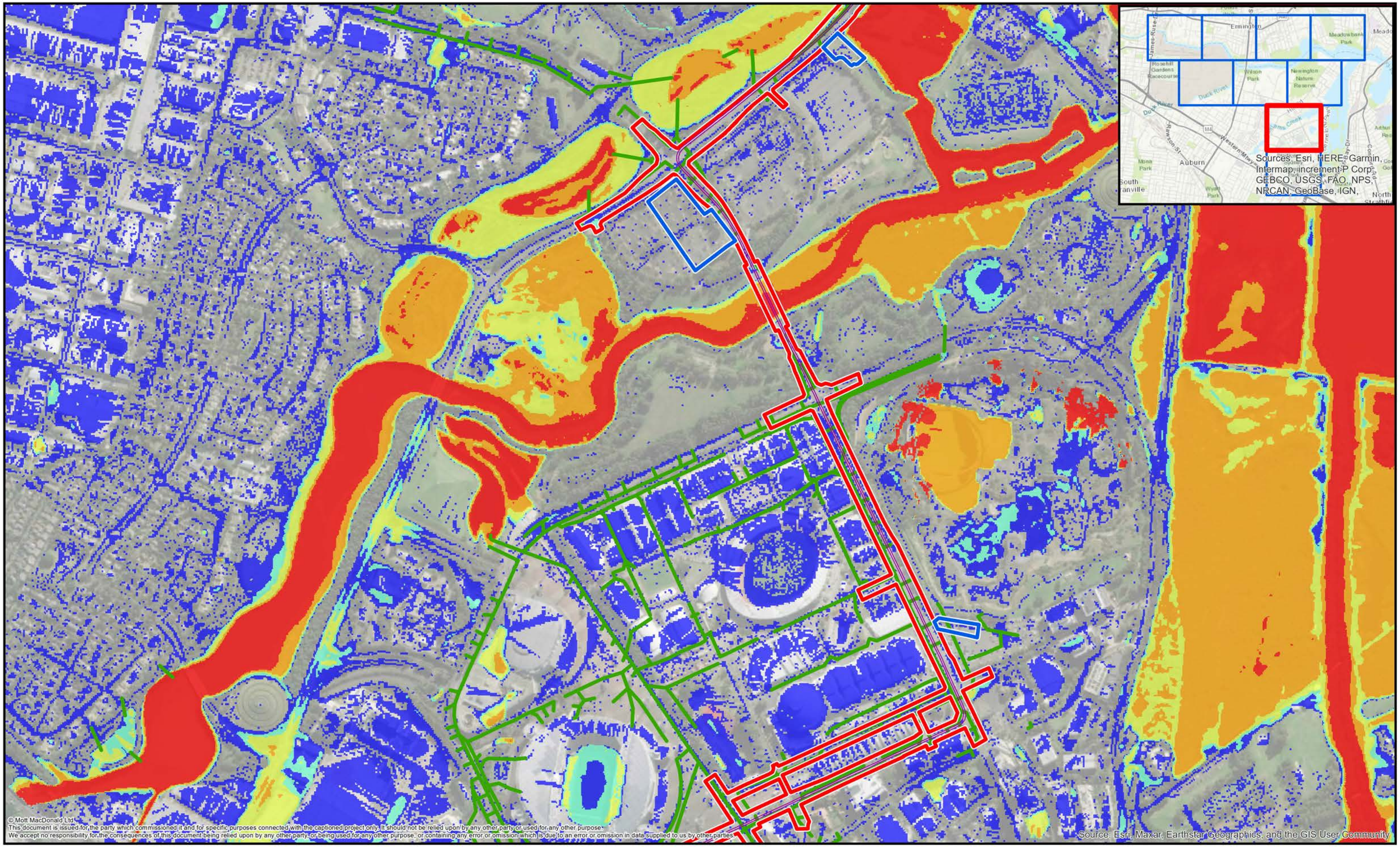
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

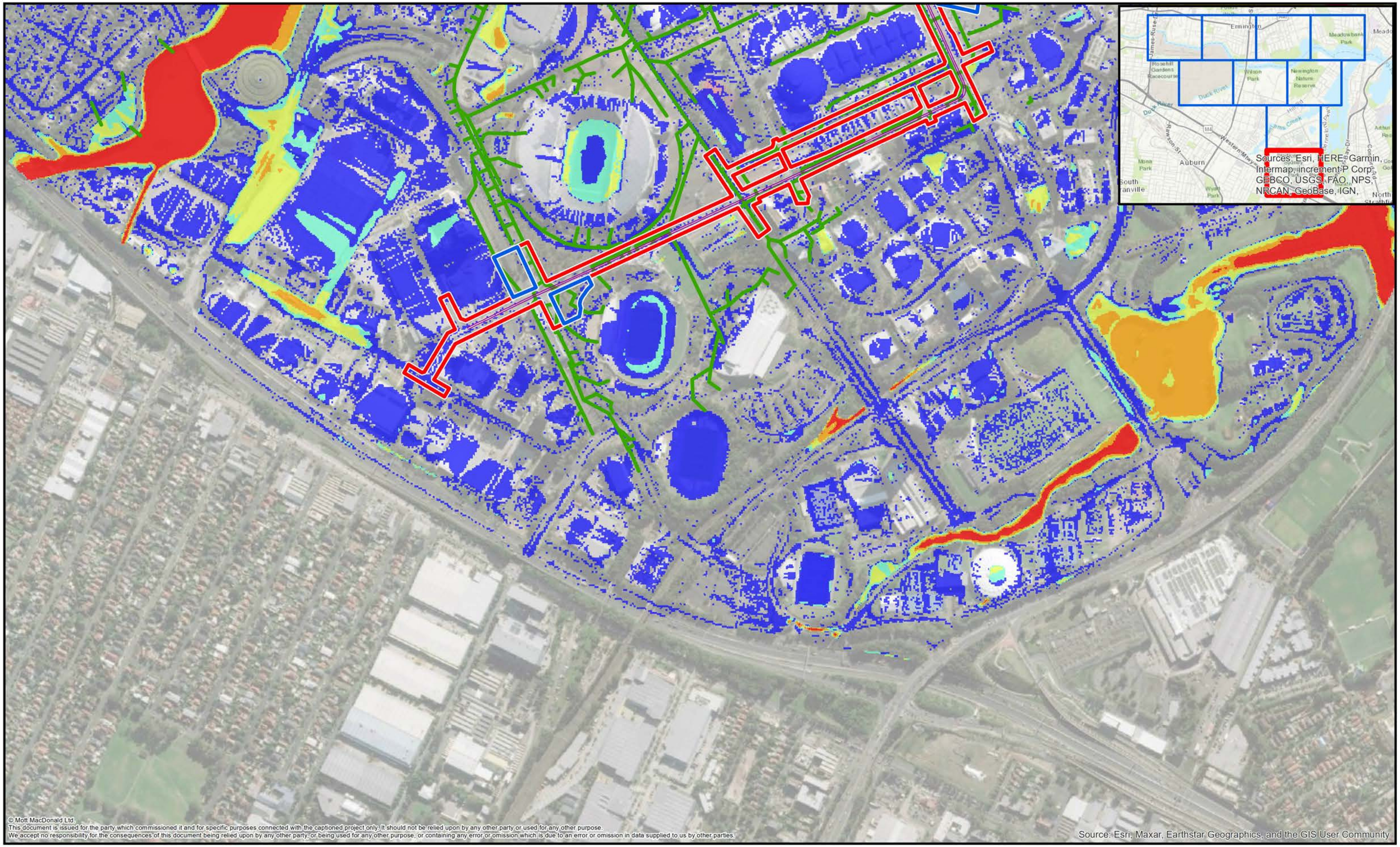
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 5% AEP
Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

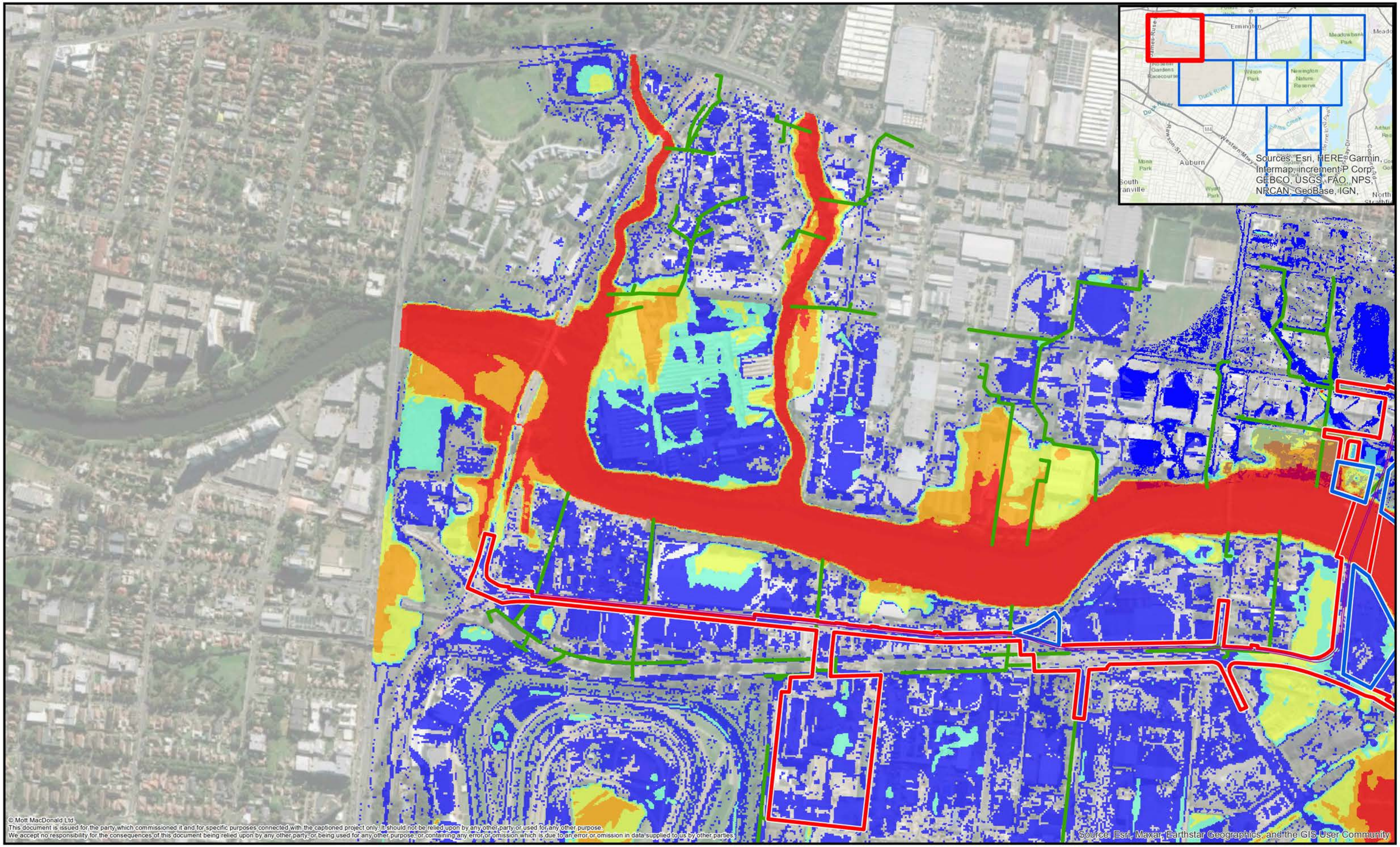
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

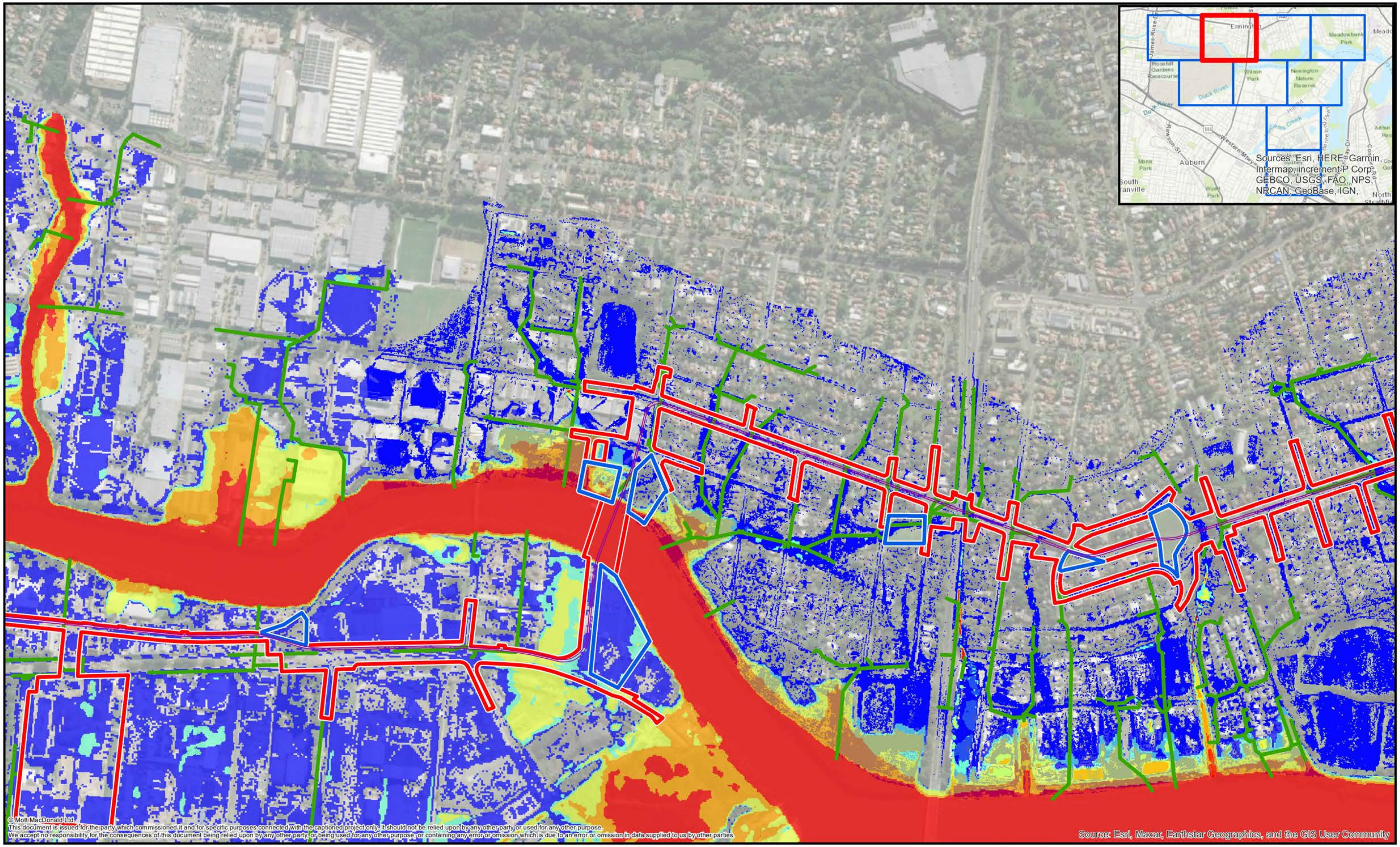
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

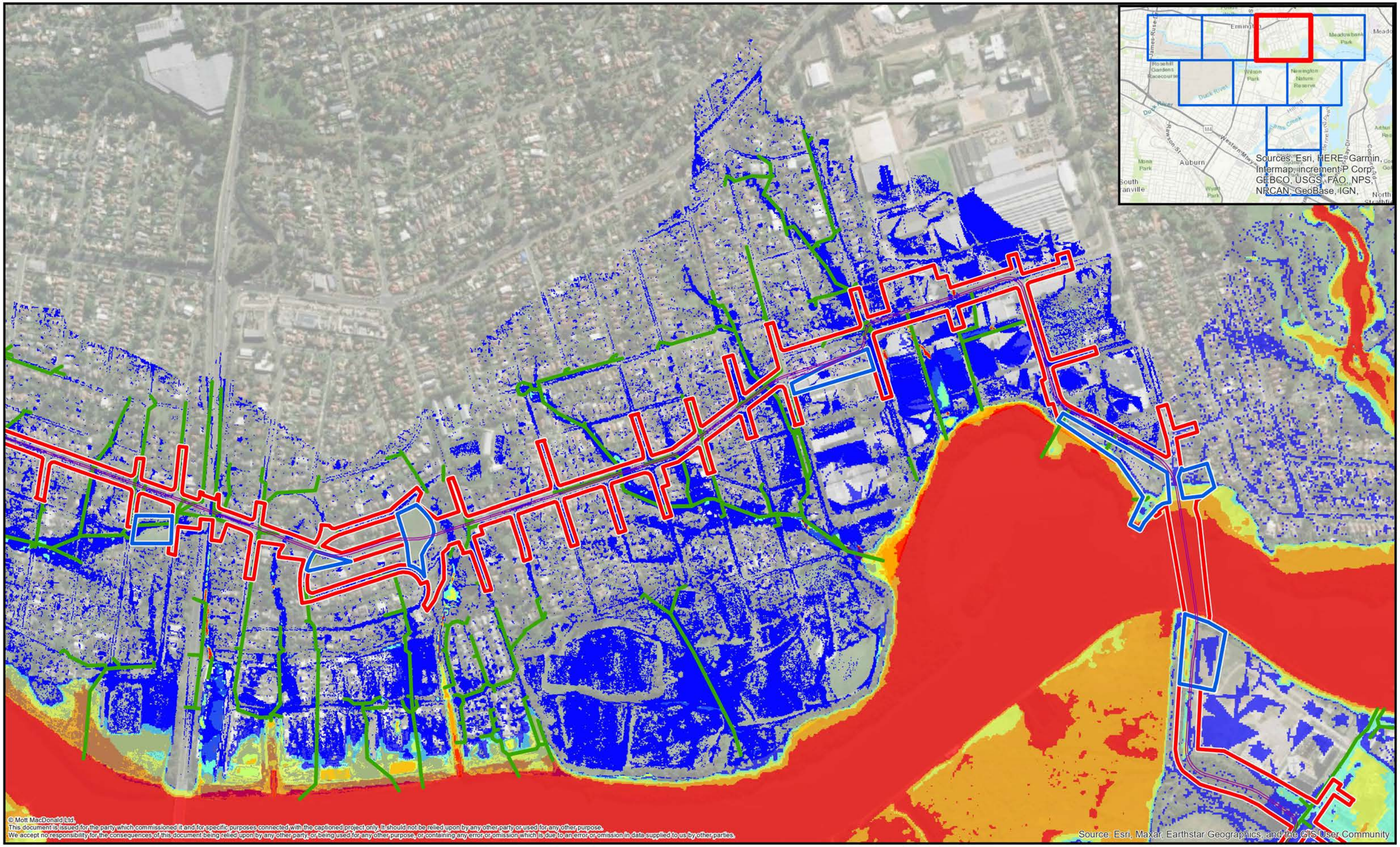
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

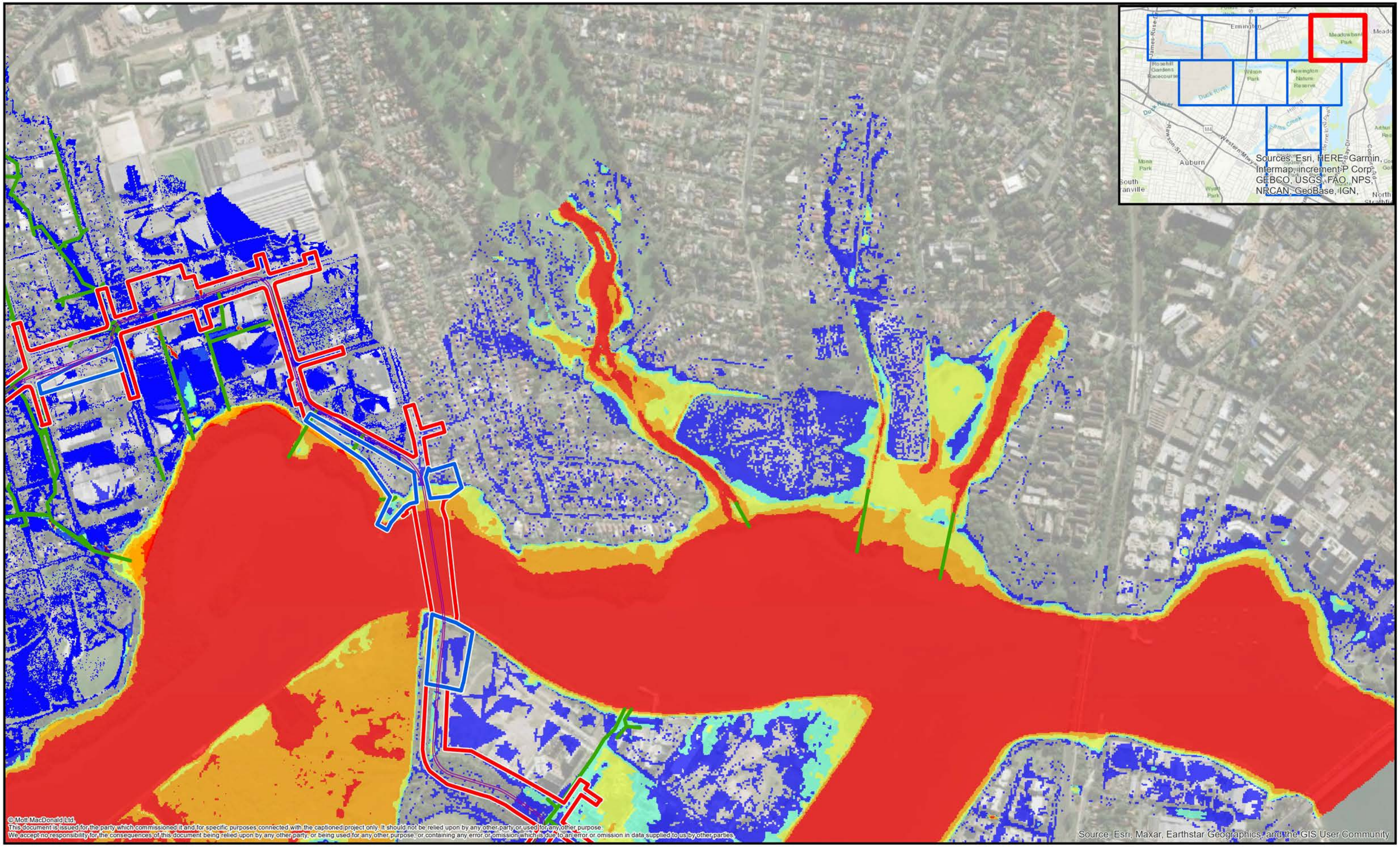
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

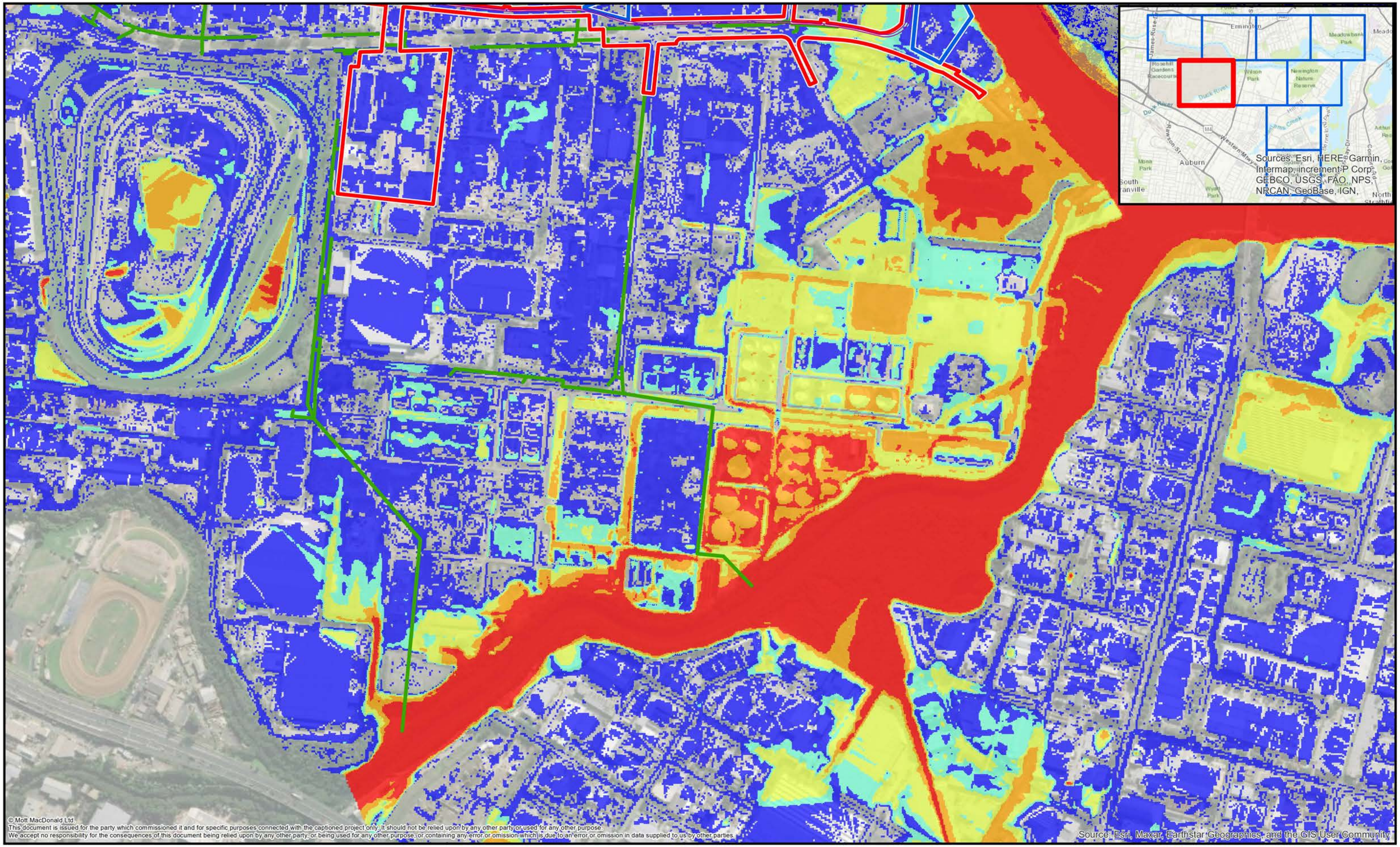
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

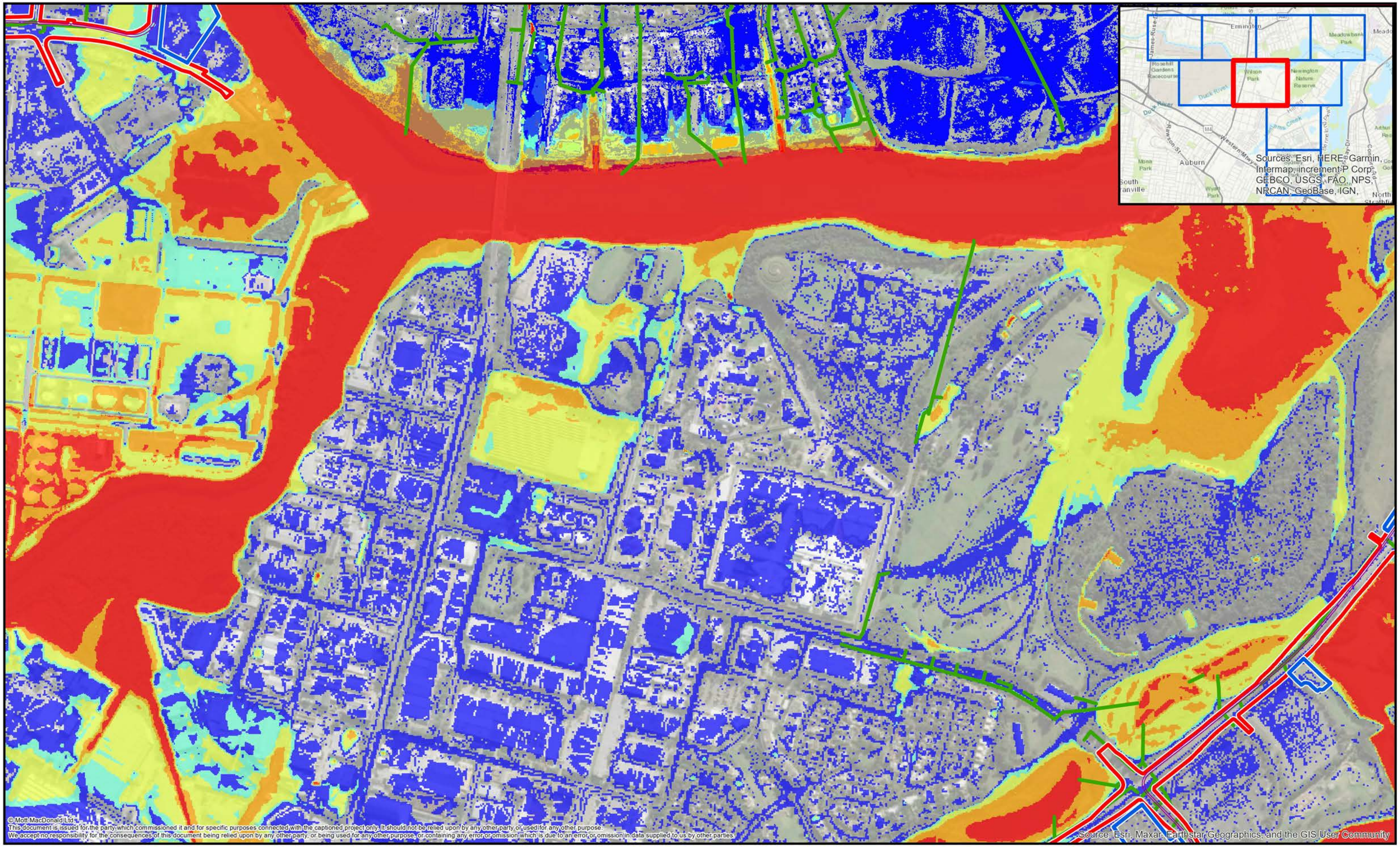
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

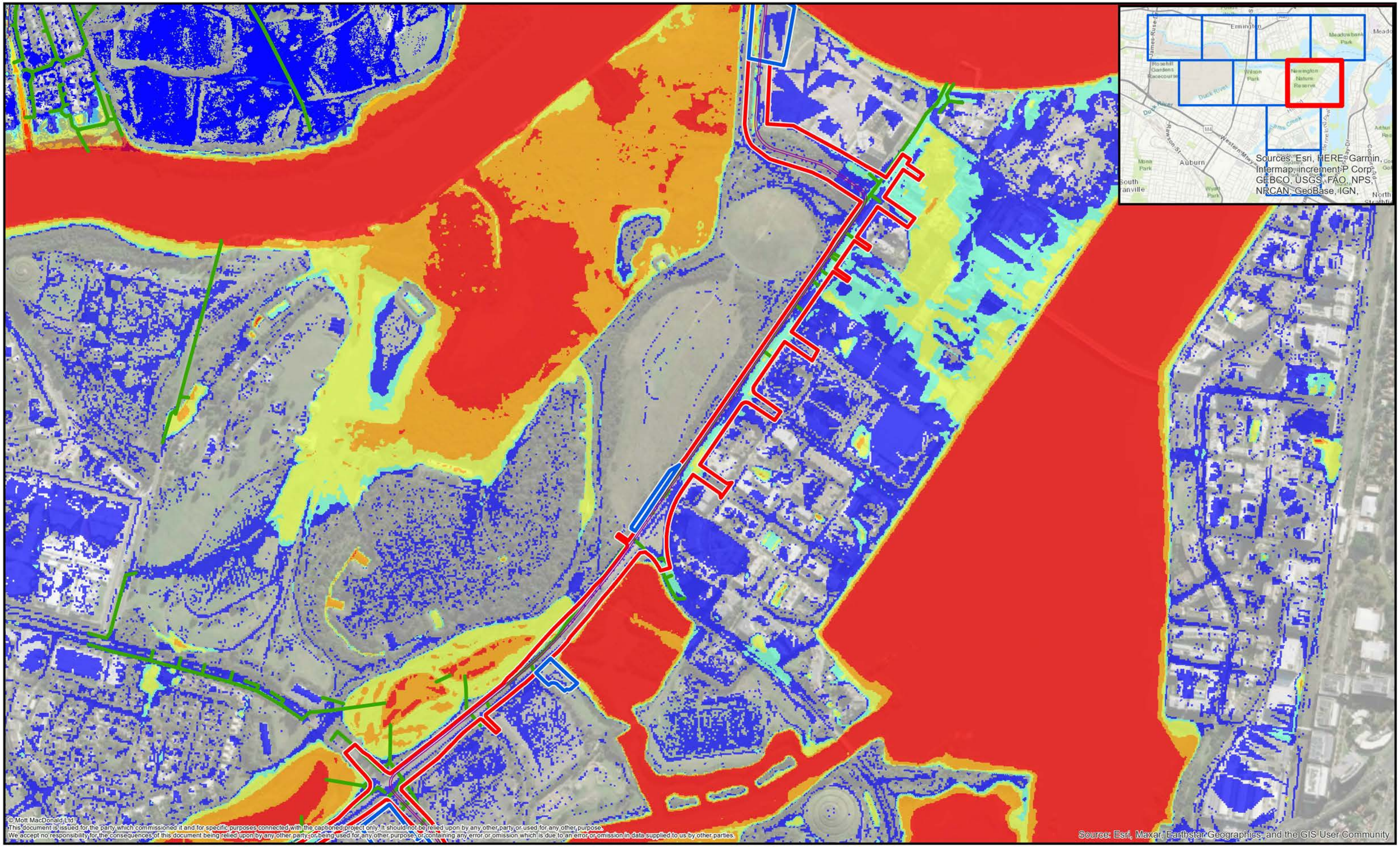
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

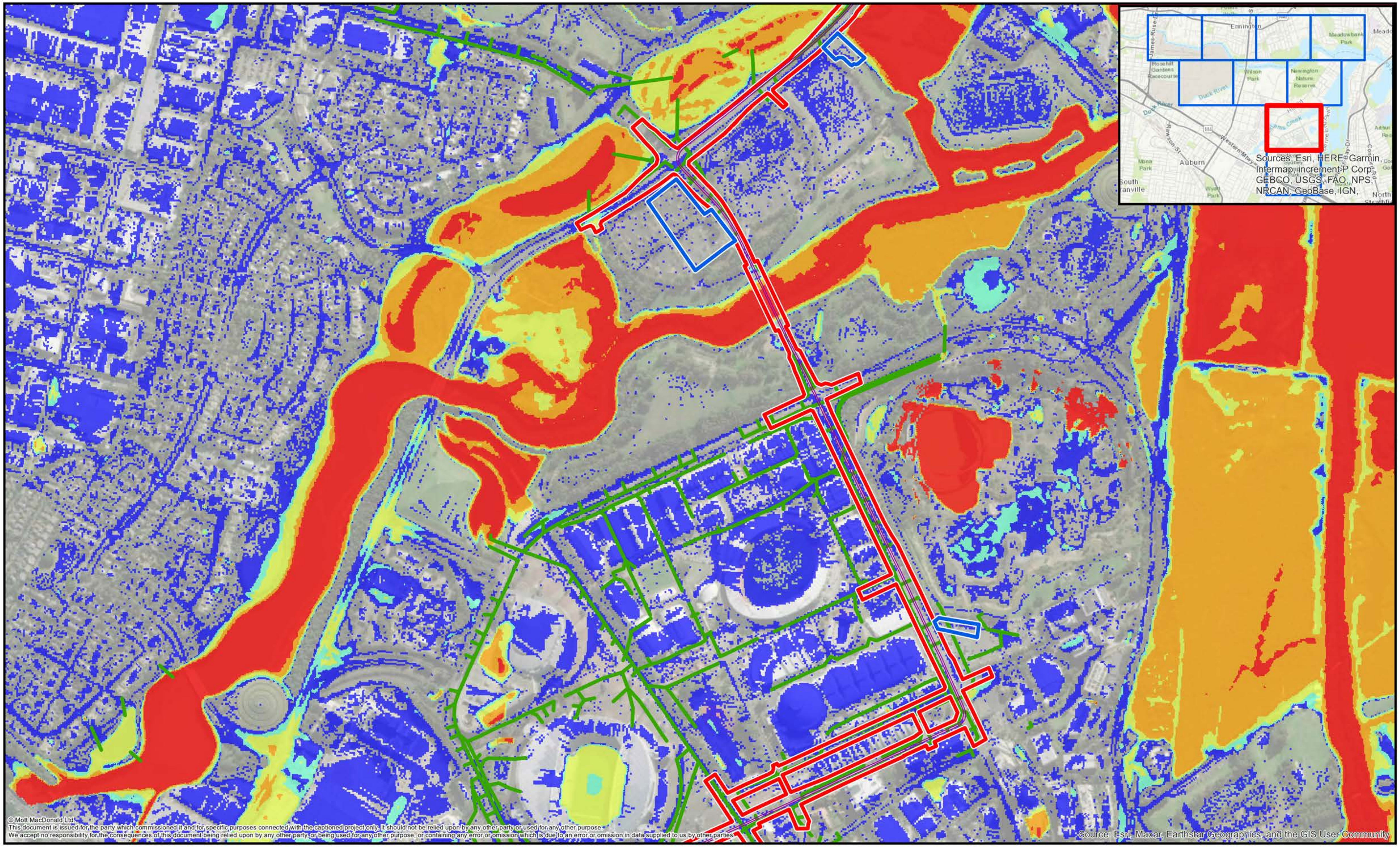
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

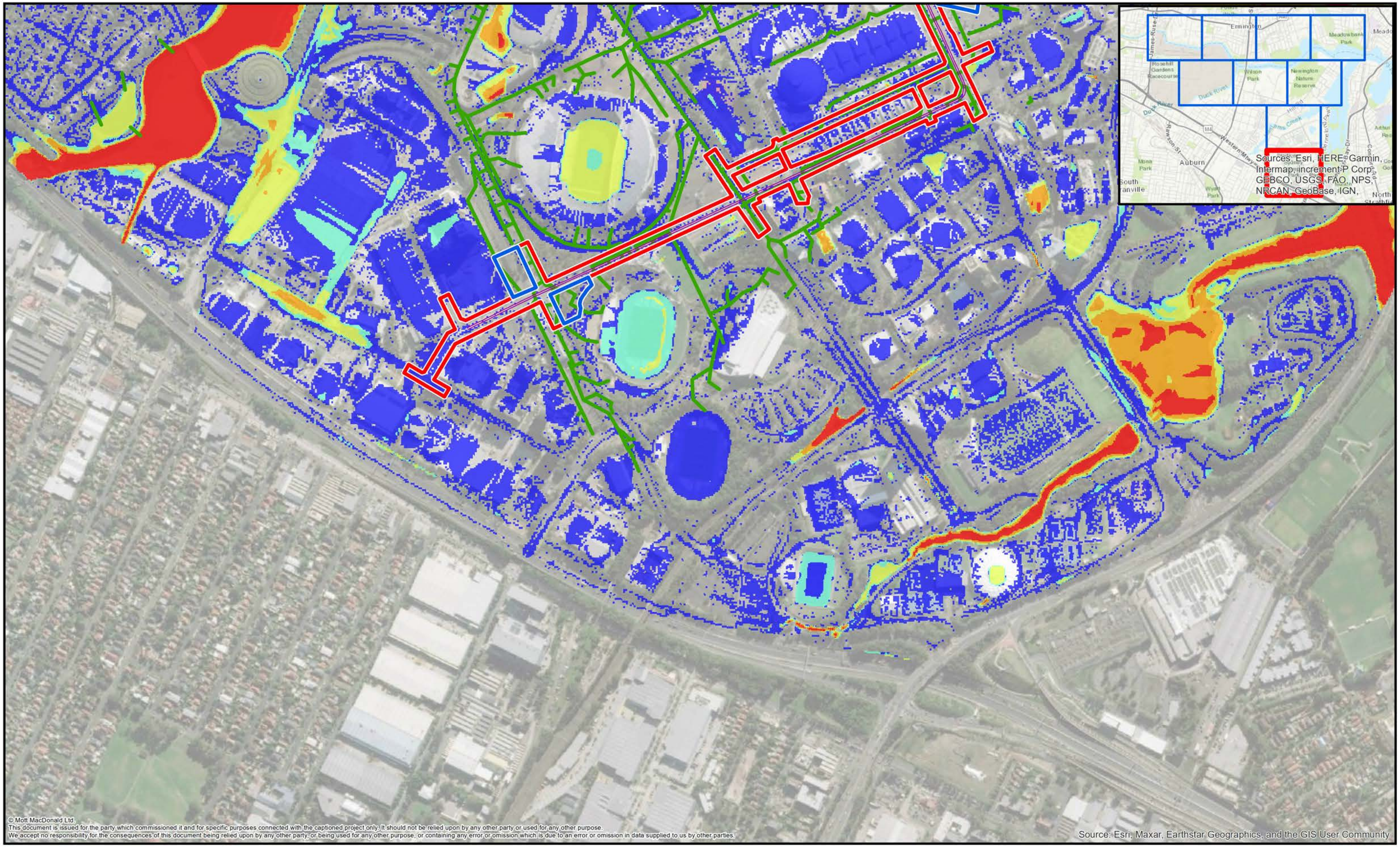
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Flood Hazard (ZAEM1)

H1

H2

H3

H4

H5

H6

Title

Existing Conditions 1%AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

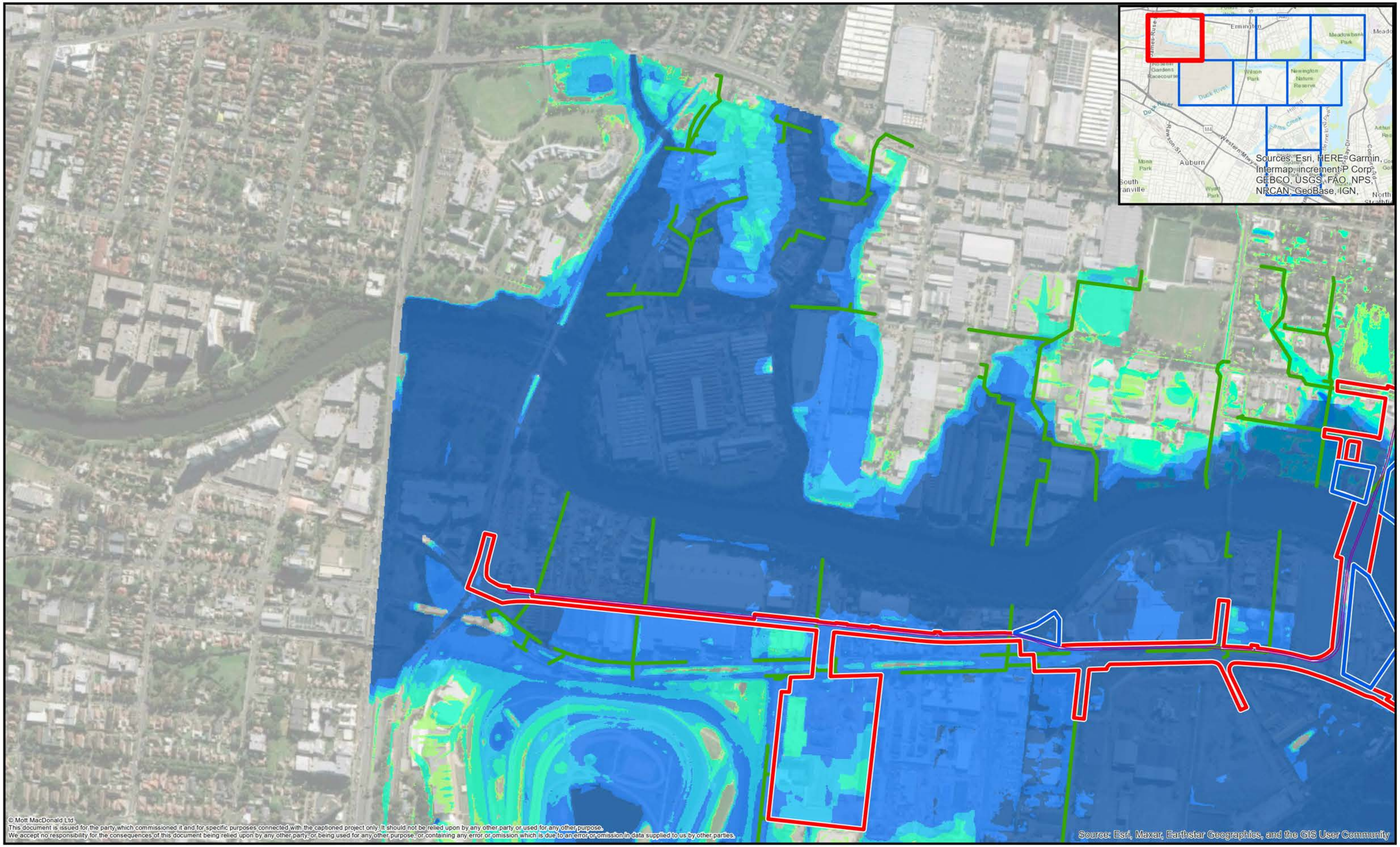
MOTT MACDONALD

Map Number

Sheet No 9 of 9

N

Appendix C2 - Flood Modelling Figures - Design Conditions



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

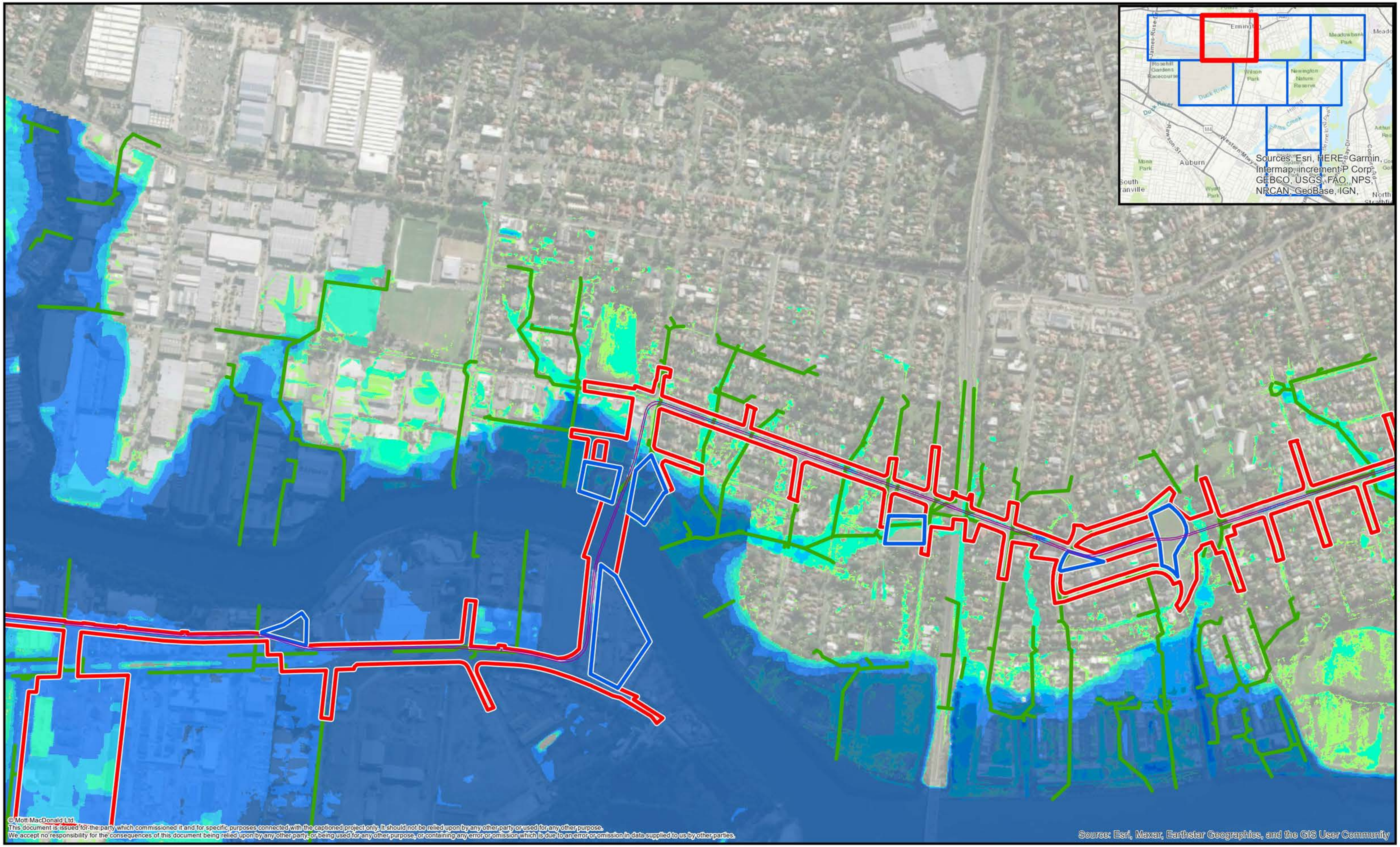
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

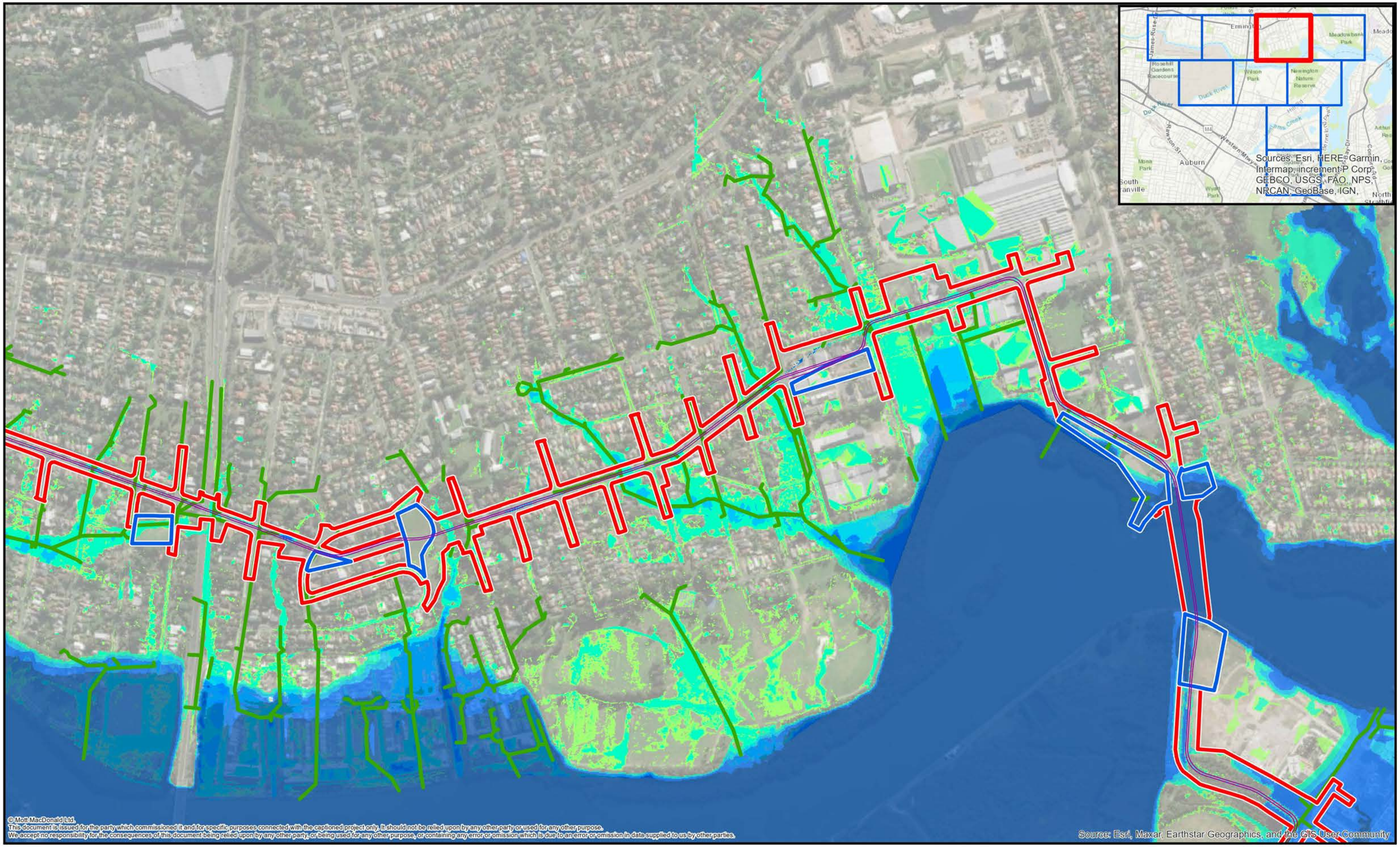
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

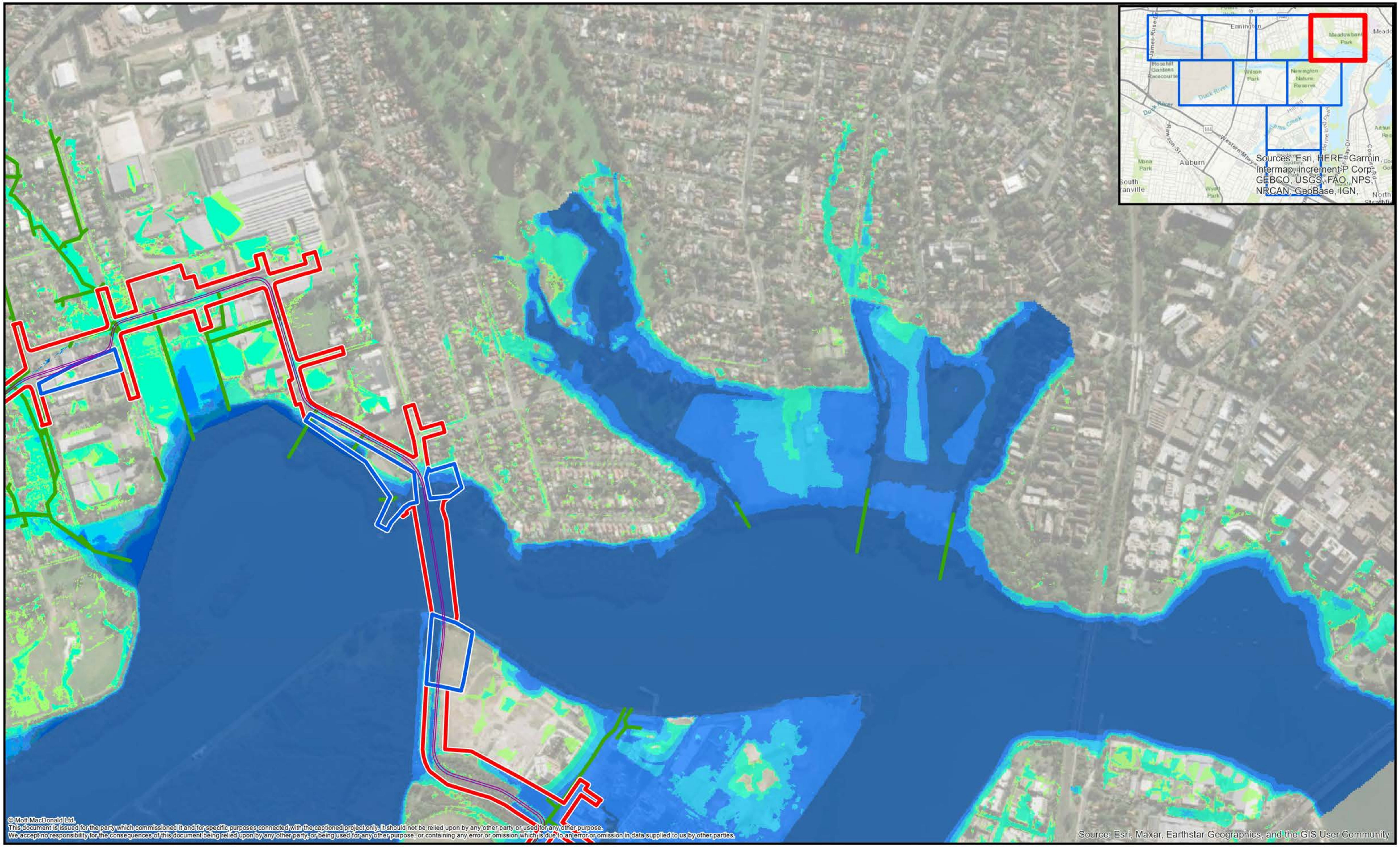
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

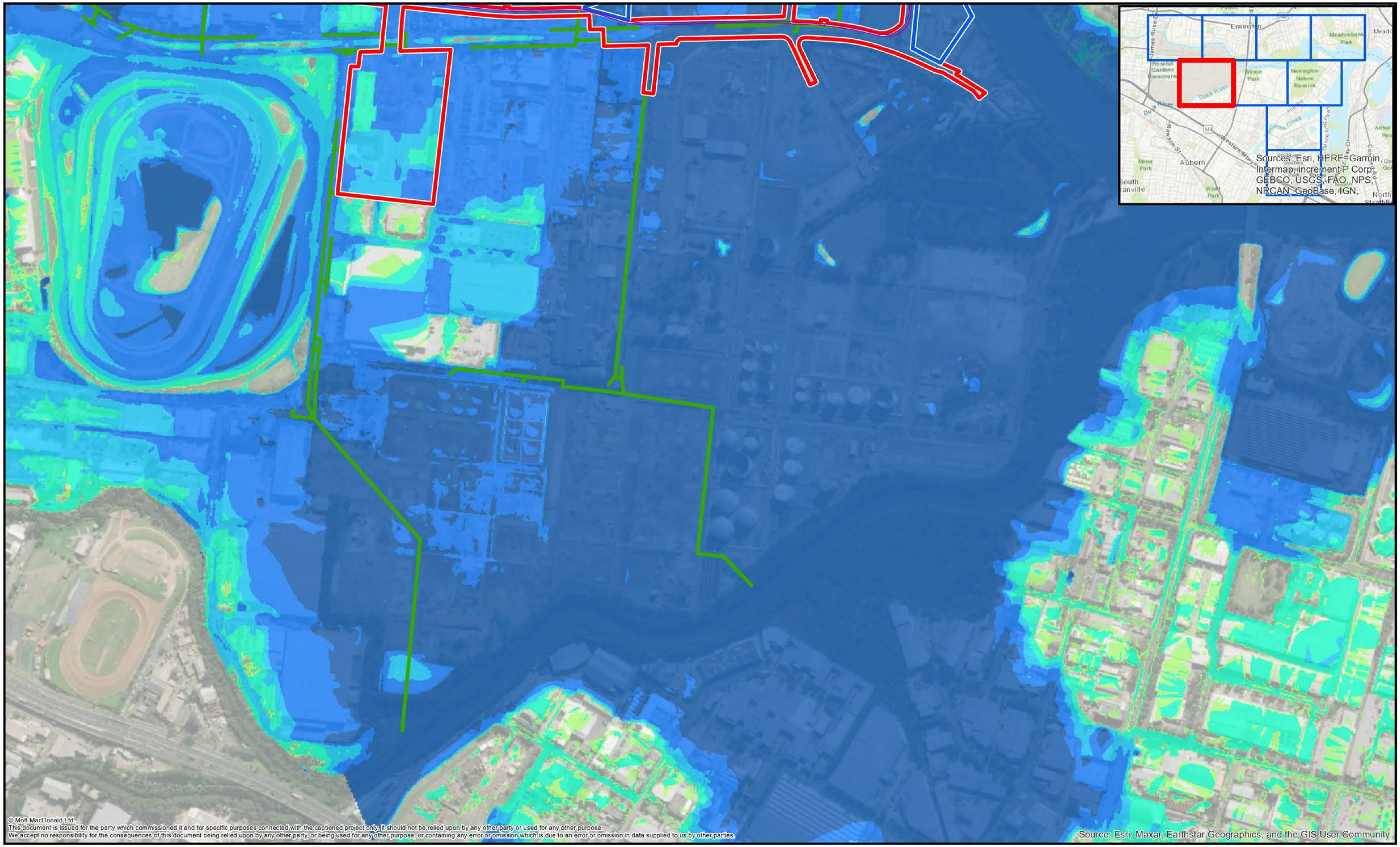
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

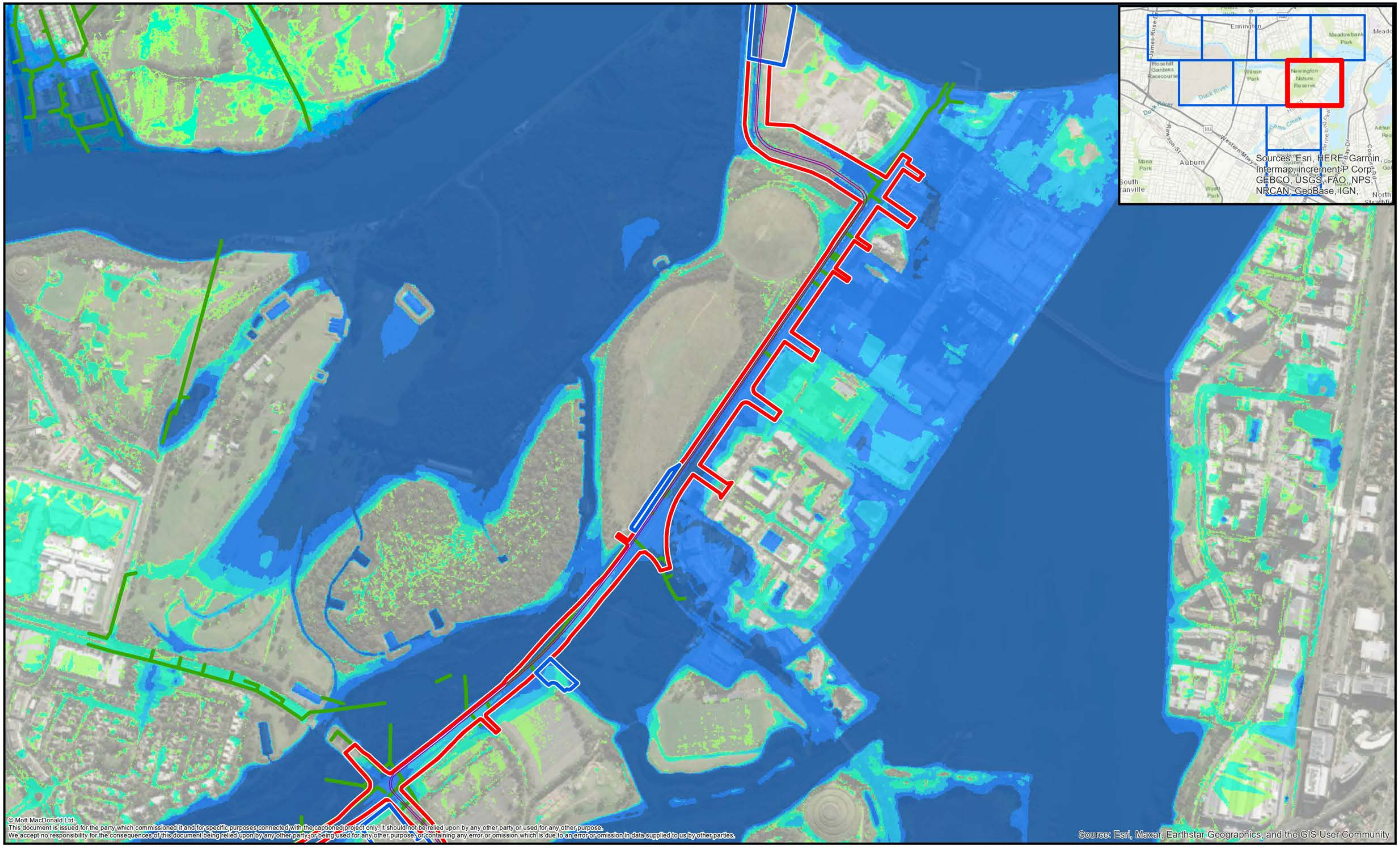
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

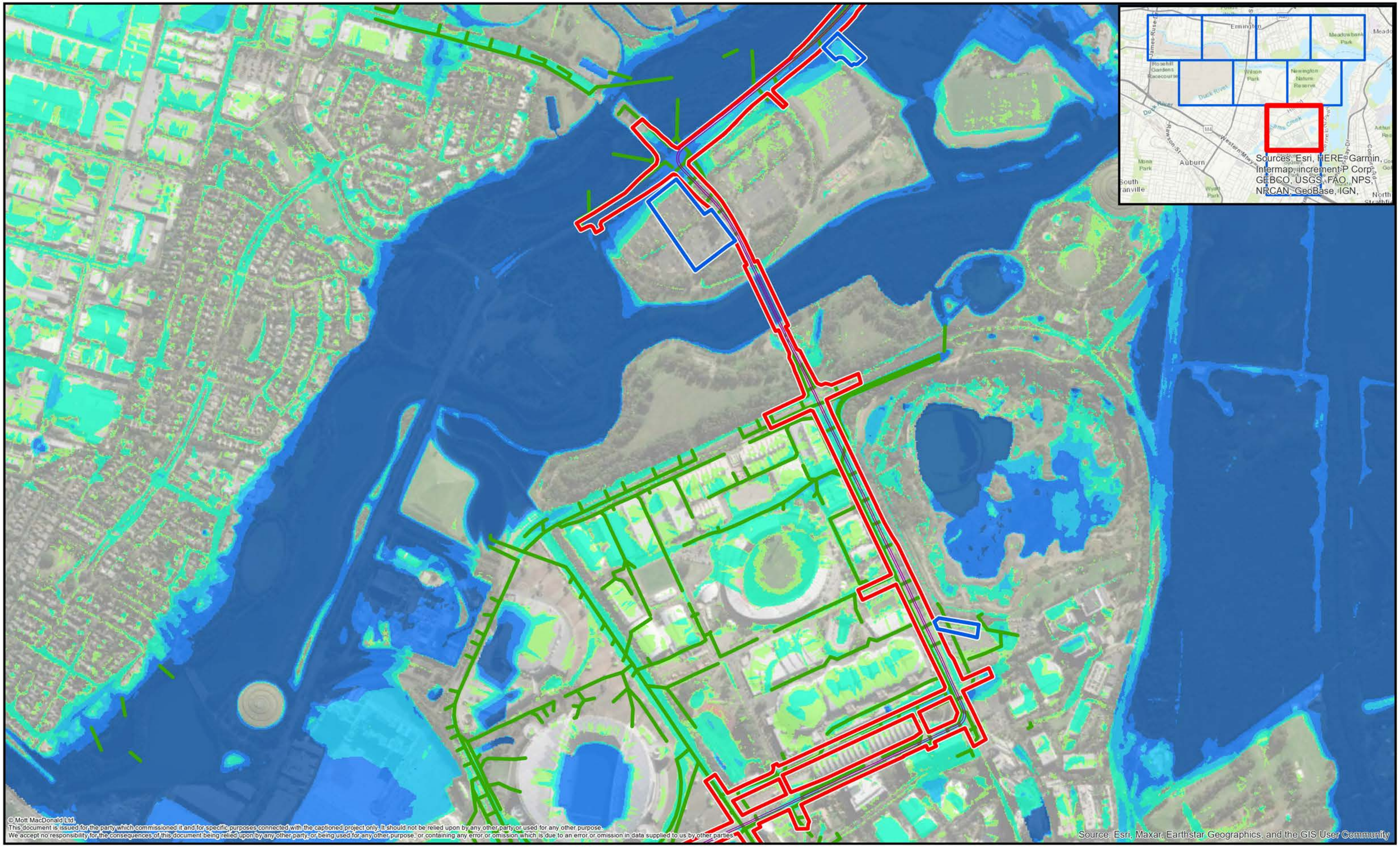
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

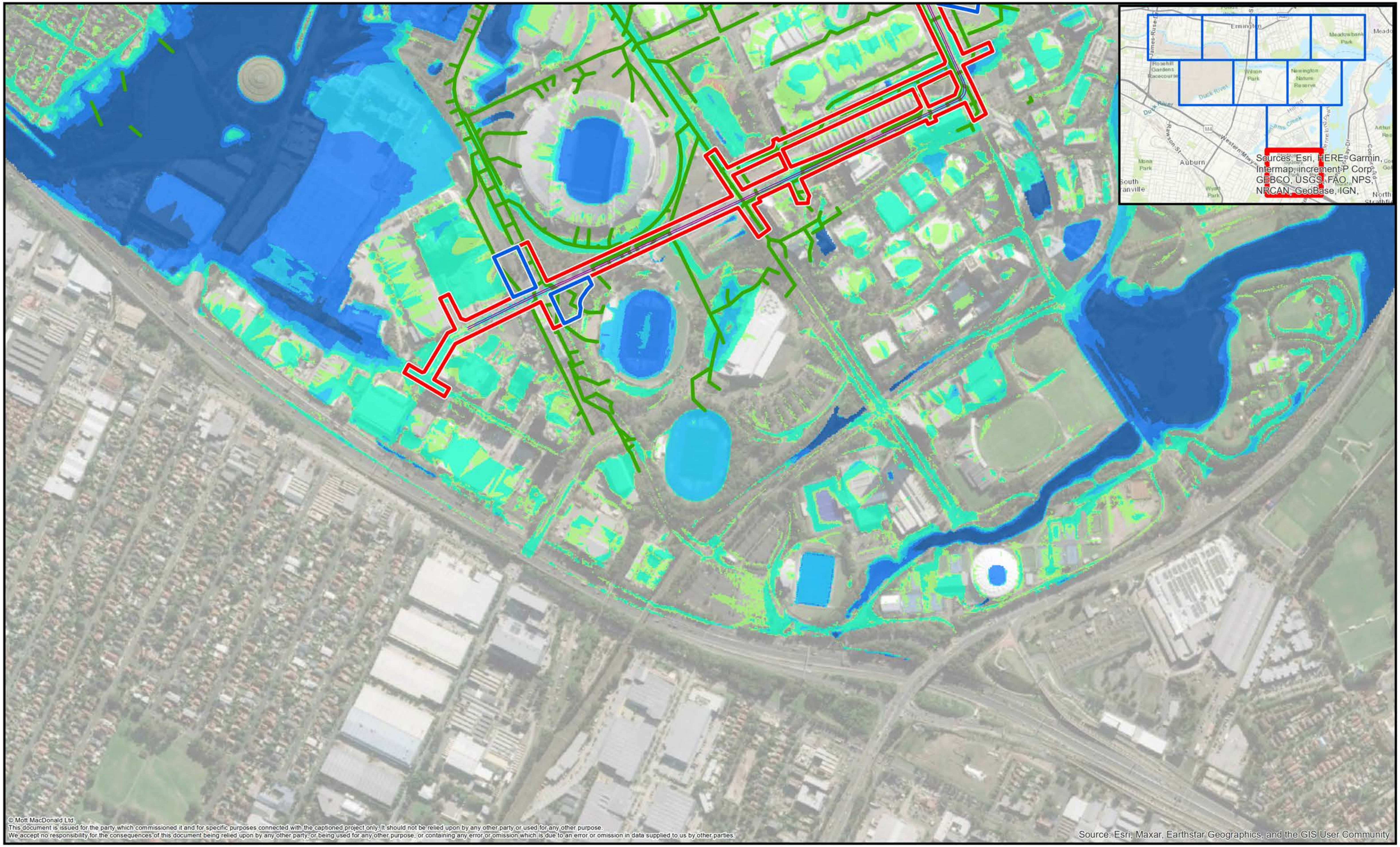
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions PMF Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

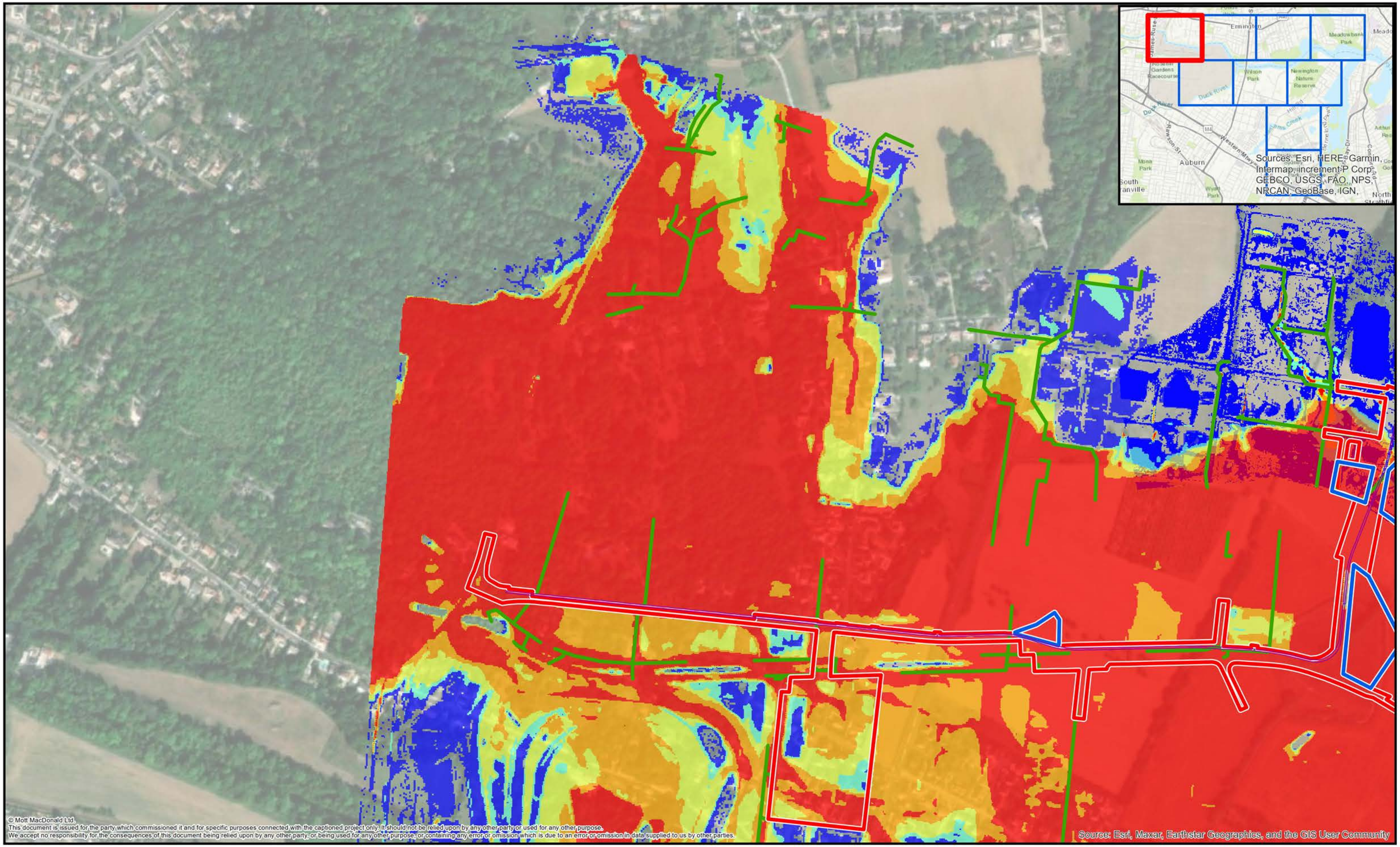
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

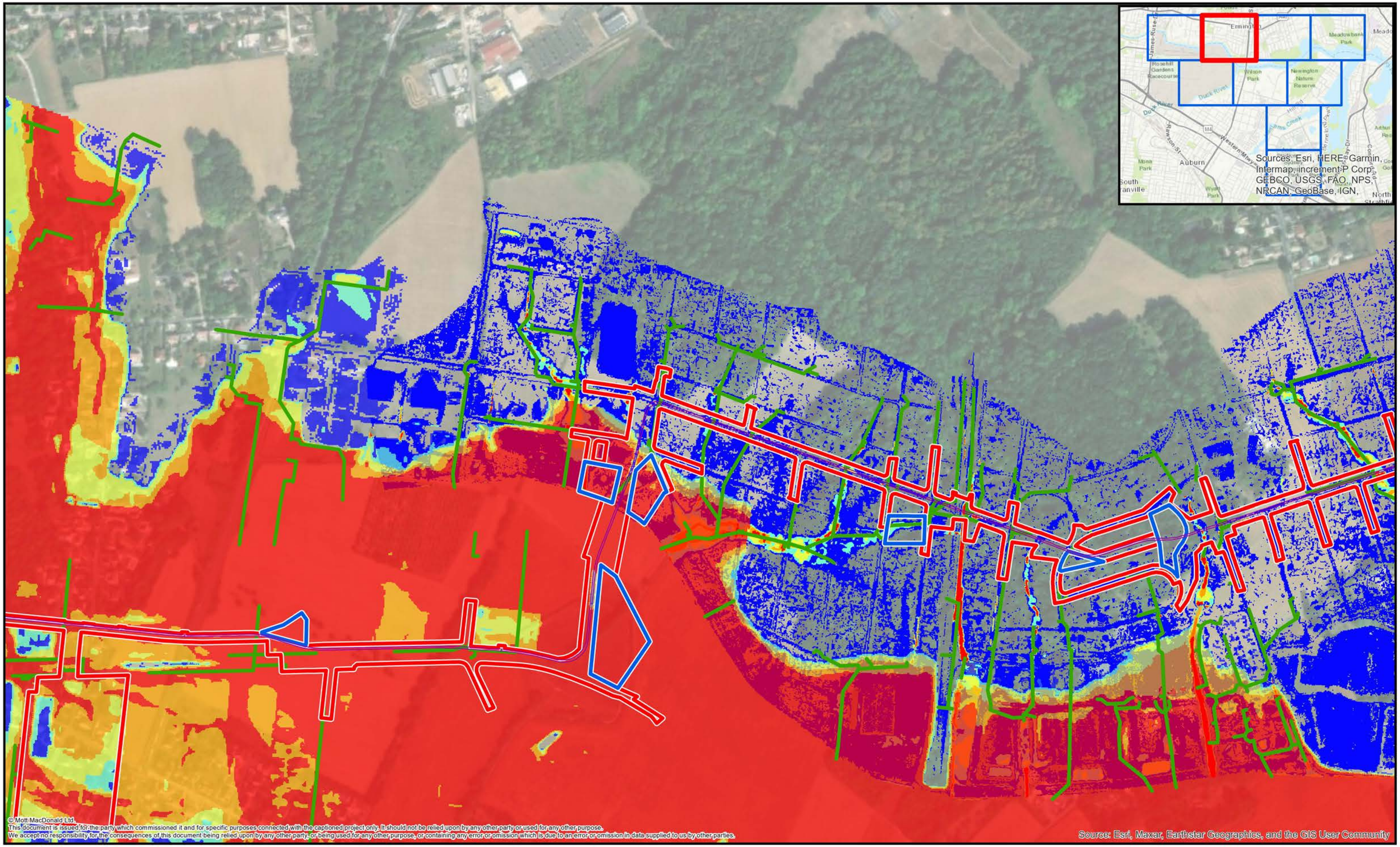
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Flood Hazard (ZAEM1)

H1

H2

H3

H4

H5

H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

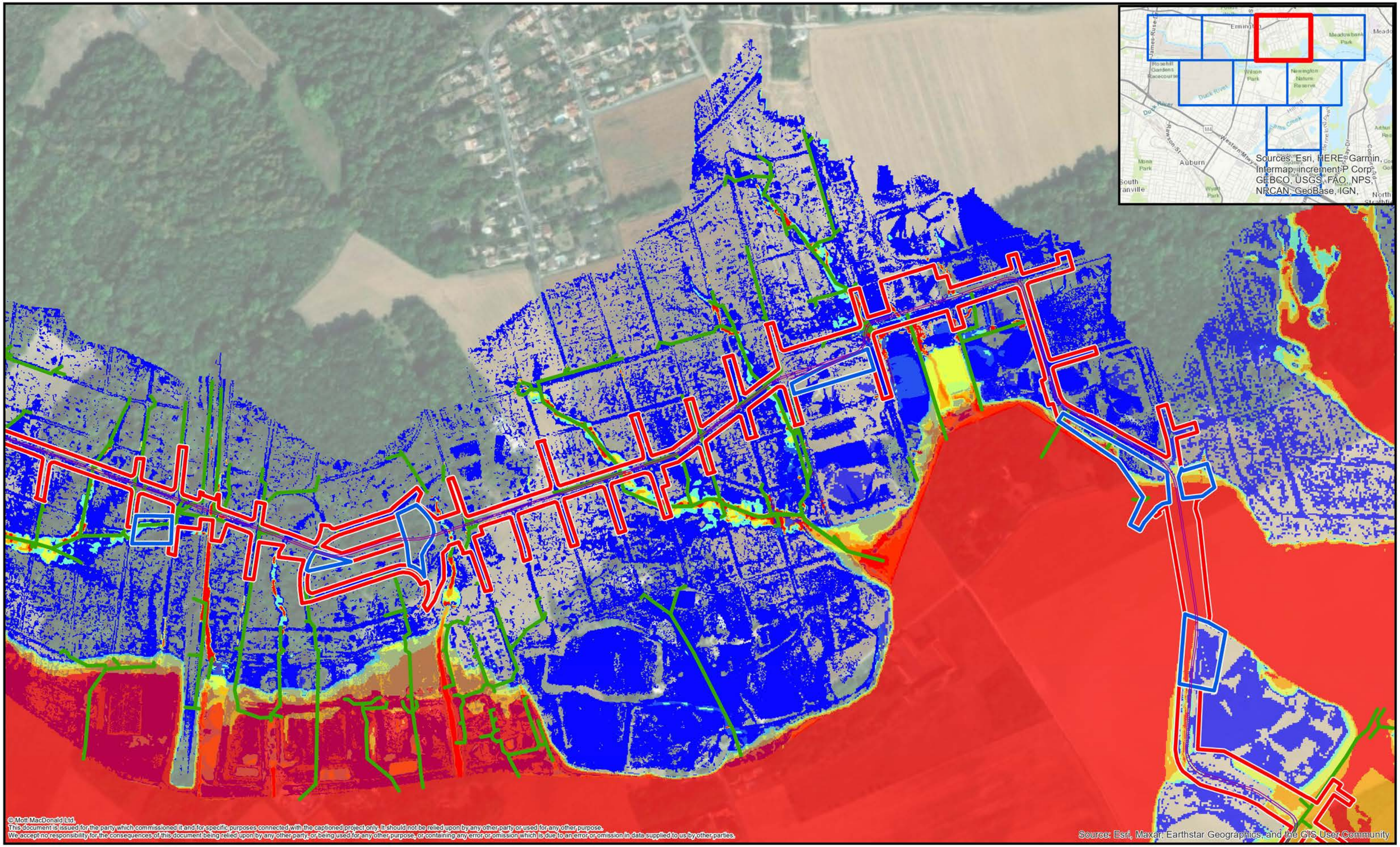
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

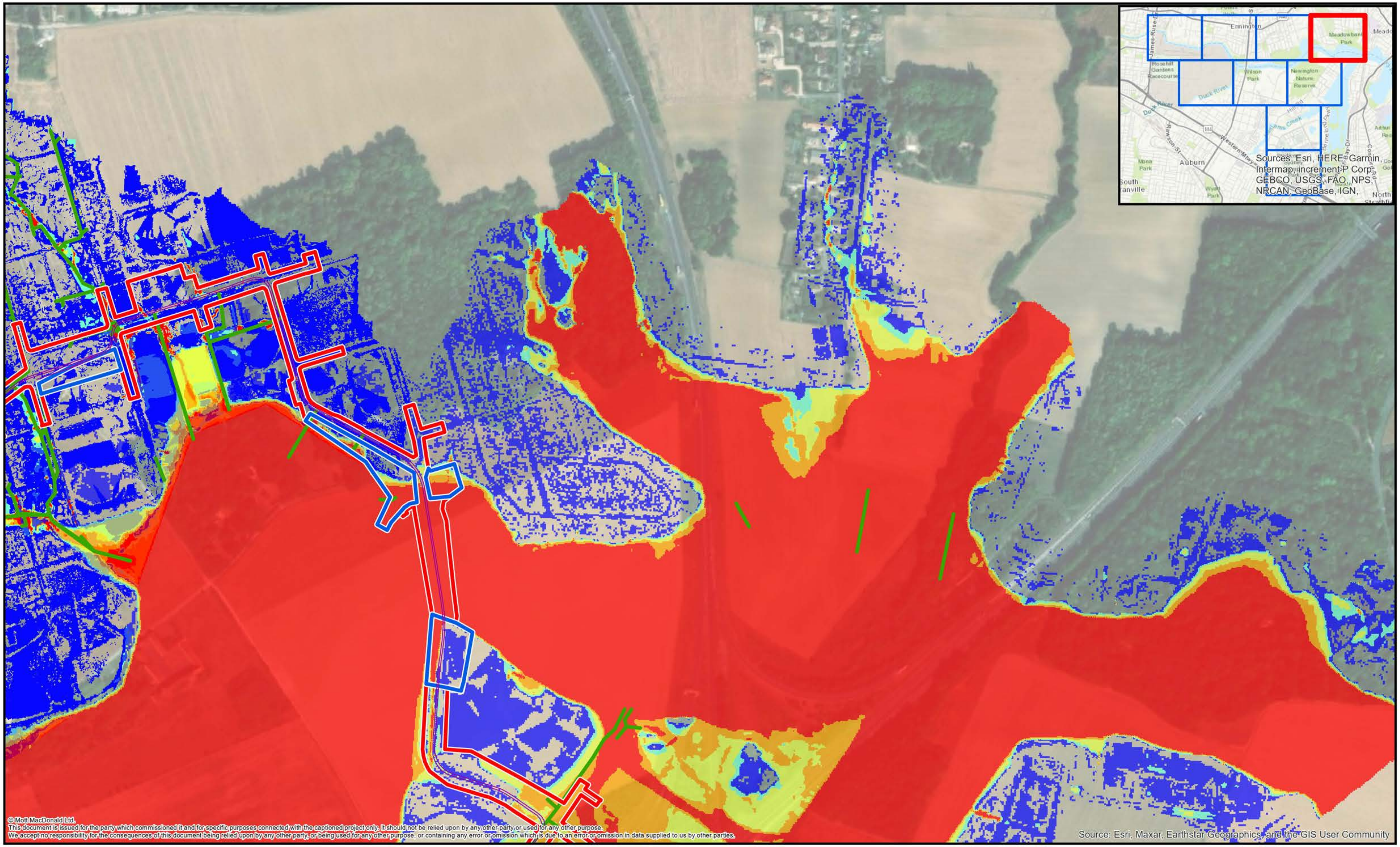
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Flood Hazard (ZAEM1)

H1

H2

H3

H4

H5

H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

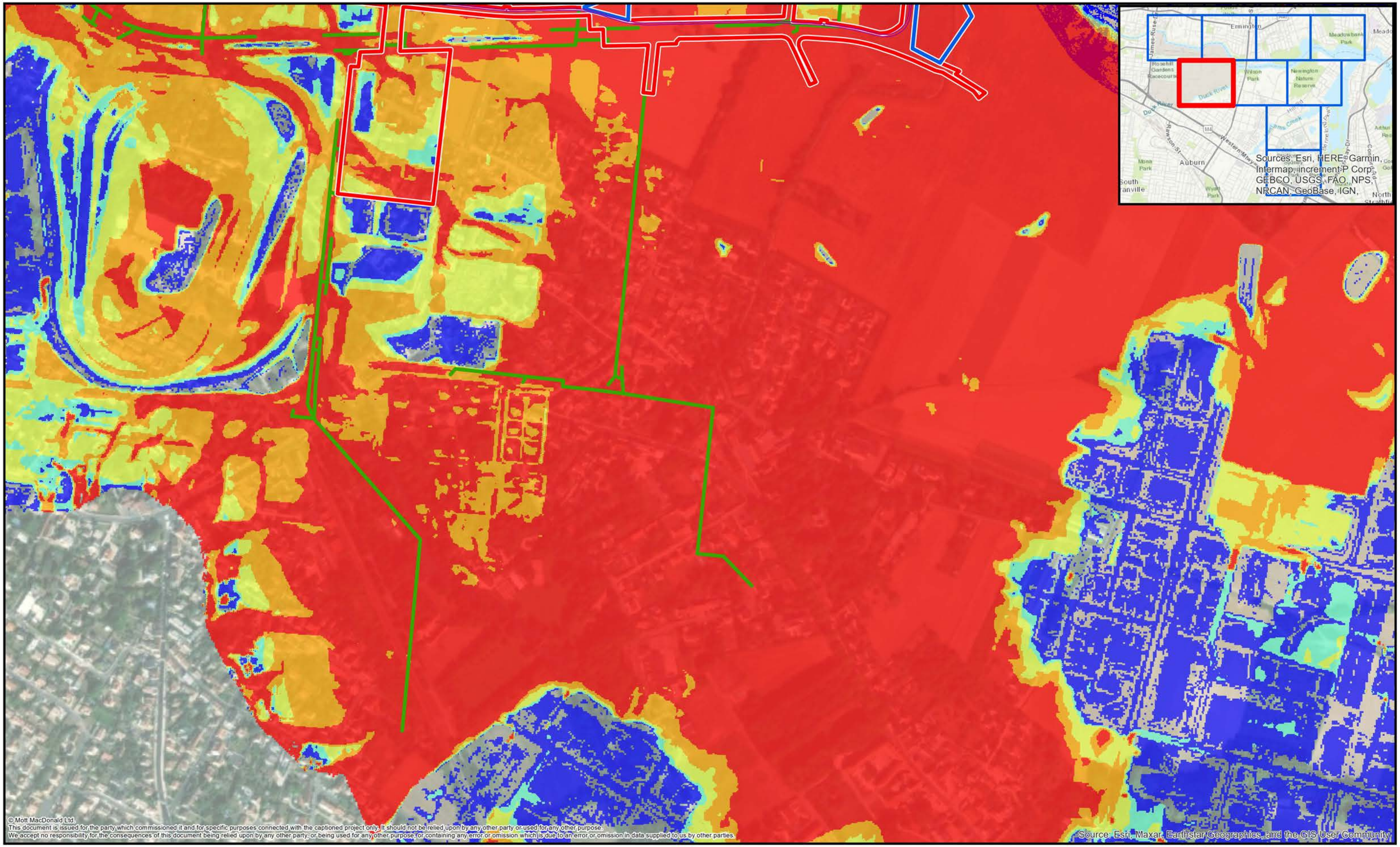
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

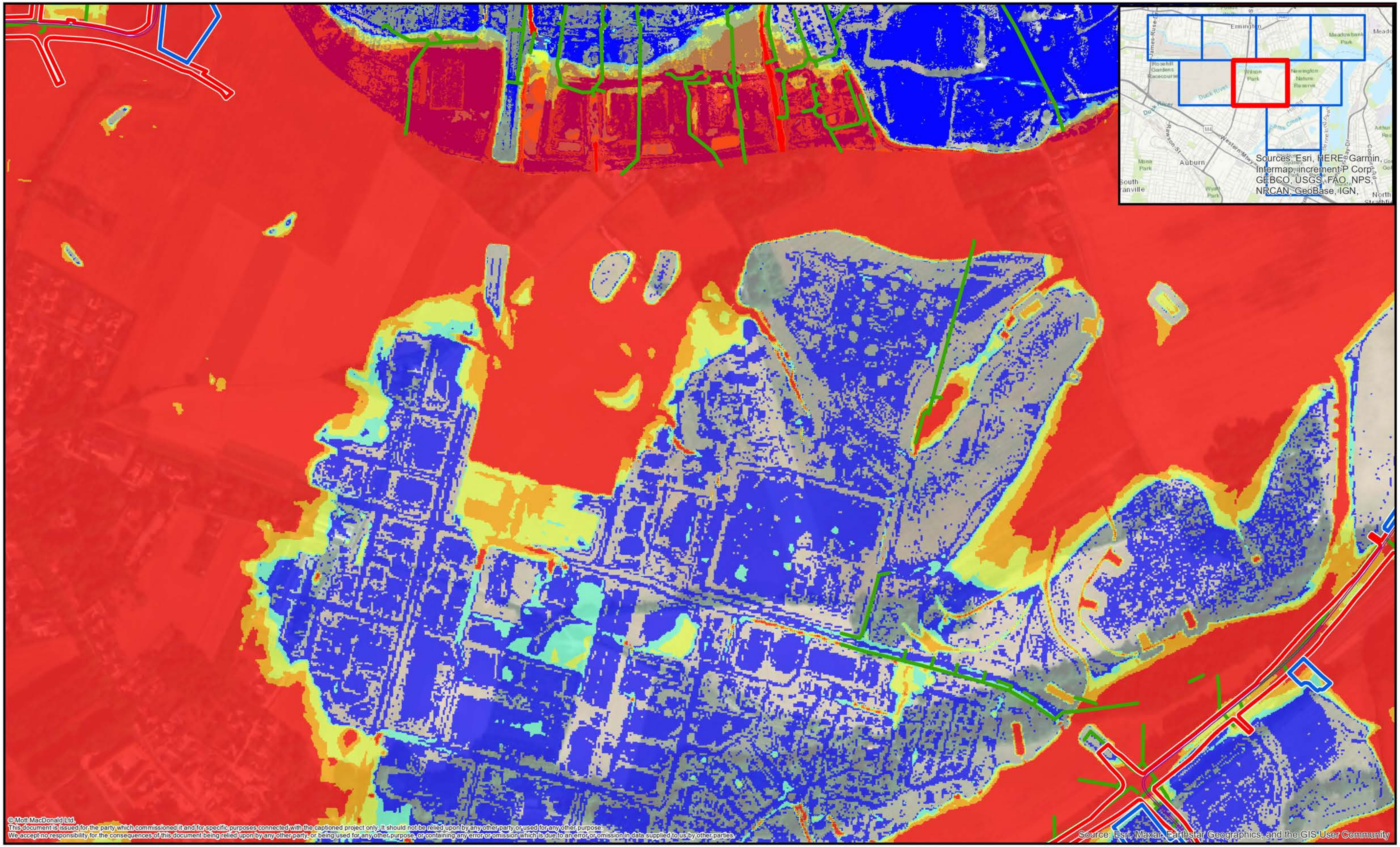
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

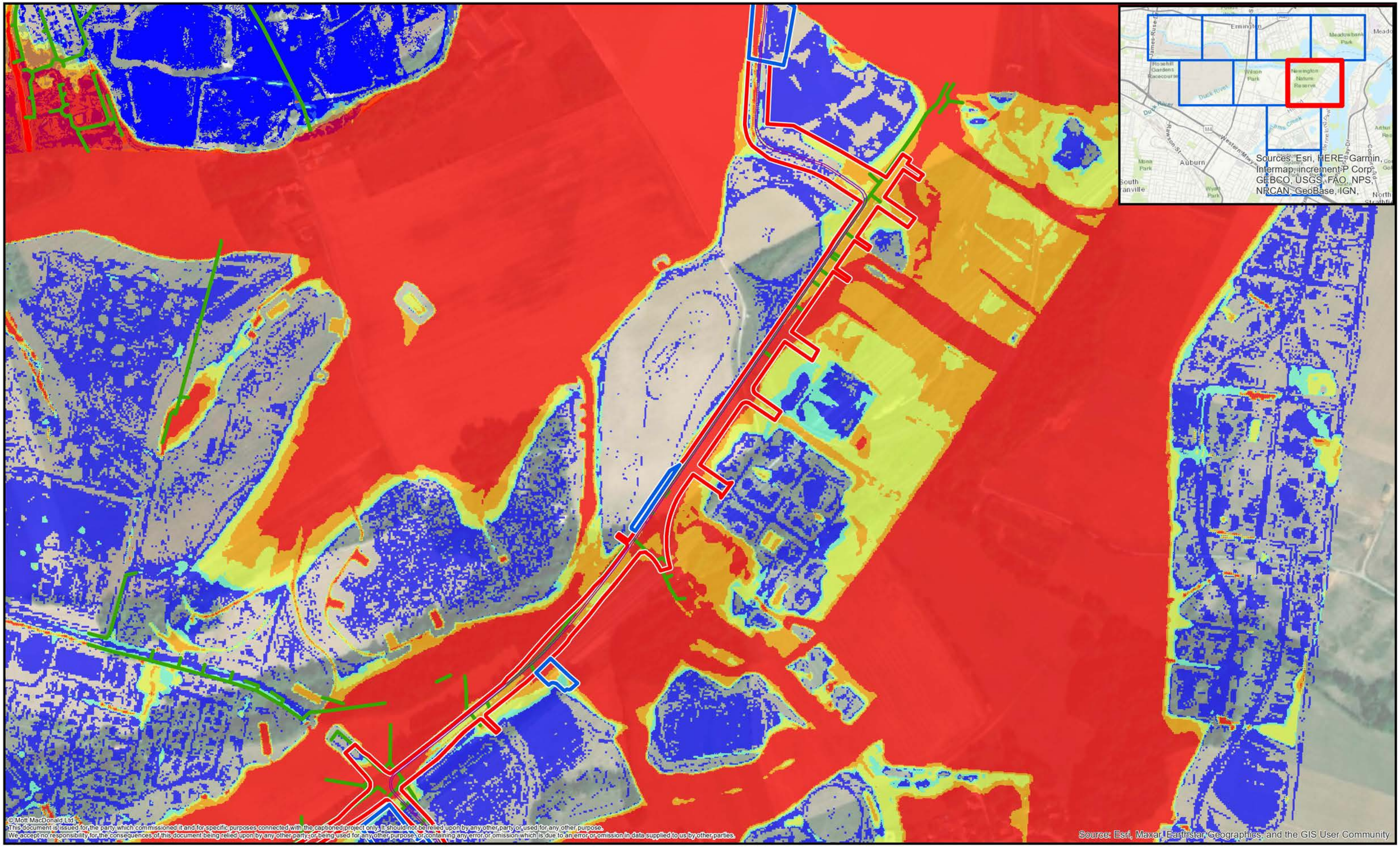
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

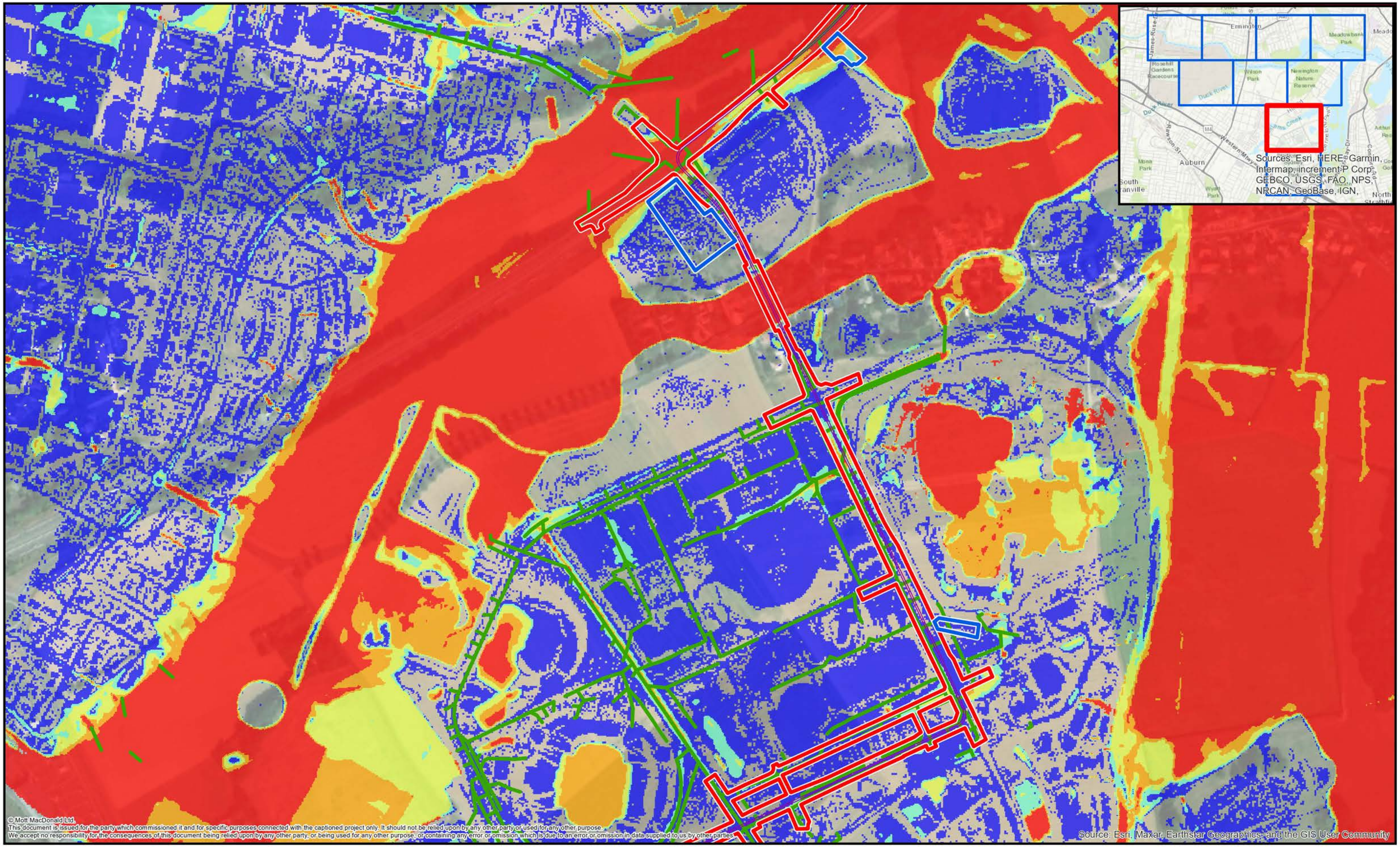
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

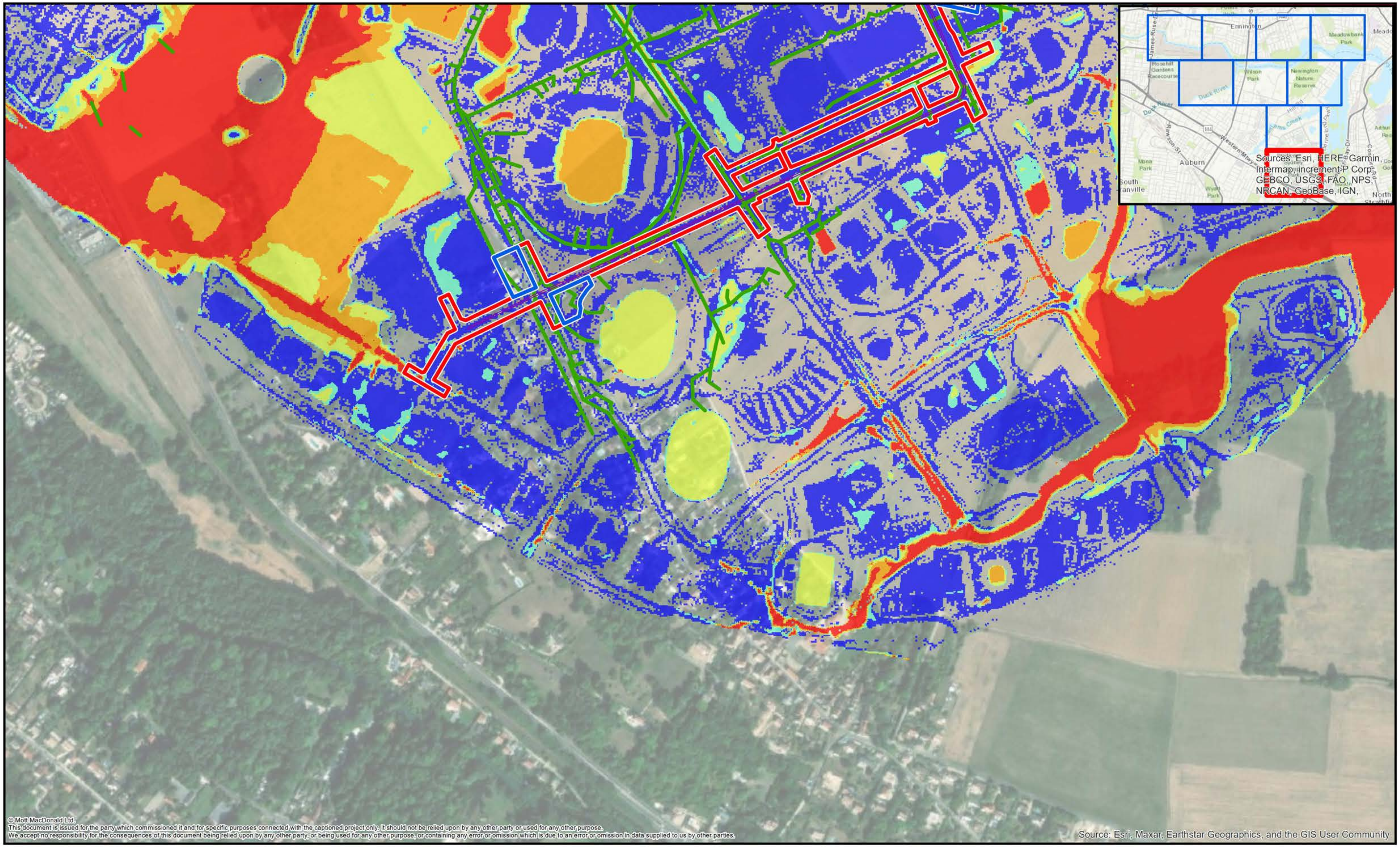
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions PMF Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

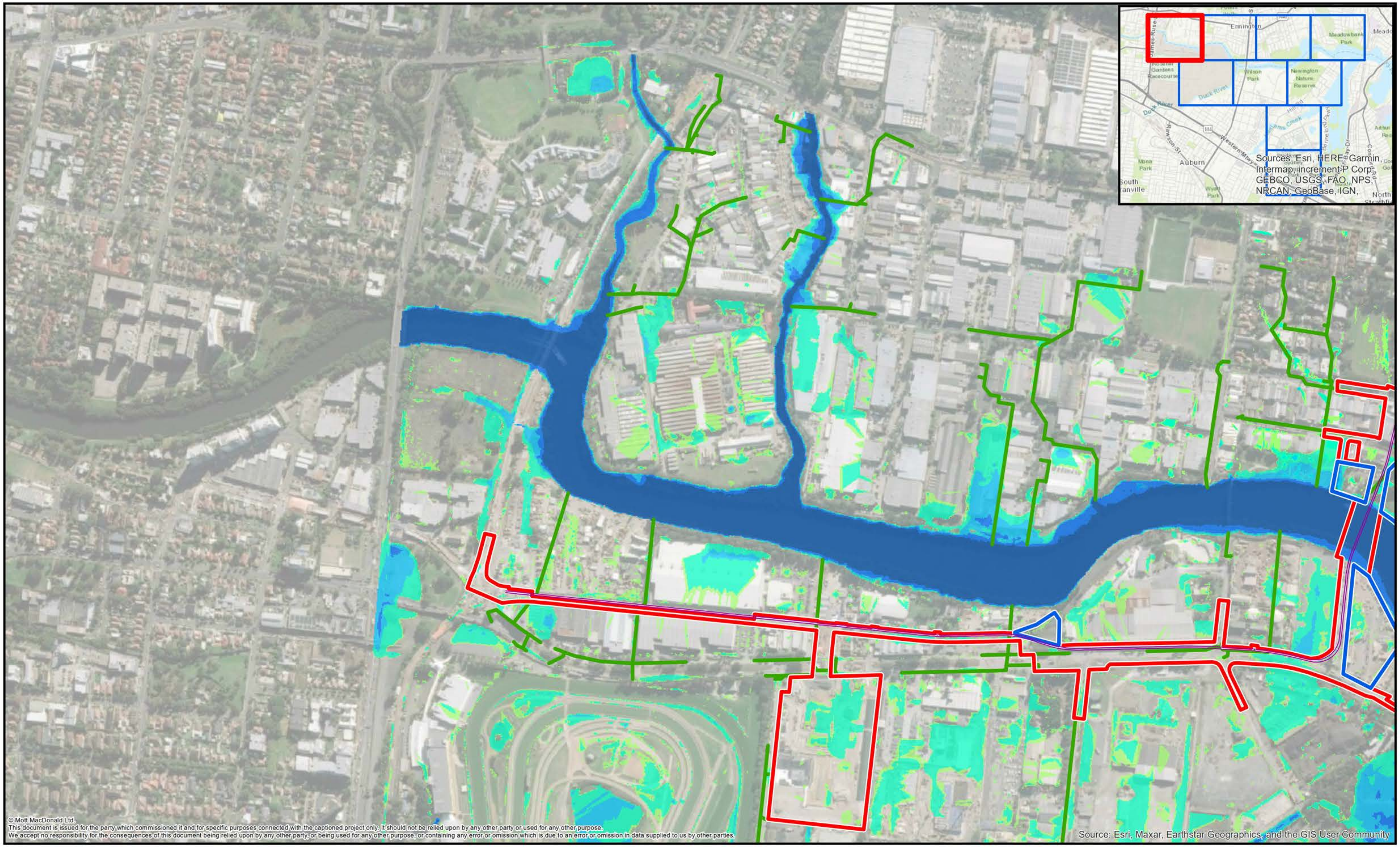
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

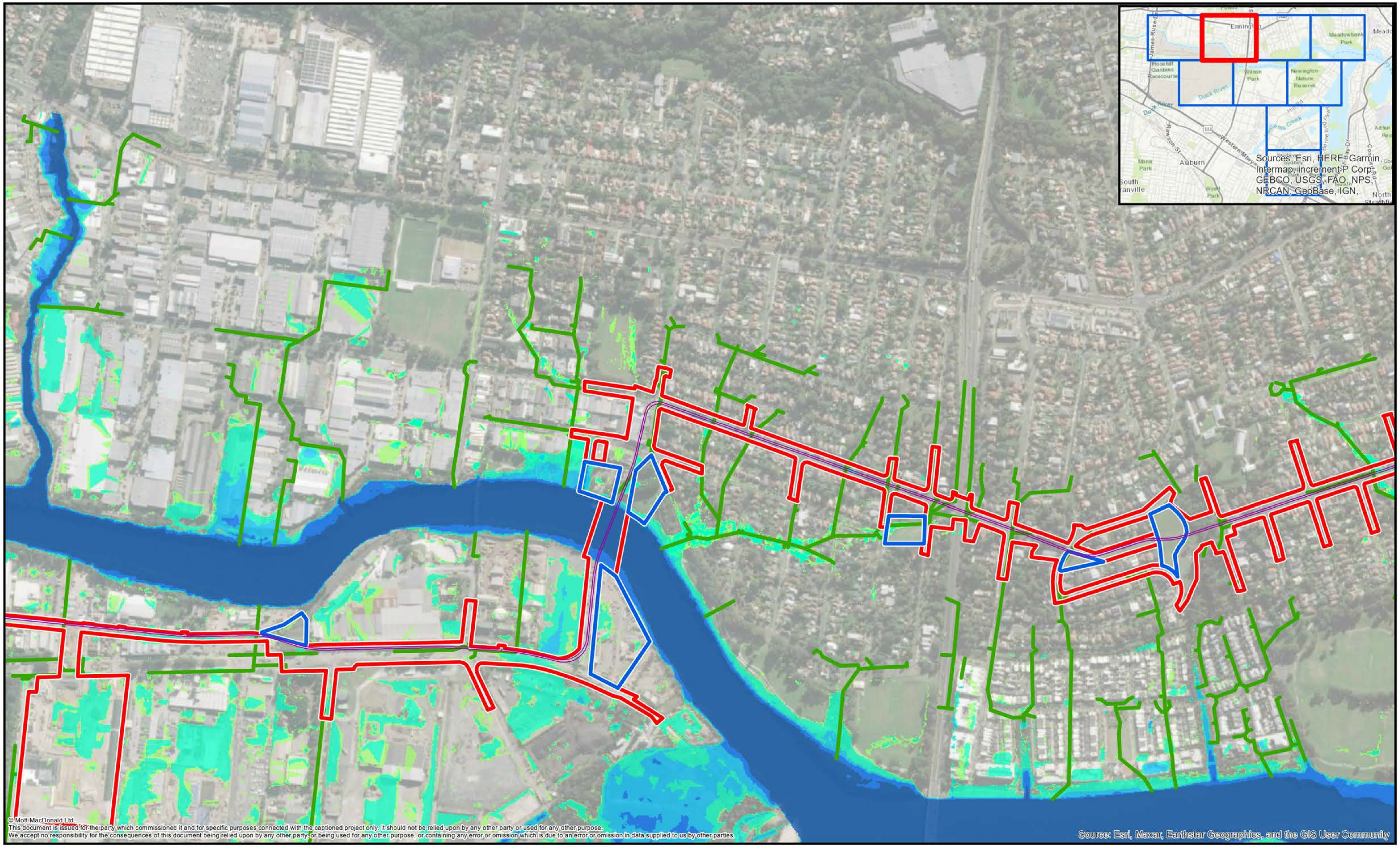
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

Project Alignment	
Construction Compounds	
Project Site	
Stormwater Pipes	
Depth (m)	
0 - 0.05	
0.05 - 0.1	
0.1 - 0.5	
0.5 - 1	
1 - 2	
>2	

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

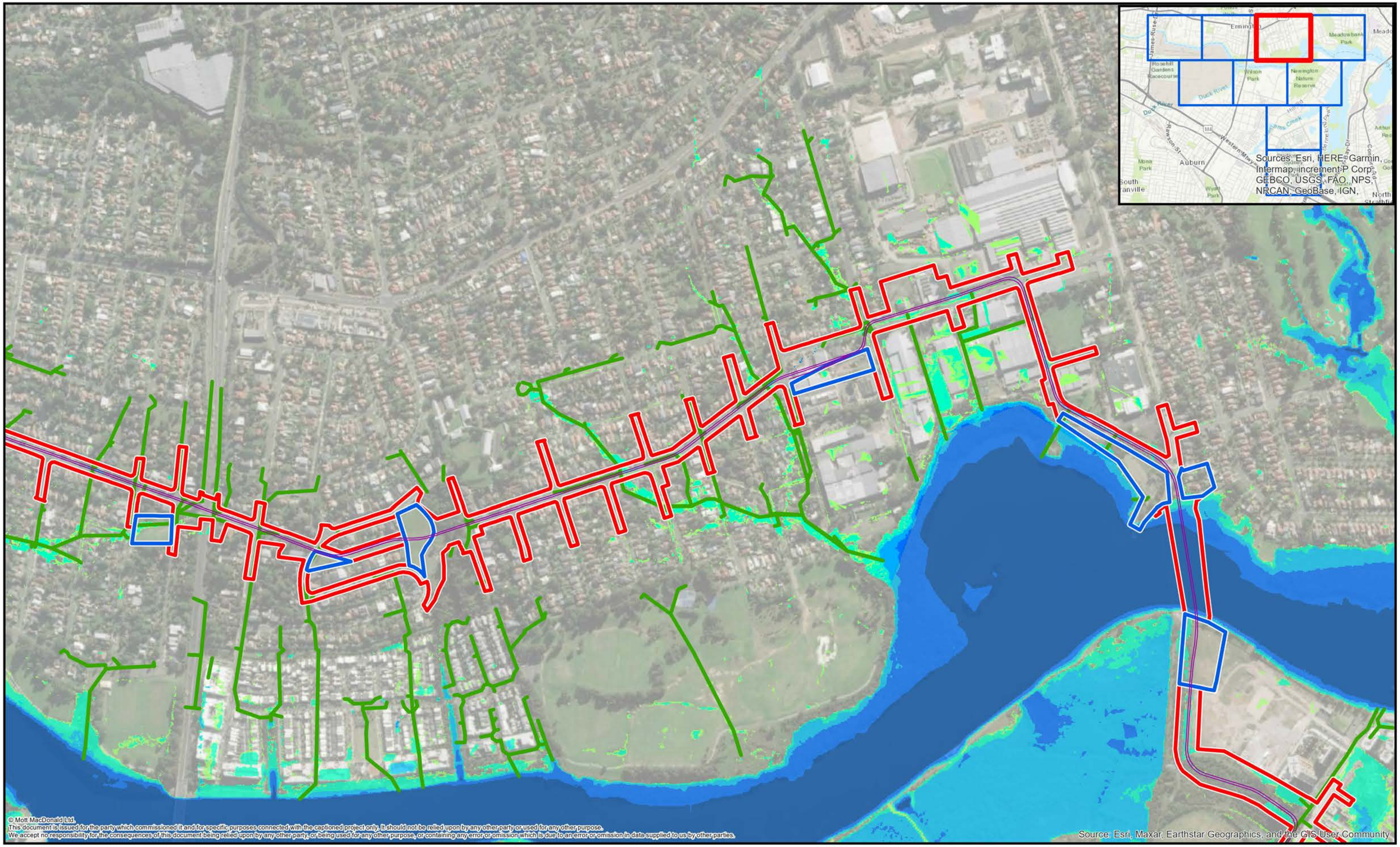
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

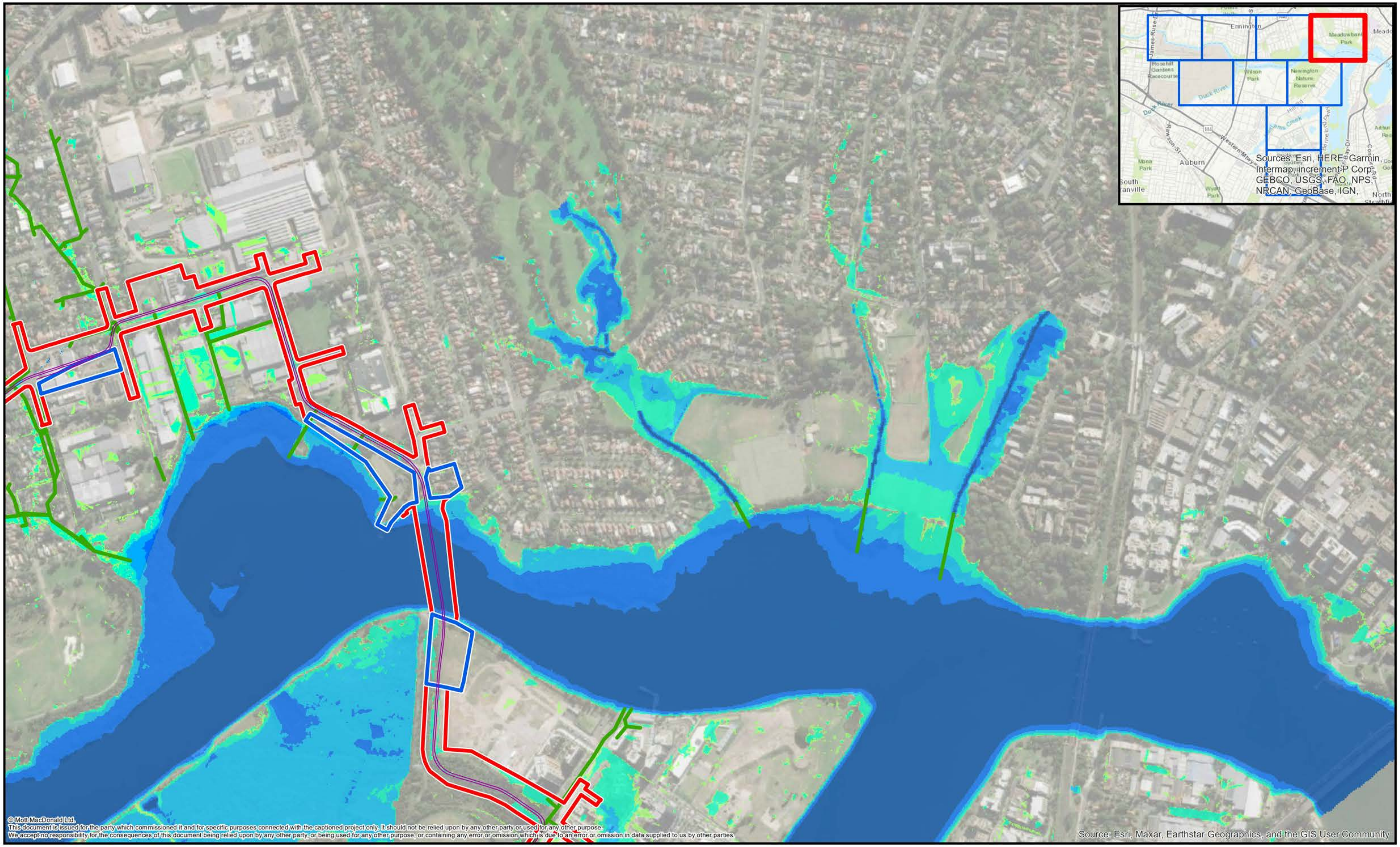
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

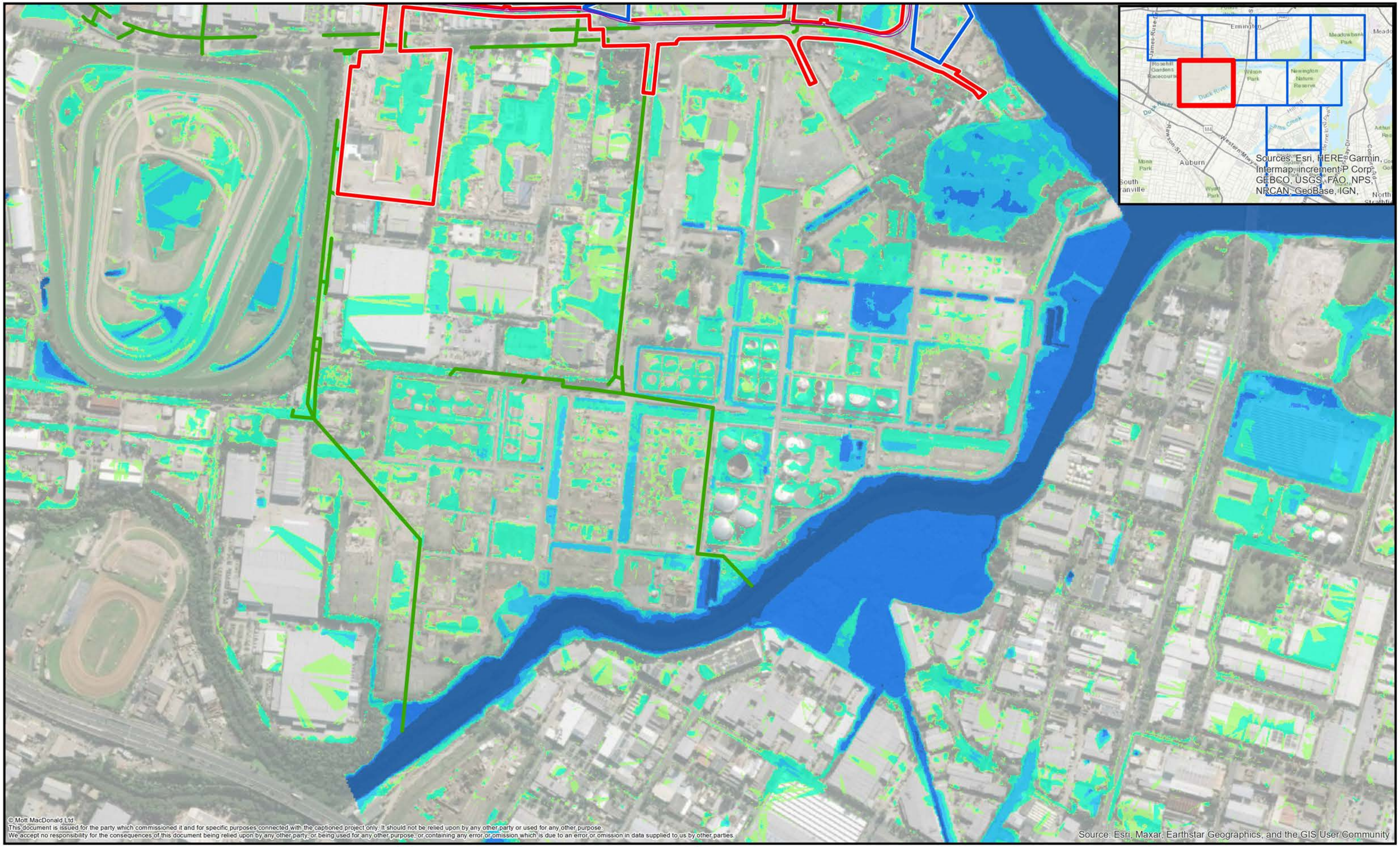
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

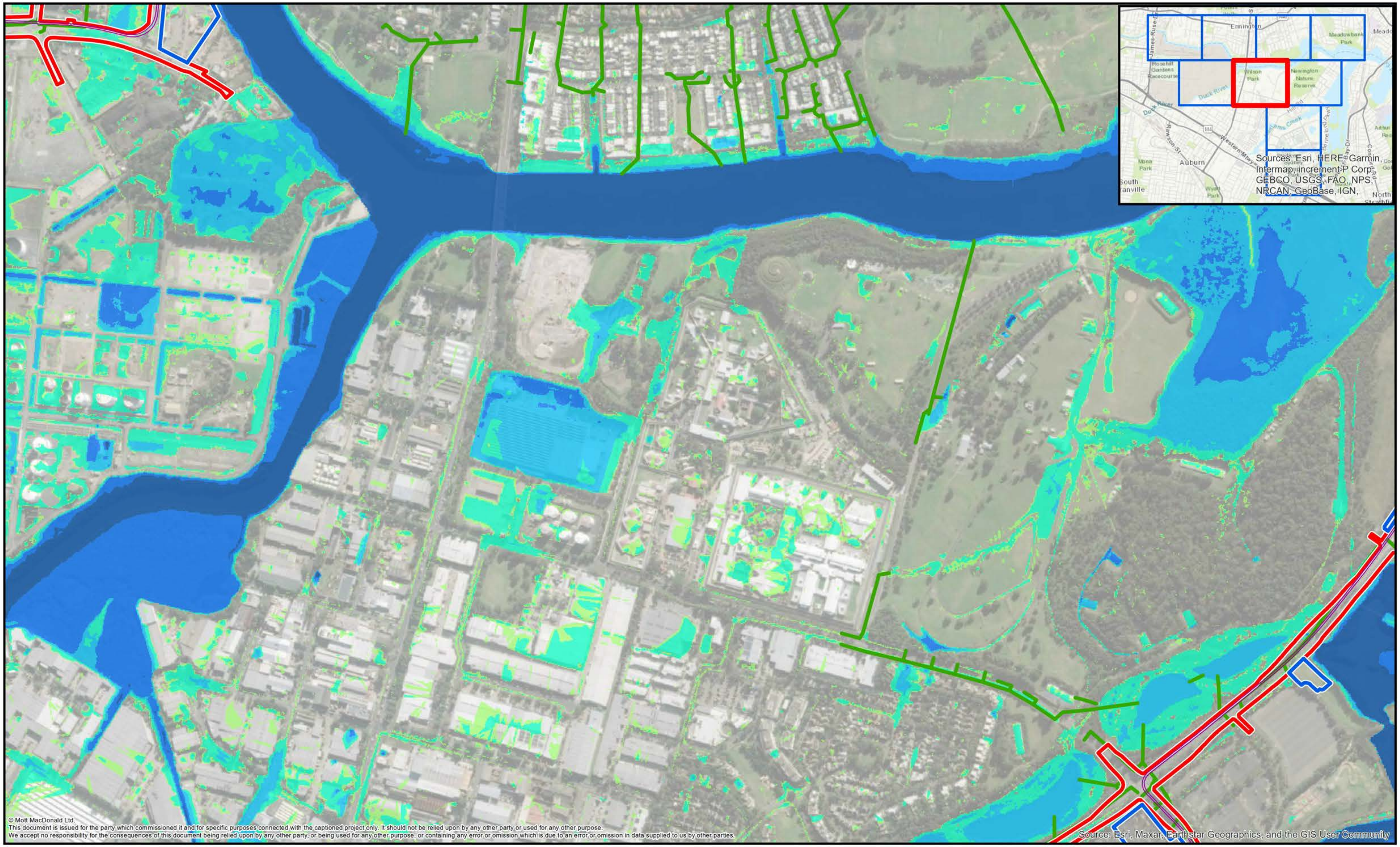
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

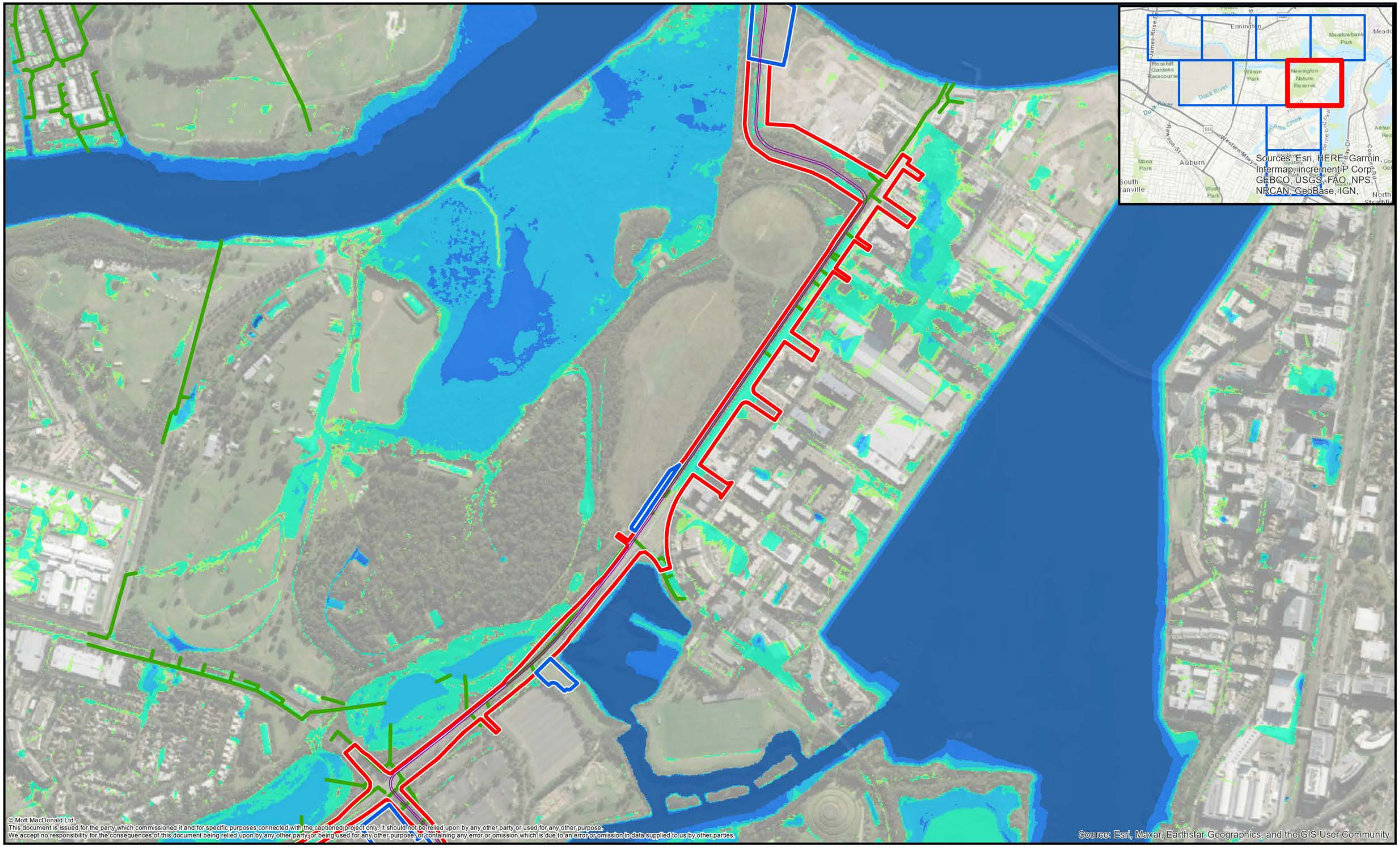
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

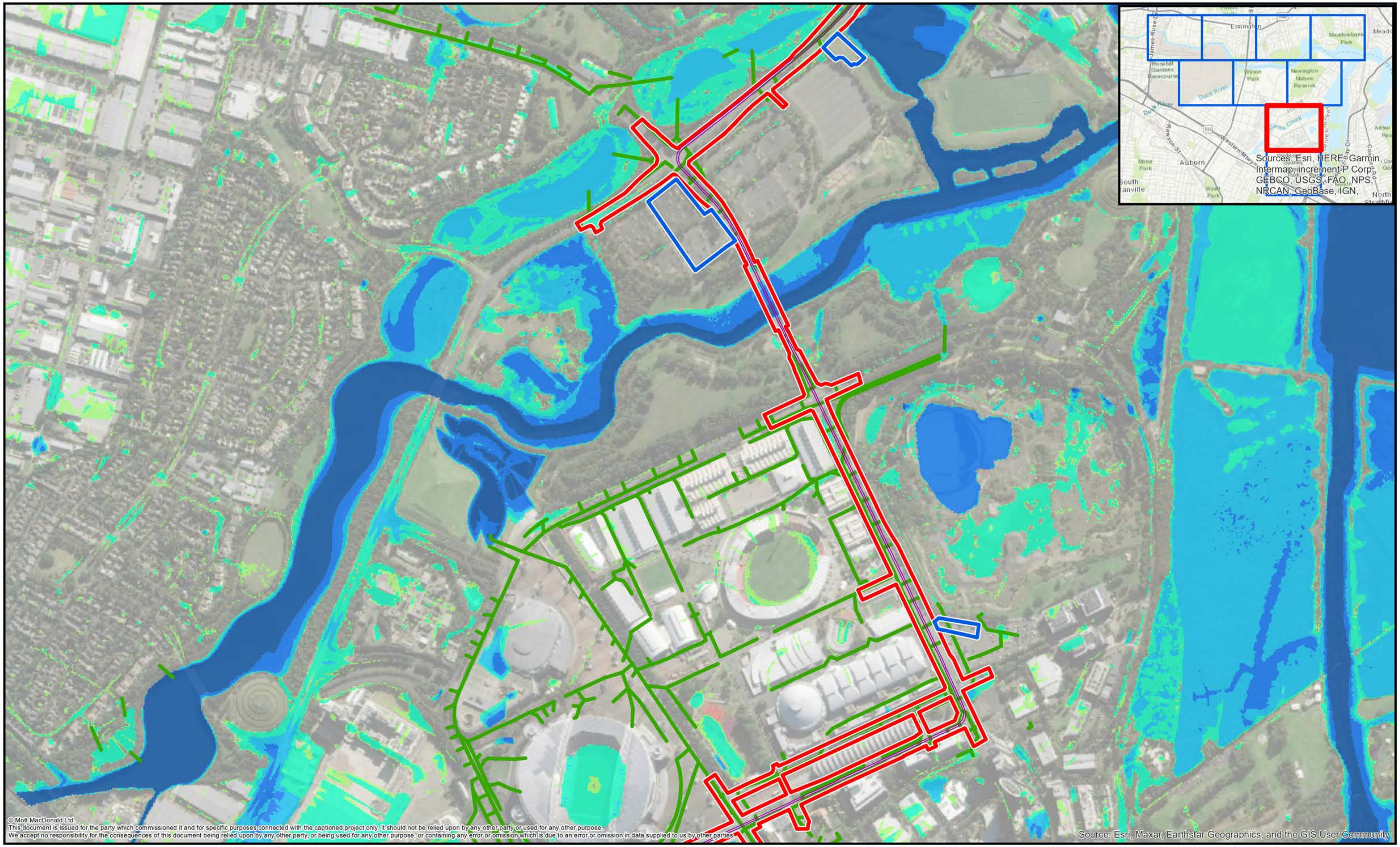
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

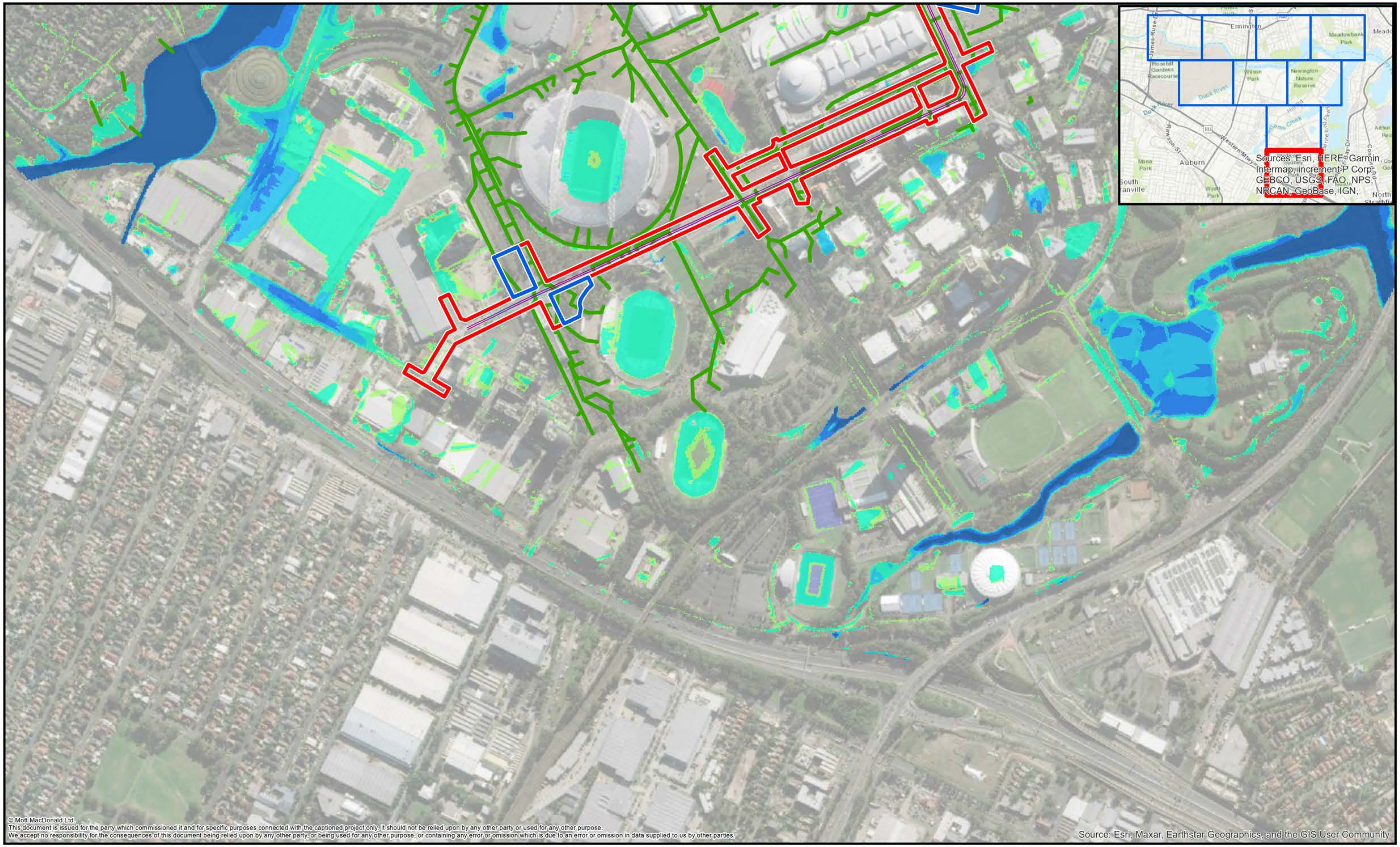
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

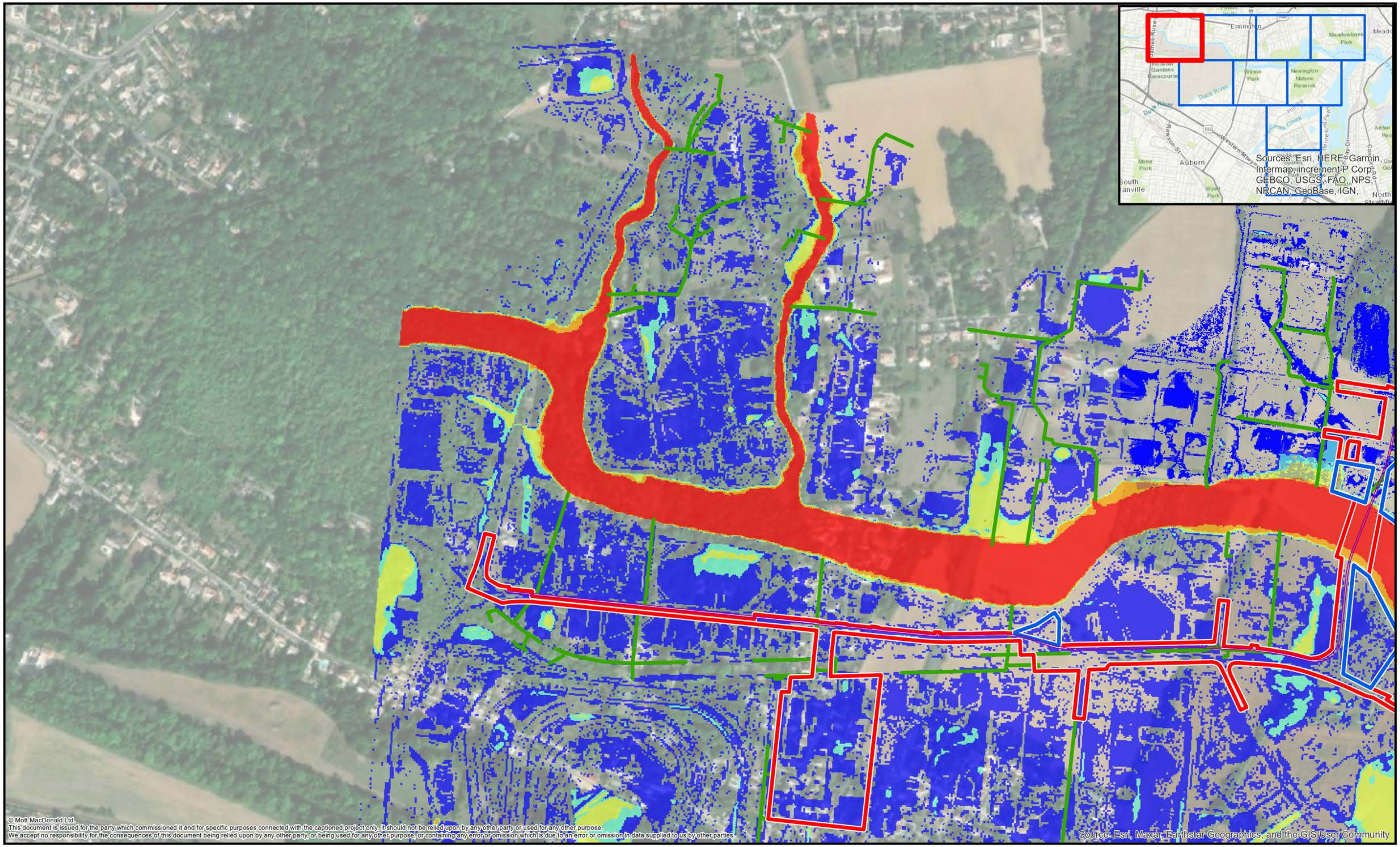
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

Project Alignment
Construction Compounds
Project Site
Stormwater Pipes

Flood Hazard (ZAEM1)

H1
H2
H3
H4
H5
H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

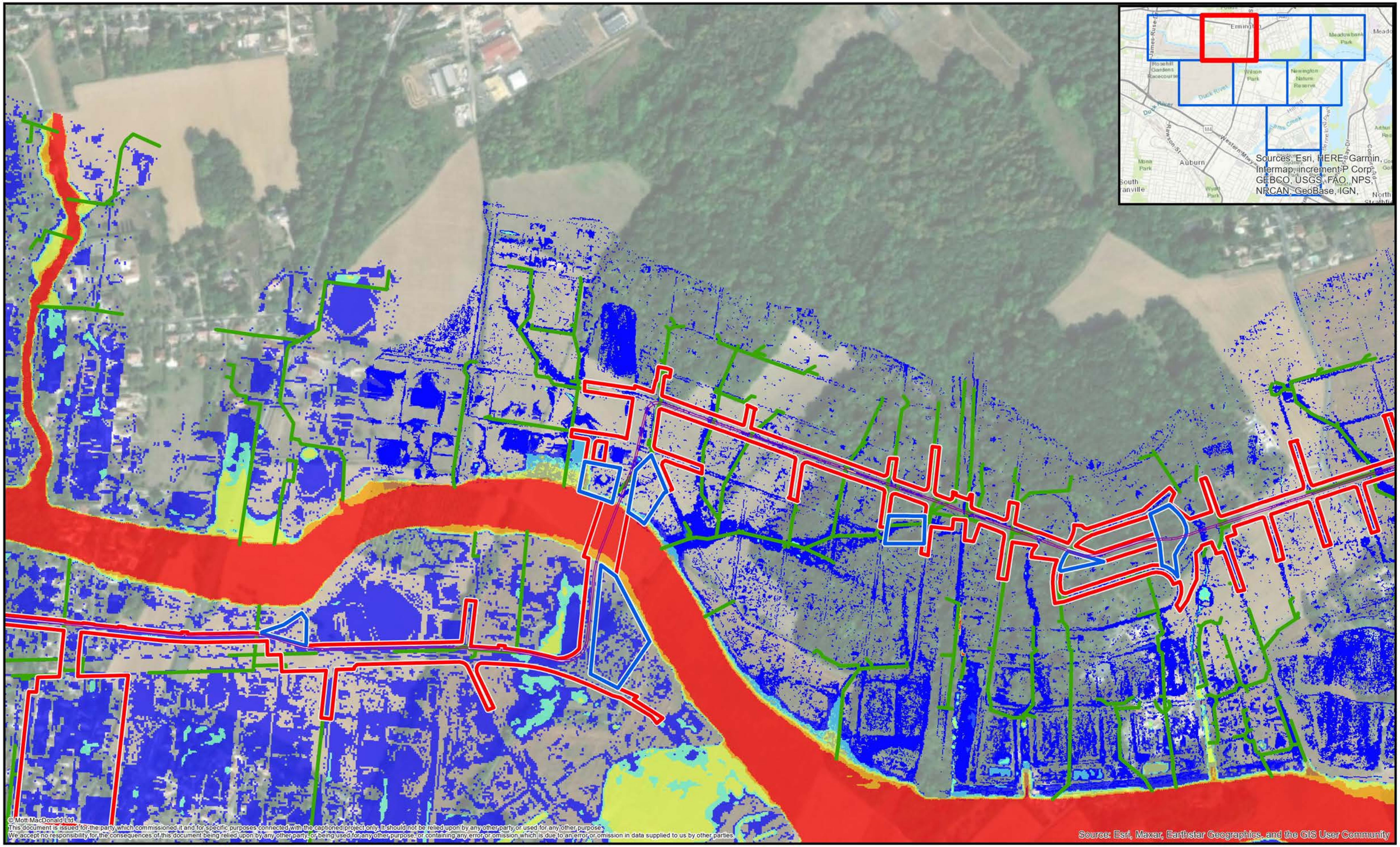
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

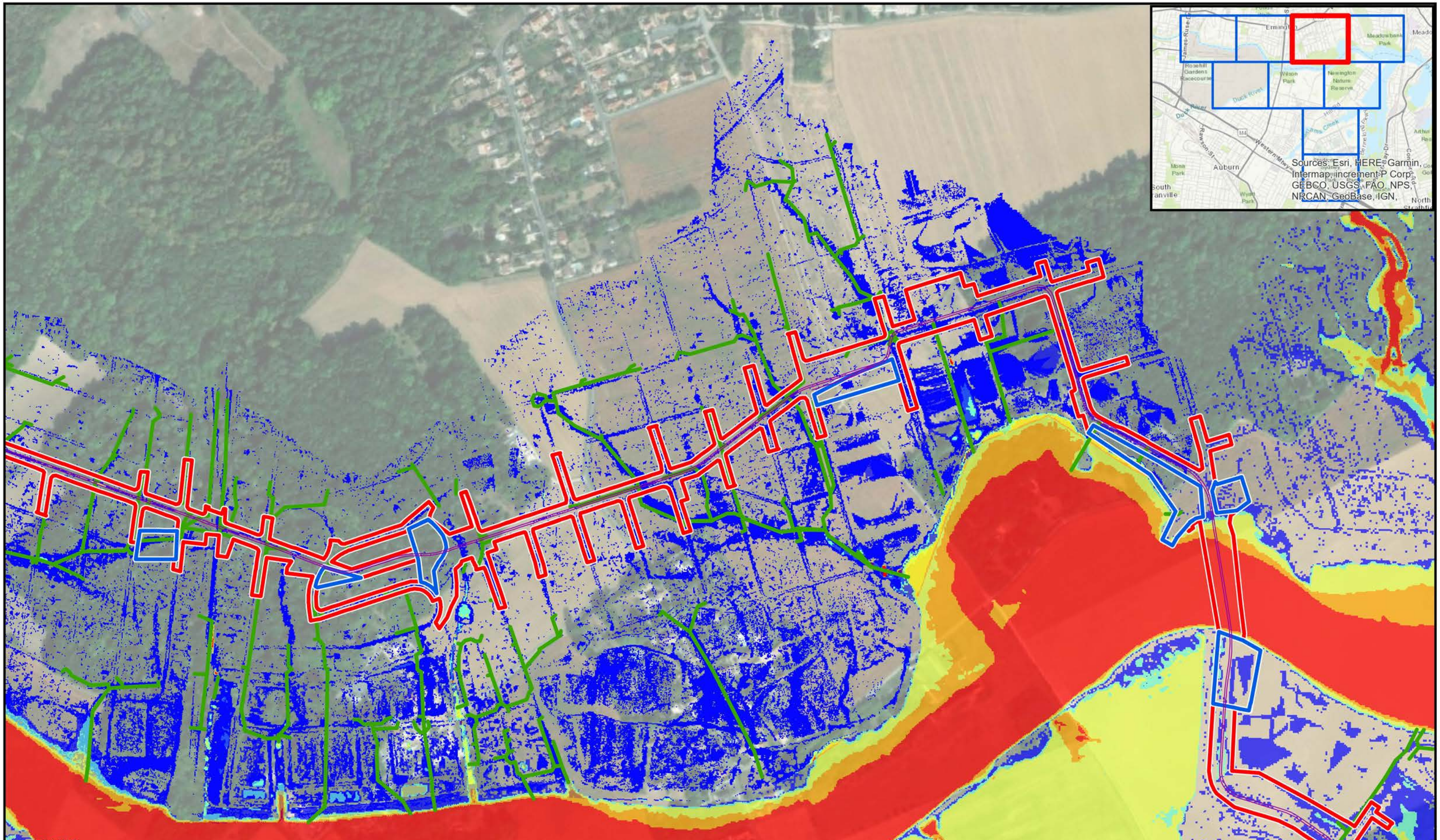
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

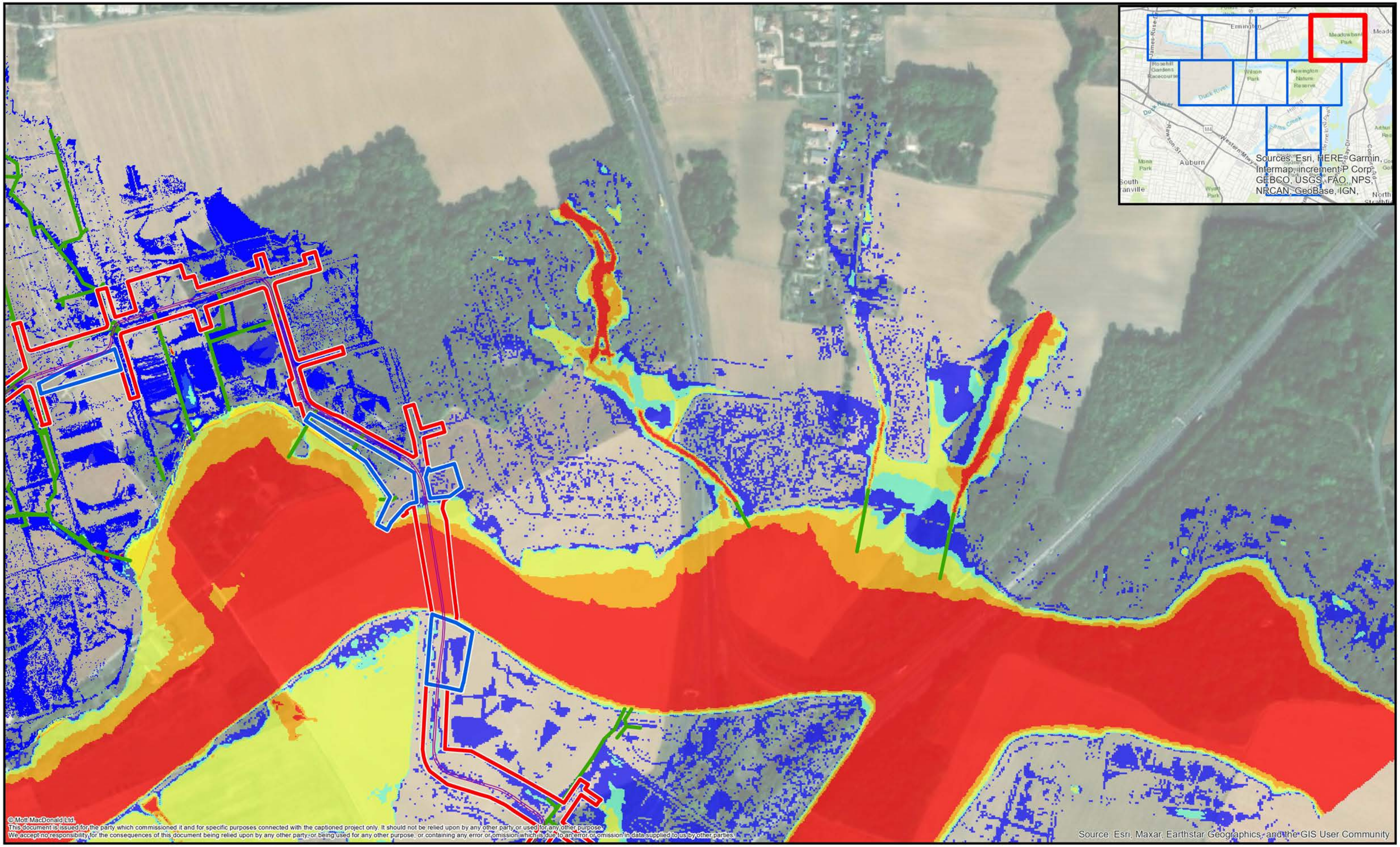
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

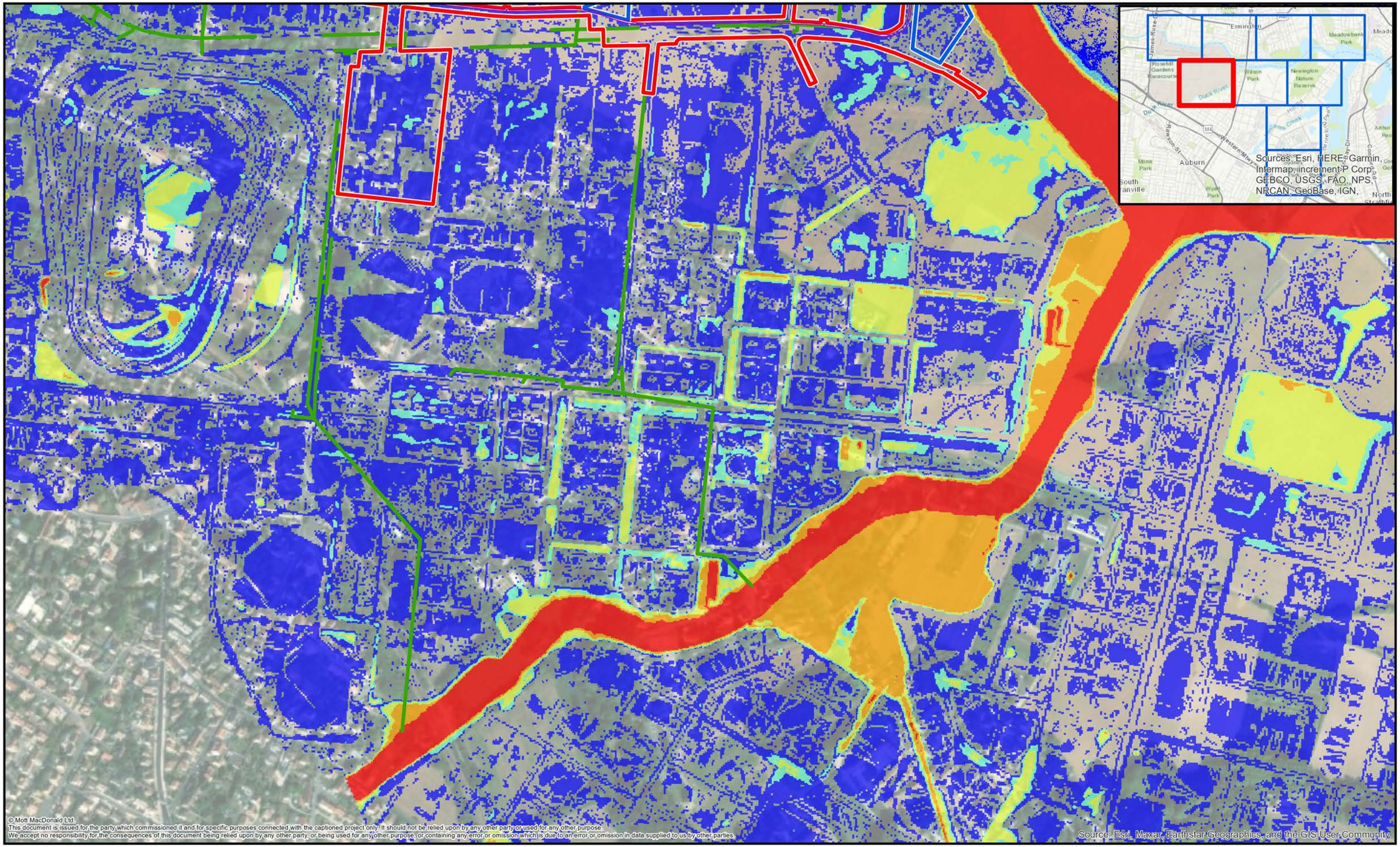
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

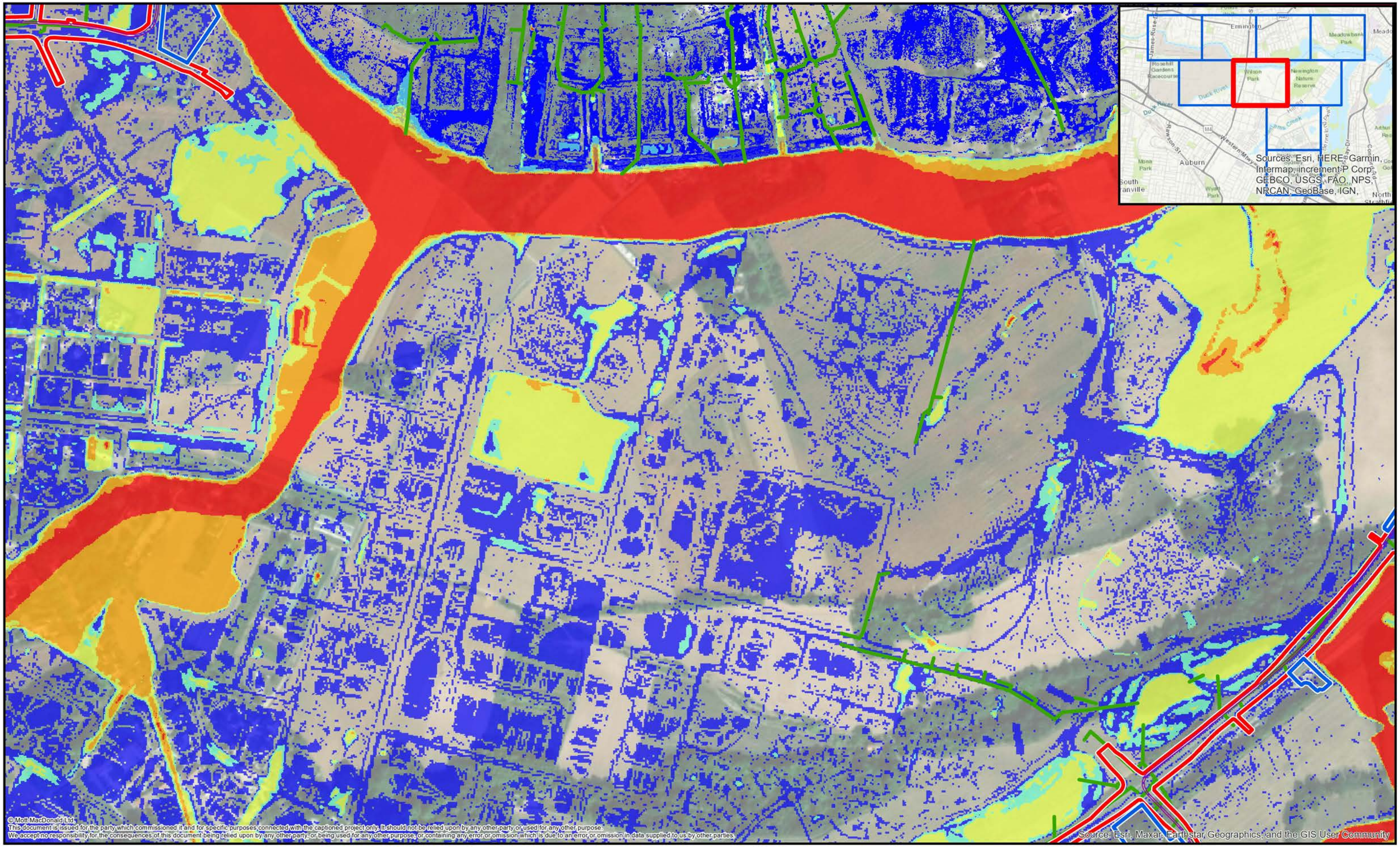
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

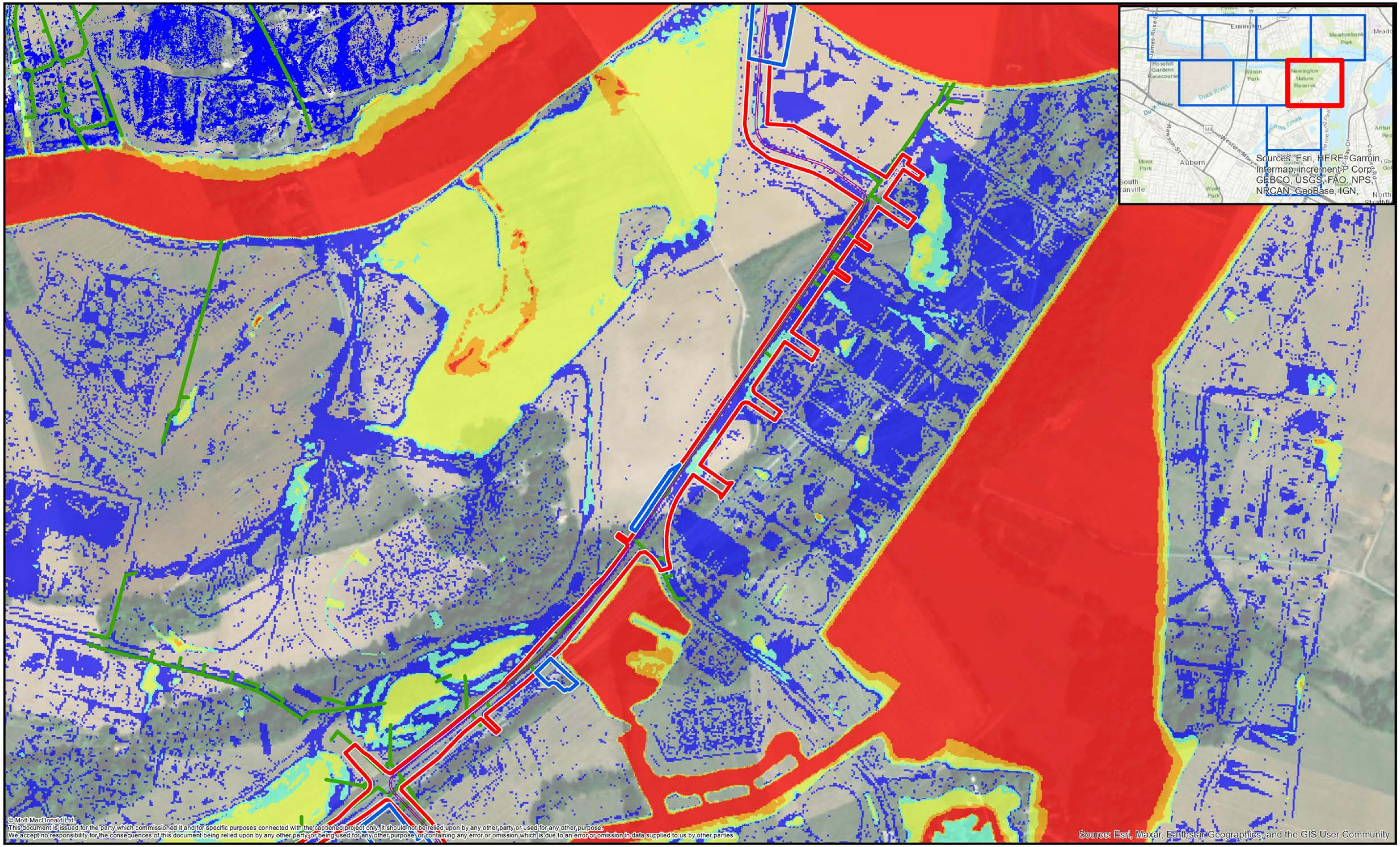
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

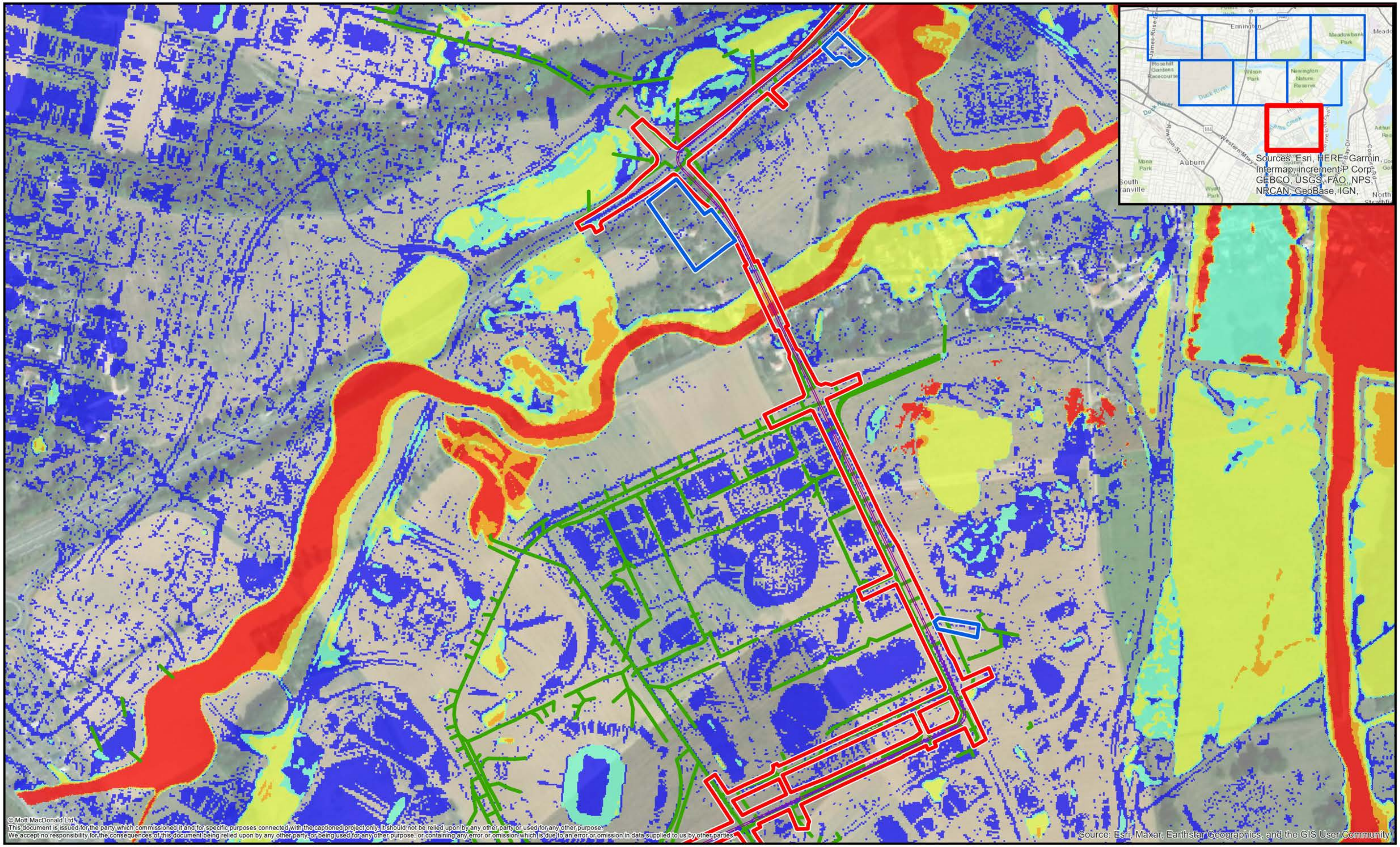
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

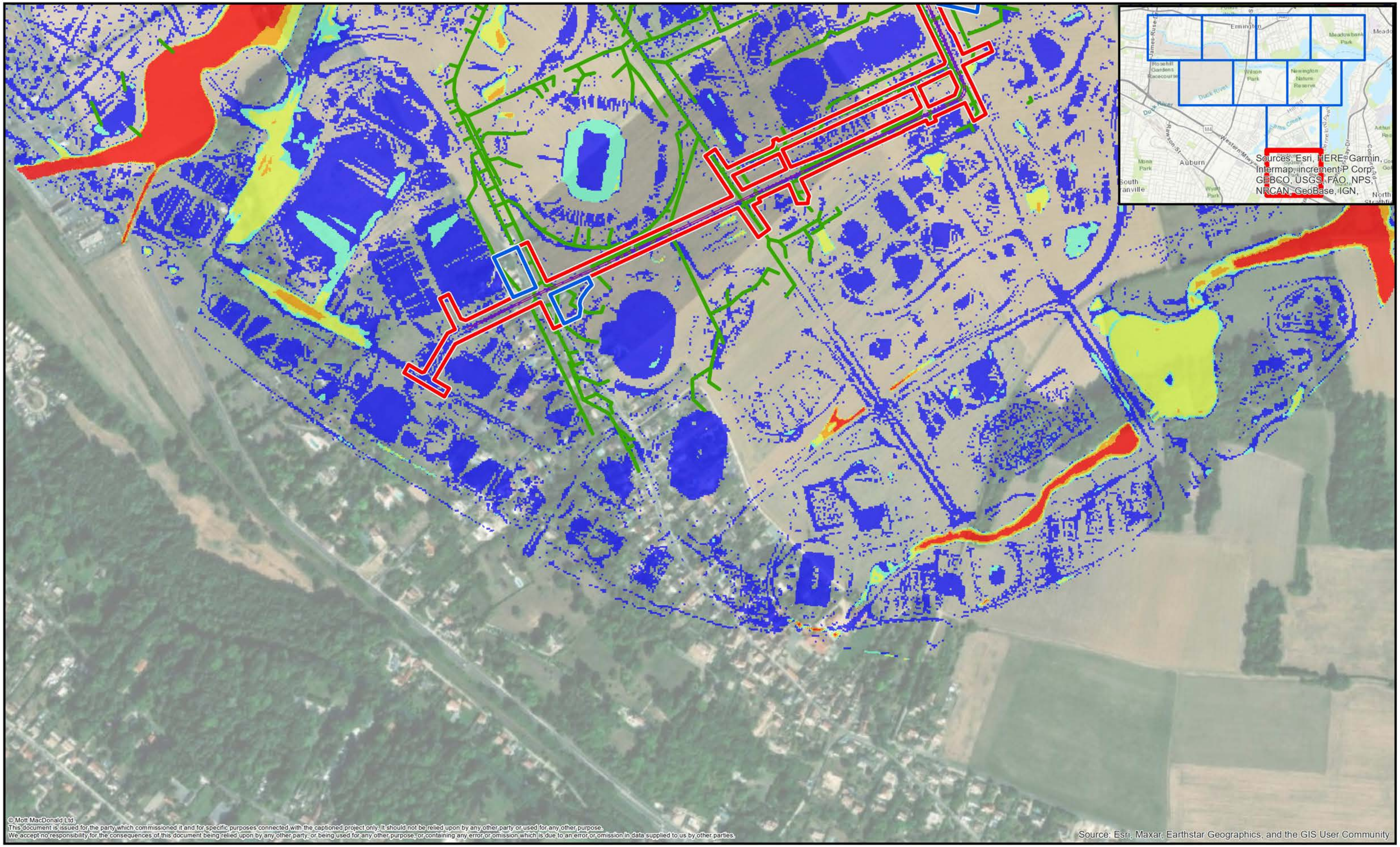
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

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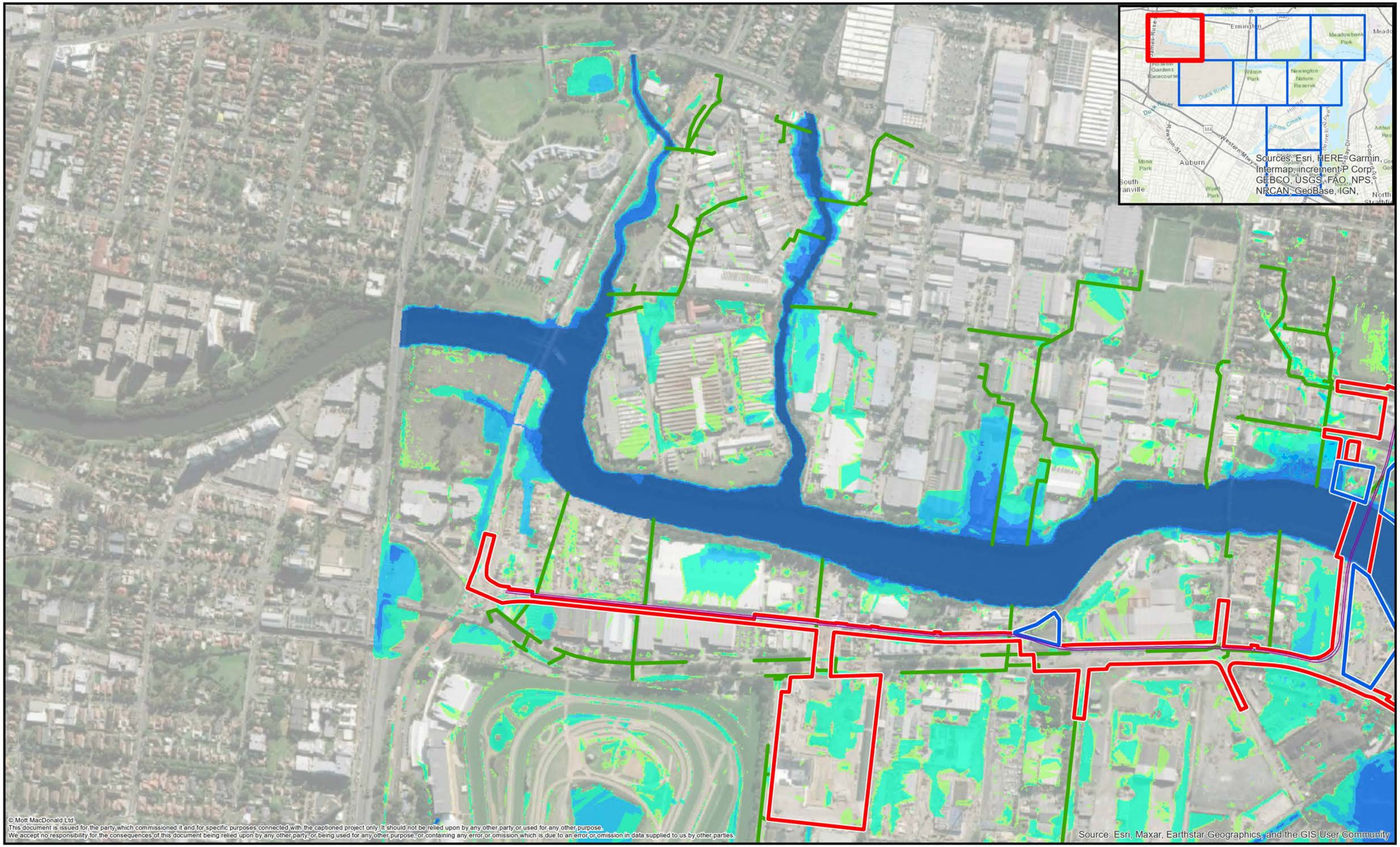


Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

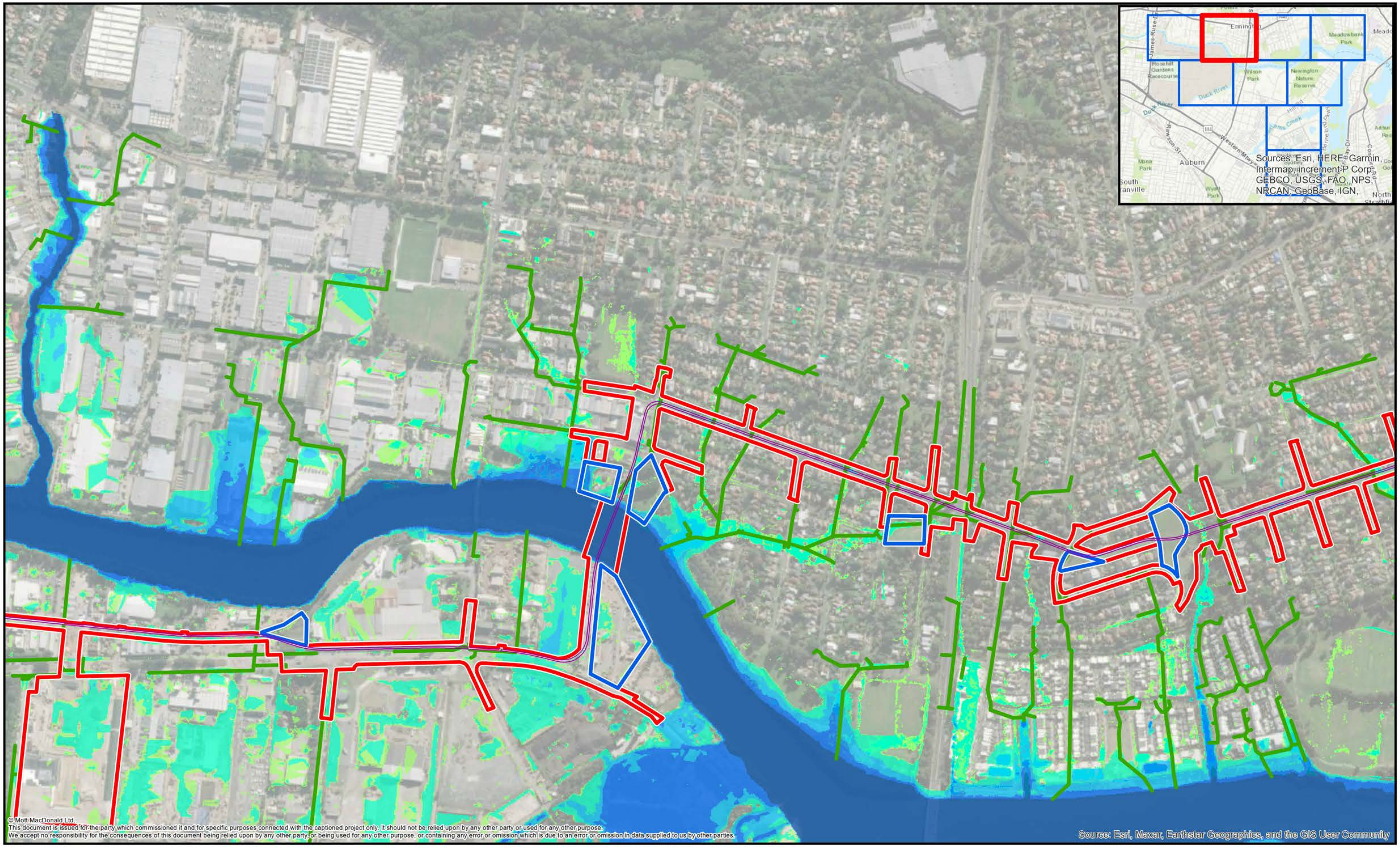
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

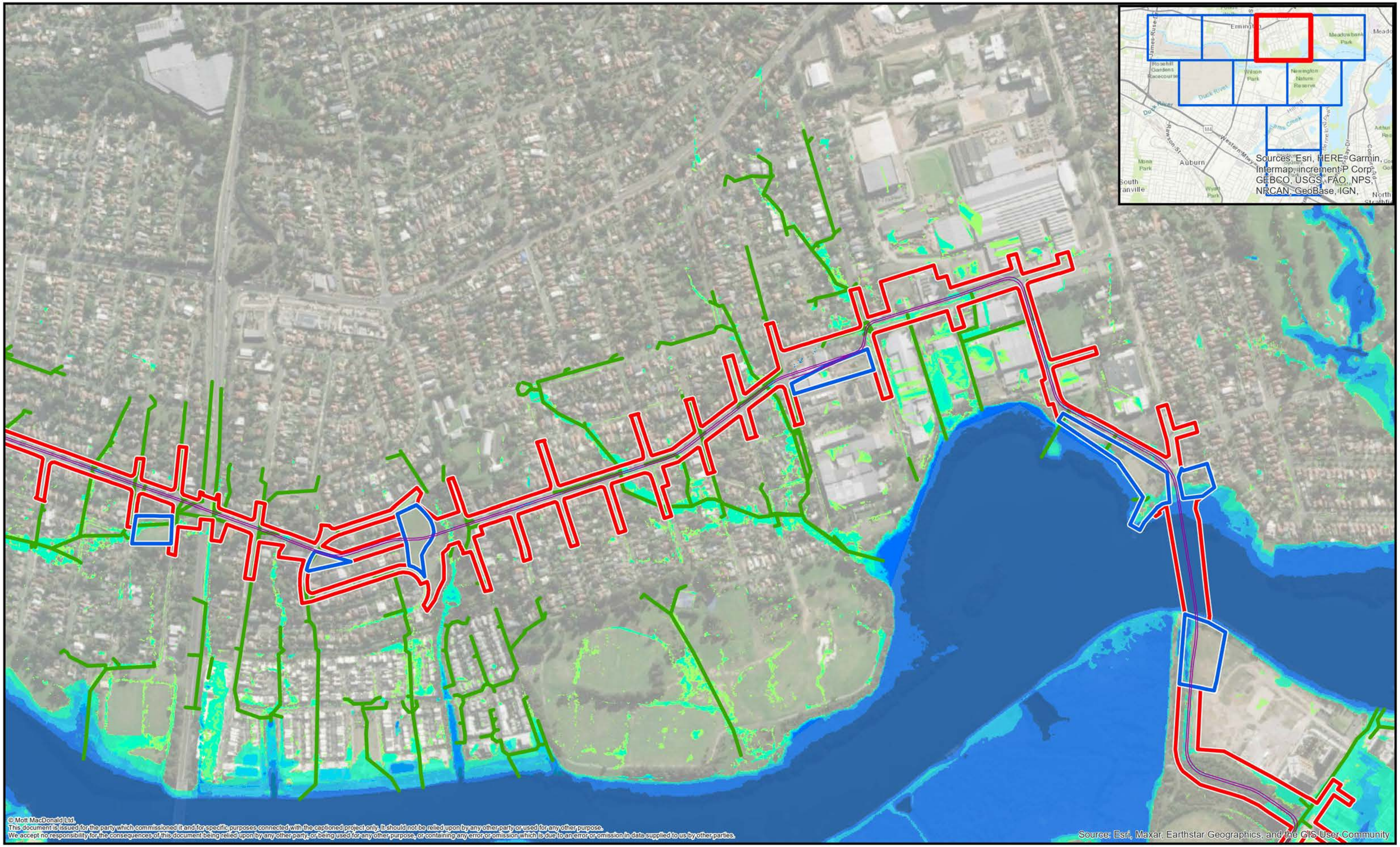
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
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- >2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

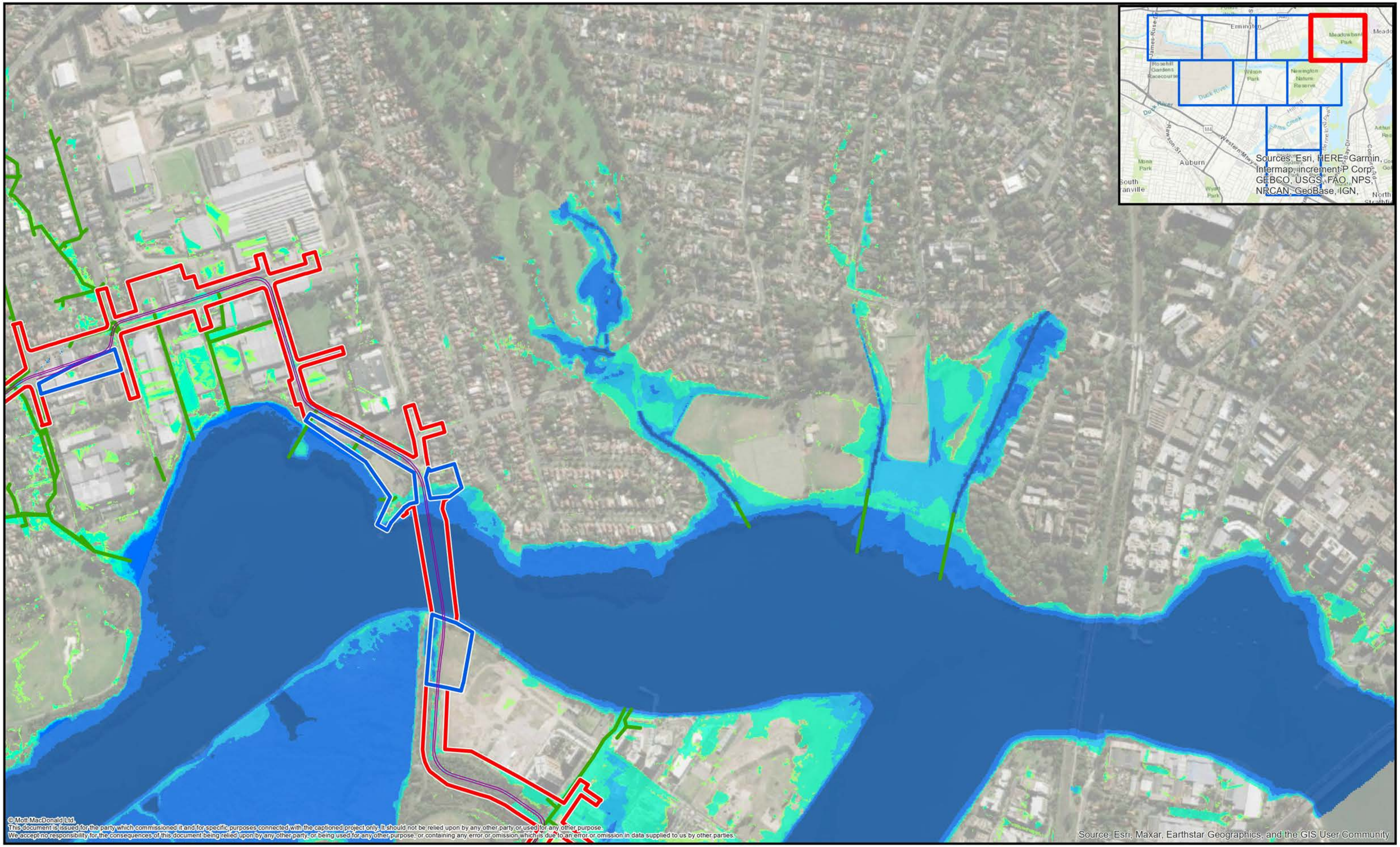
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

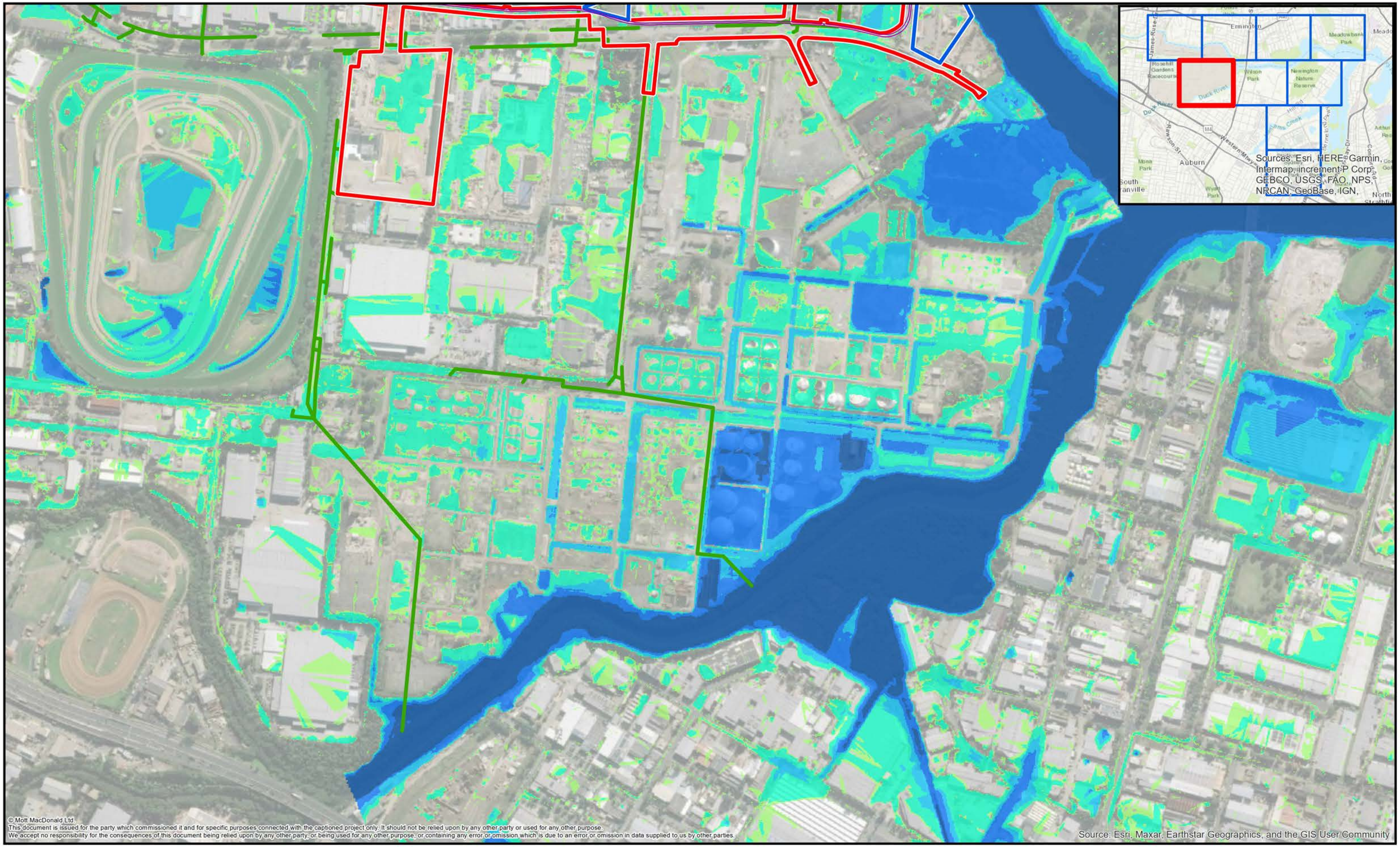
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

Project Alignment
Construction Compounds
Project Site
Stormwater Pipes

Depth (m)

0 - 0.05
0.05 - 0.1
0.1 - 0.5
0.5 - 1
1 - 2
>2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

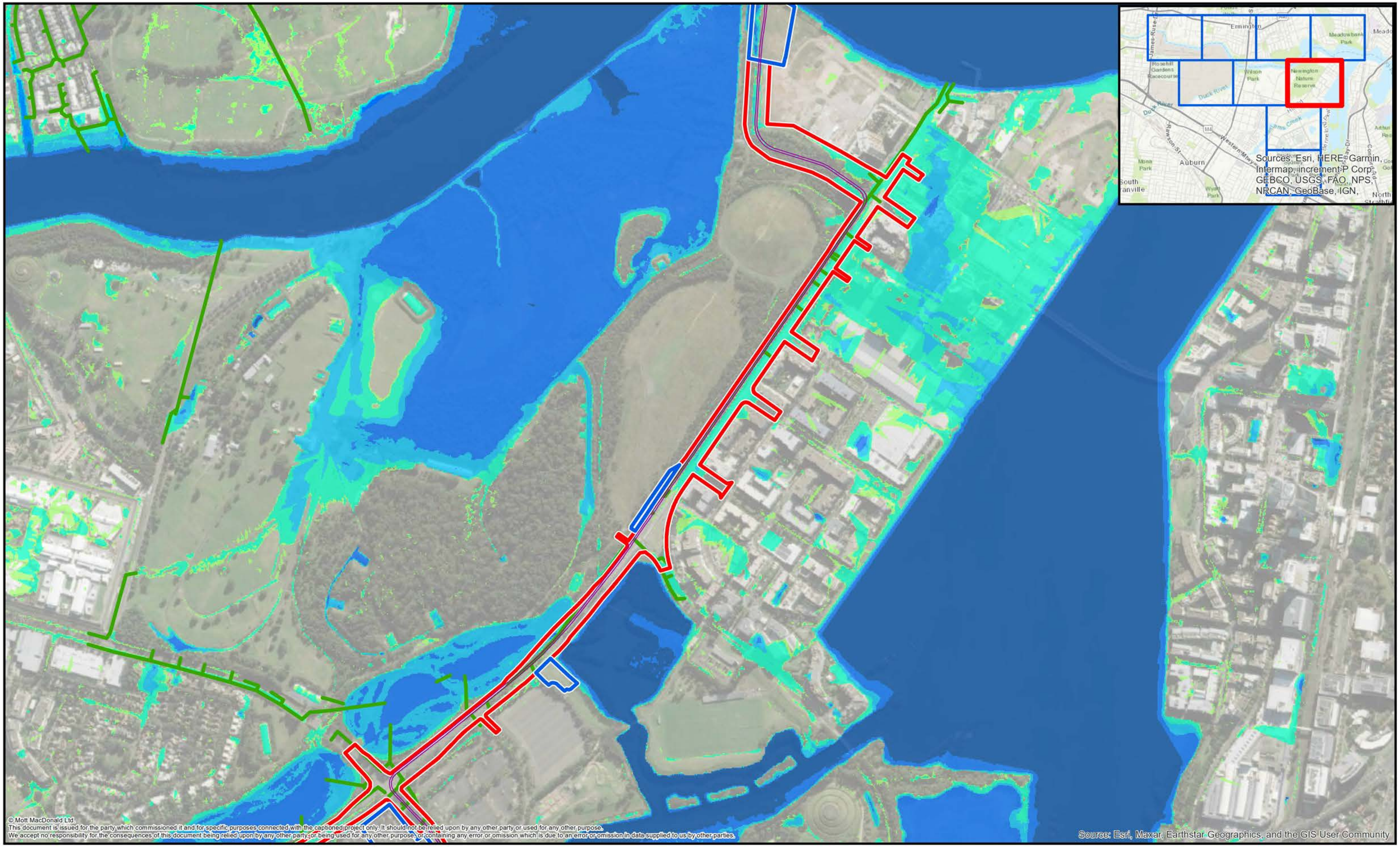
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

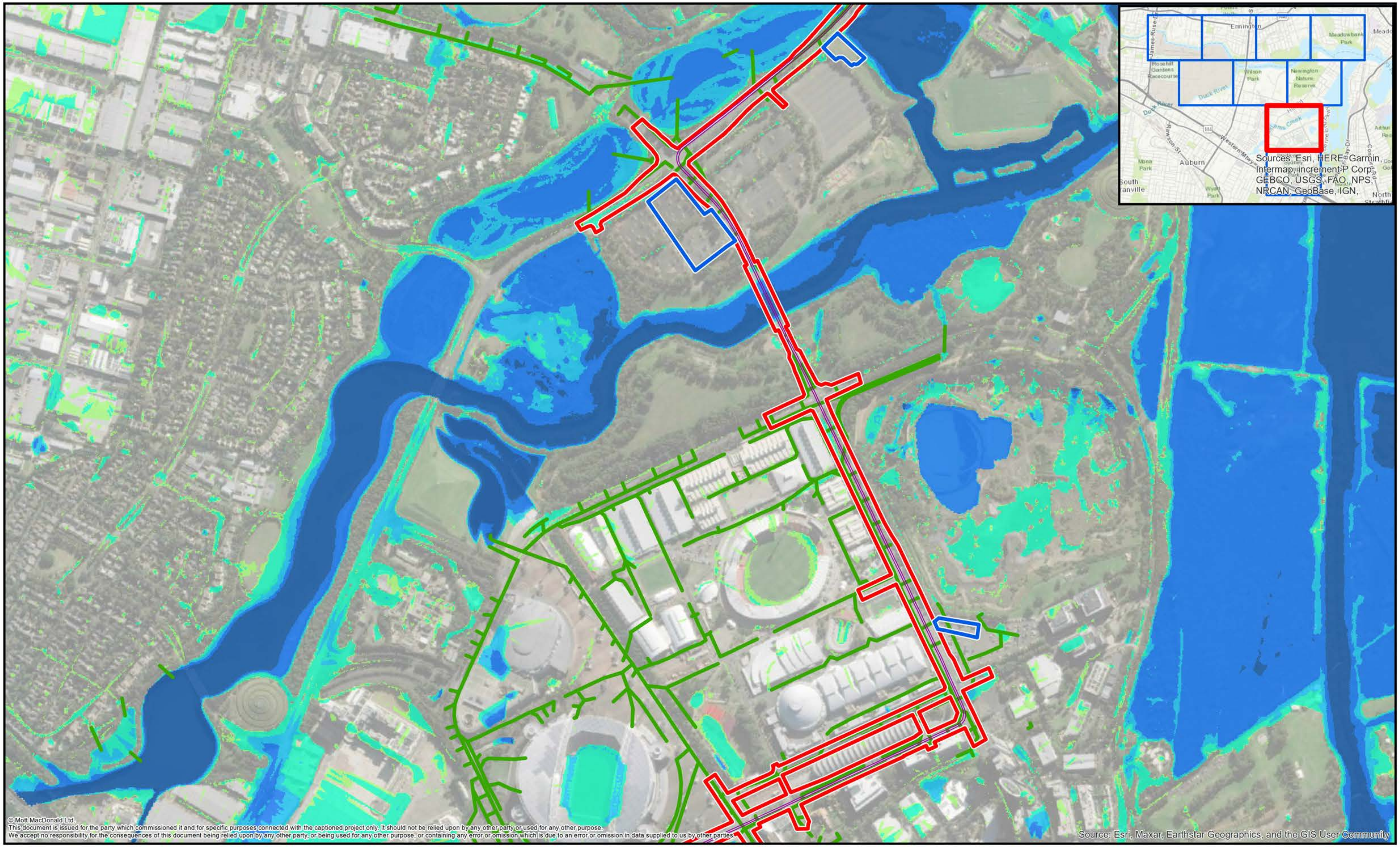
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

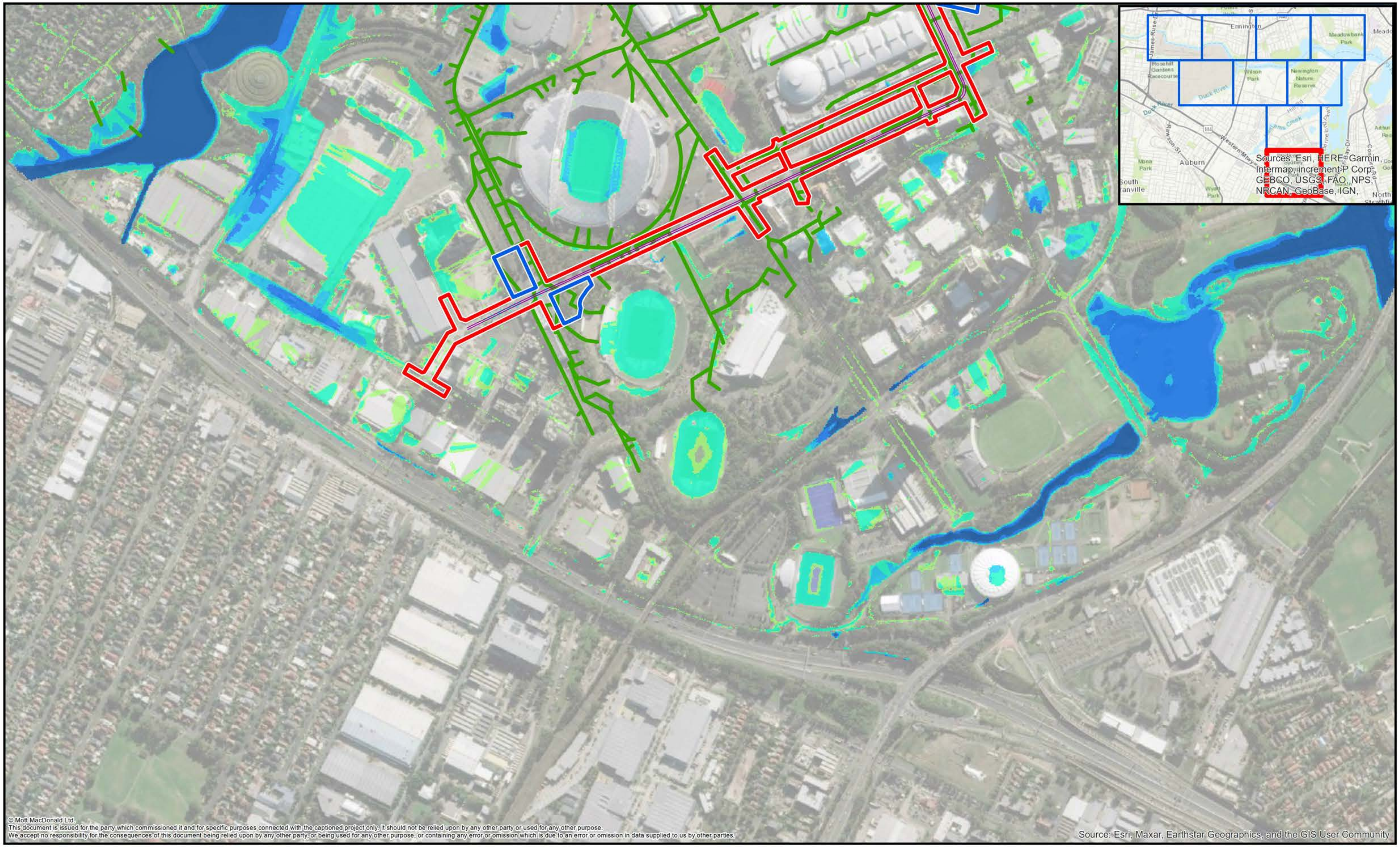
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 5% Climate Change AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

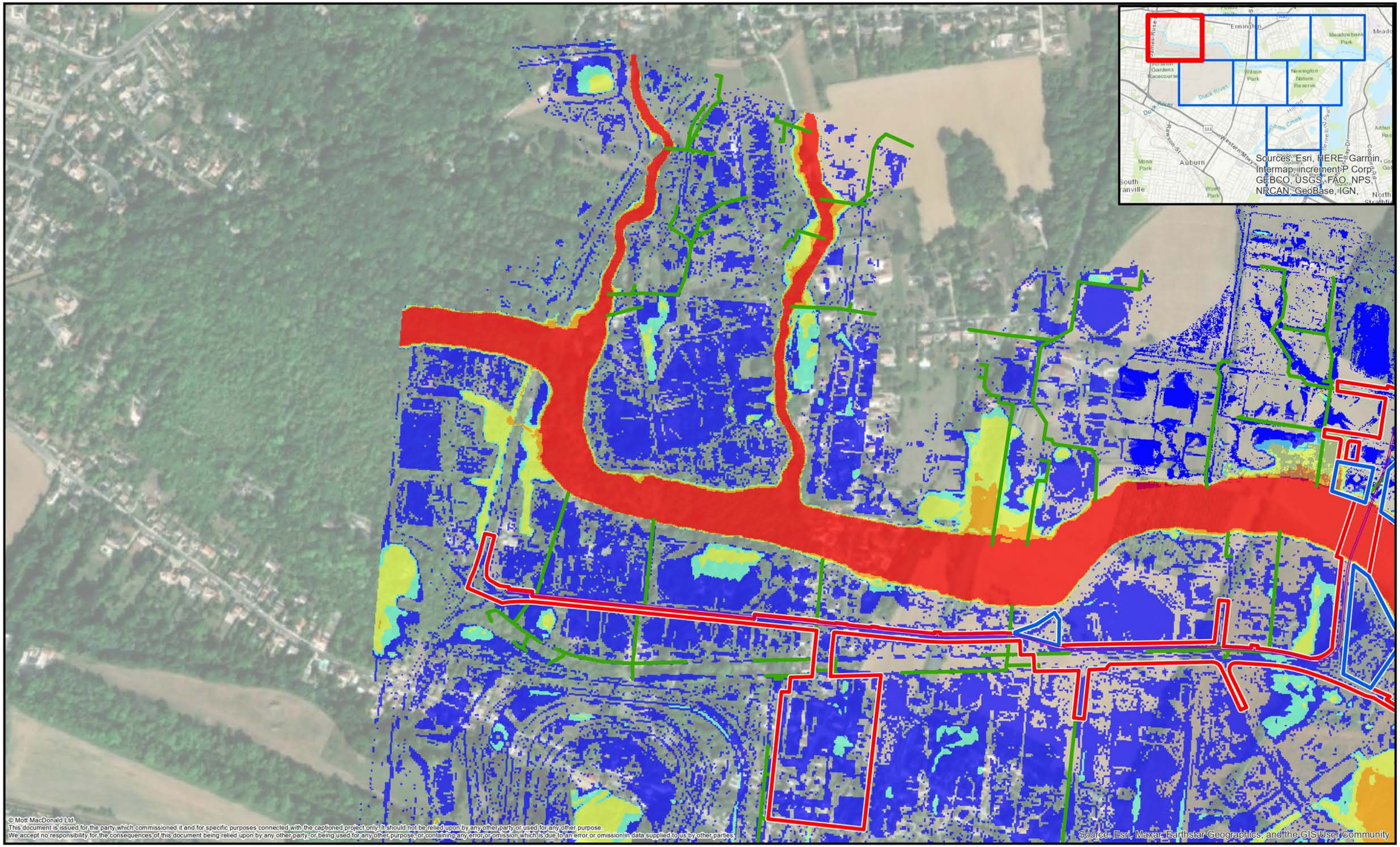
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

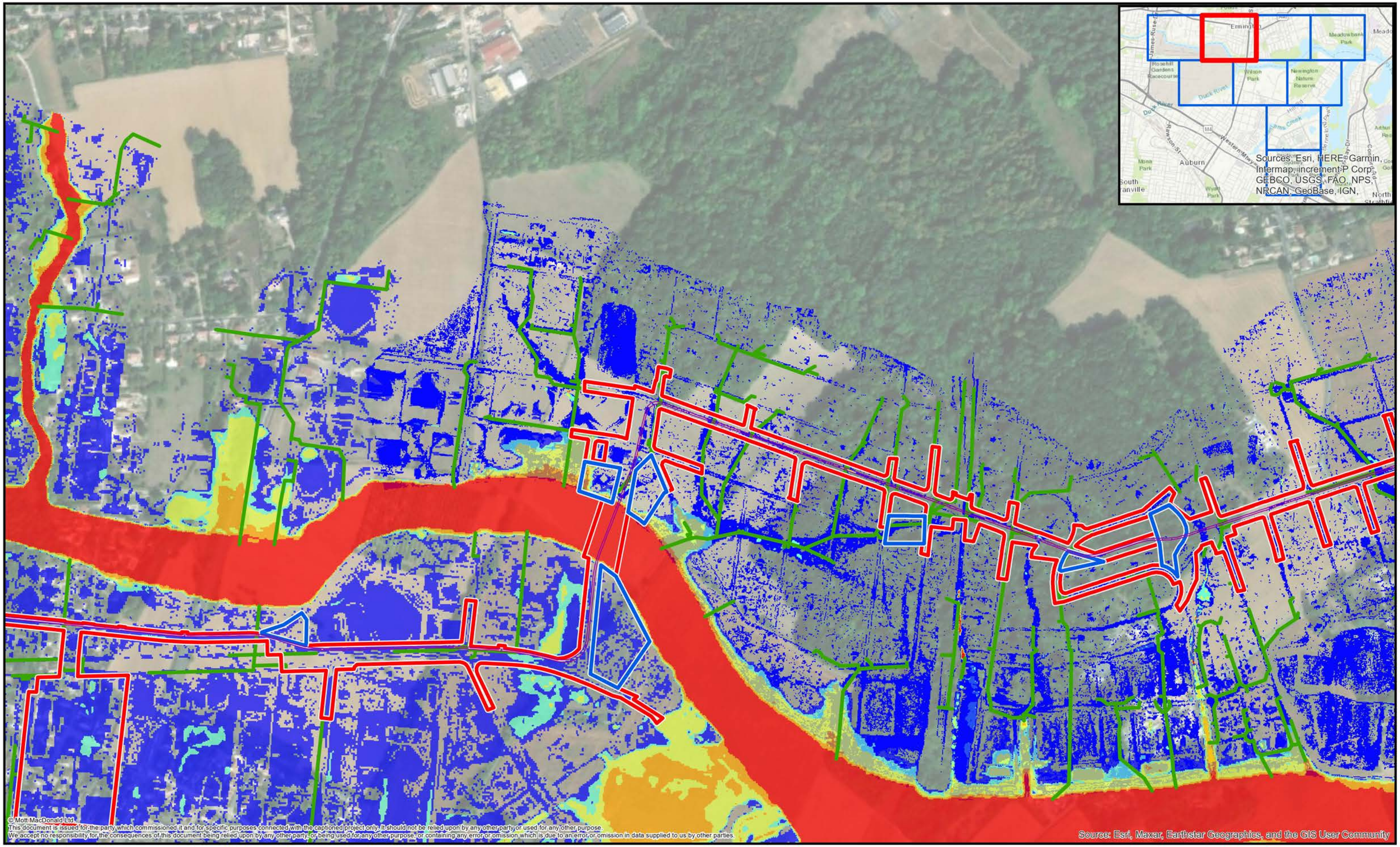
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

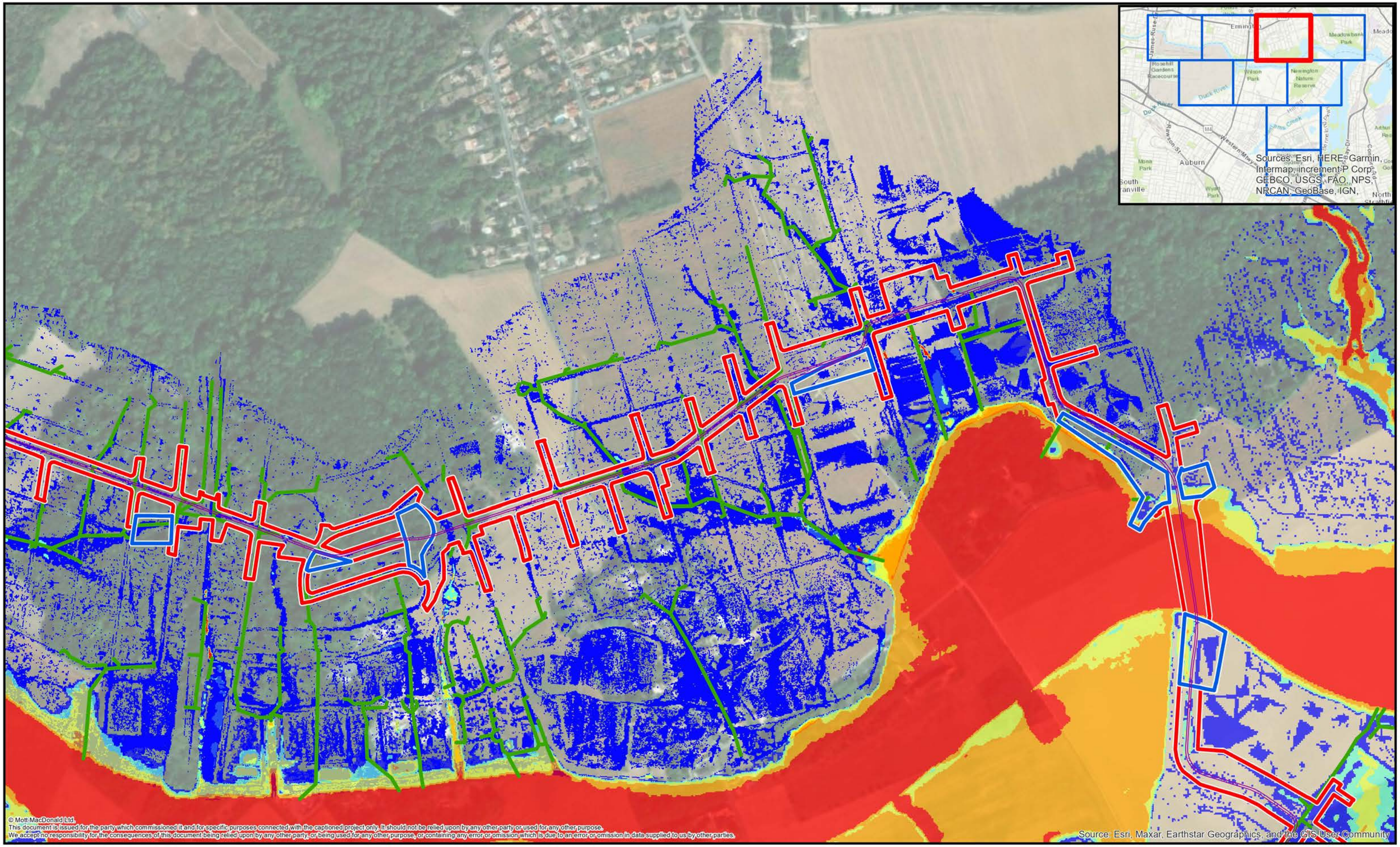
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

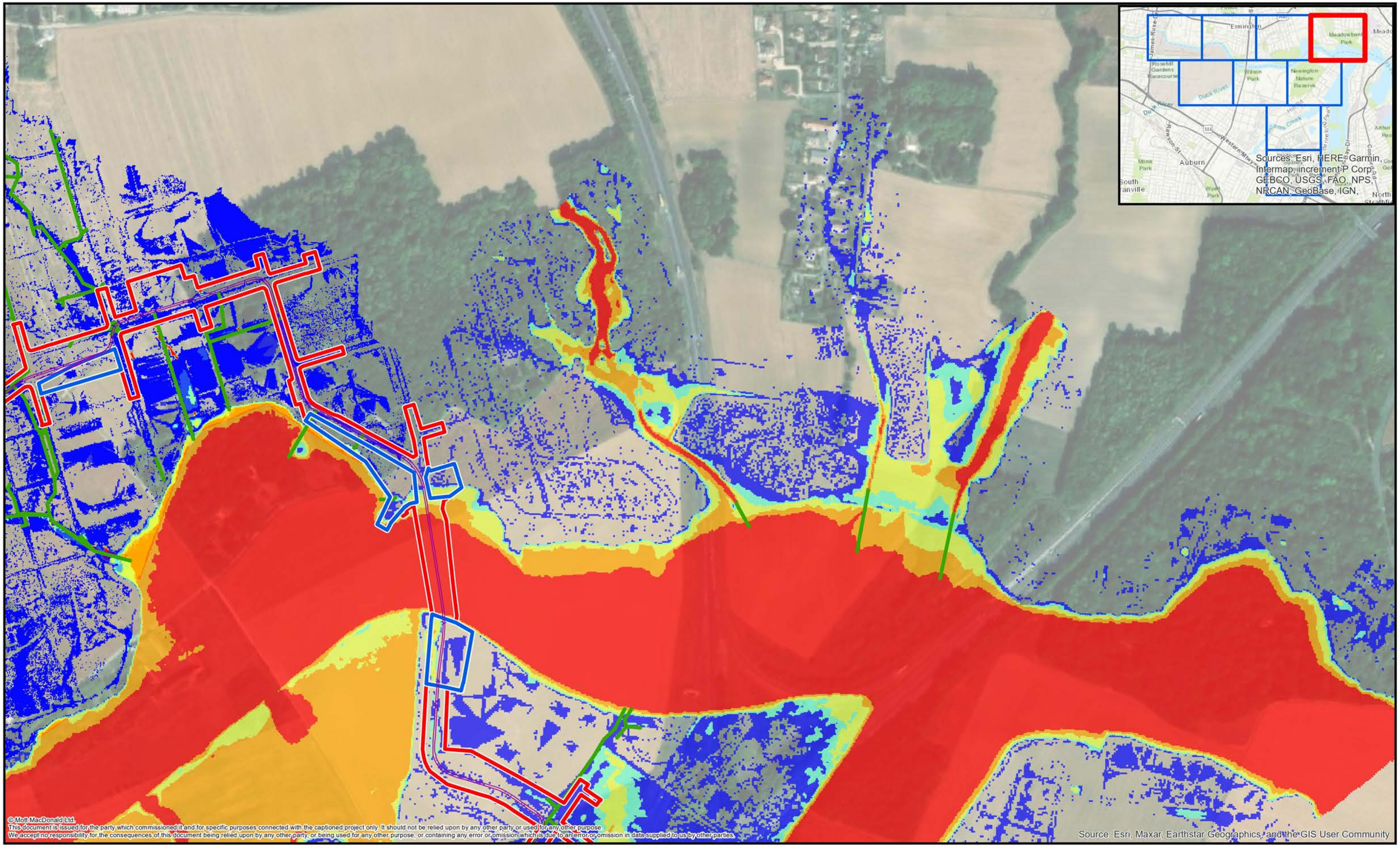
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

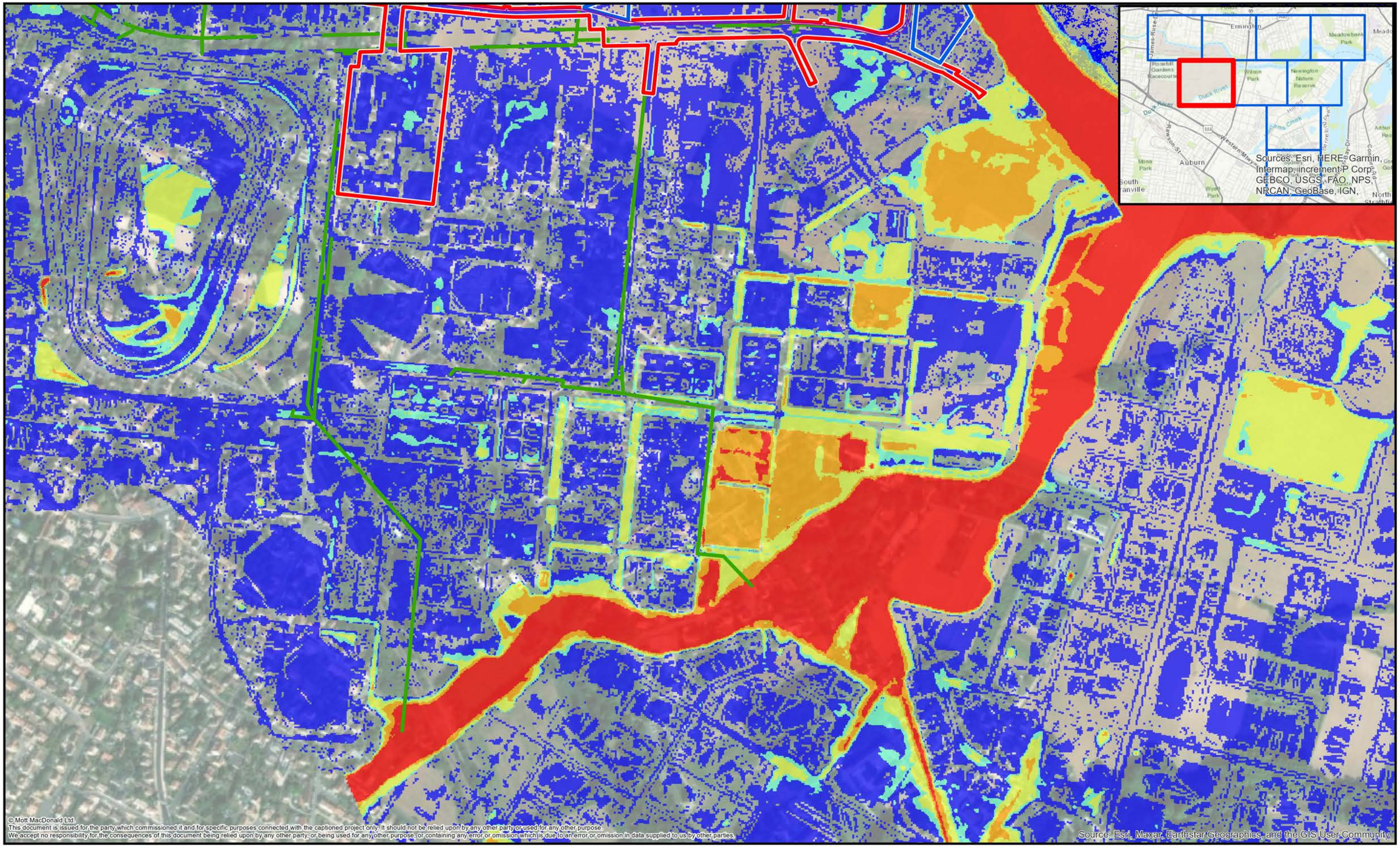
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

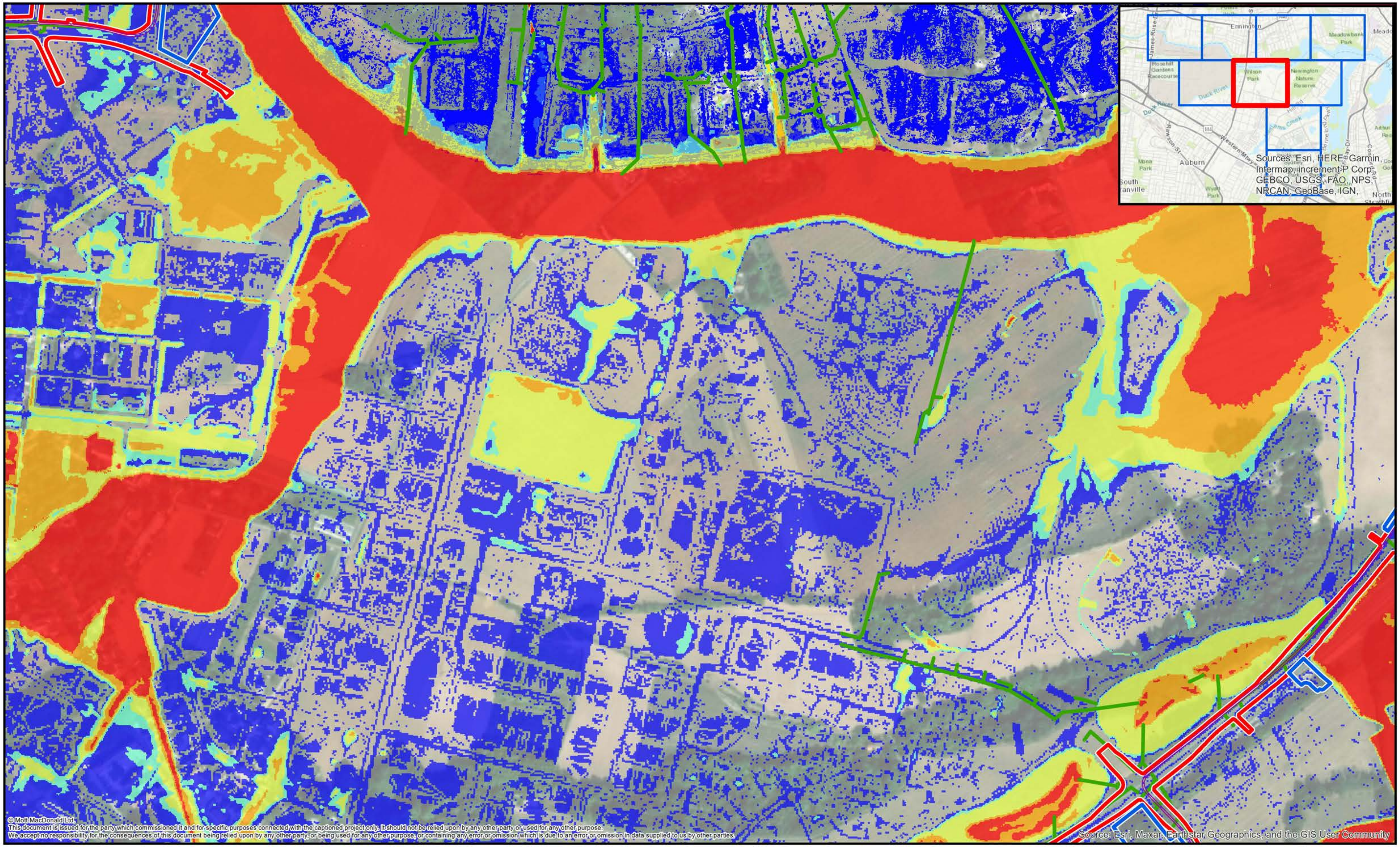
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

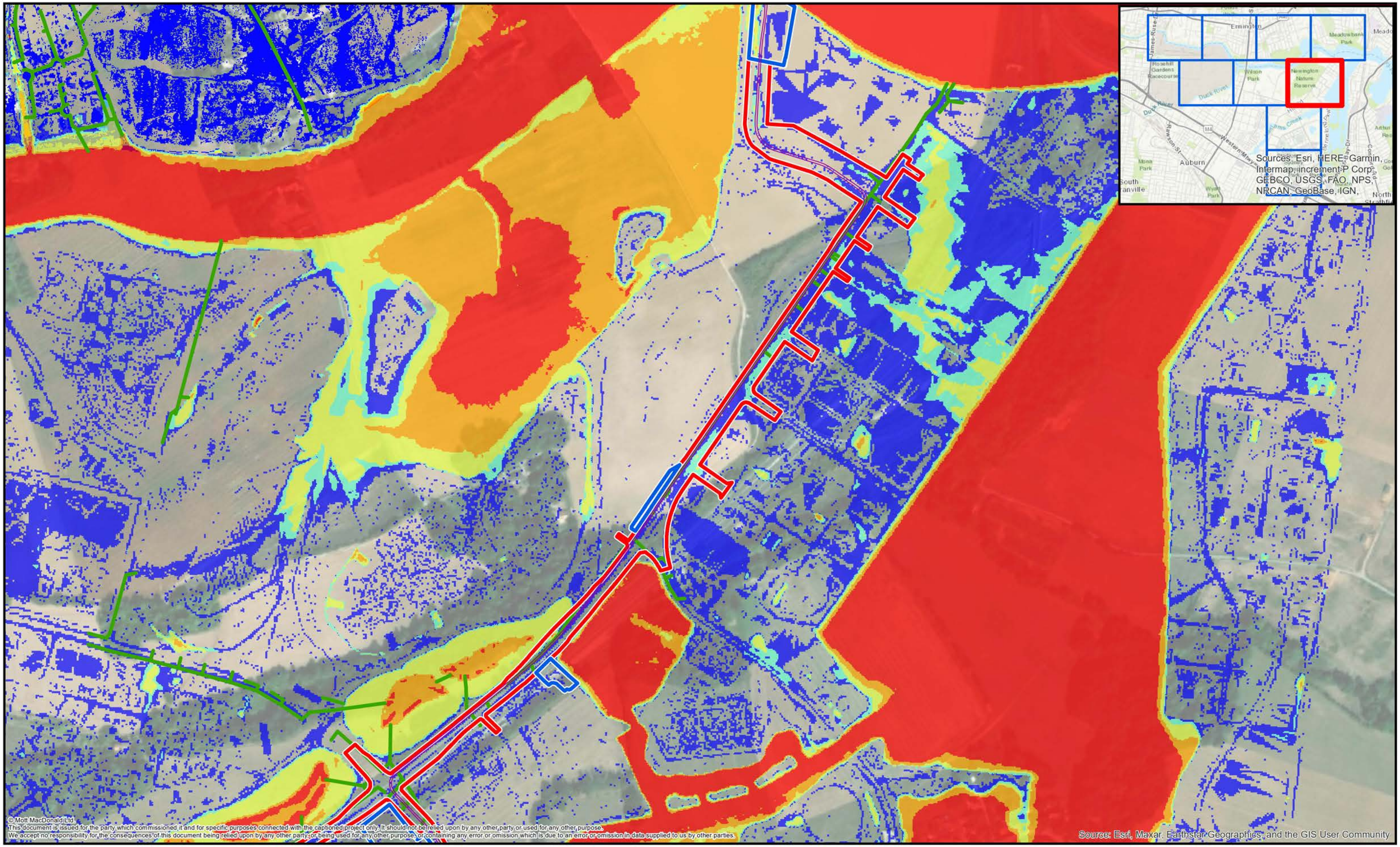
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

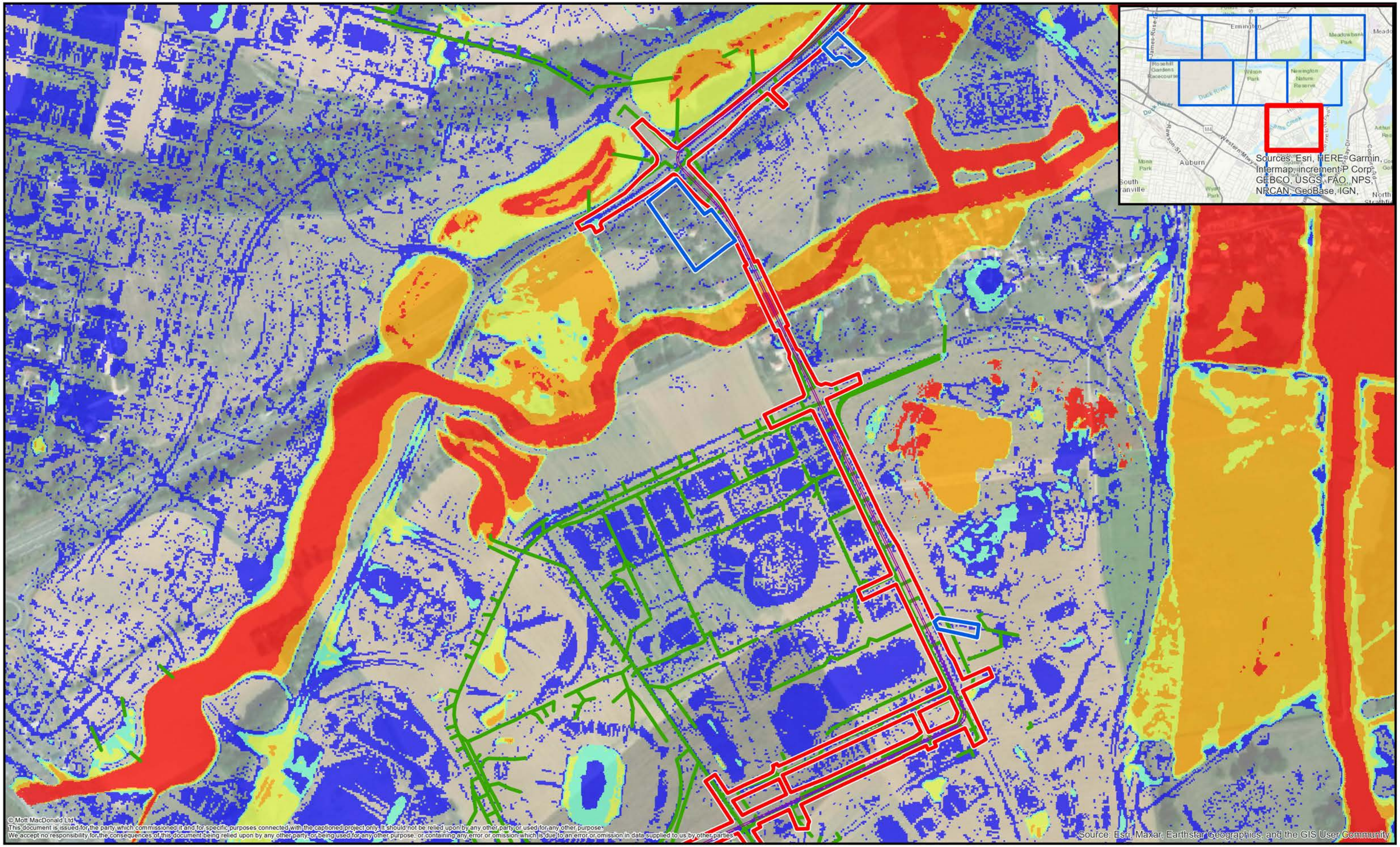
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

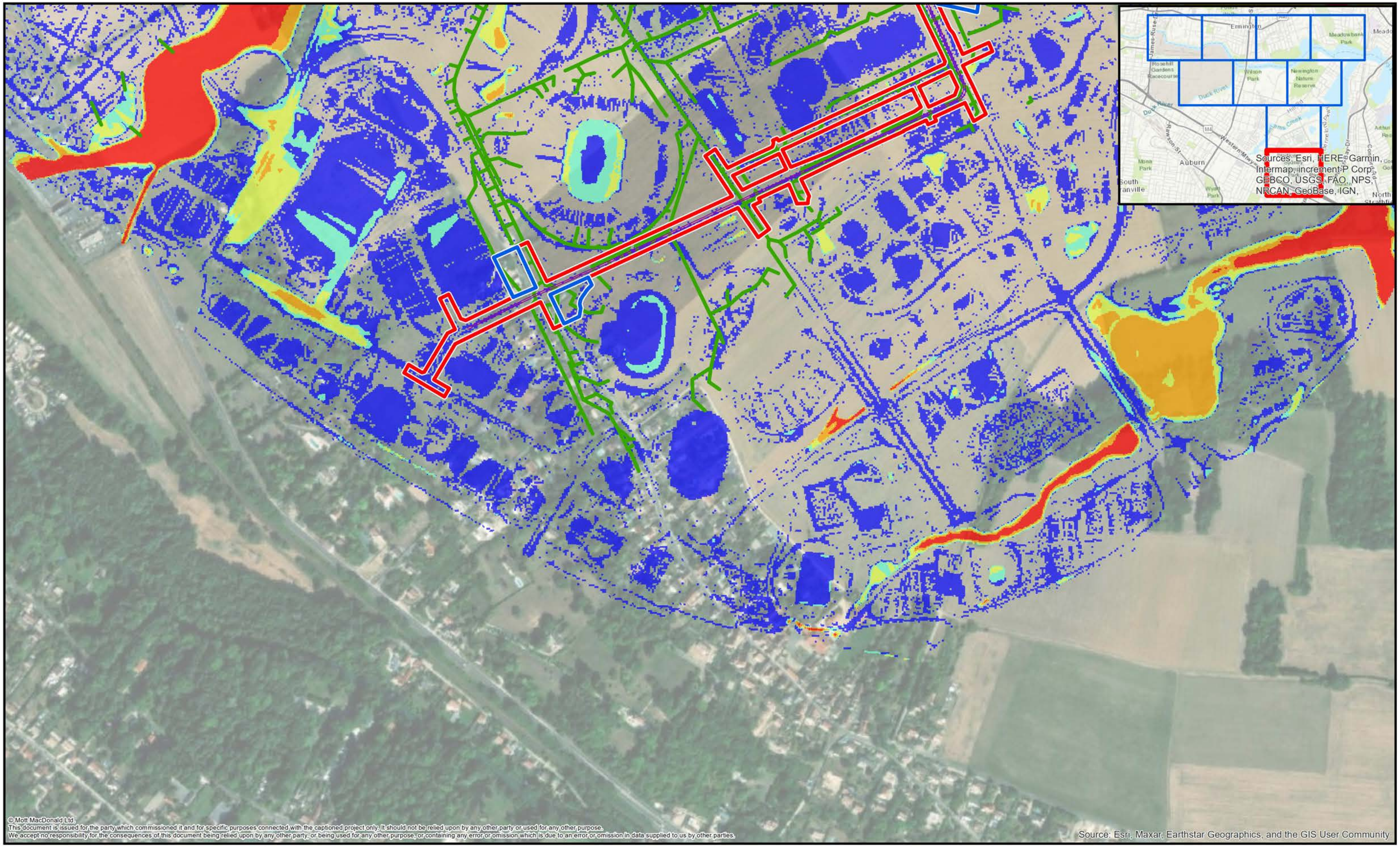
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 5% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

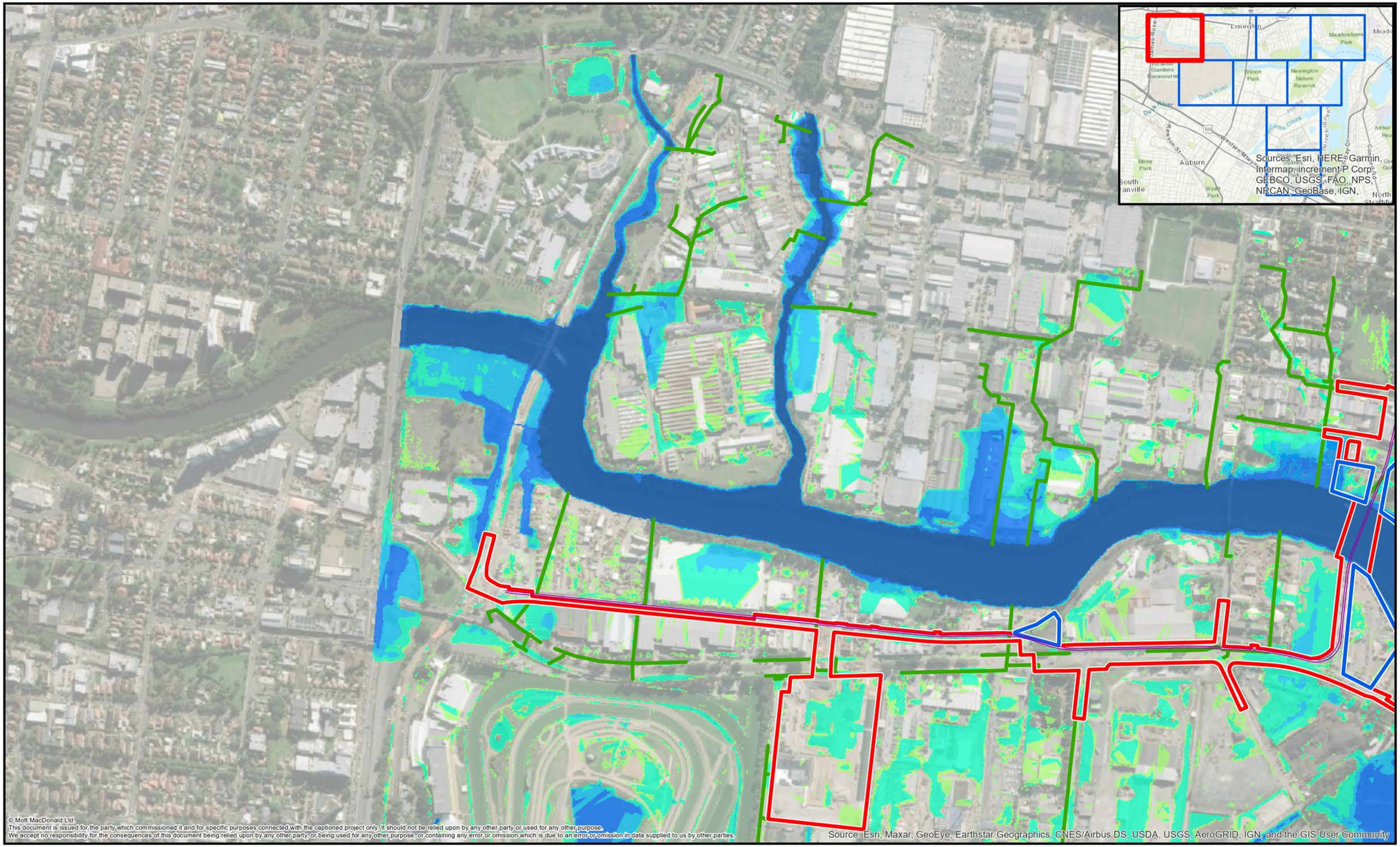
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

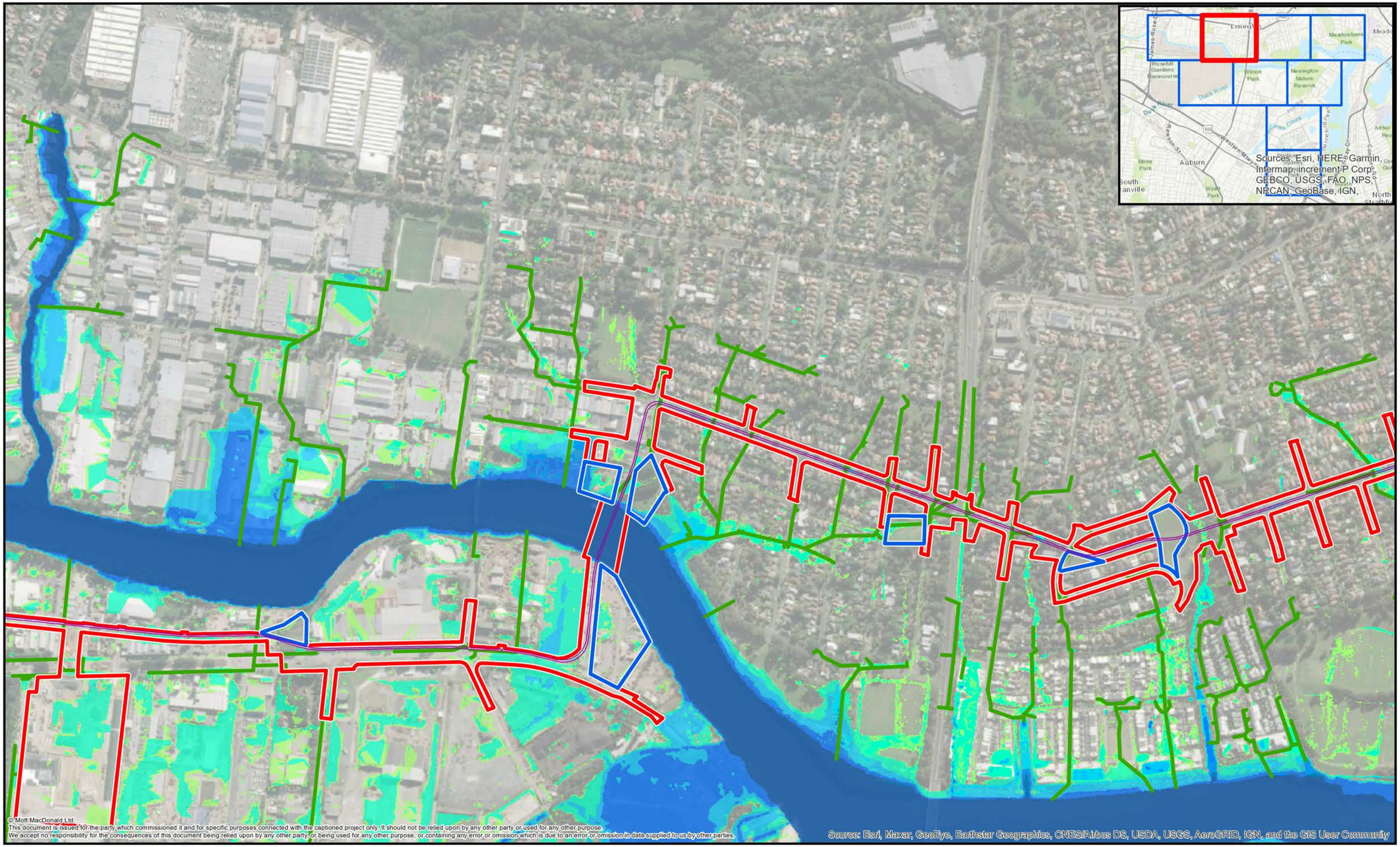
1:7,000

Scale at A3

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

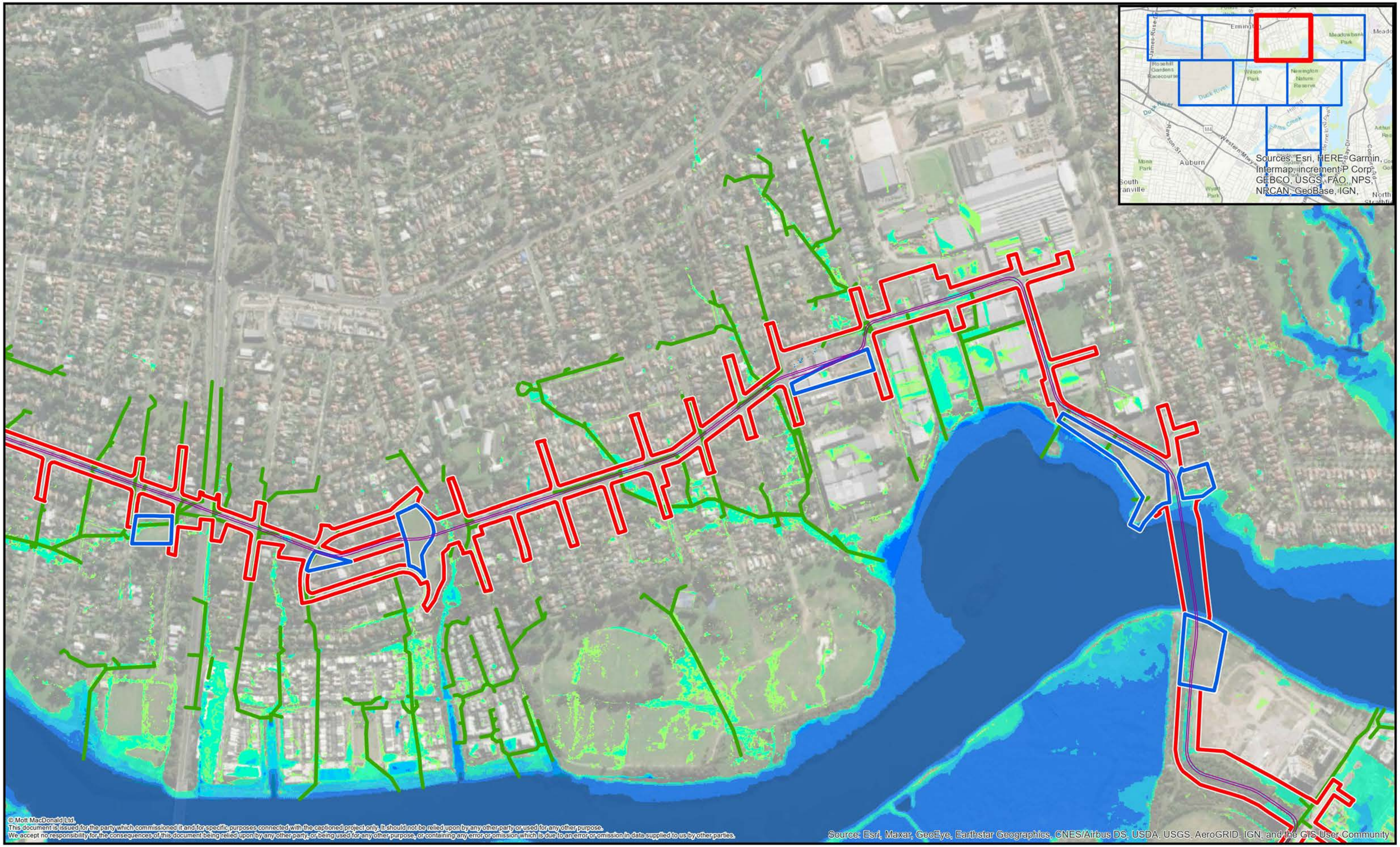
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
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Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

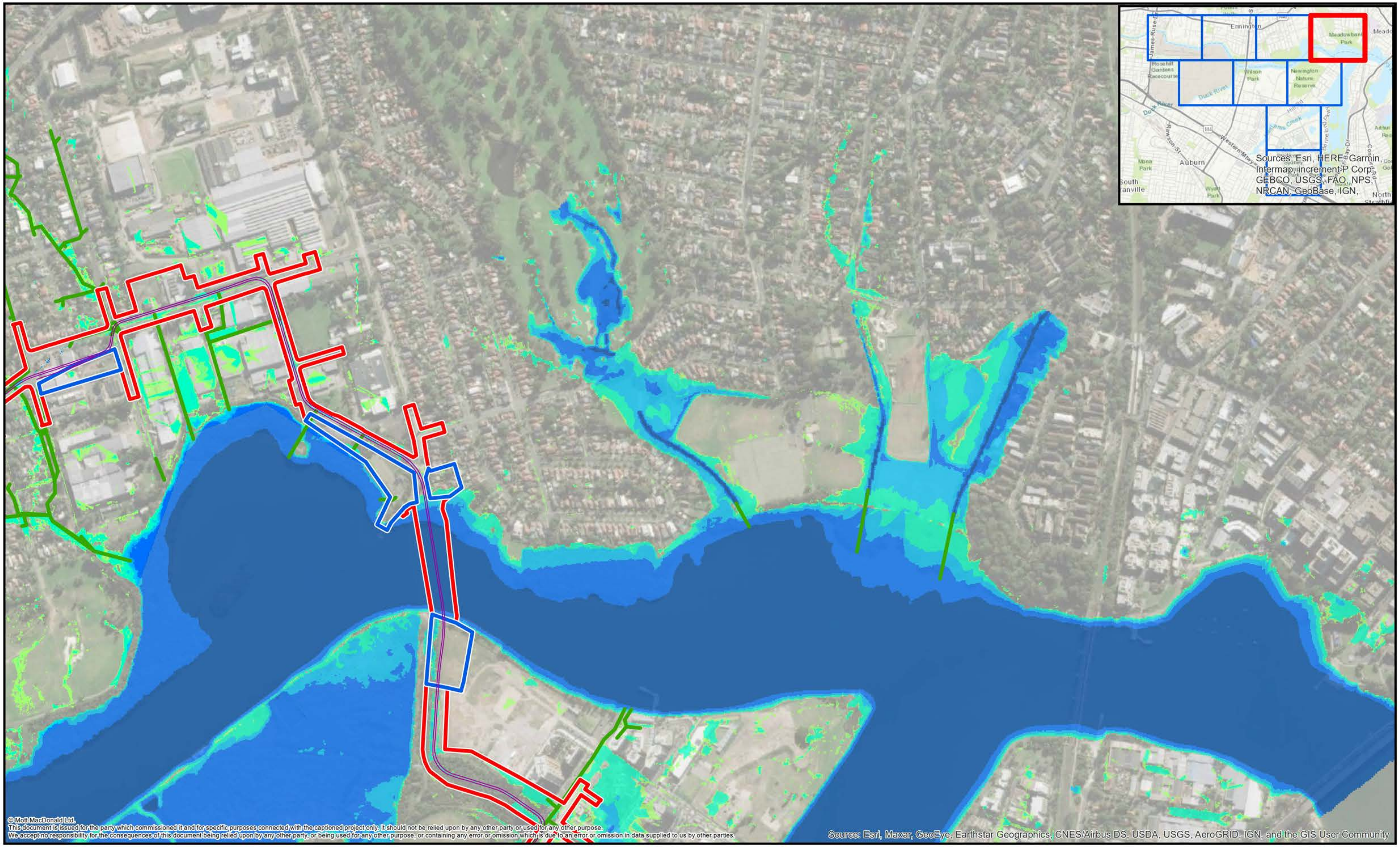
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
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Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

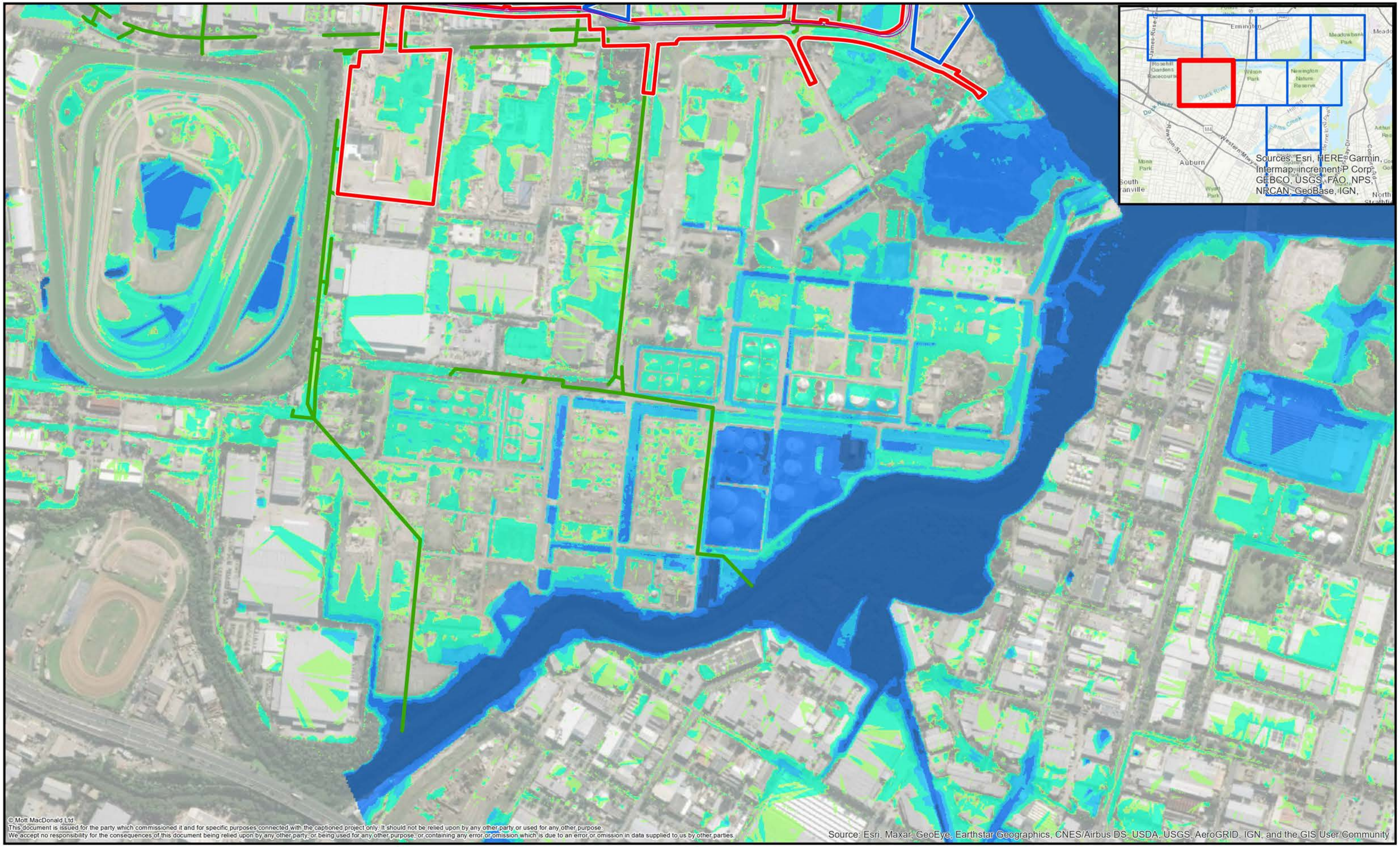
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
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Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

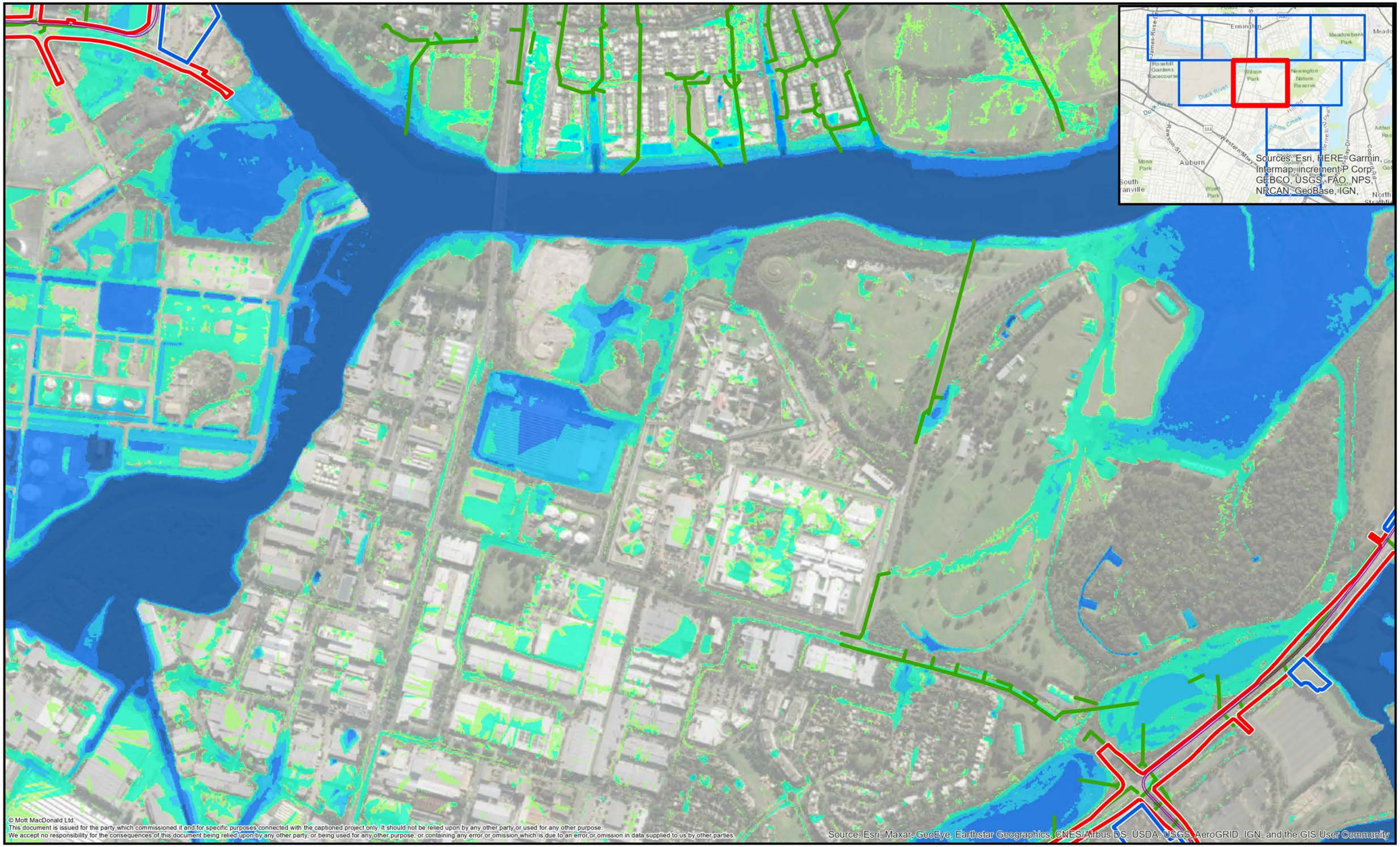
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
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Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

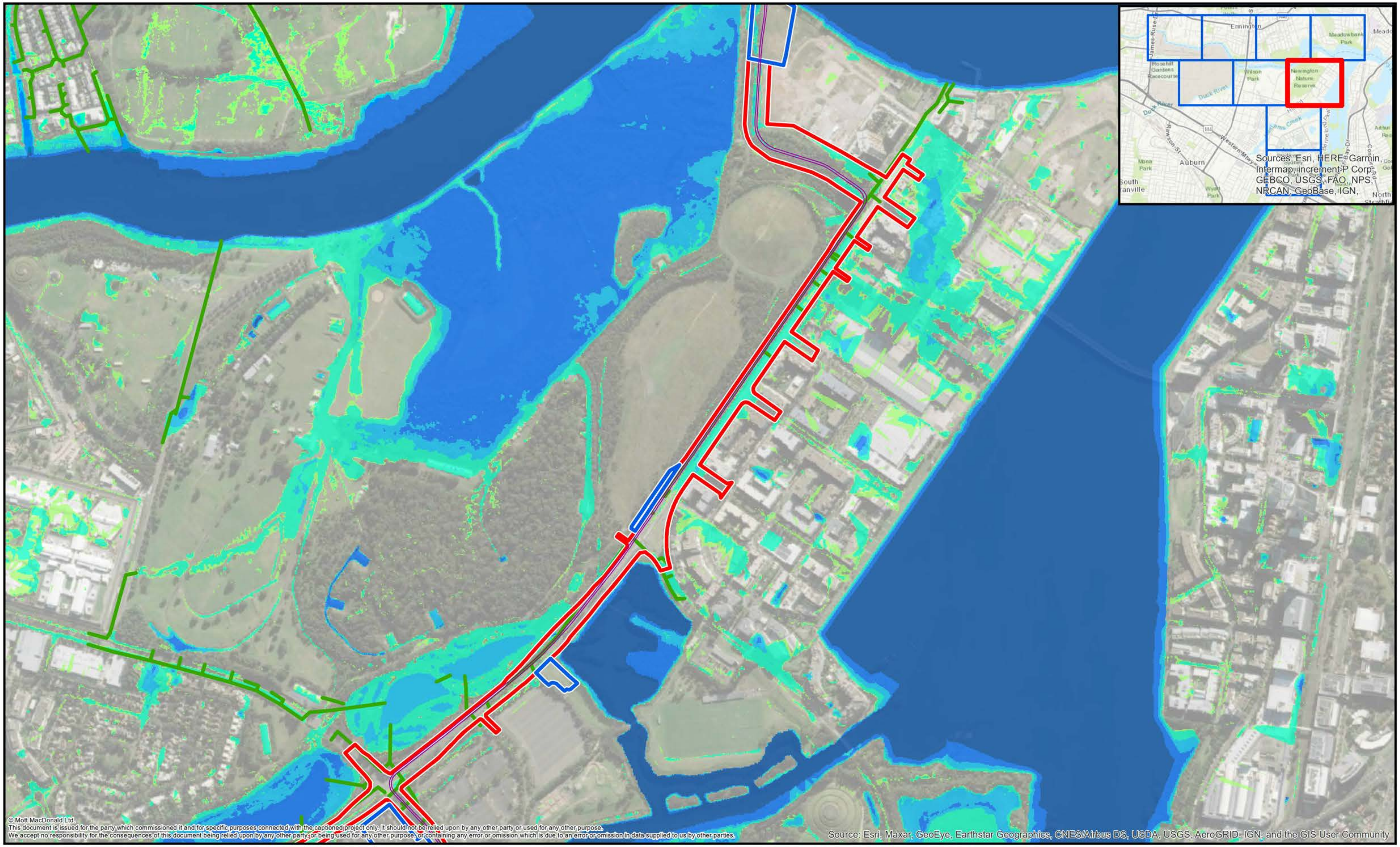
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

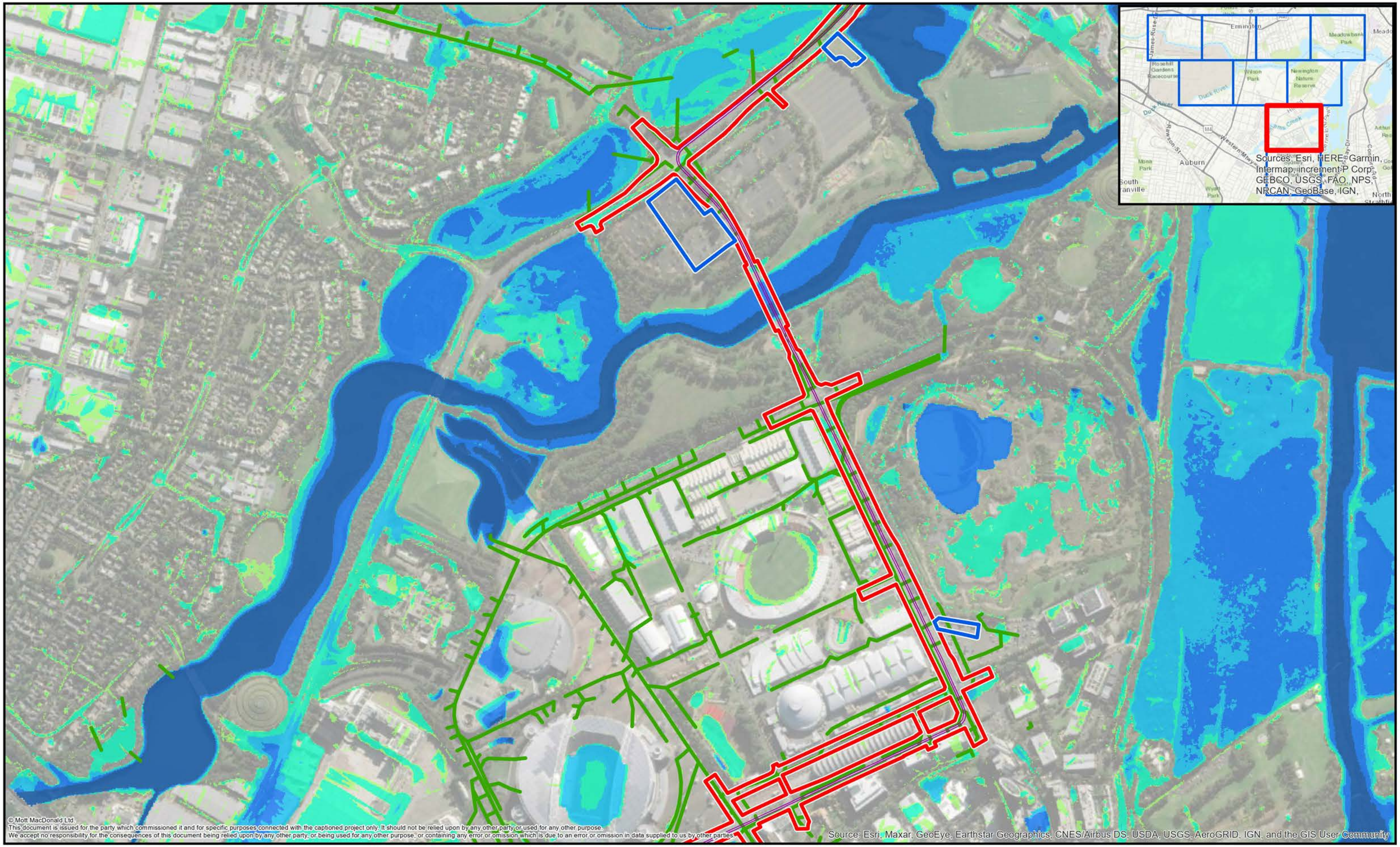
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

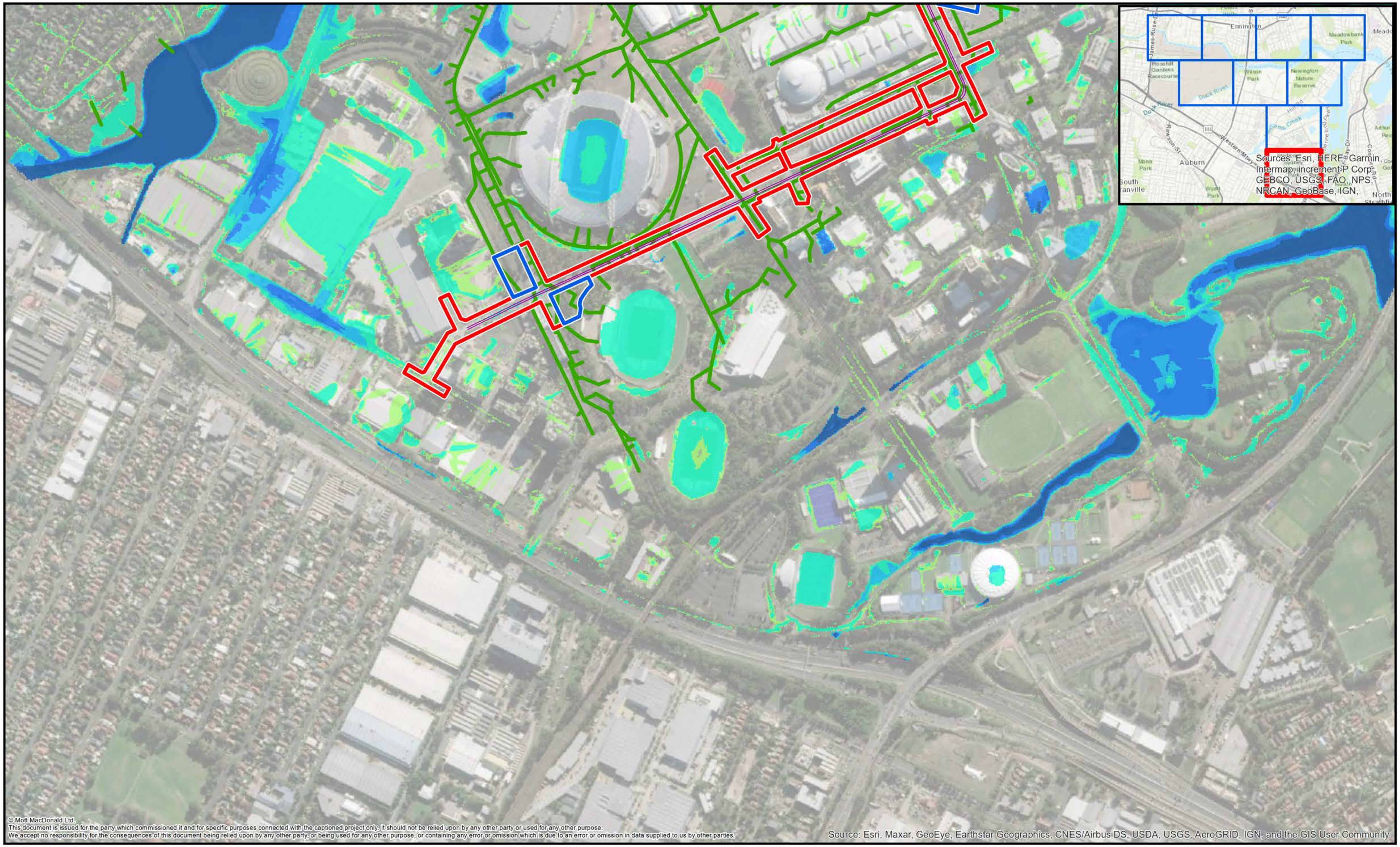
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

Project Alignment
Construction Compounds
Project Site
Stormwater Pipes

Depth (m)
0 - 0.05
0.05 - 0.1
0.1 - 0.5
0.5 - 1
1 - 2
>2

Title

Design Conditions 1% AEP Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

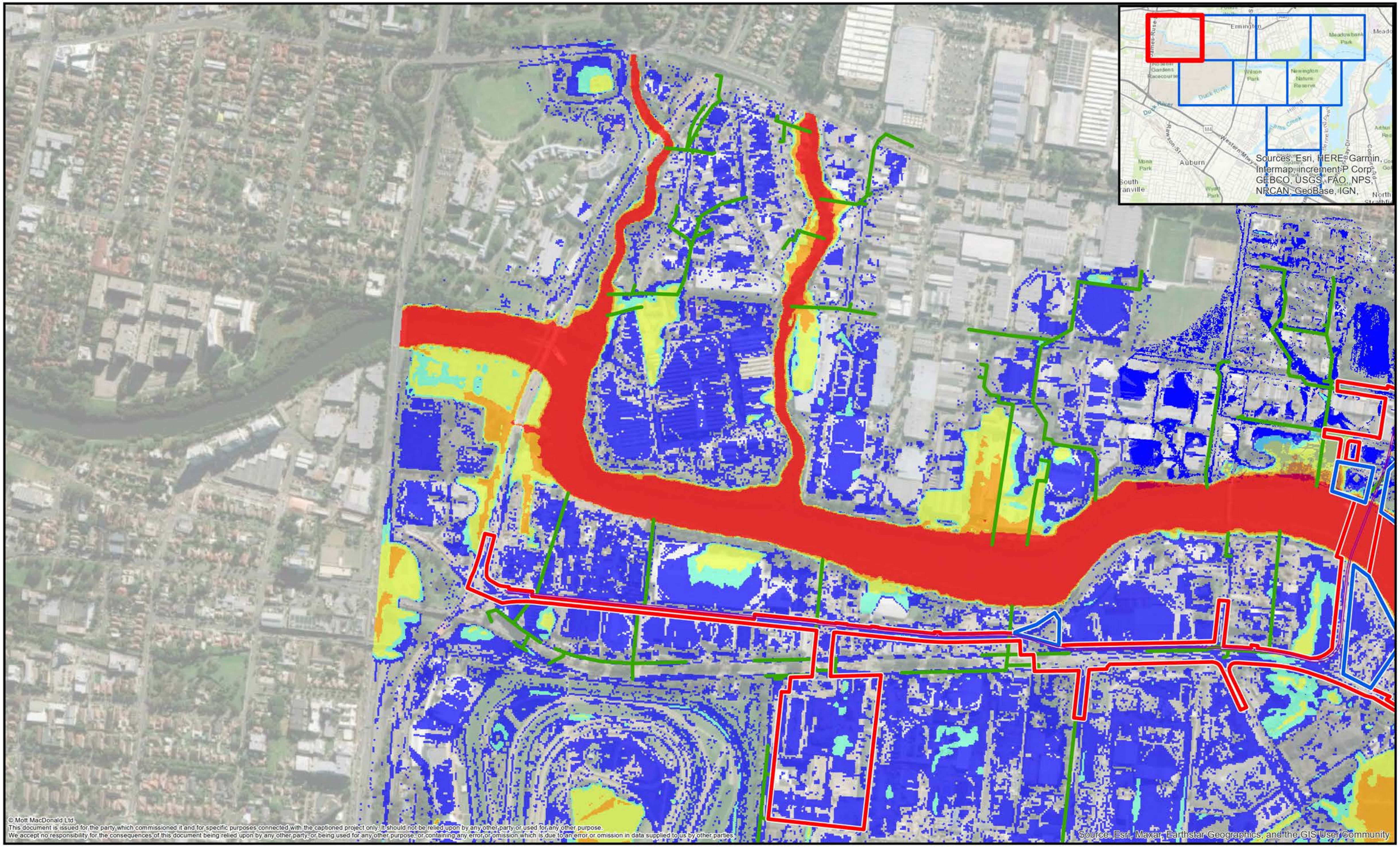
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

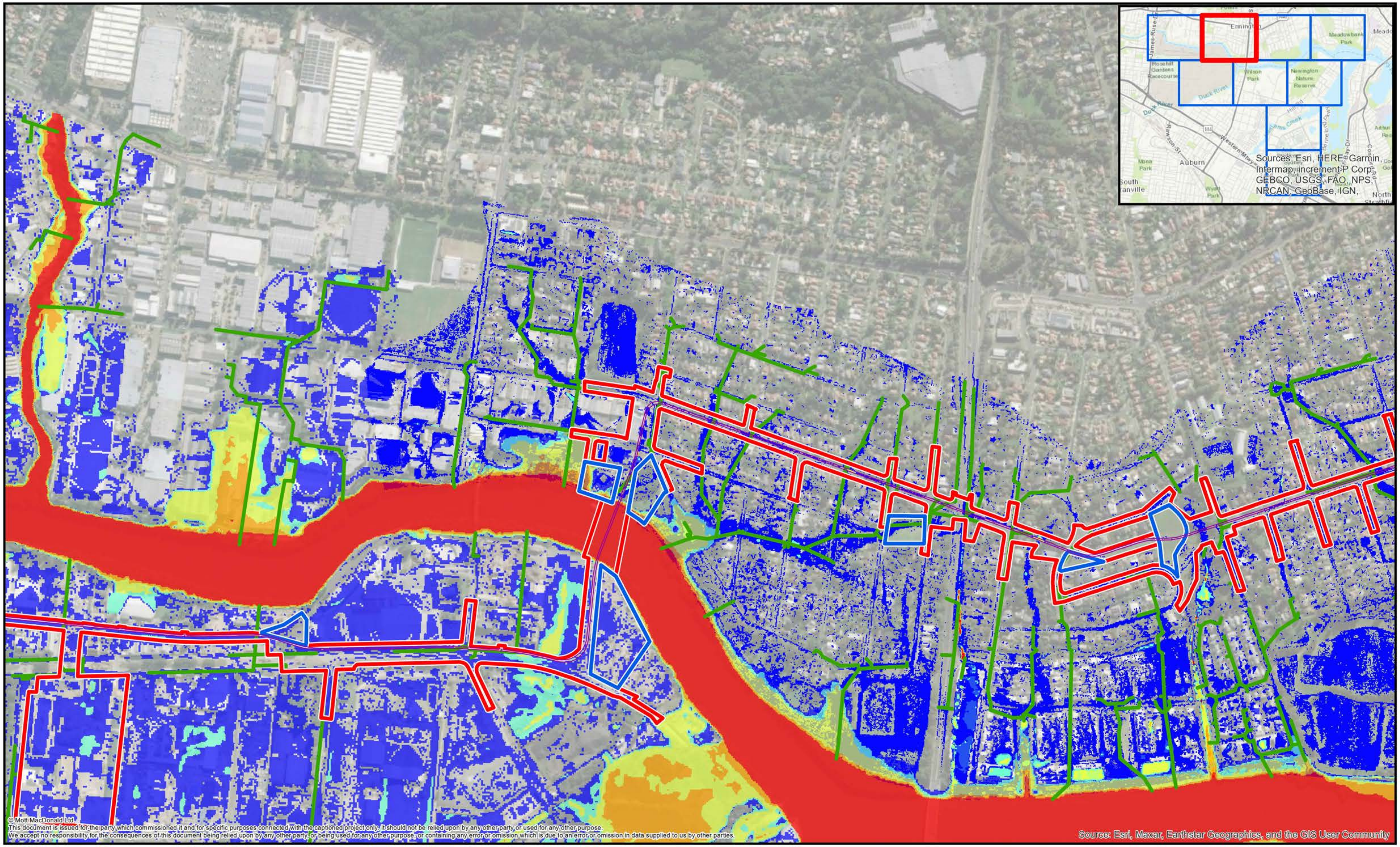
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

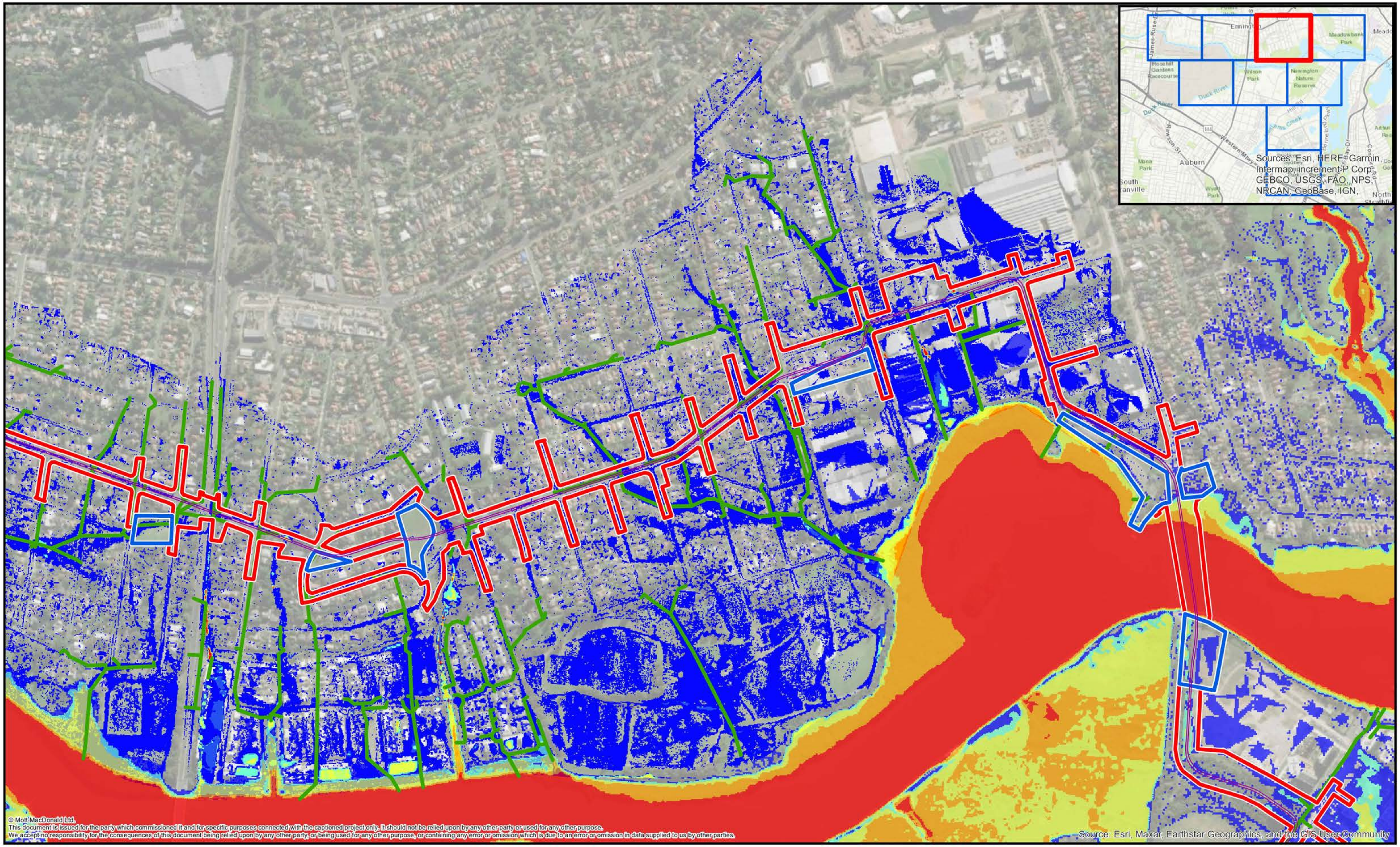
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

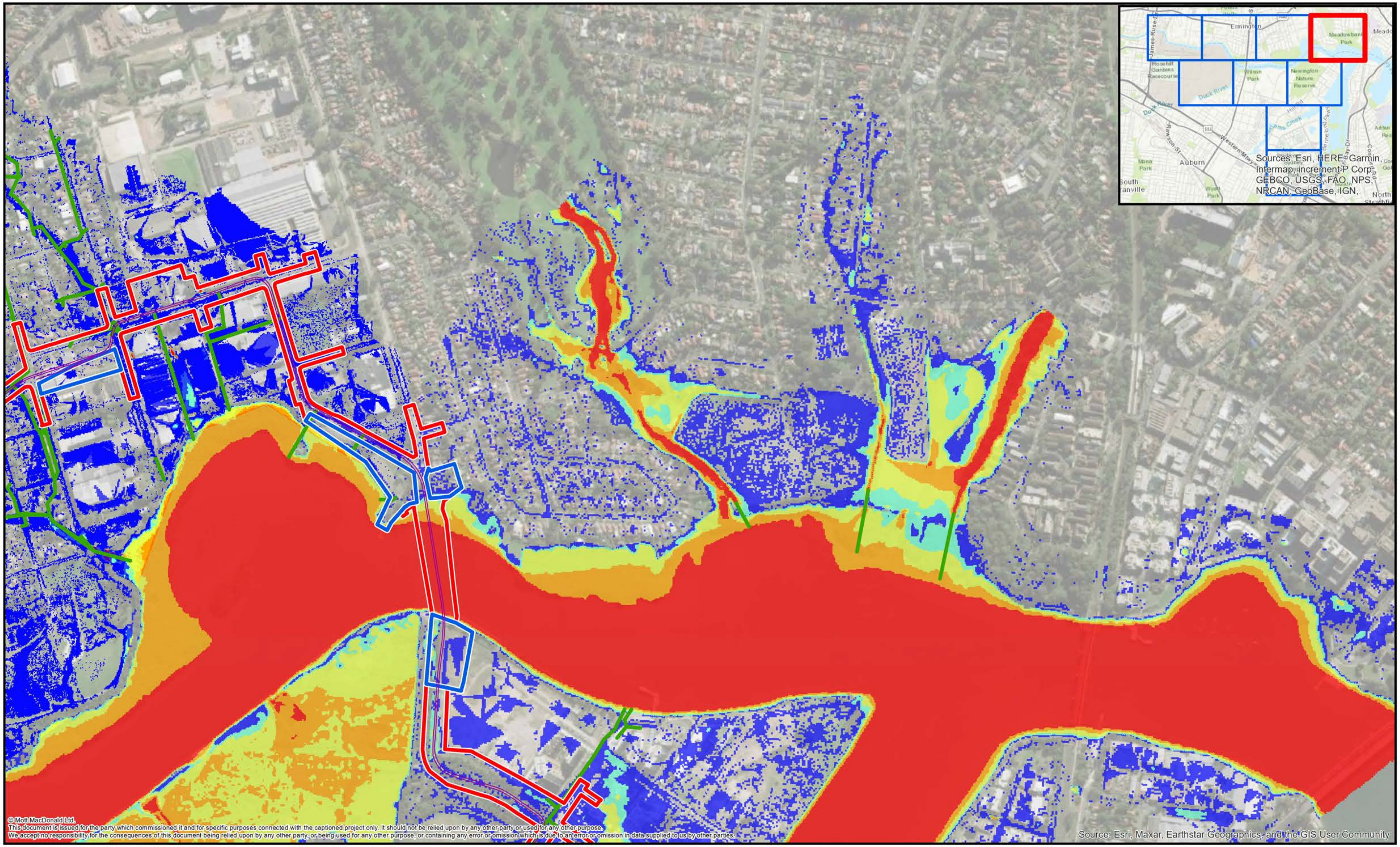
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

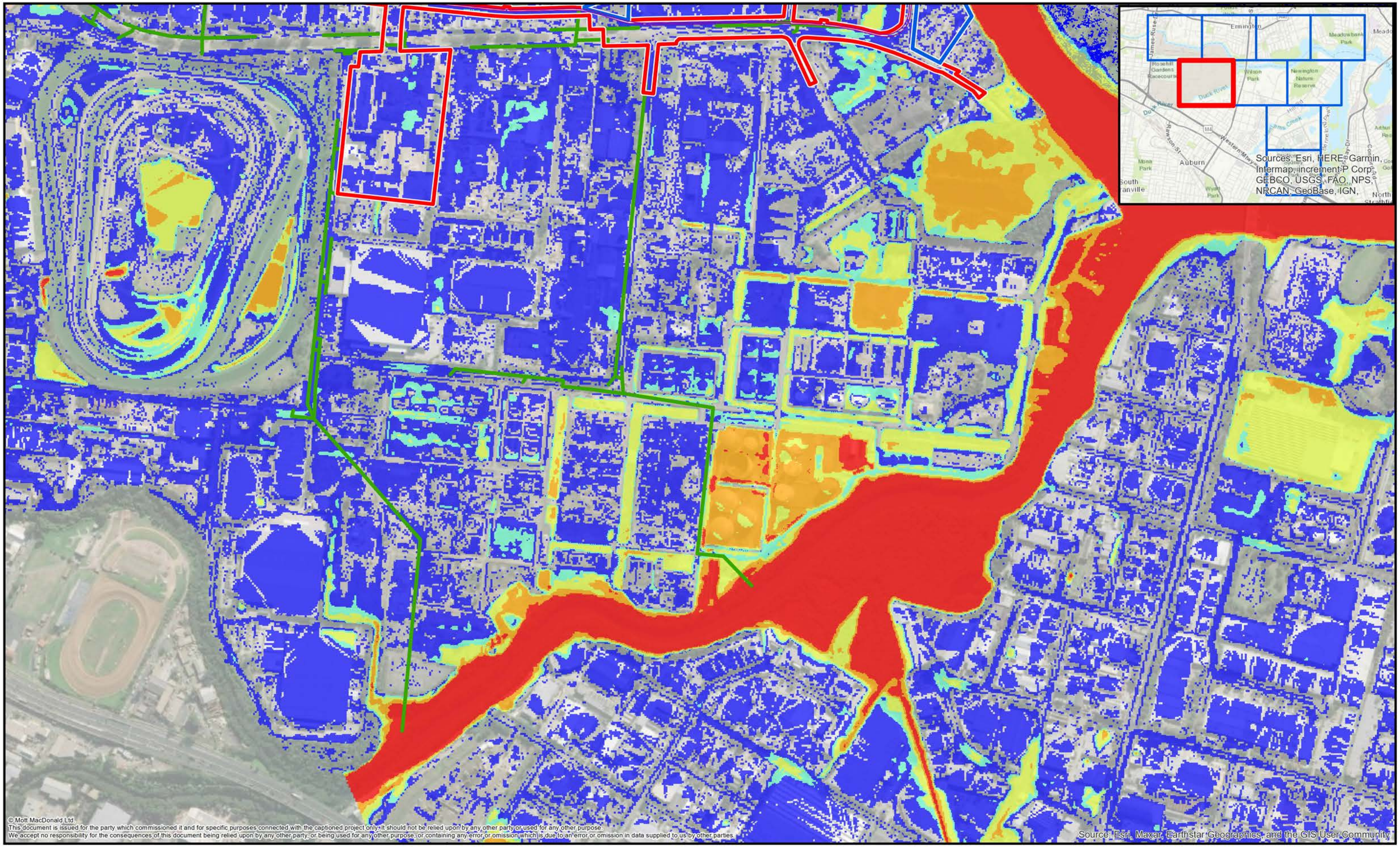
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

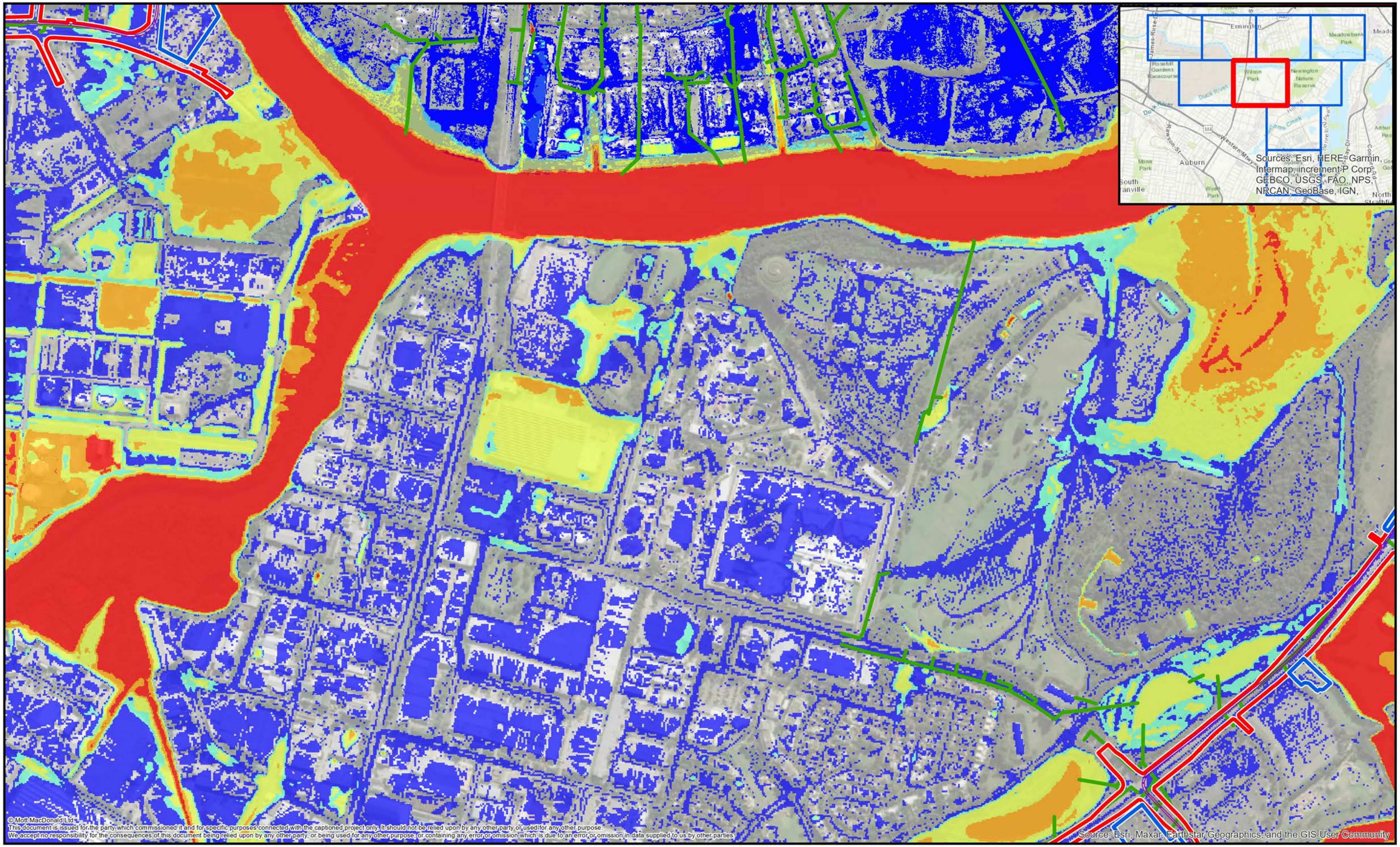
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

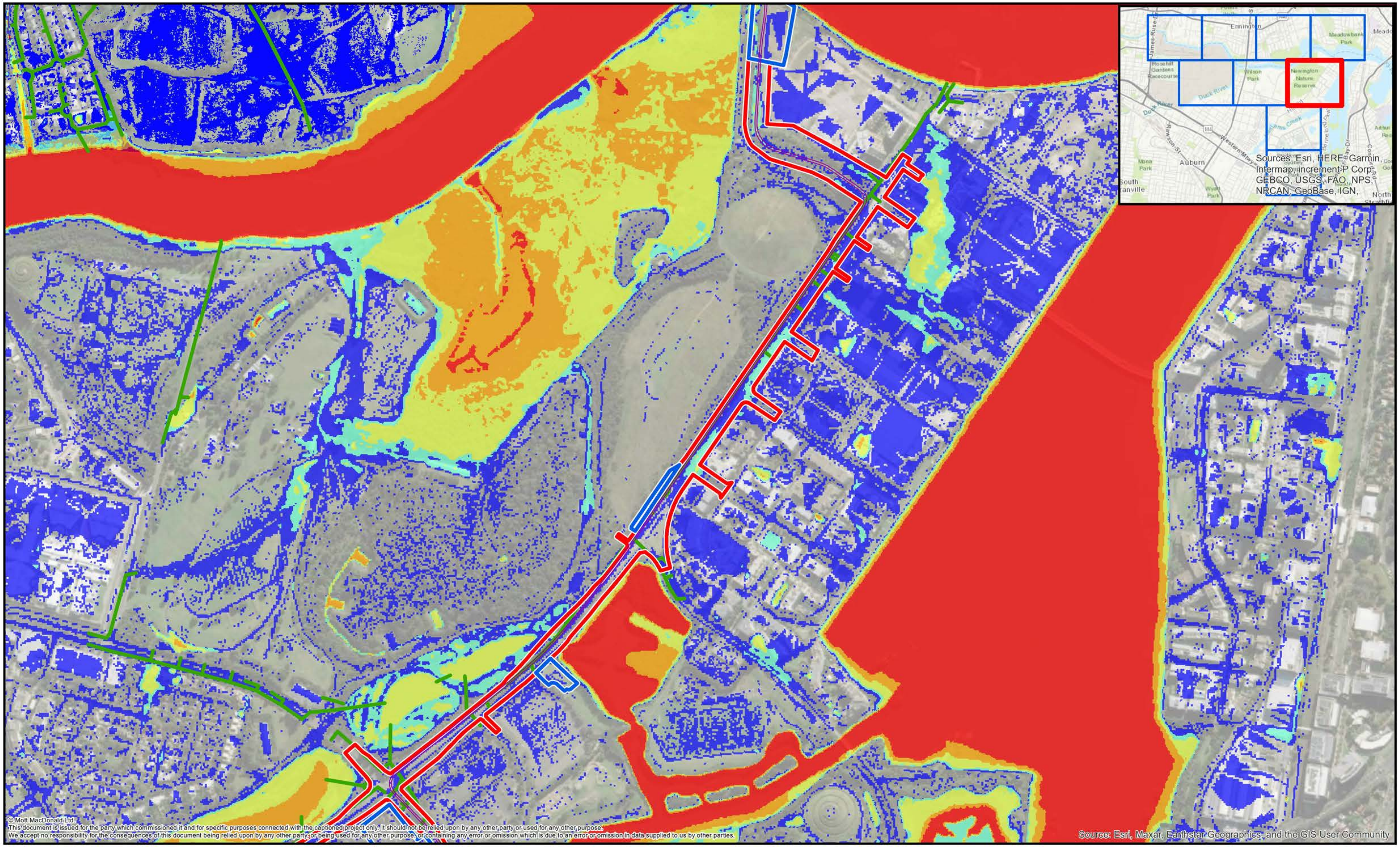
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

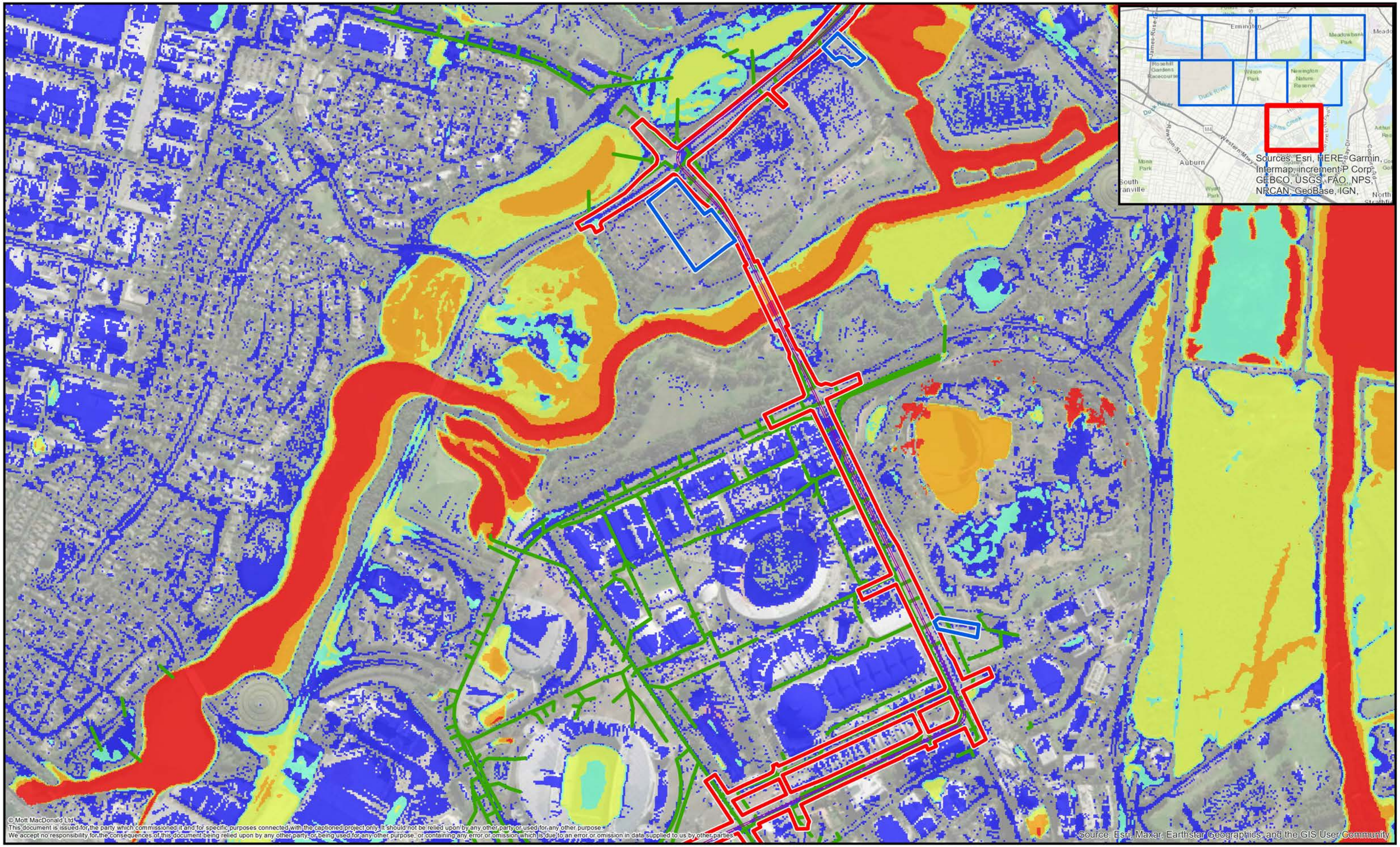
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

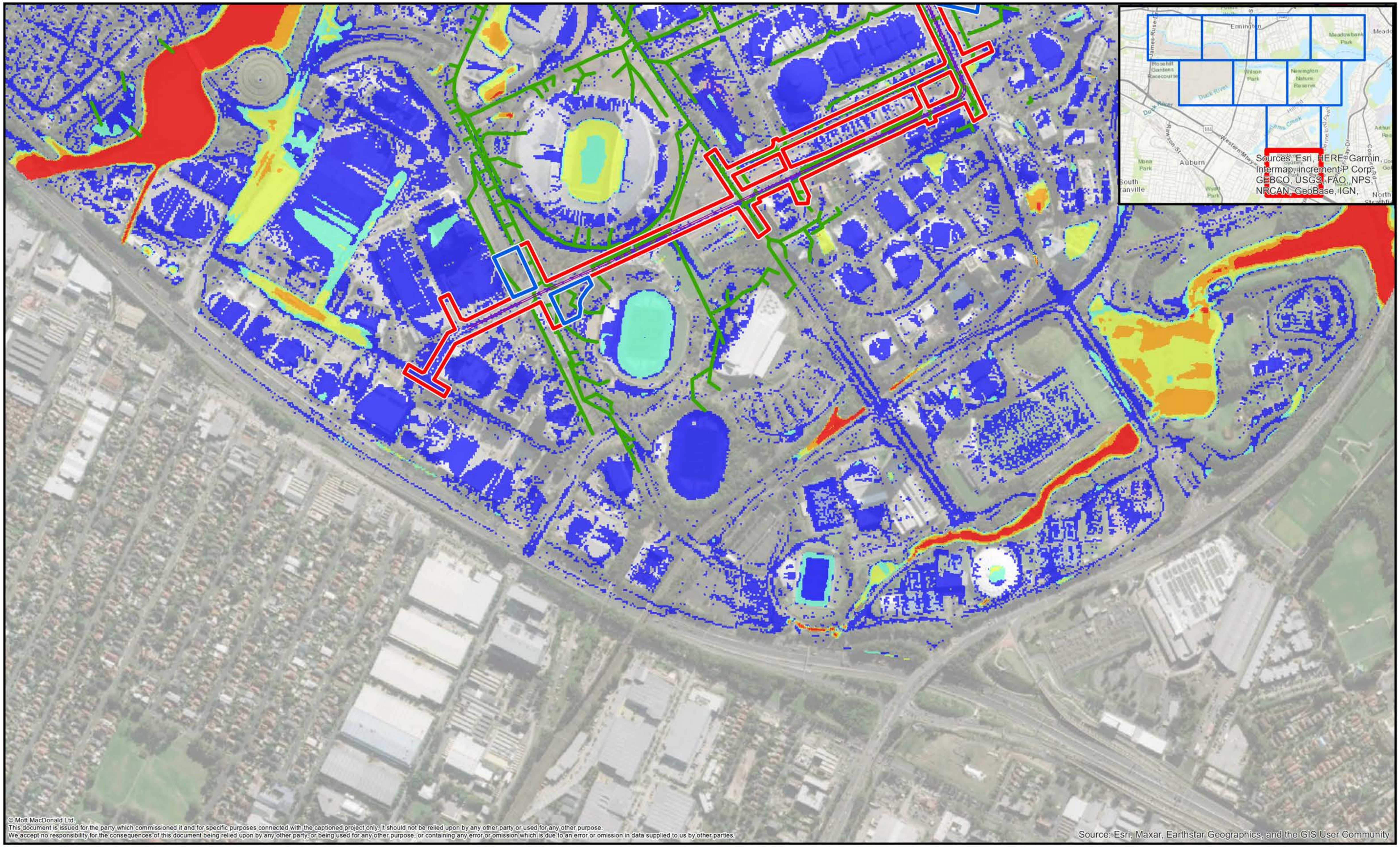
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

Project Alignment
Construction Compounds
Project Site
Stormwater Pipes

Flood Hazard (ZAEM1)

H1
H2
H3
H4
H5
H6

Title

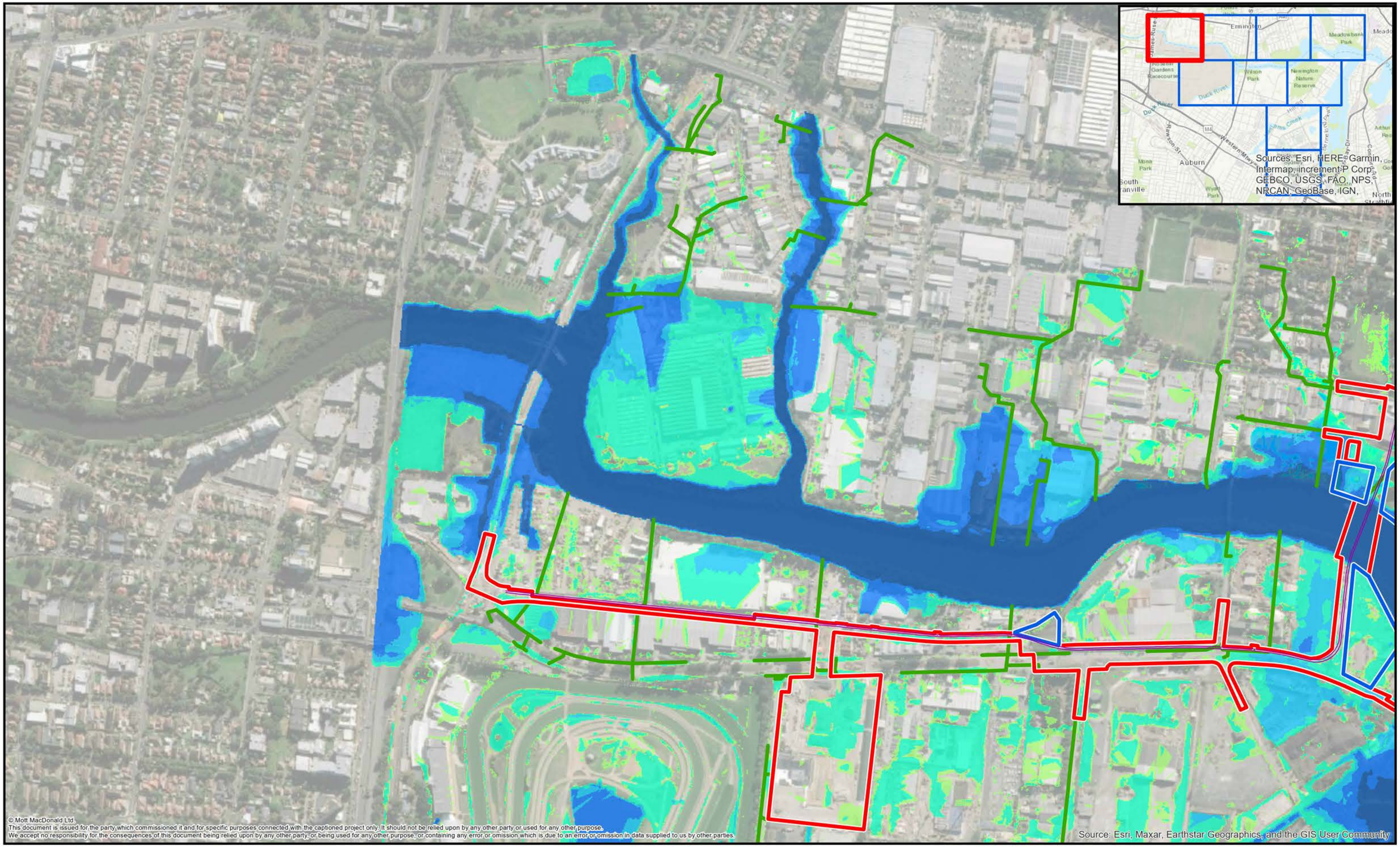
Design Conditions 1% AEP Flood Hazard

0 0.05 0.1 0.2 Kilometers
1:7,000
Scale at A3

MOTT MACDONALD

Map Number
Sheet No 9 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

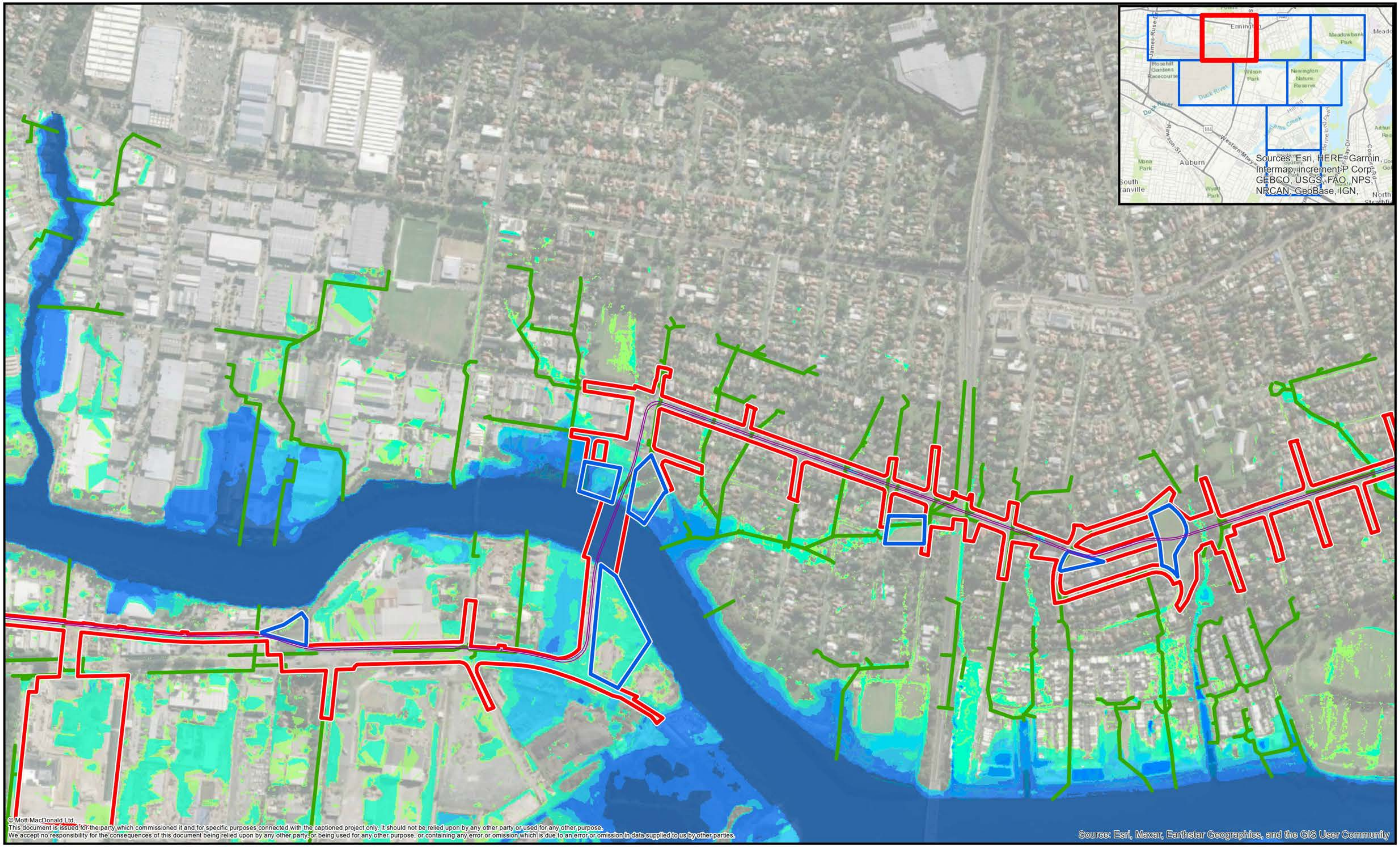
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

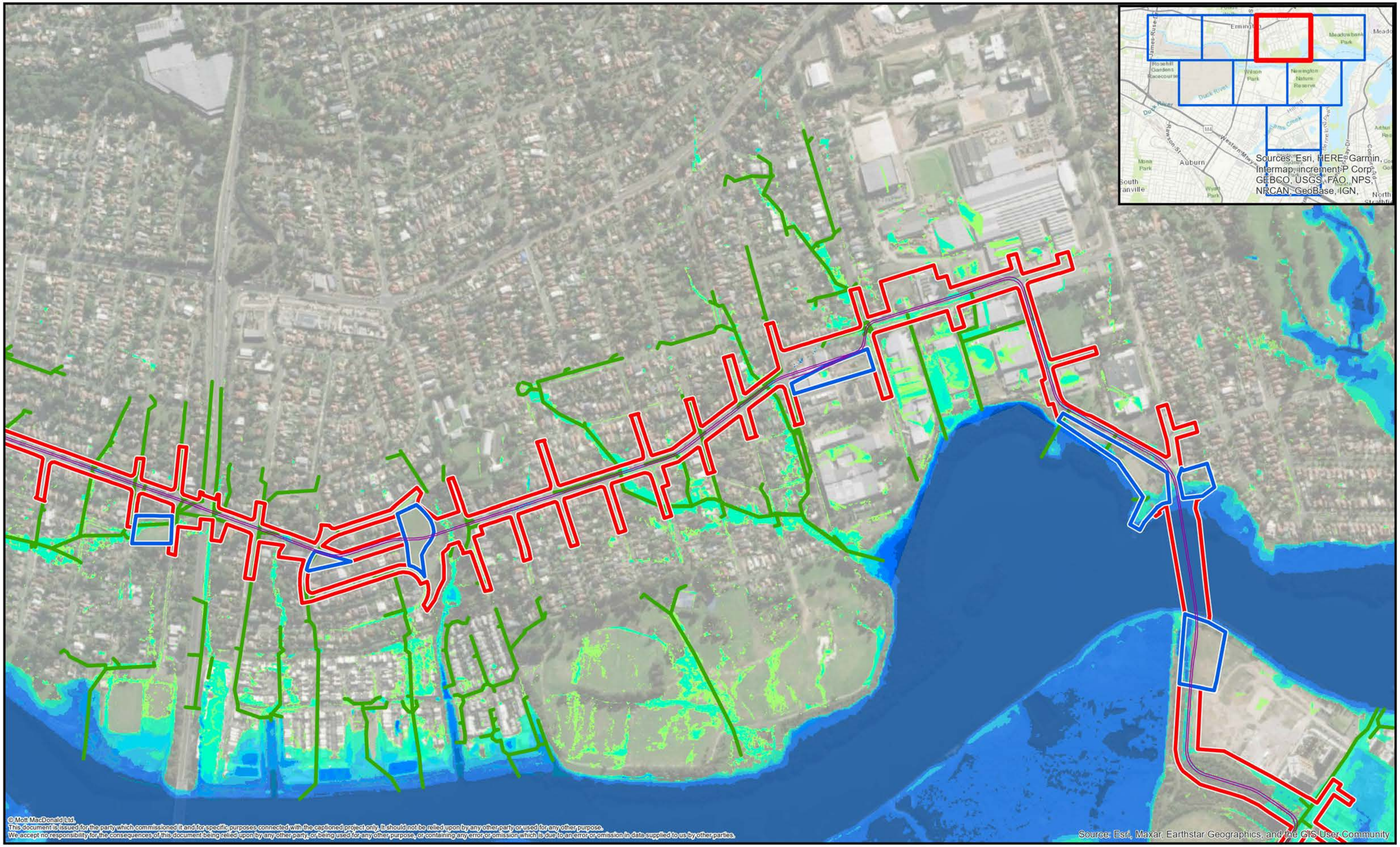
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

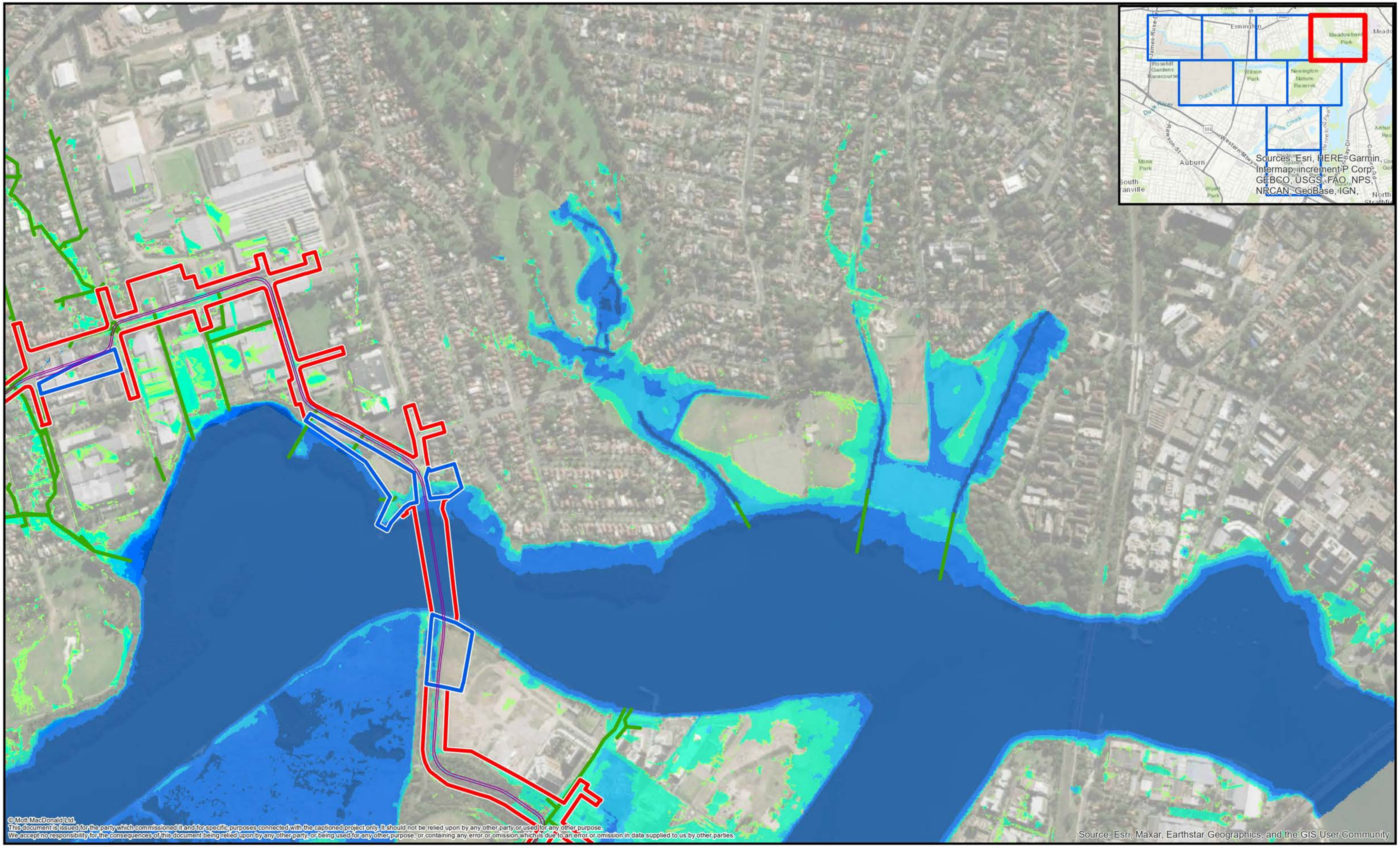
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

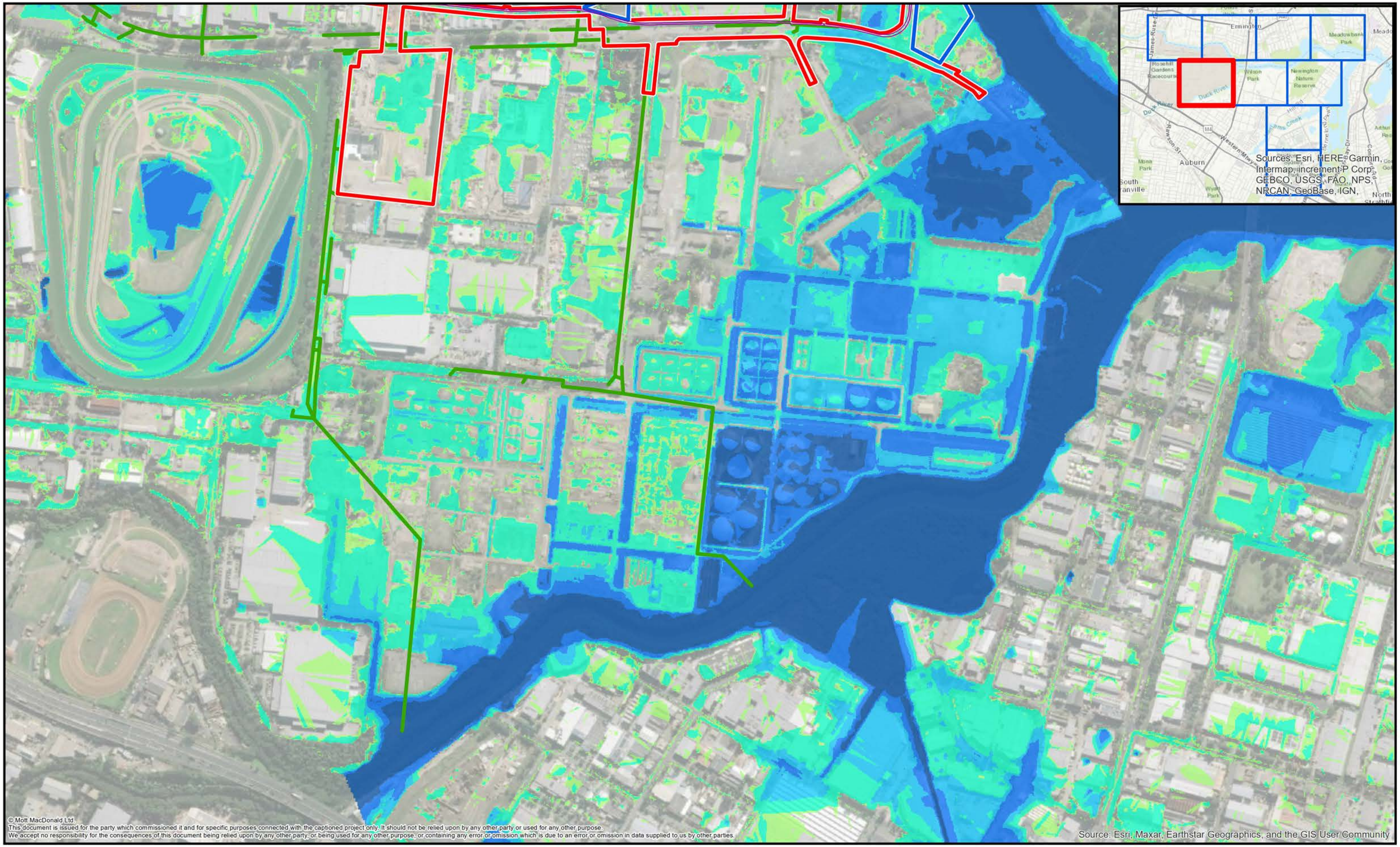
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

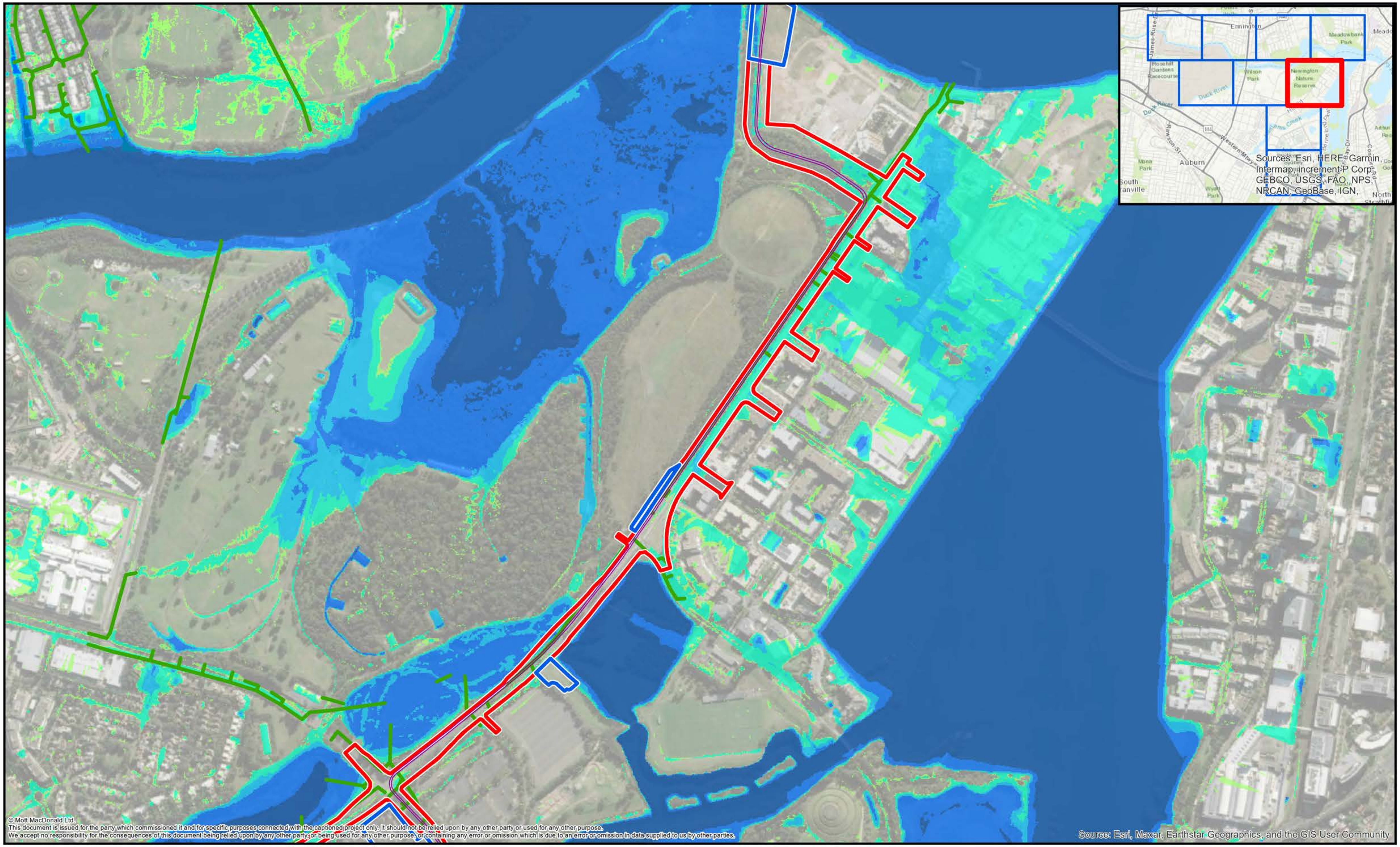
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

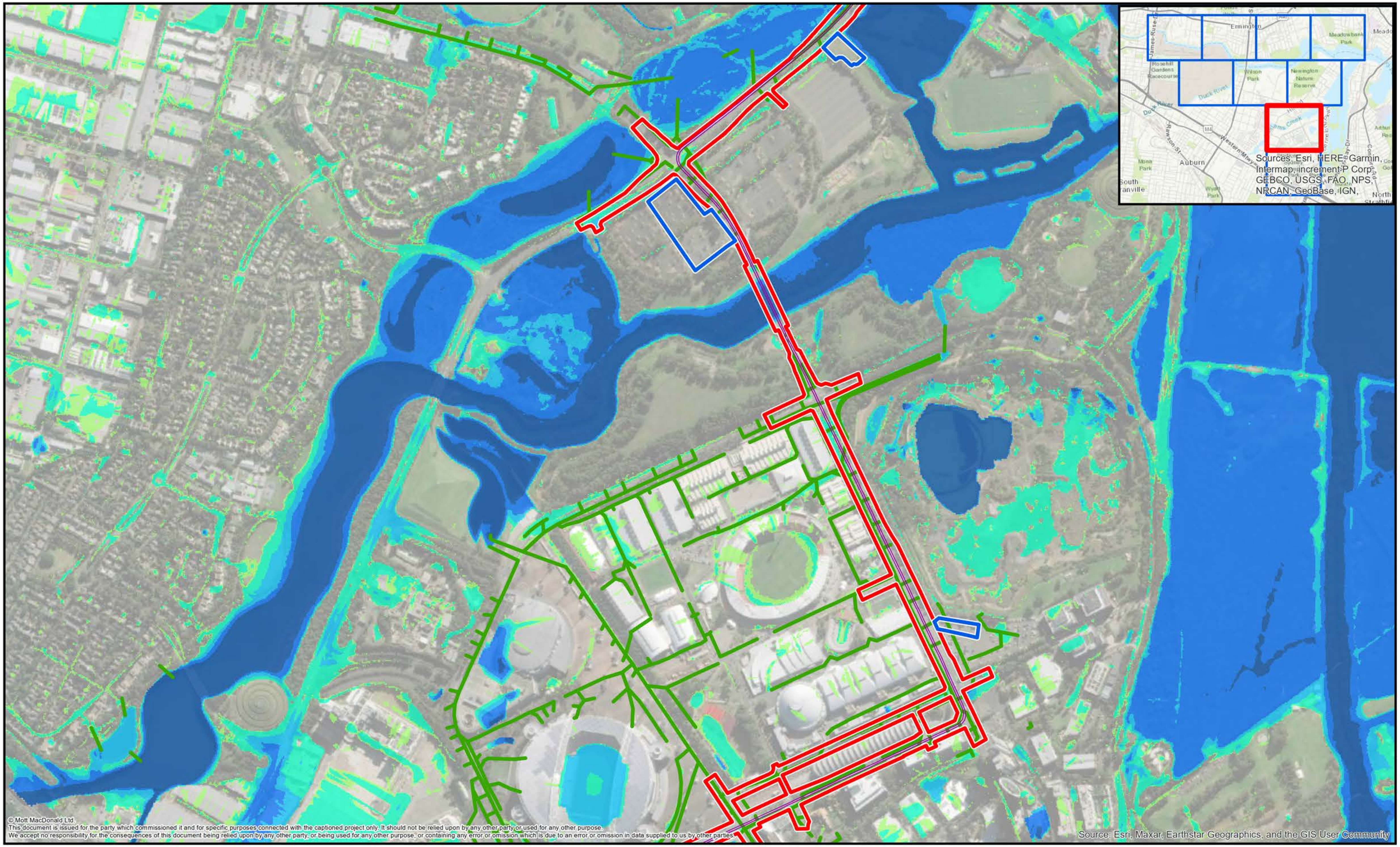
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- >2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

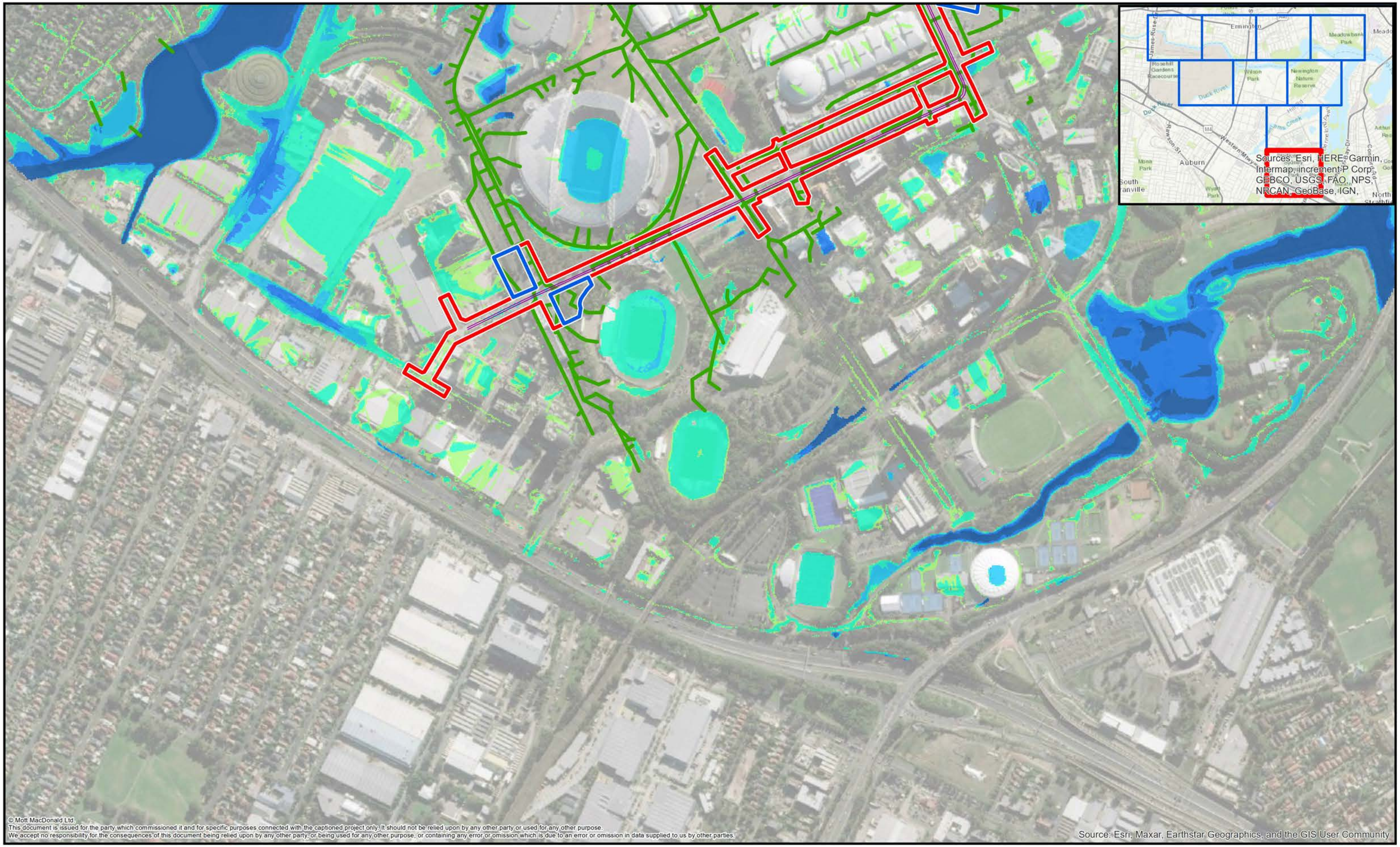
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Depth (m)

0 - 0.05

0.05 - 0.1

0.1 - 0.5

0.5 - 1

1 - 2

>2

Title

Design Conditions 1% AEP Climate Change Flood Depth

0 0.05 0.1 0.2 Kilometers

1:7,000

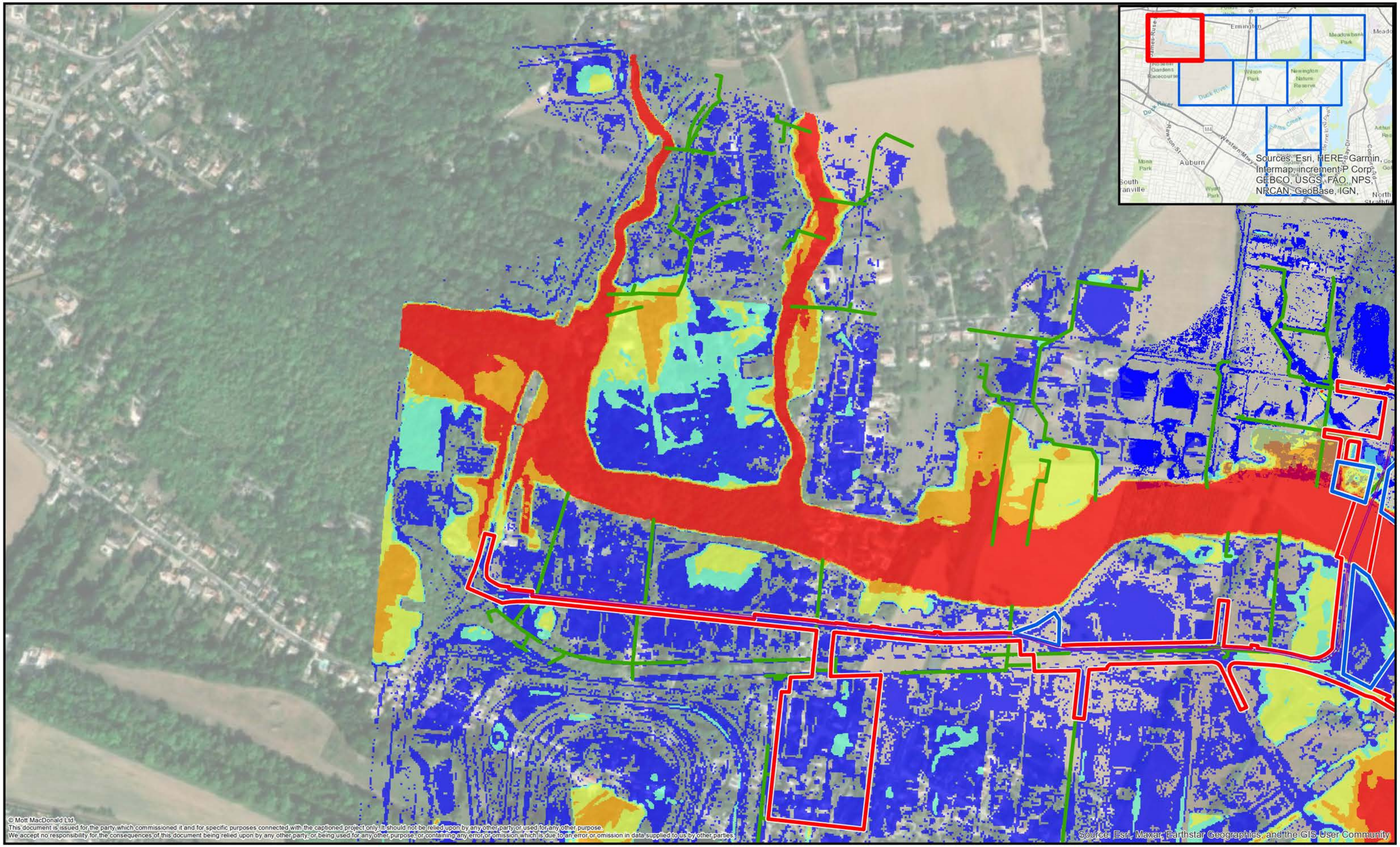
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Flood Hazard (ZAEM1)

H1

H2

H3

H4

H5

H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

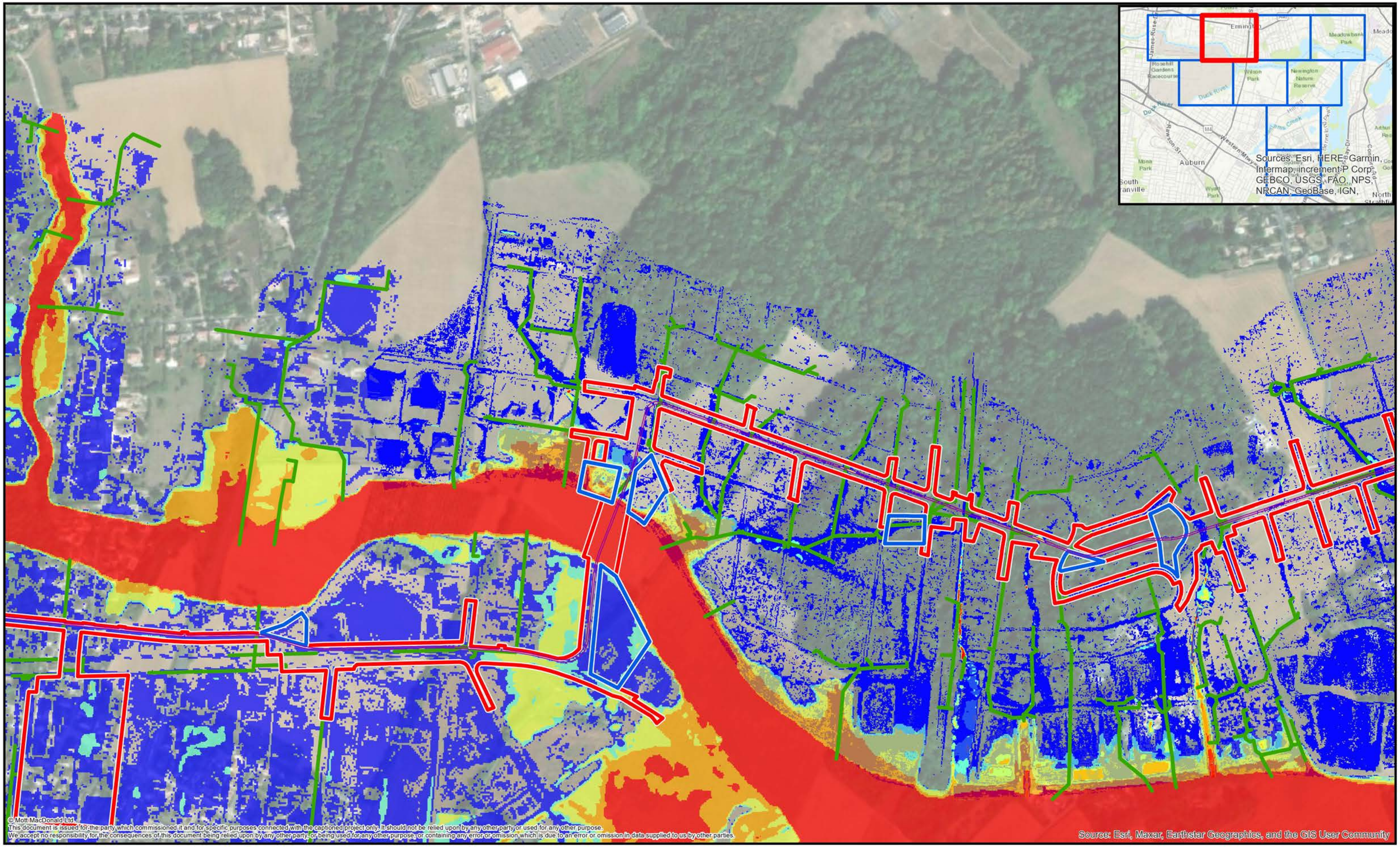
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

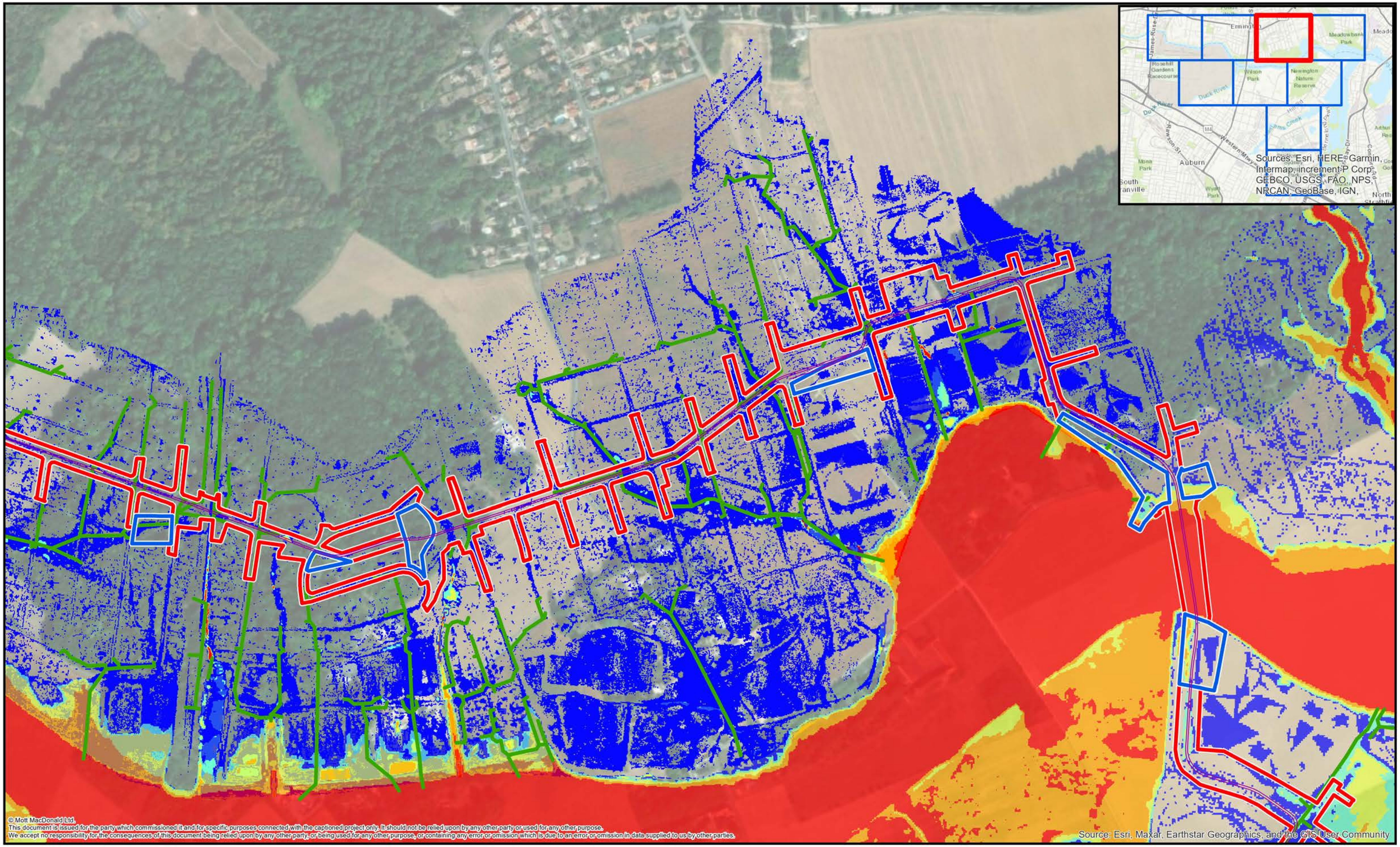
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

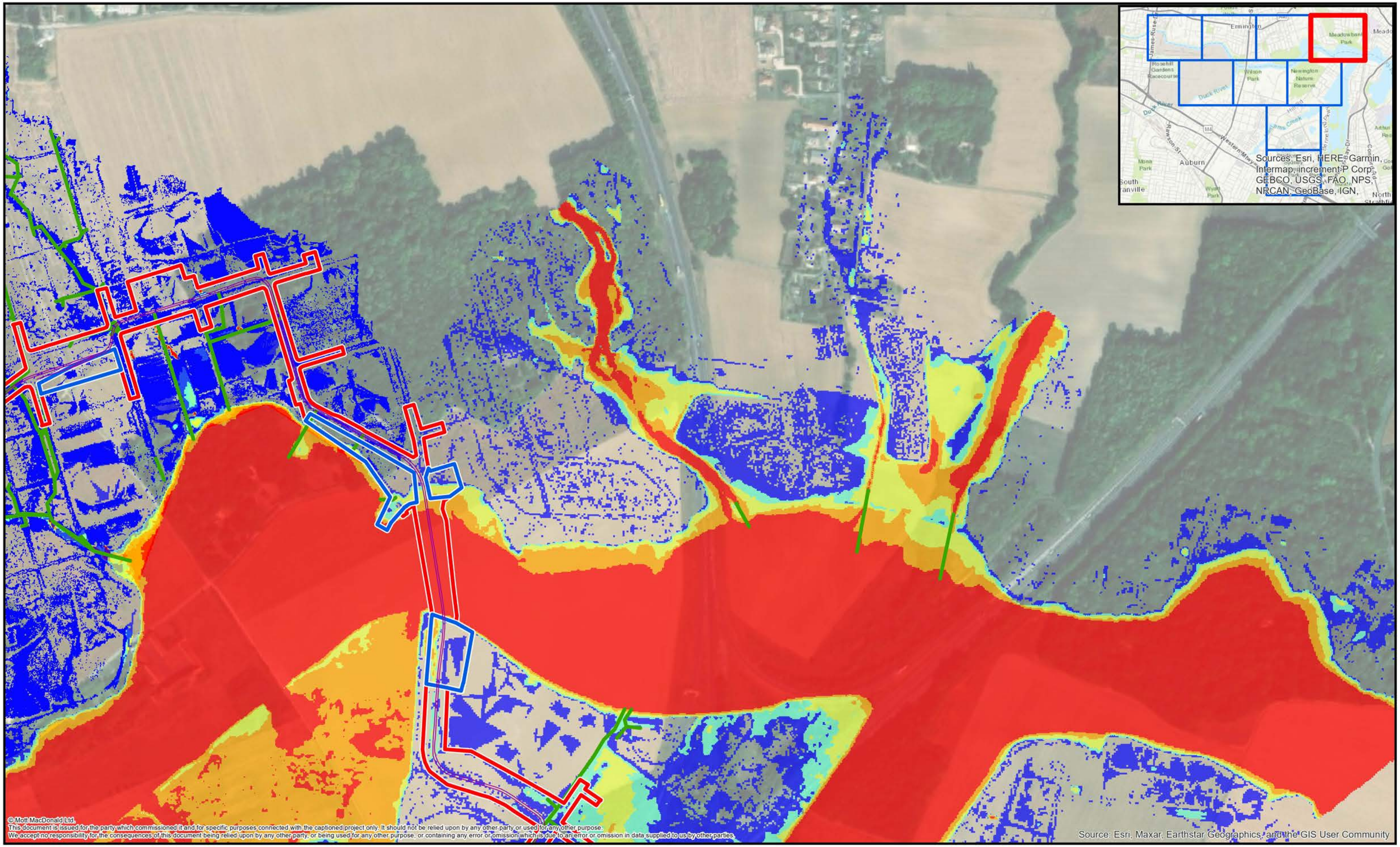
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

Flood Hazard (ZAEM1)

H1

H2

H3

H4

H5

H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

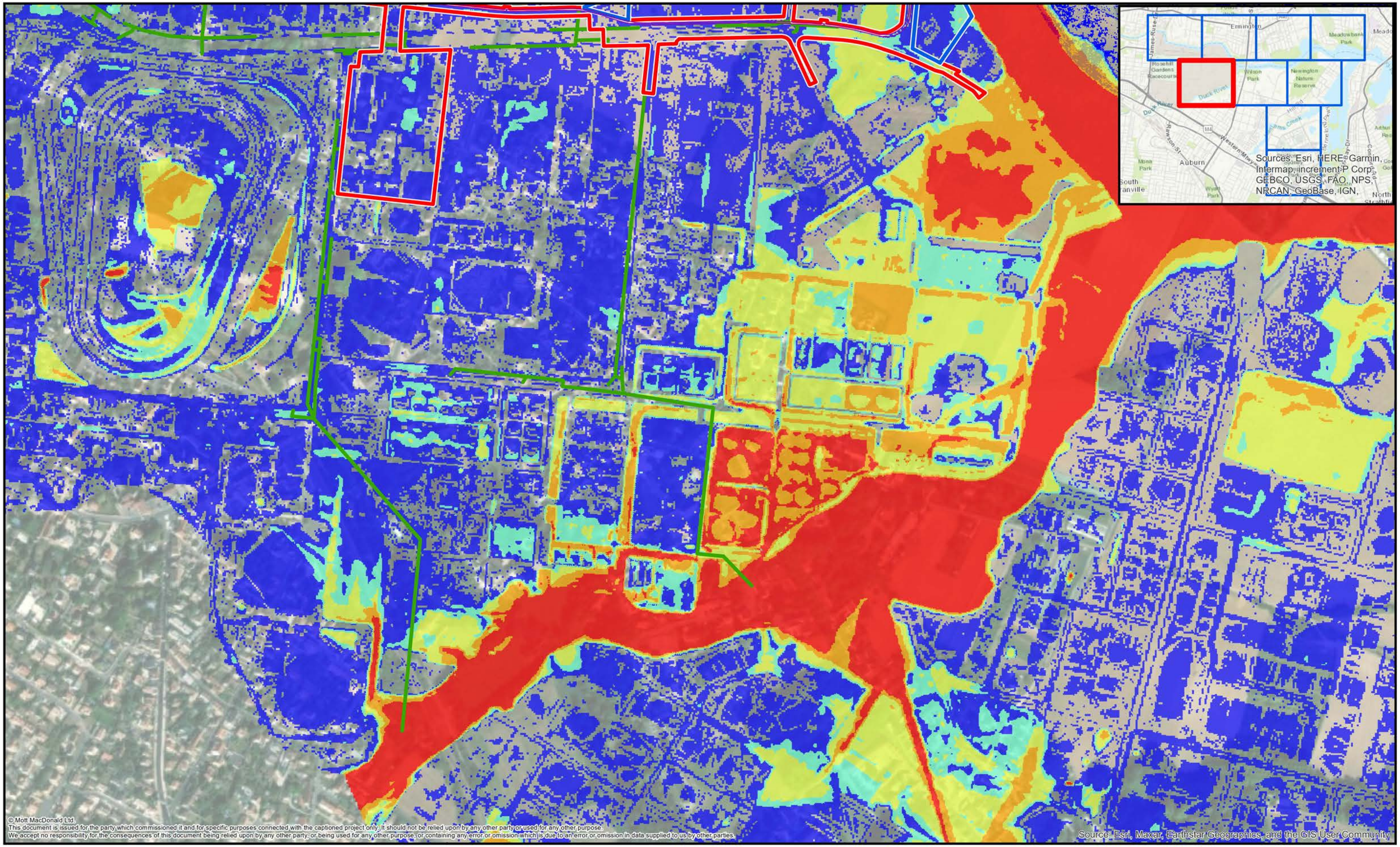
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

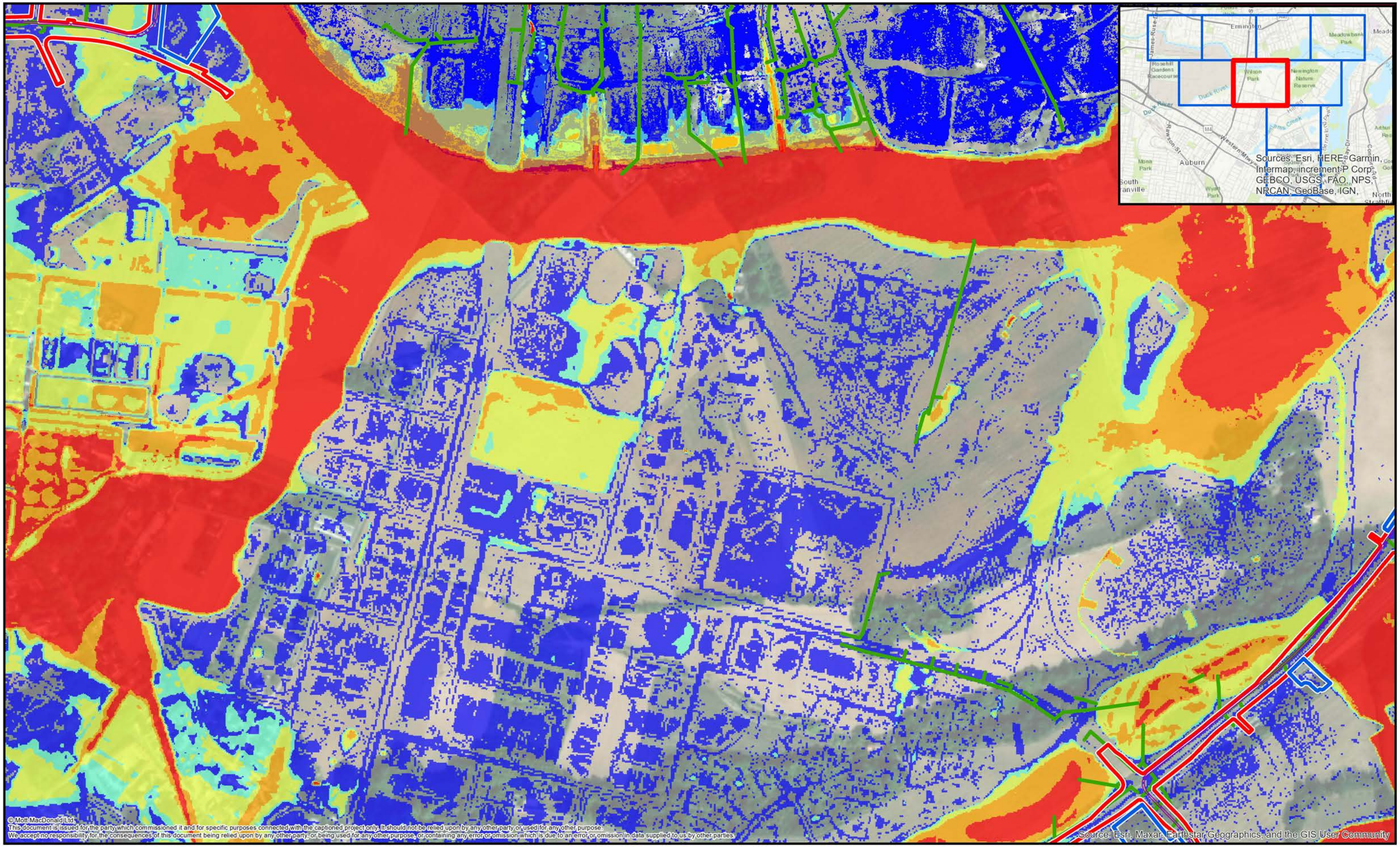
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

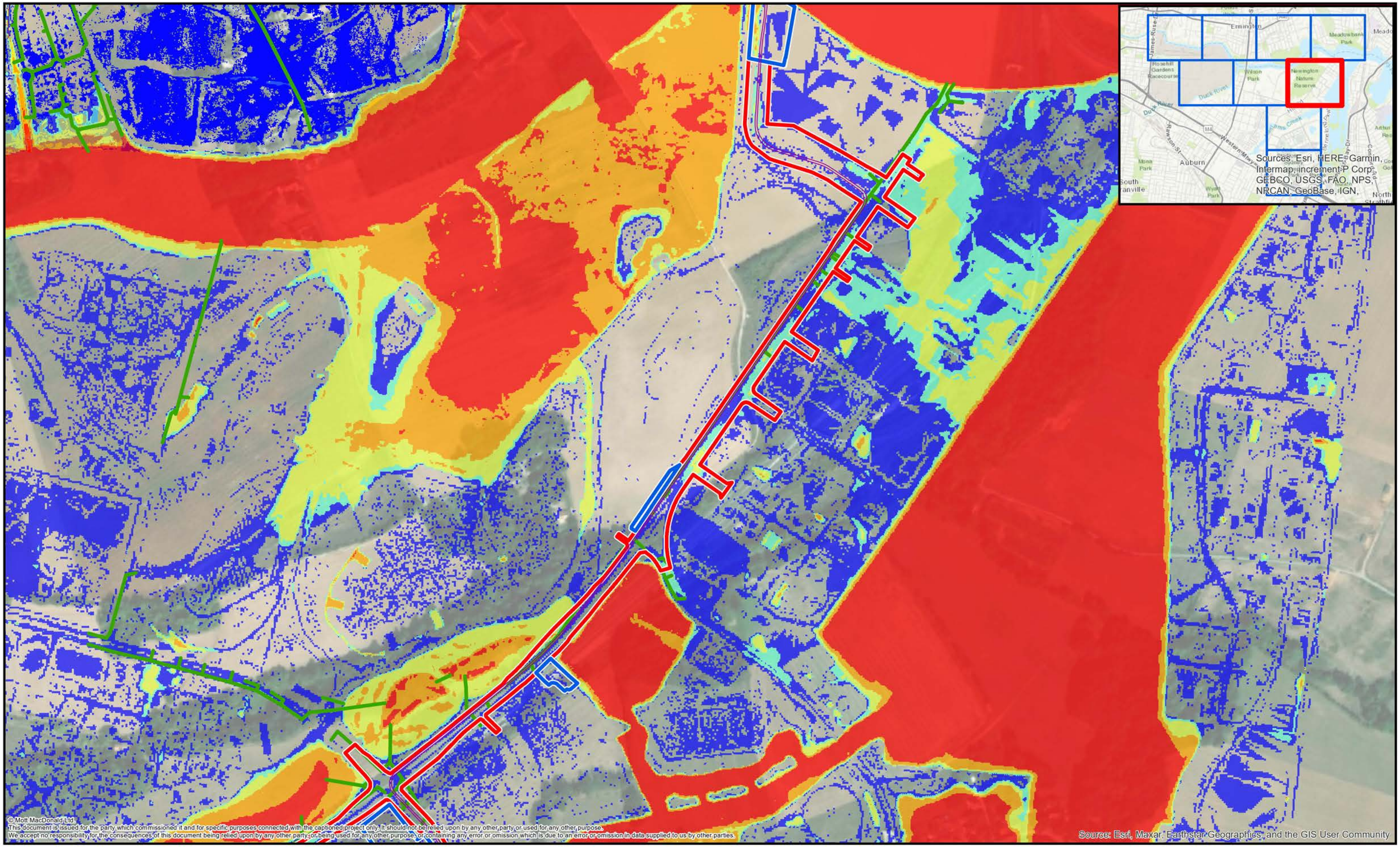
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

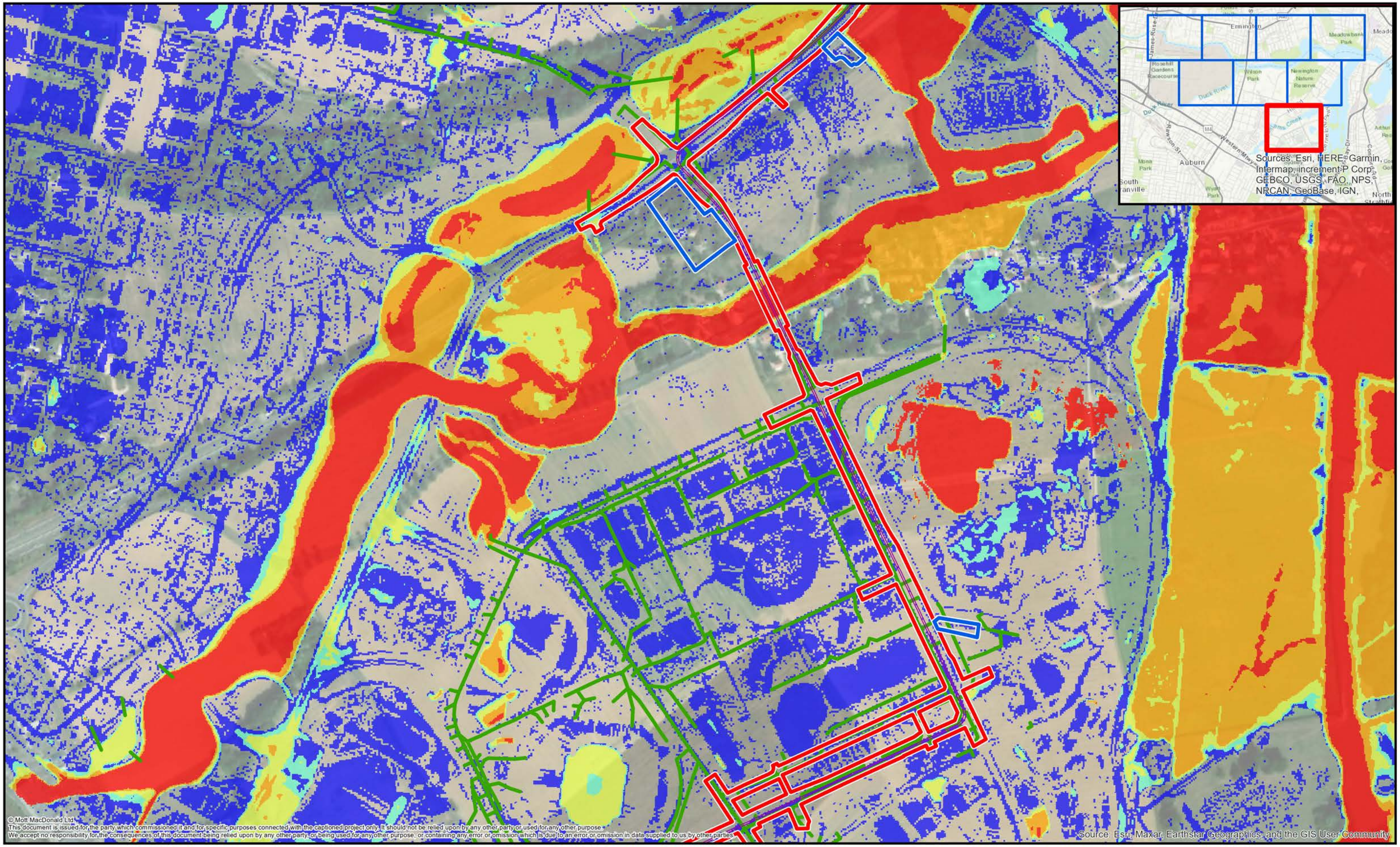
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

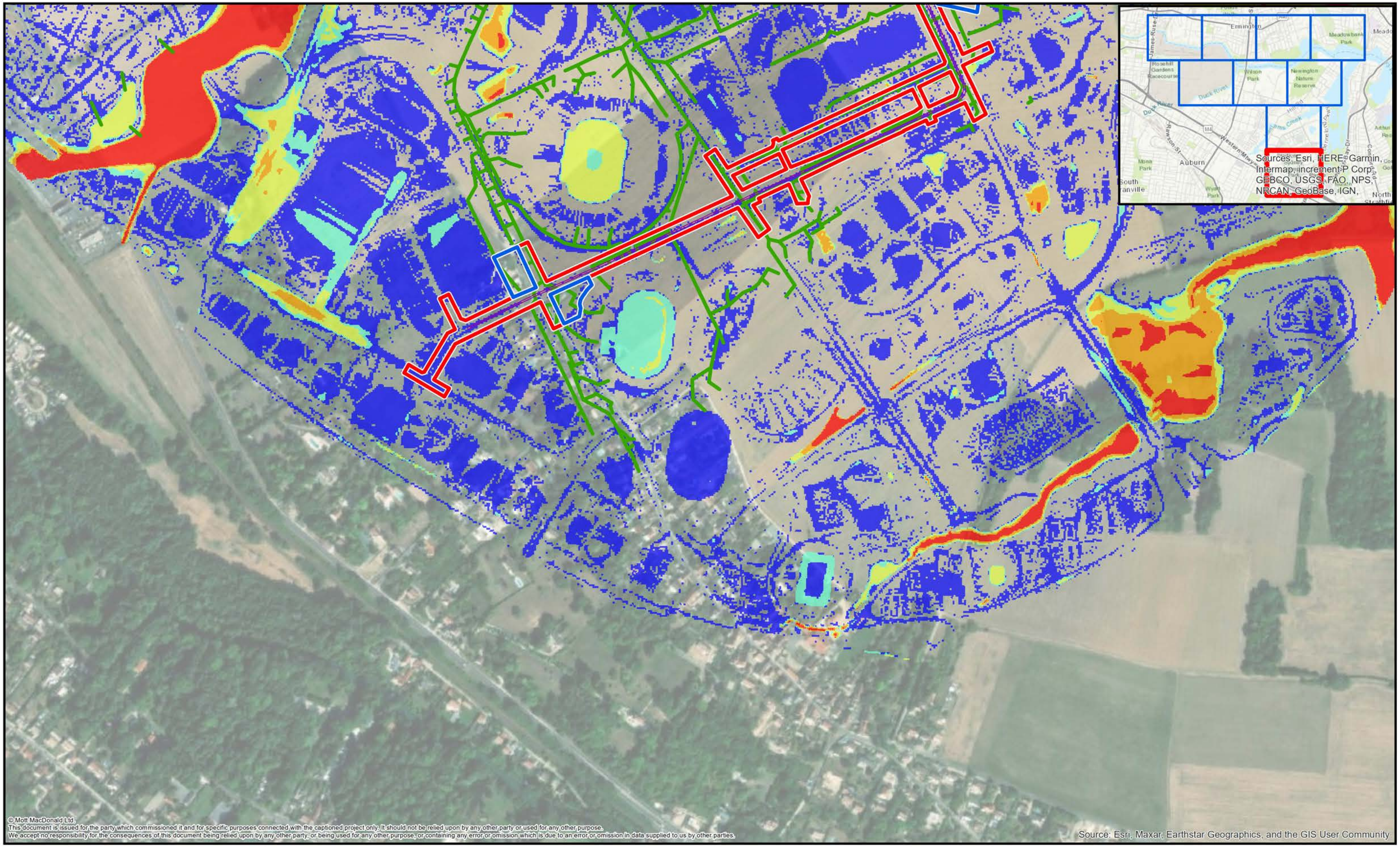
1:7,000

Scale at A3

MOTT MACDONALD

Map Number
Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

Flood Hazard (ZAEM1)

- H1
- H2
- H3
- H4
- H5
- H6

Title

Design Conditions 1% AEP Climate Change Flood Hazard

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

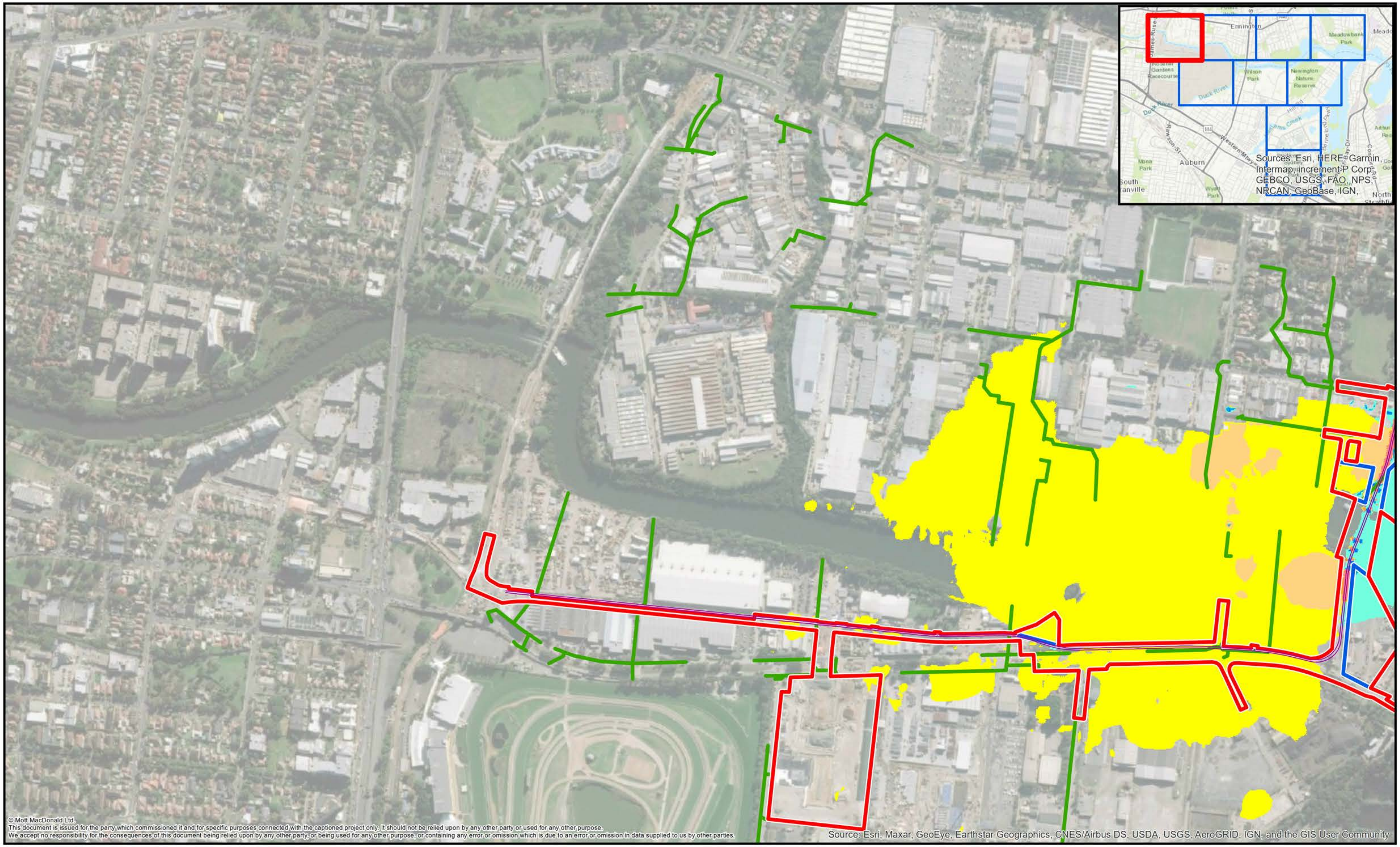
MOTT MACDONALD

Map Number

Sheet No 9 of 9

N

Appendix C3 - Flood Modelling Figures - Flood Level Difference



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

PMF Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- \> 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

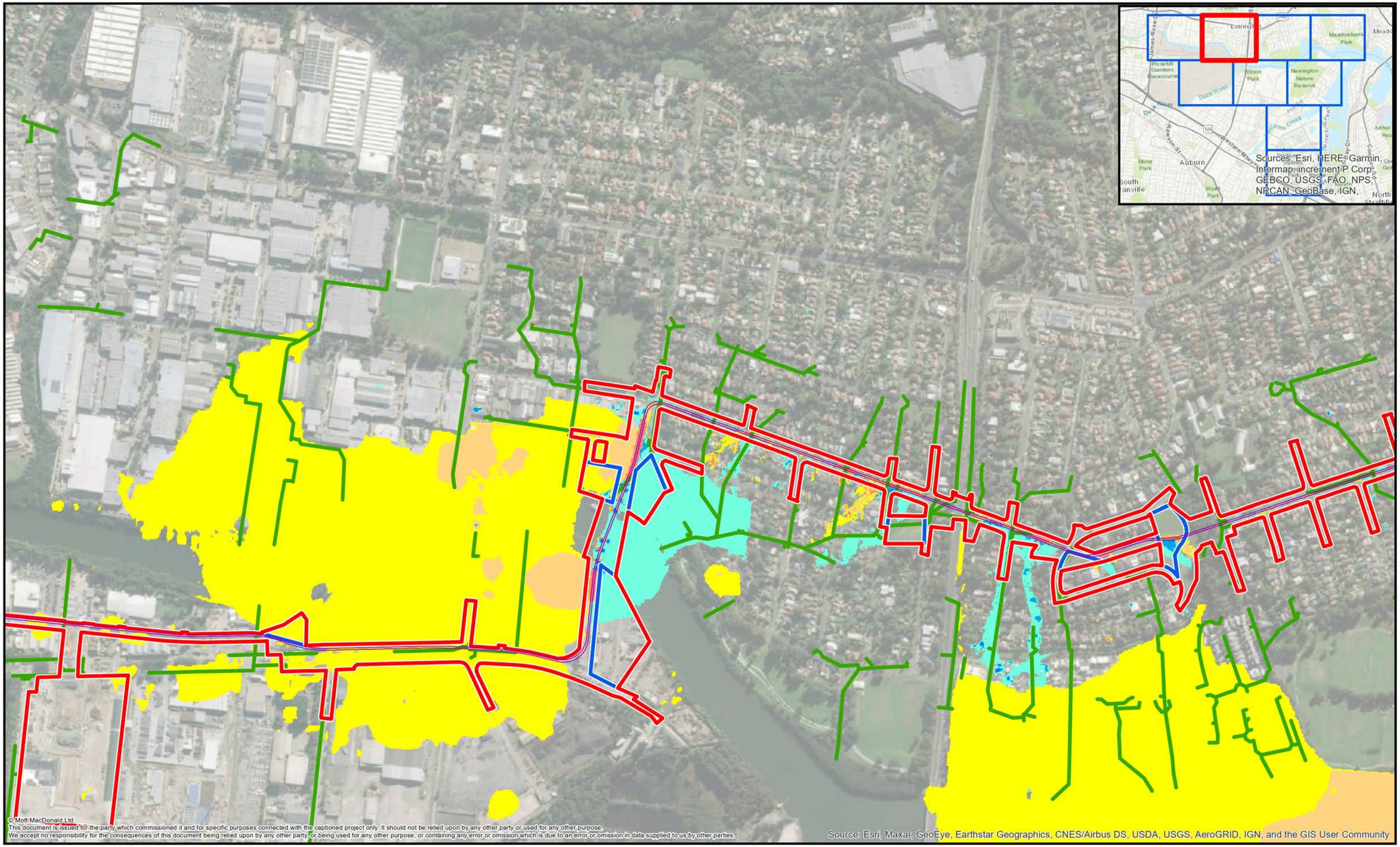
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

PMF Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

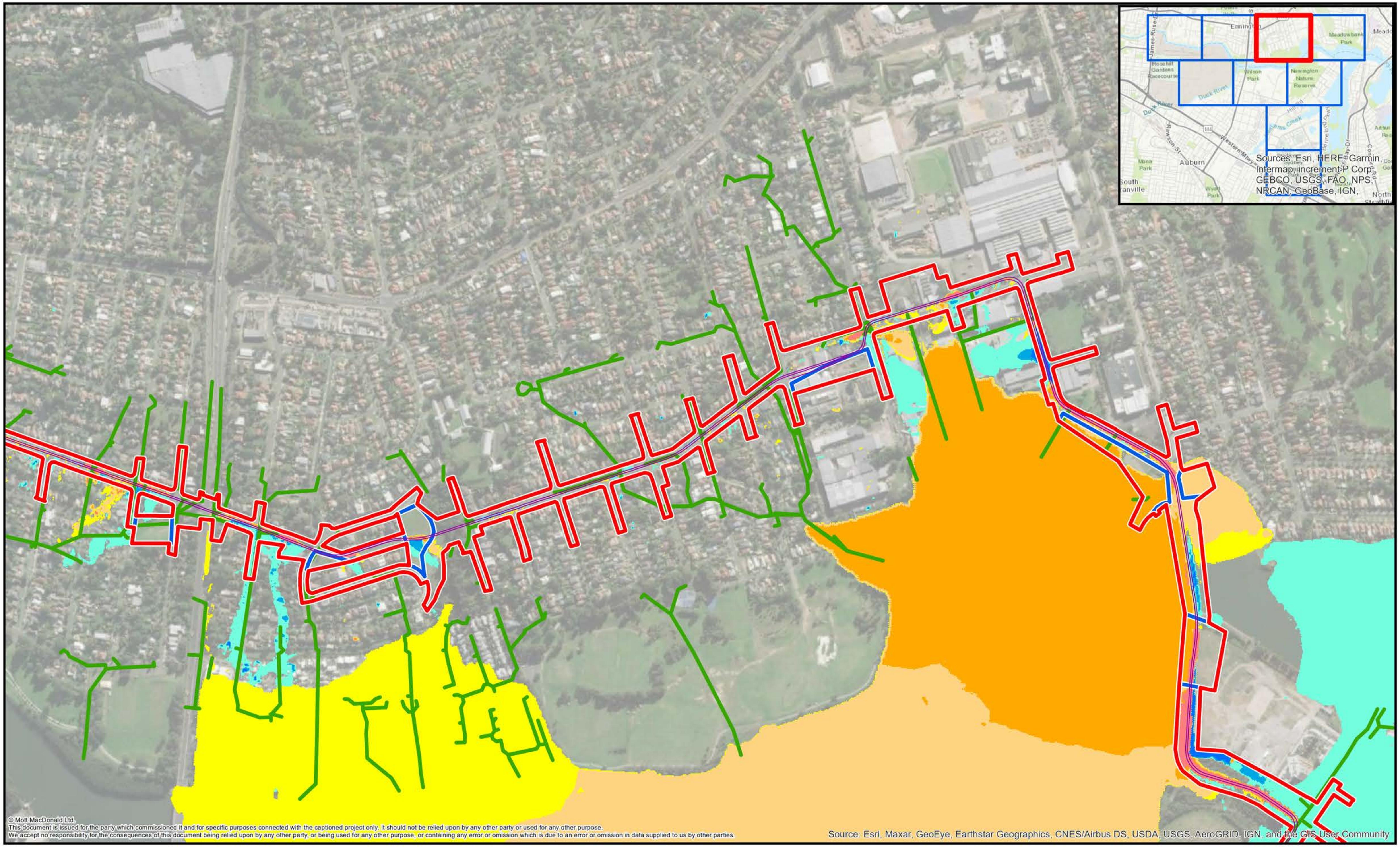
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

Project Alignment

Stormwater Pipes

Construction Compounds

Project Site

PMF Flood Level Difference (m)

< -0.1

-0.1 - -0.05

-0.05 - -0.01

-0.01 - 0.01

0.01 - 0.02

0.02 - 0.05

0.05 - 0.1

> 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

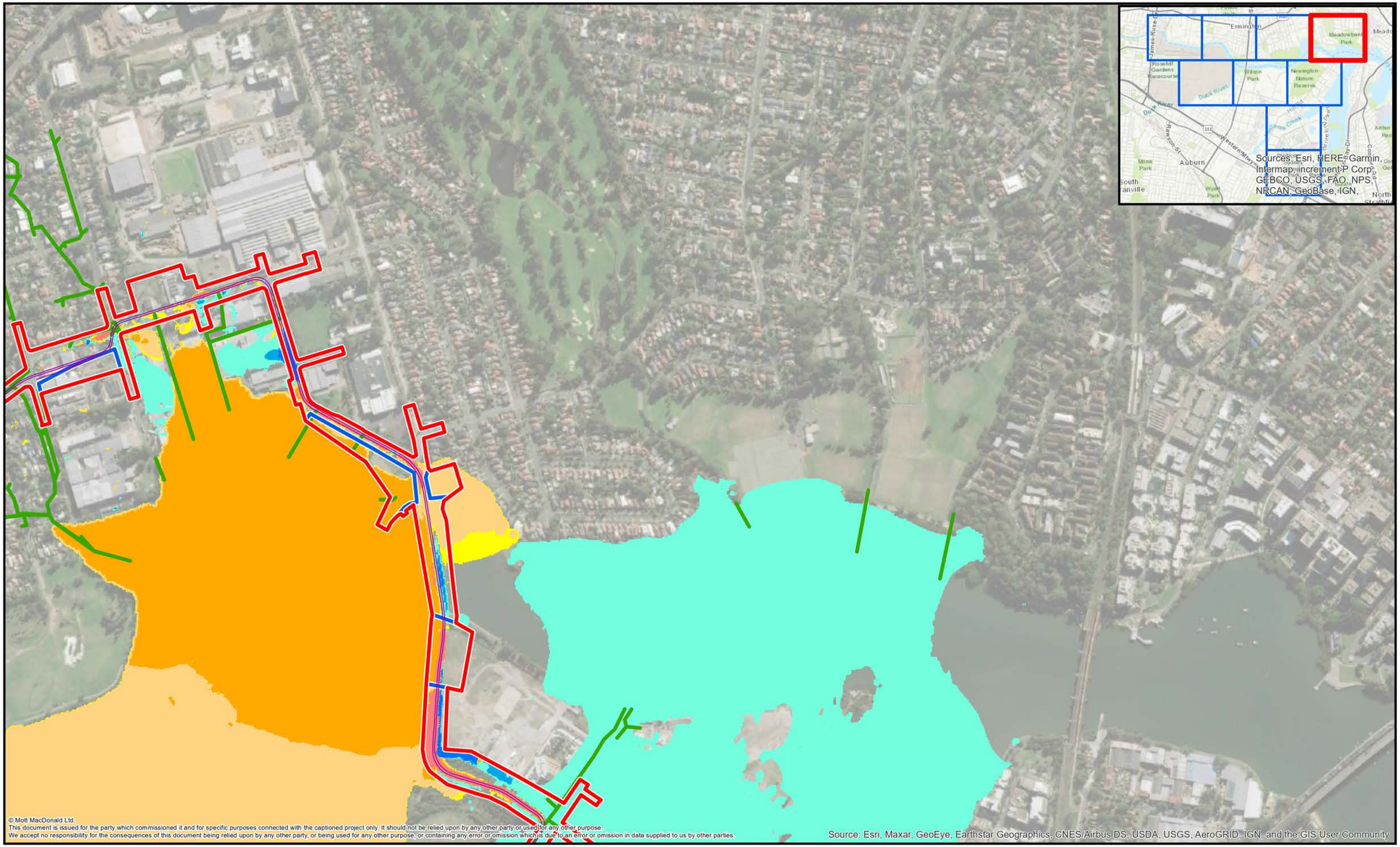
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

PMF Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

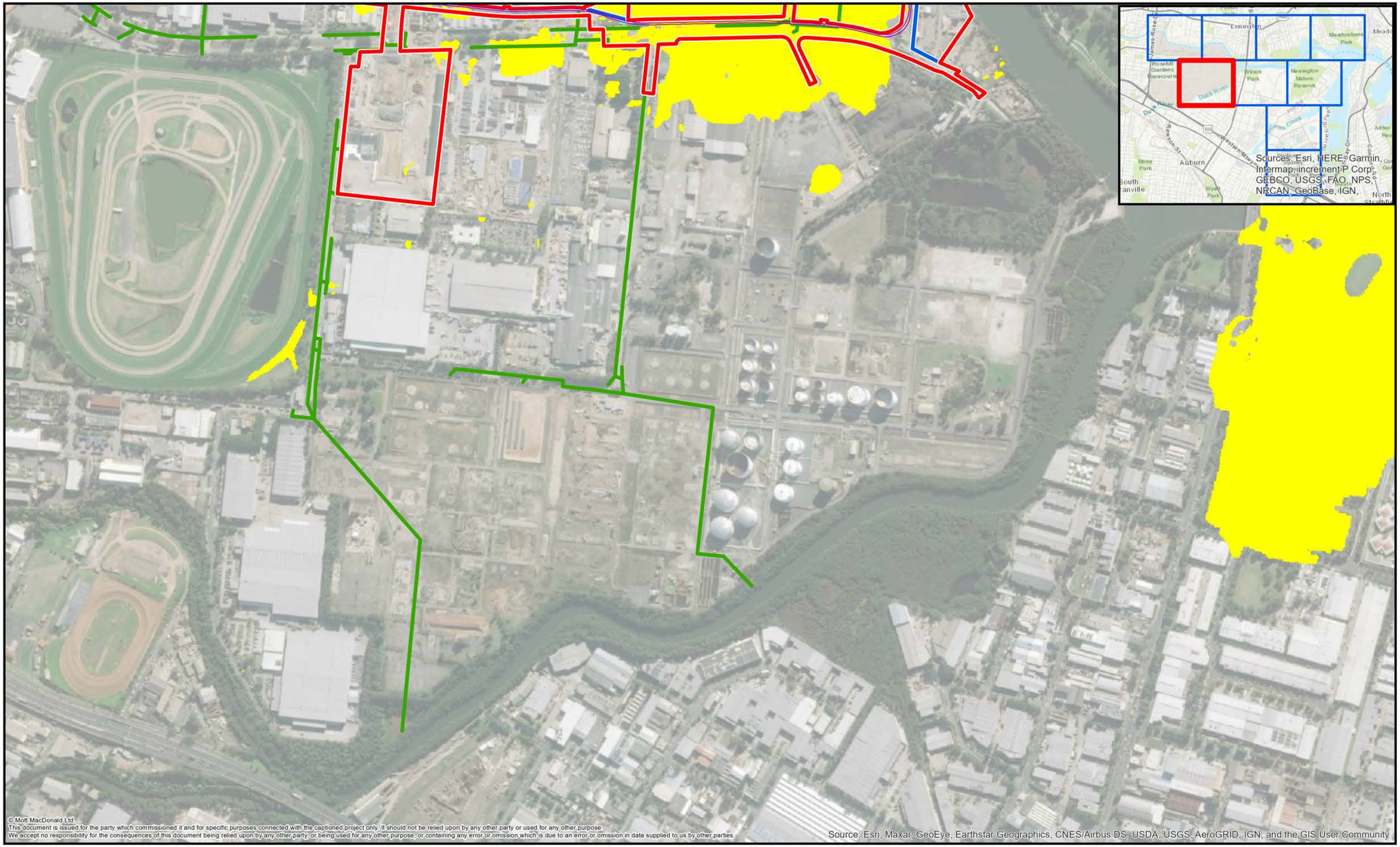
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

PMF Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

PMF Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

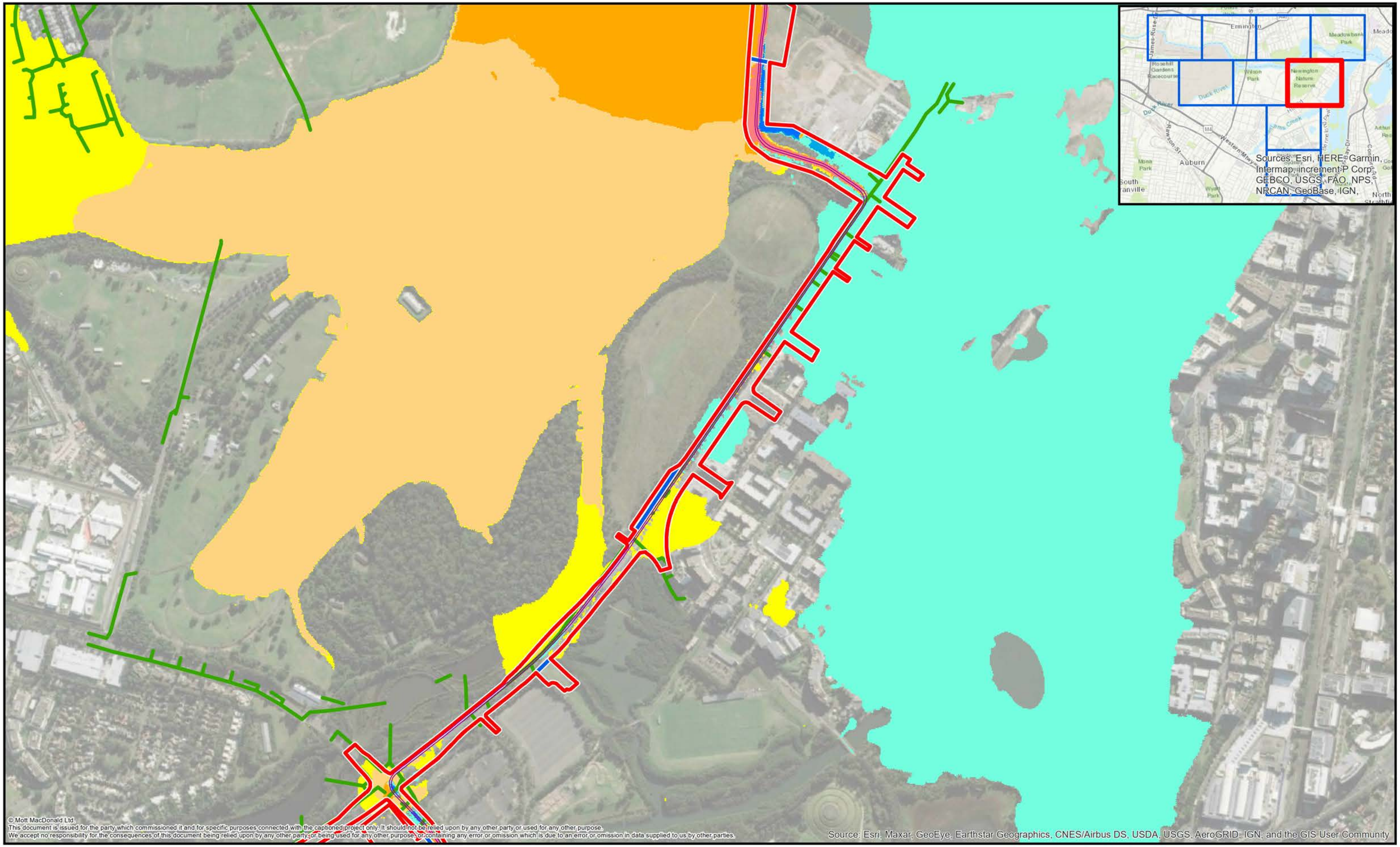
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

PMF Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

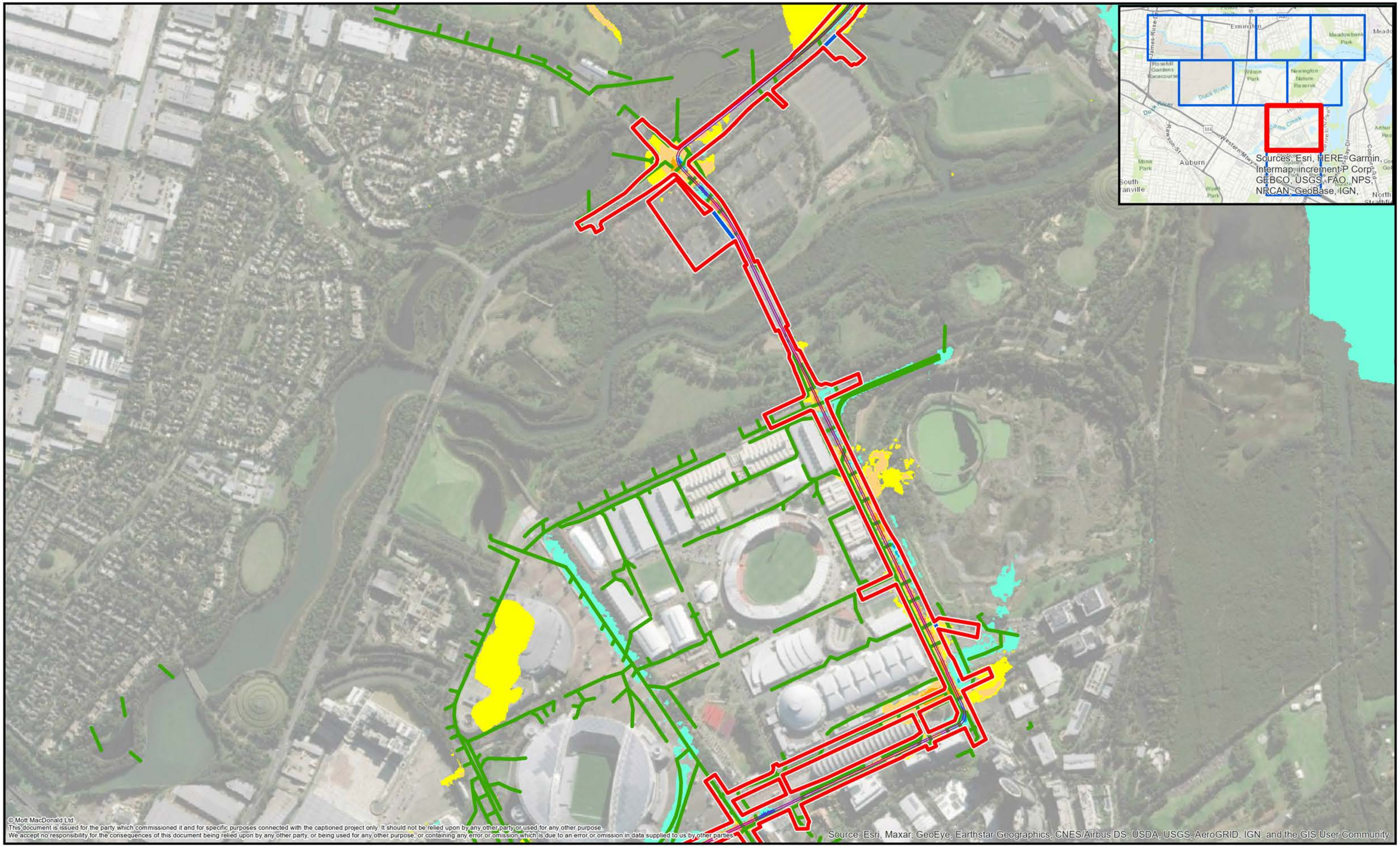
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N



Legend

Project Alignment

Stormwater Pipes

Construction Compounds

Project Site

PMF Flood Level Difference (m)

< -0.1

-0.1 - -0.05

-0.05 - -0.01

-0.01 - 0.01

0.01 - 0.02

0.02 - 0.05

0.05 - 0.1

> 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

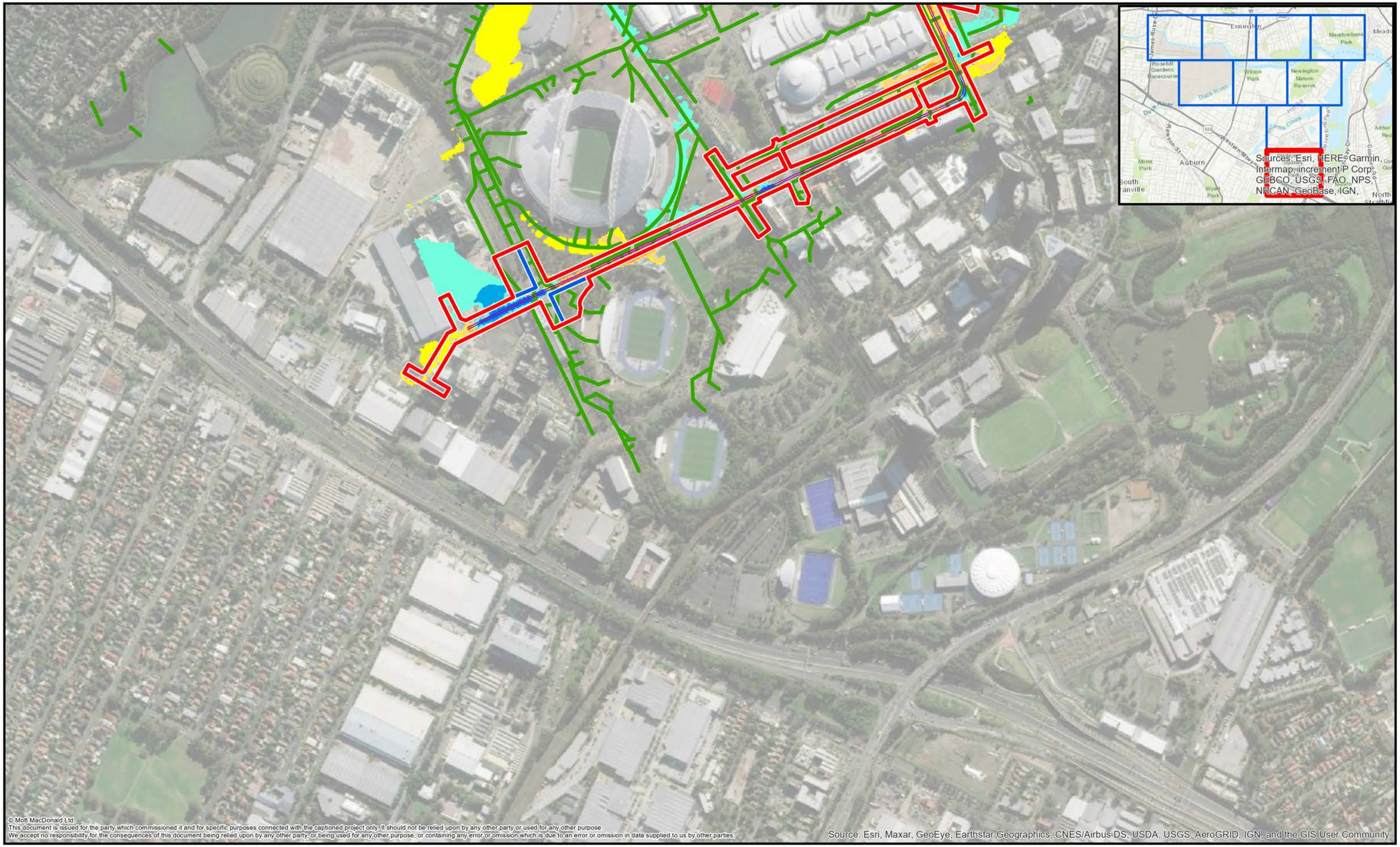
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

PMF Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

PMF Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

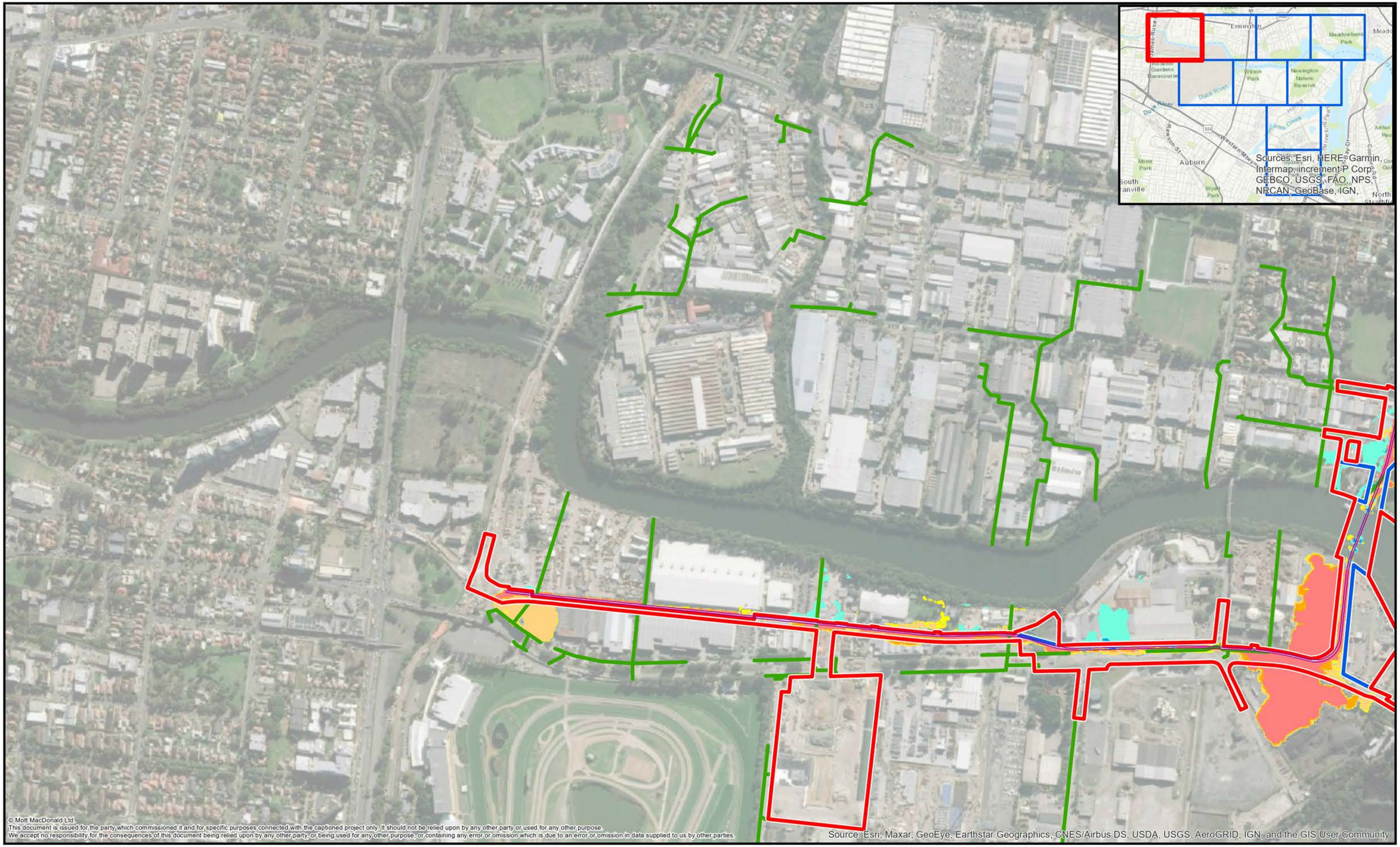
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

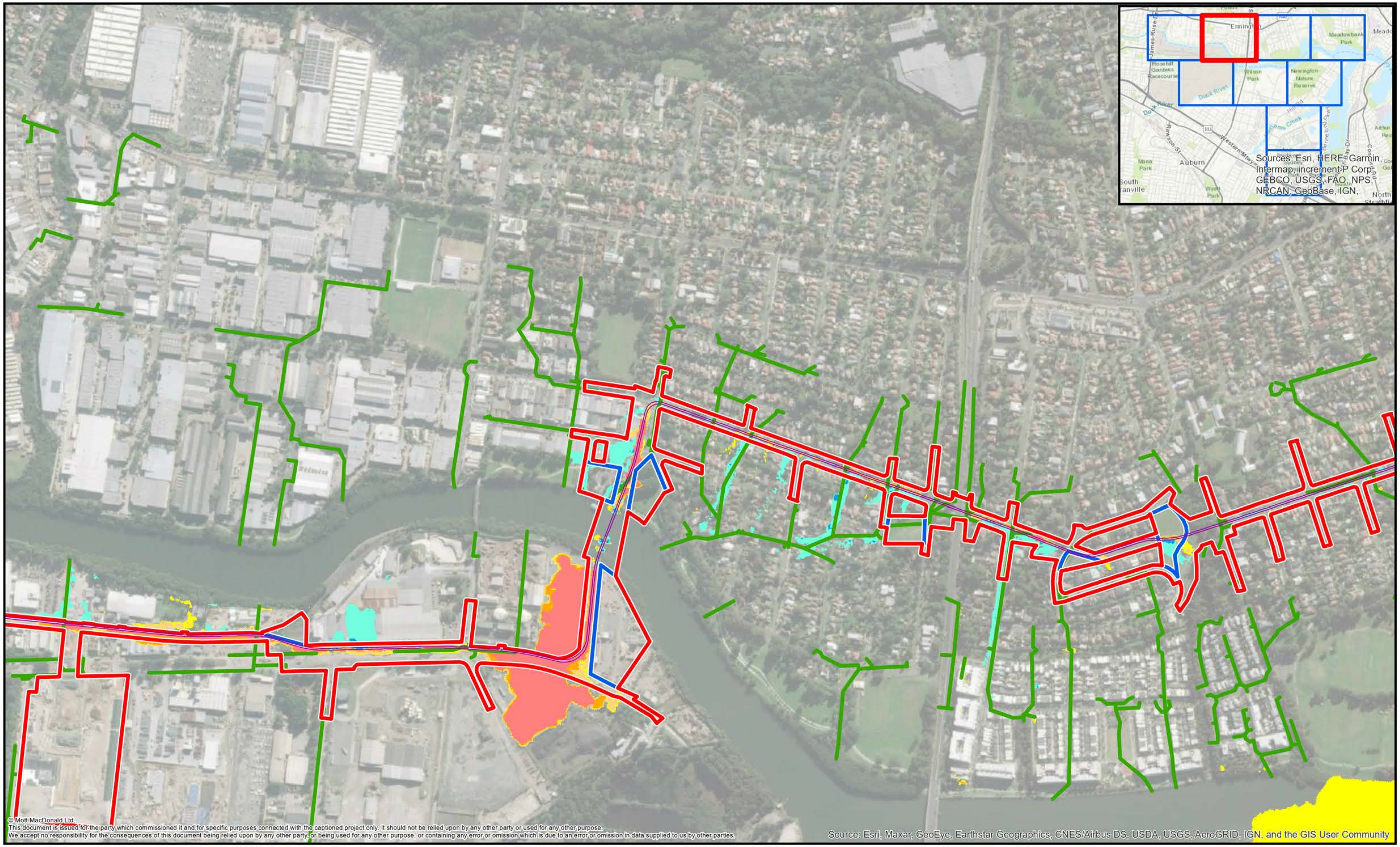
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

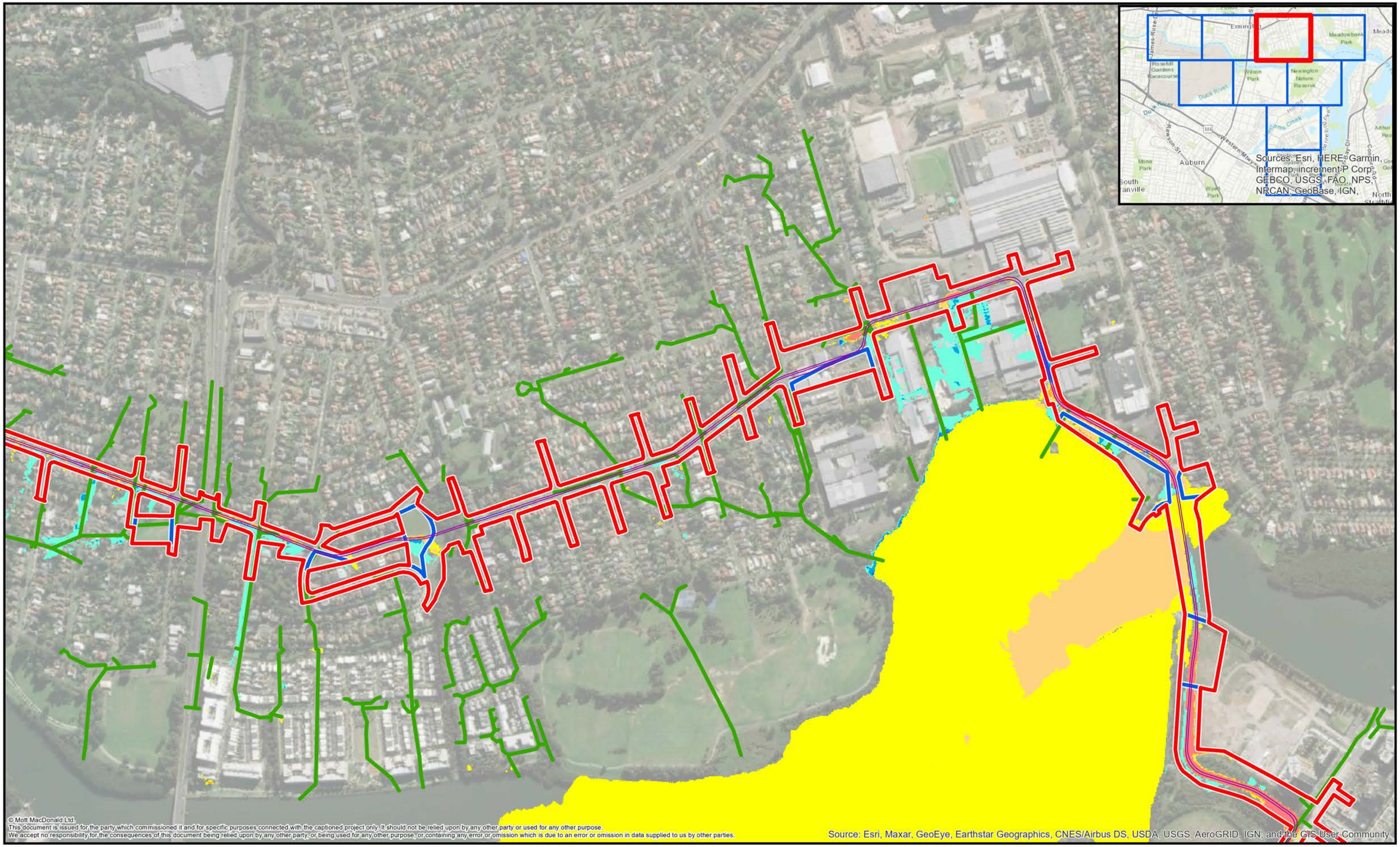
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

Project Alignment

Stormwater Pipes

Construction Compounds

Project Site

1%Flood Level Difference (m)

< -0.1

-0.1 - -0.05

-0.05 - -0.01

-0.01 - 0.01

0.01 - 0.02

0.02 - 0.05

0.05 - 0.1

> 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

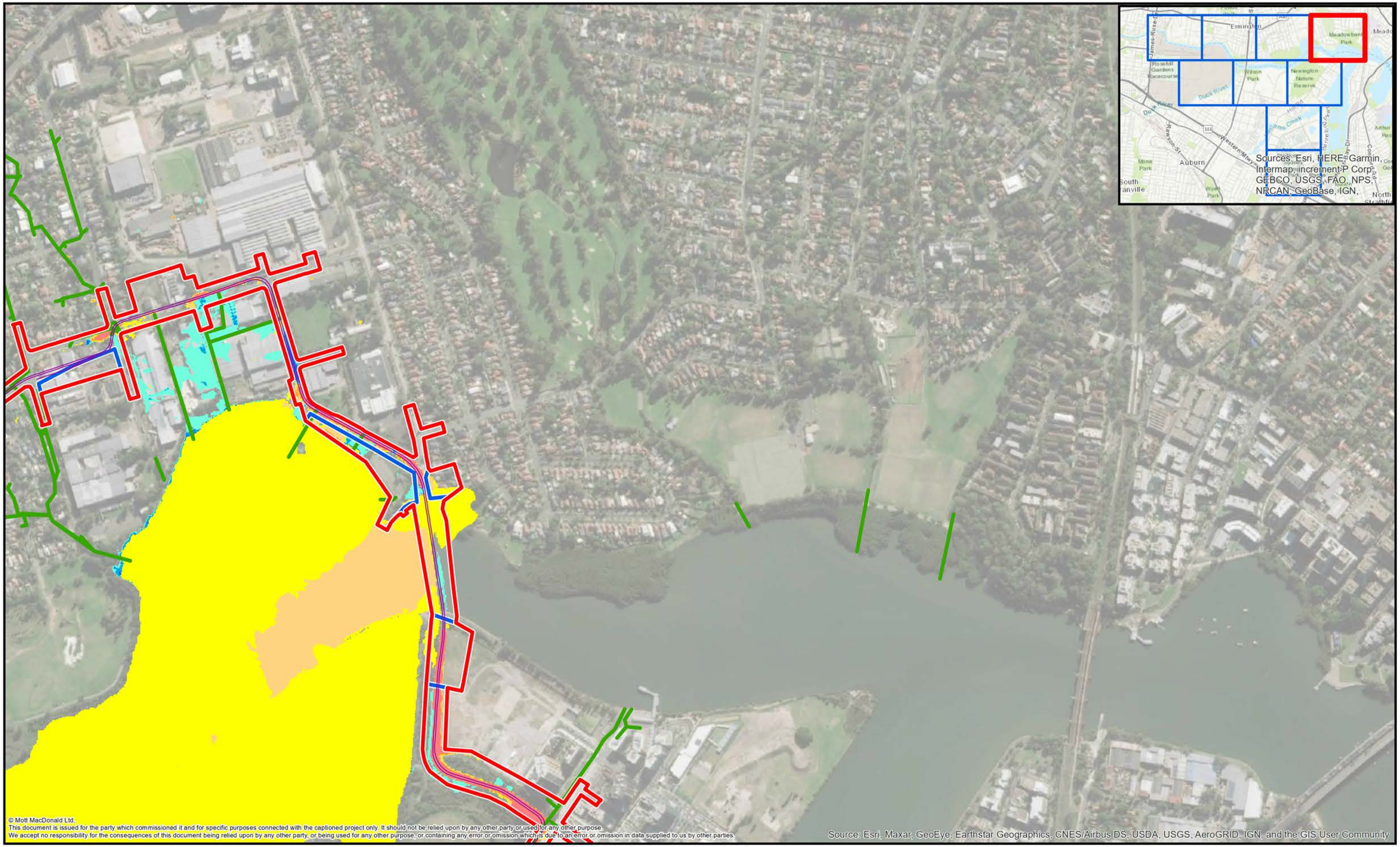
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

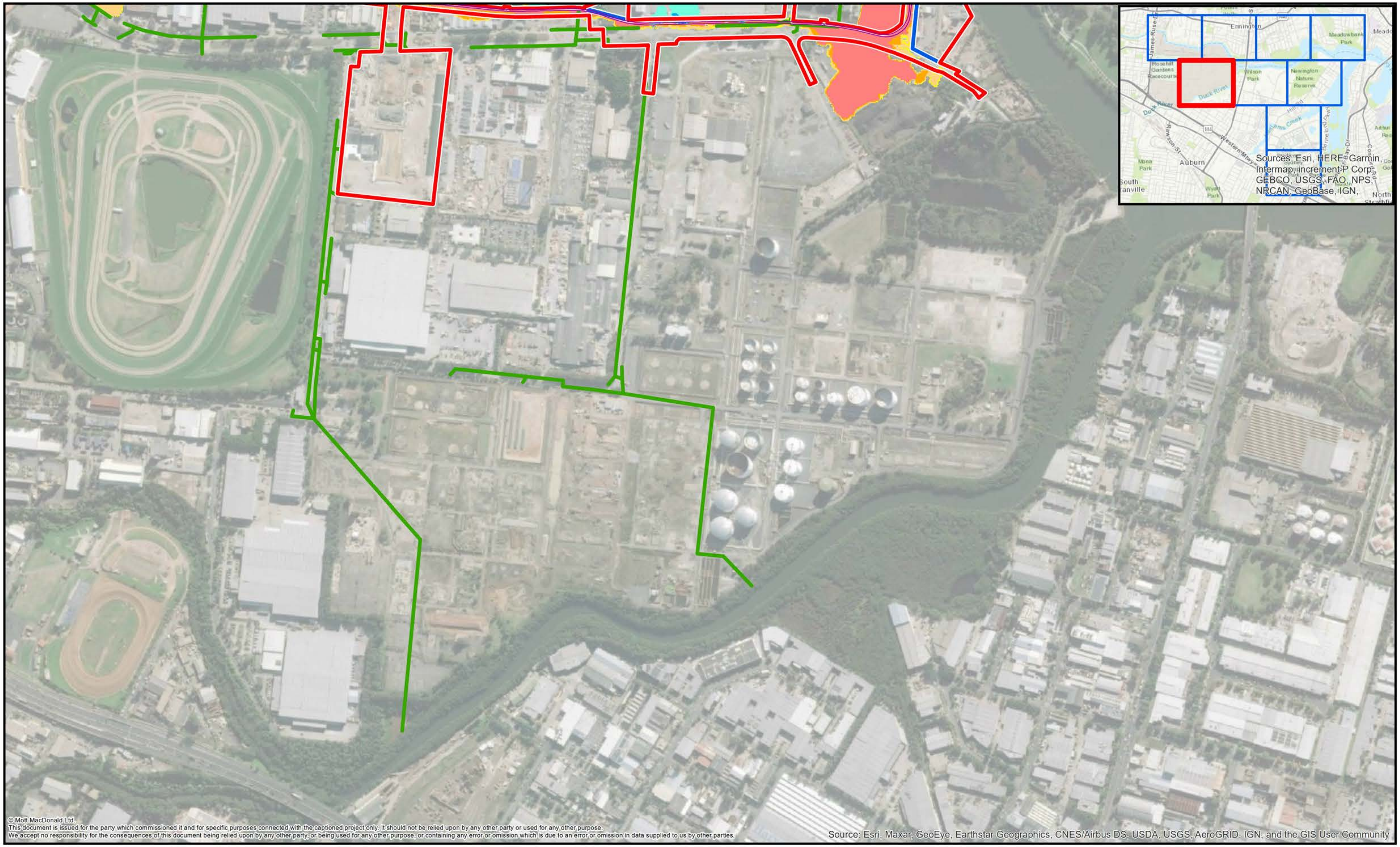
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

1%Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

1%Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

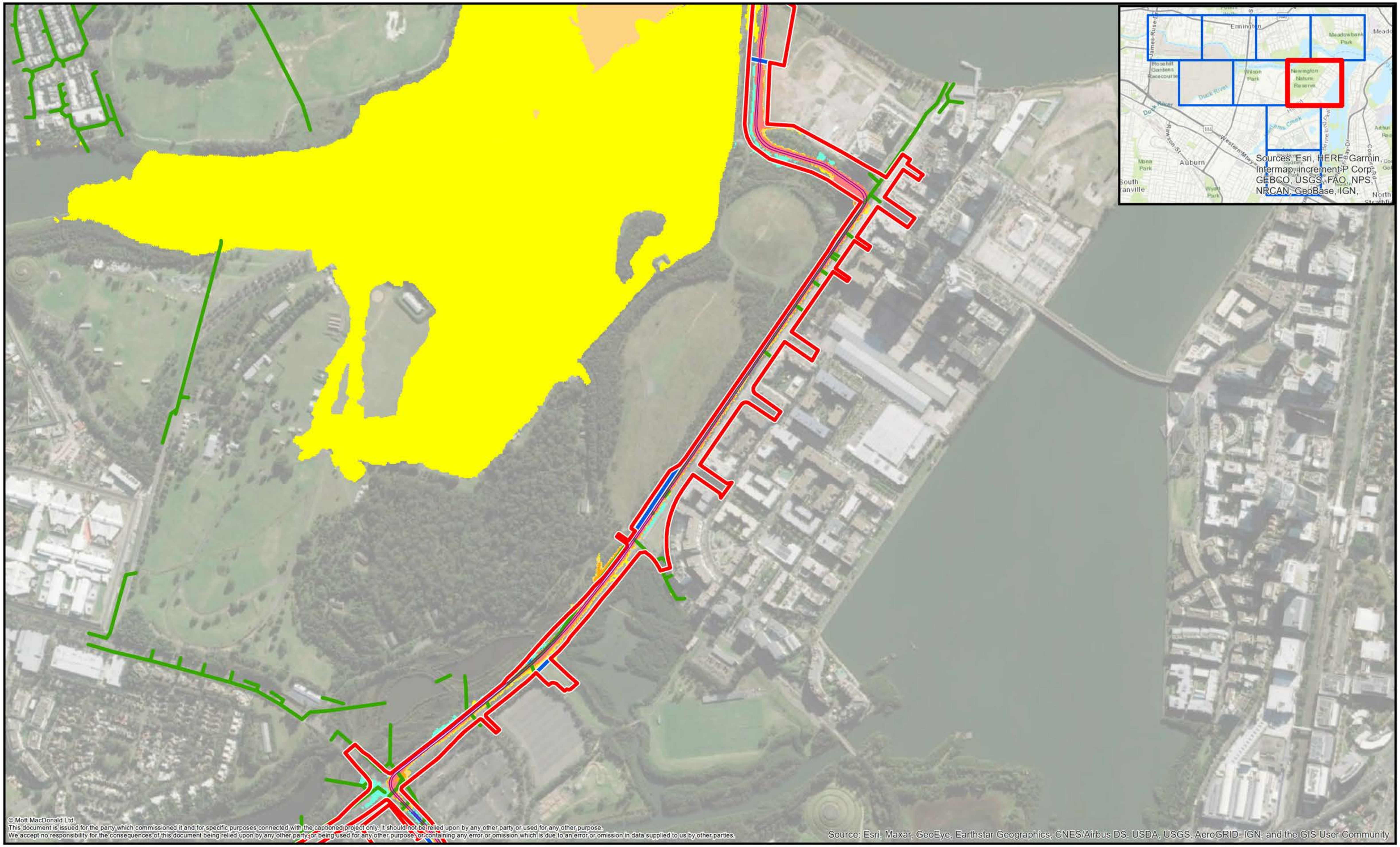
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%Flood Level Difference (m)

Blue	< -0.1
Light blue	-0.1 - -0.05
Cyan	-0.05 - -0.01
White	-0.01 - 0.01
Yellow	0.01 - 0.02
Light orange	0.02 - 0.05
Orange	0.05 - 0.1
Pink	> 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N

Legend

Project Alignment

Stormwater Pipes

Construction Compounds

Project Site

1%Flood Level Difference (m)

< -0.1

-0.1 - -0.05

-0.05 - -0.01

-0.01 - 0.01

0.01 - 0.02

0.02 - 0.05

0.05 - 0.1

> 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

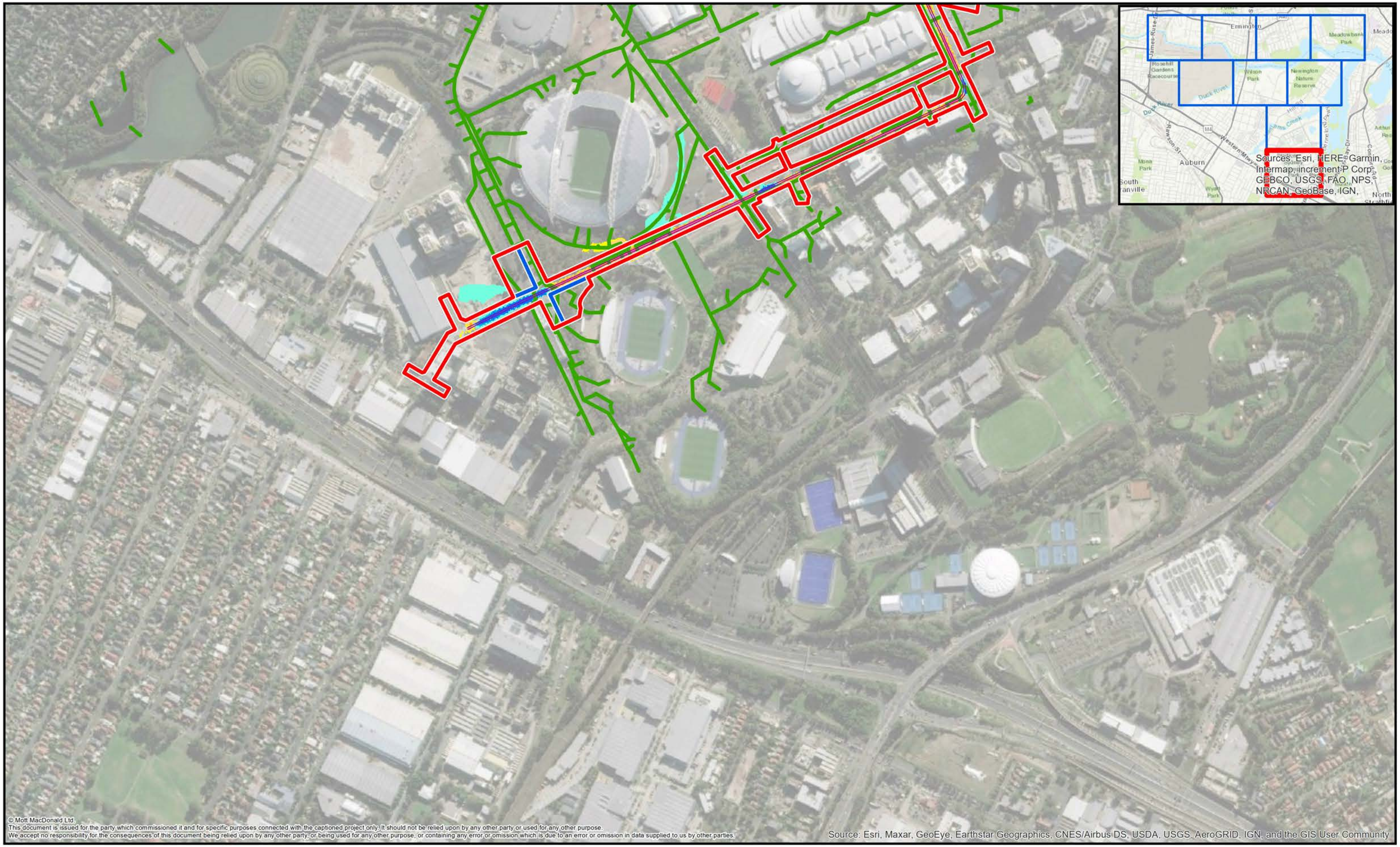
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

1%Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

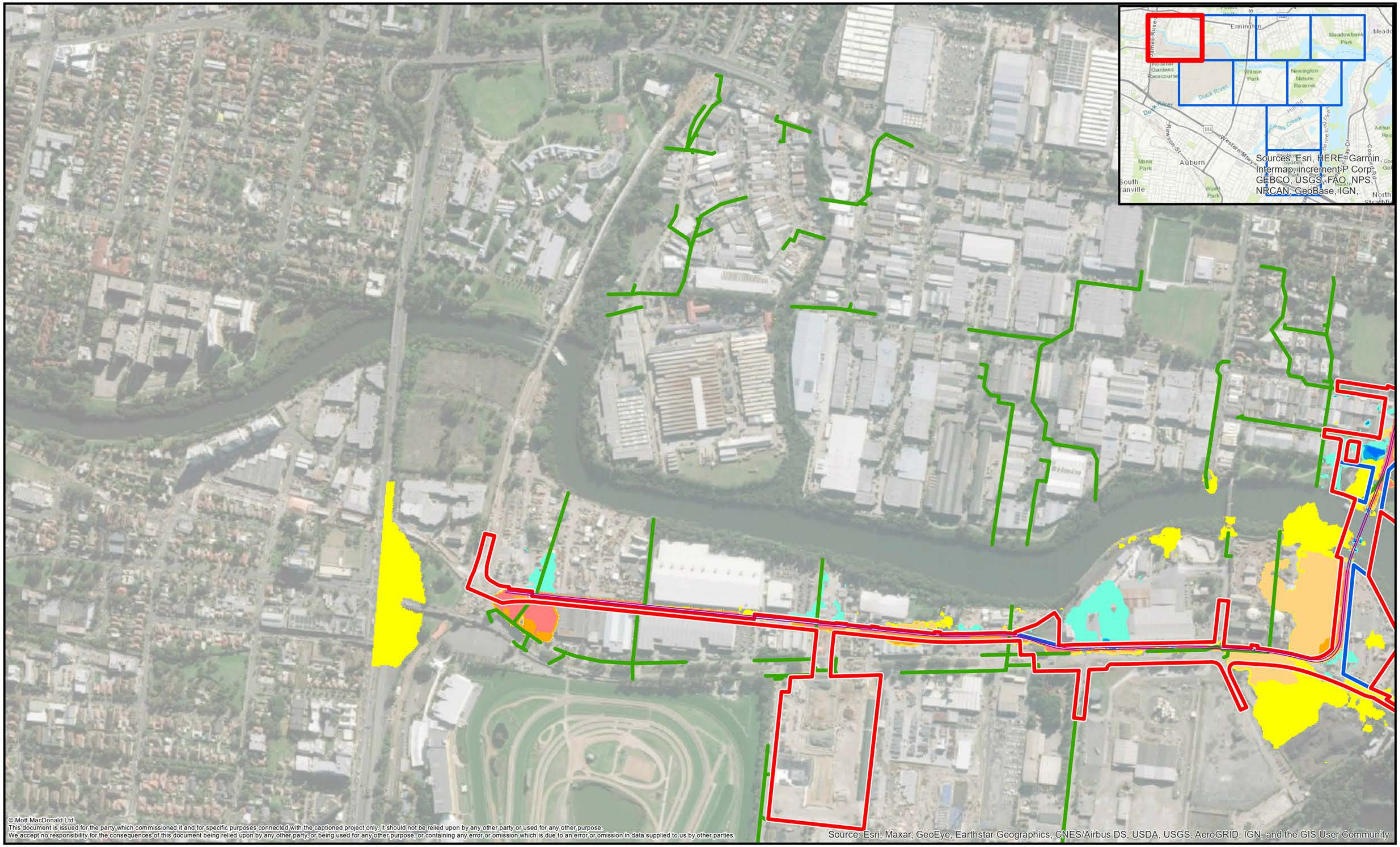
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 9 of 9

N



Legend

Project Alignment
Construction Compounds
Project Site
Stormwater Pipes

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

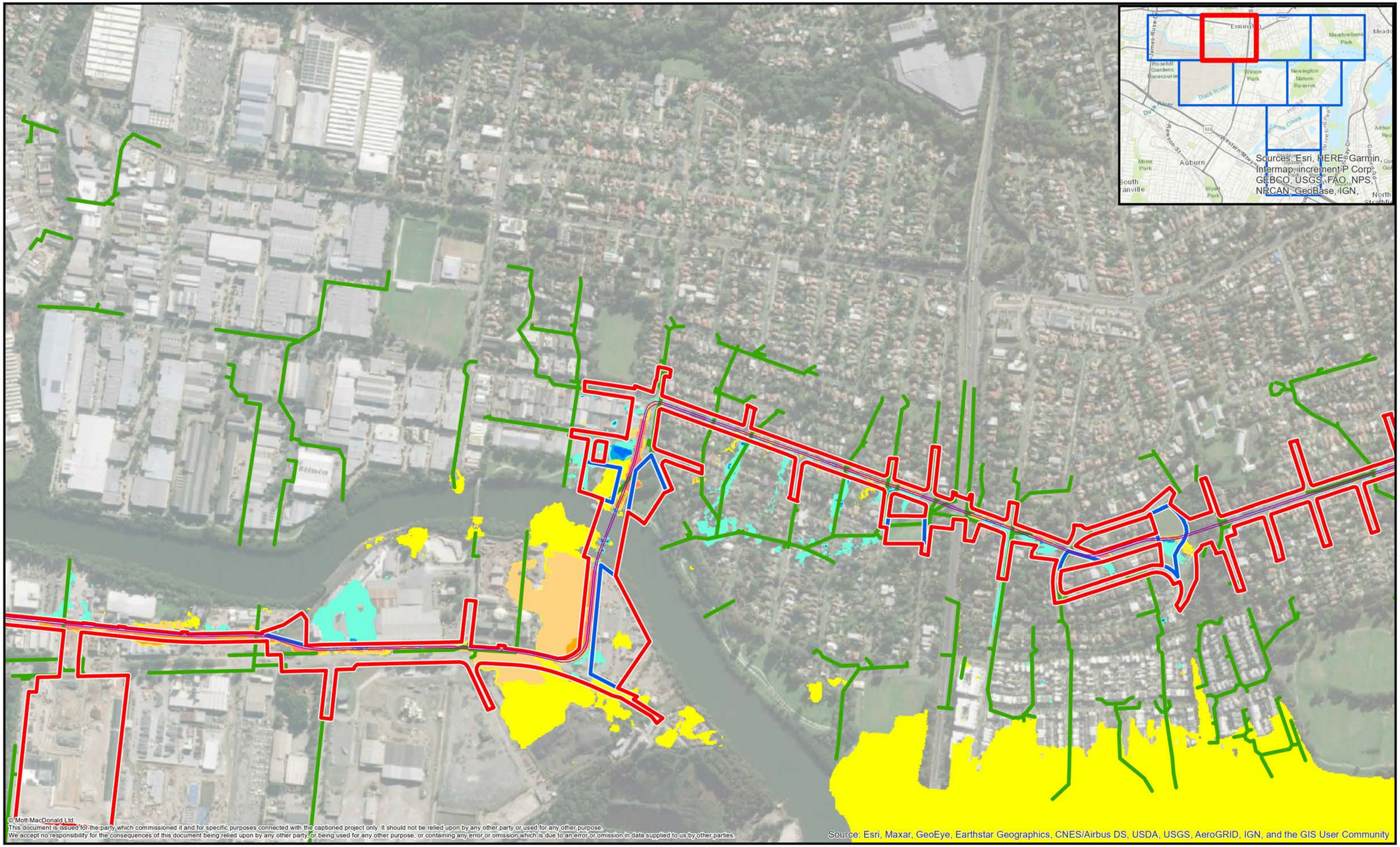
0 0.05 0.1 0.2 Kilometers

1:7,000
Scale at A3

MOTT MACDONALD

Map Number
Sheet No 1 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

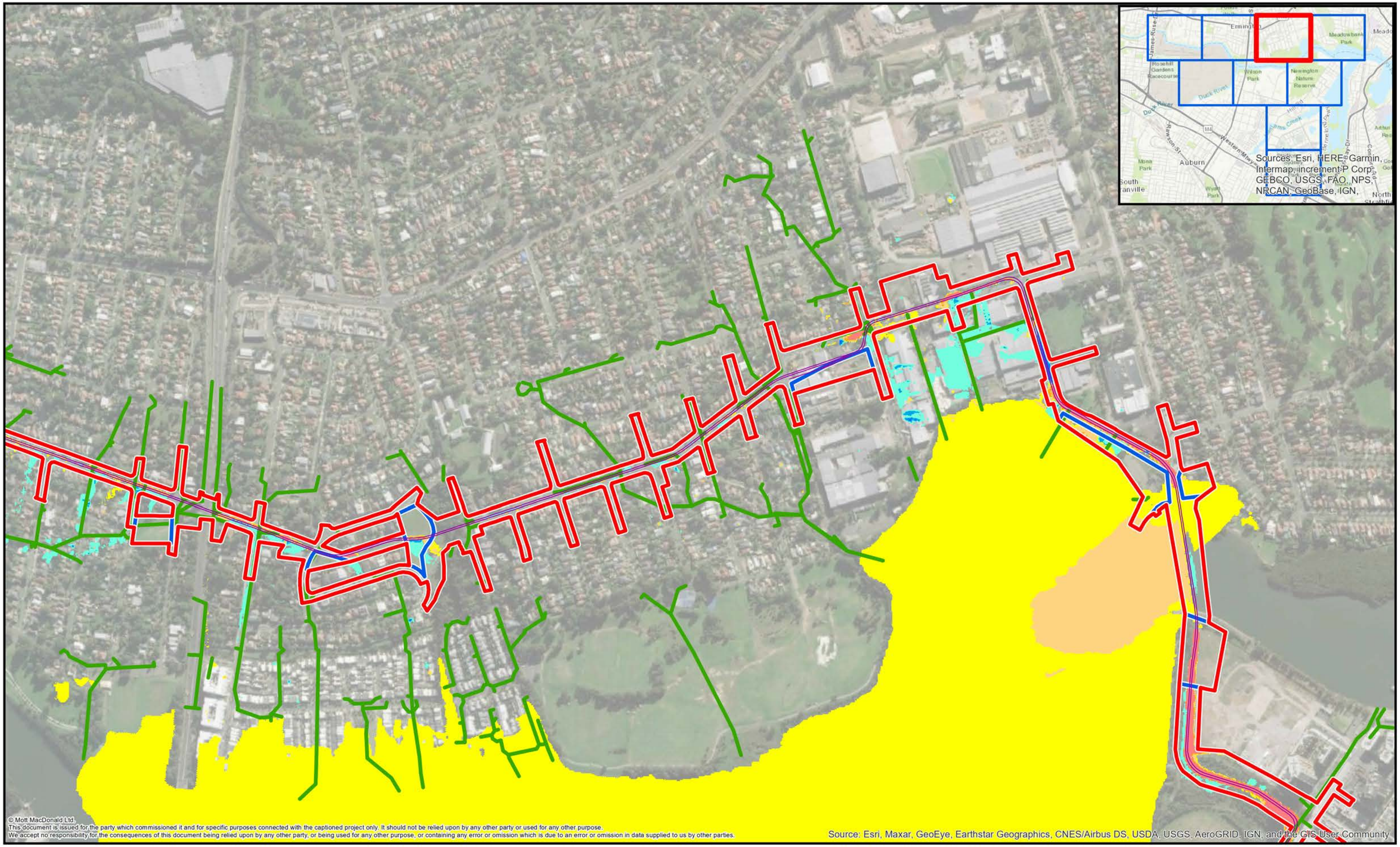
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

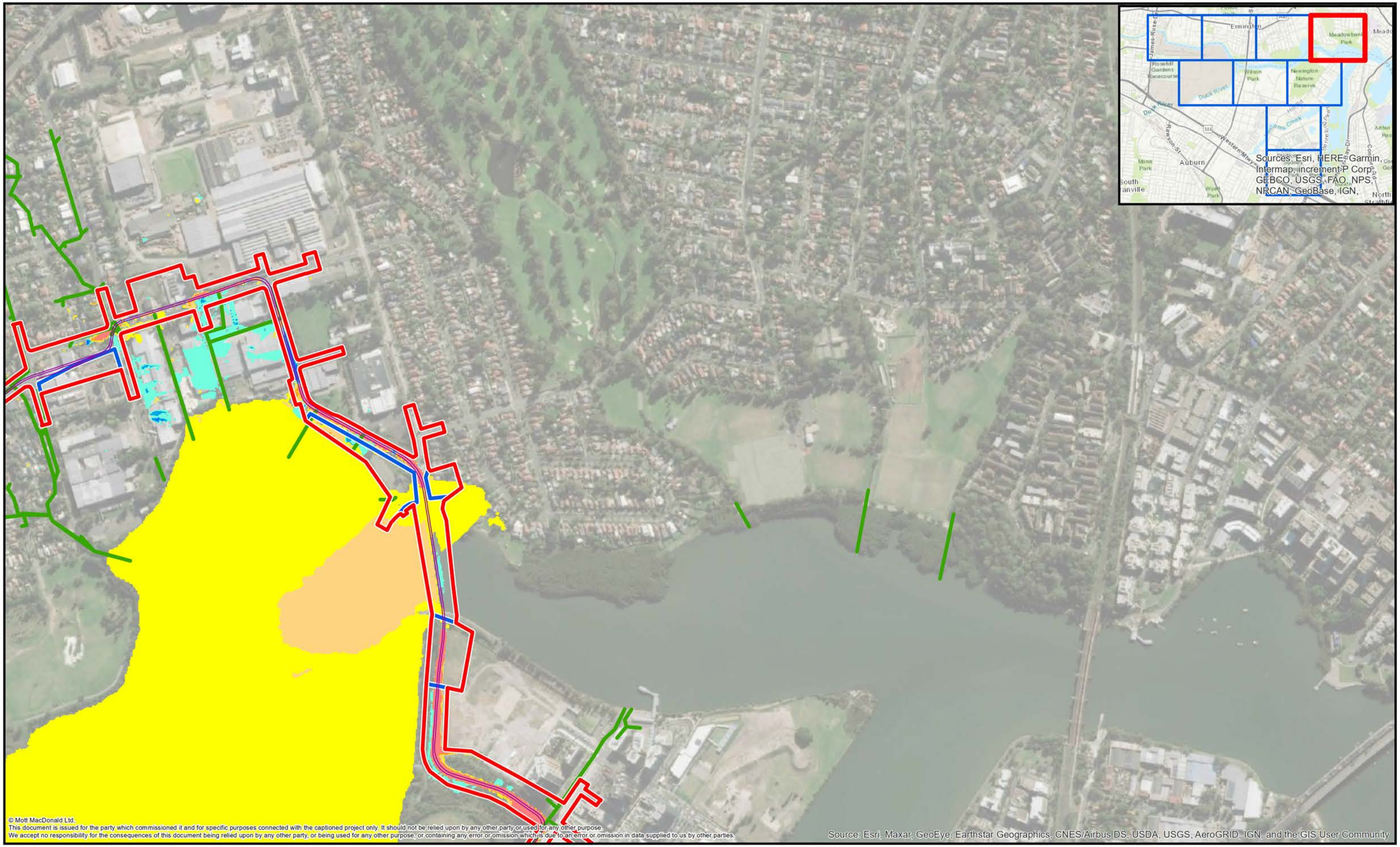
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- \> 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

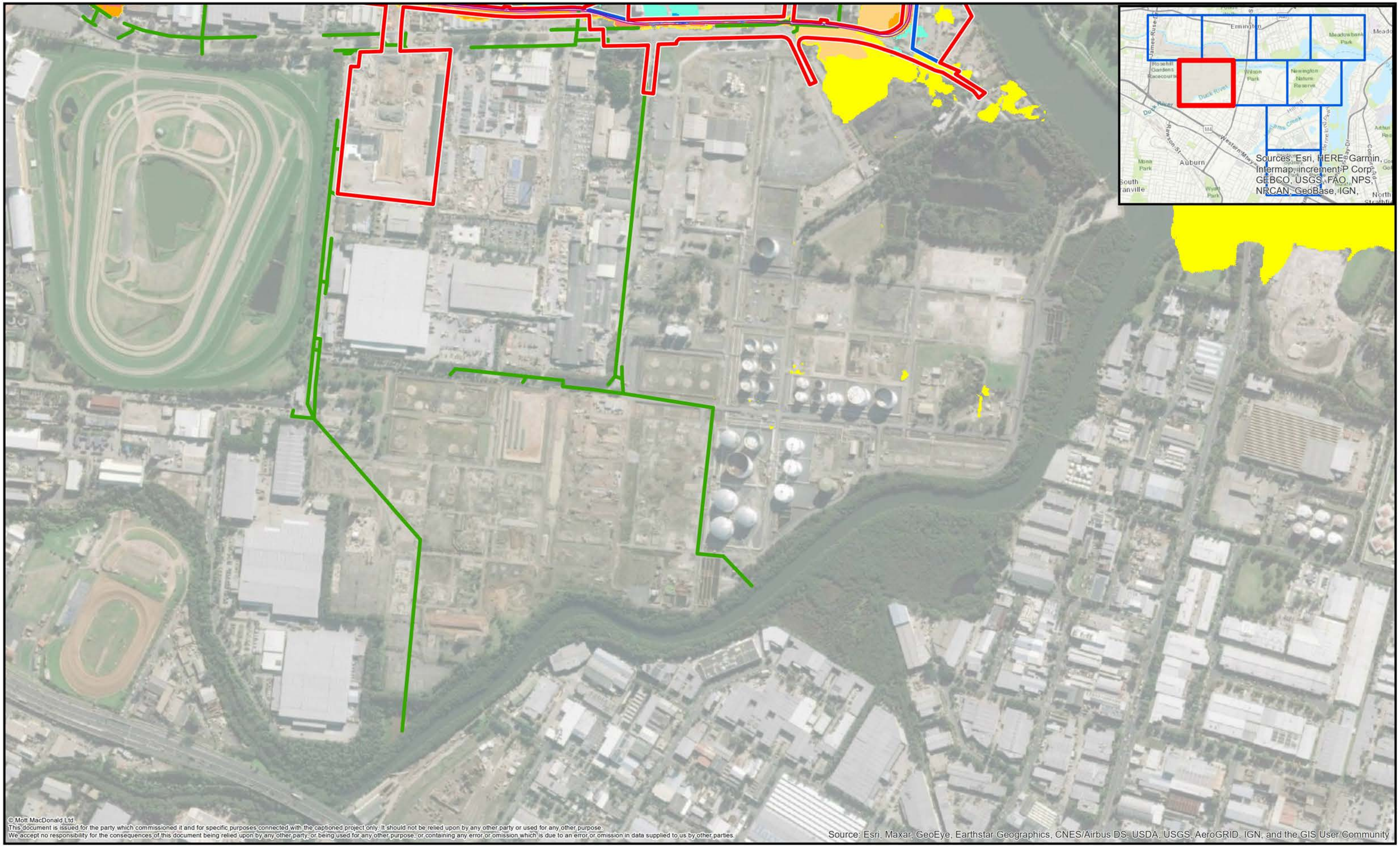
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 4 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Stormwater Pipes

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

Project Alignment

Construction Compounds

Project Site

Stormwater Pipes

1%CC Flood Level Difference (m)

< -0.1

-0.1 - -0.05

-0.05 - -0.01

-0.01 - 0.01

0.01 - 0.02

0.02 - 0.05

0.05 - 0.1

> 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

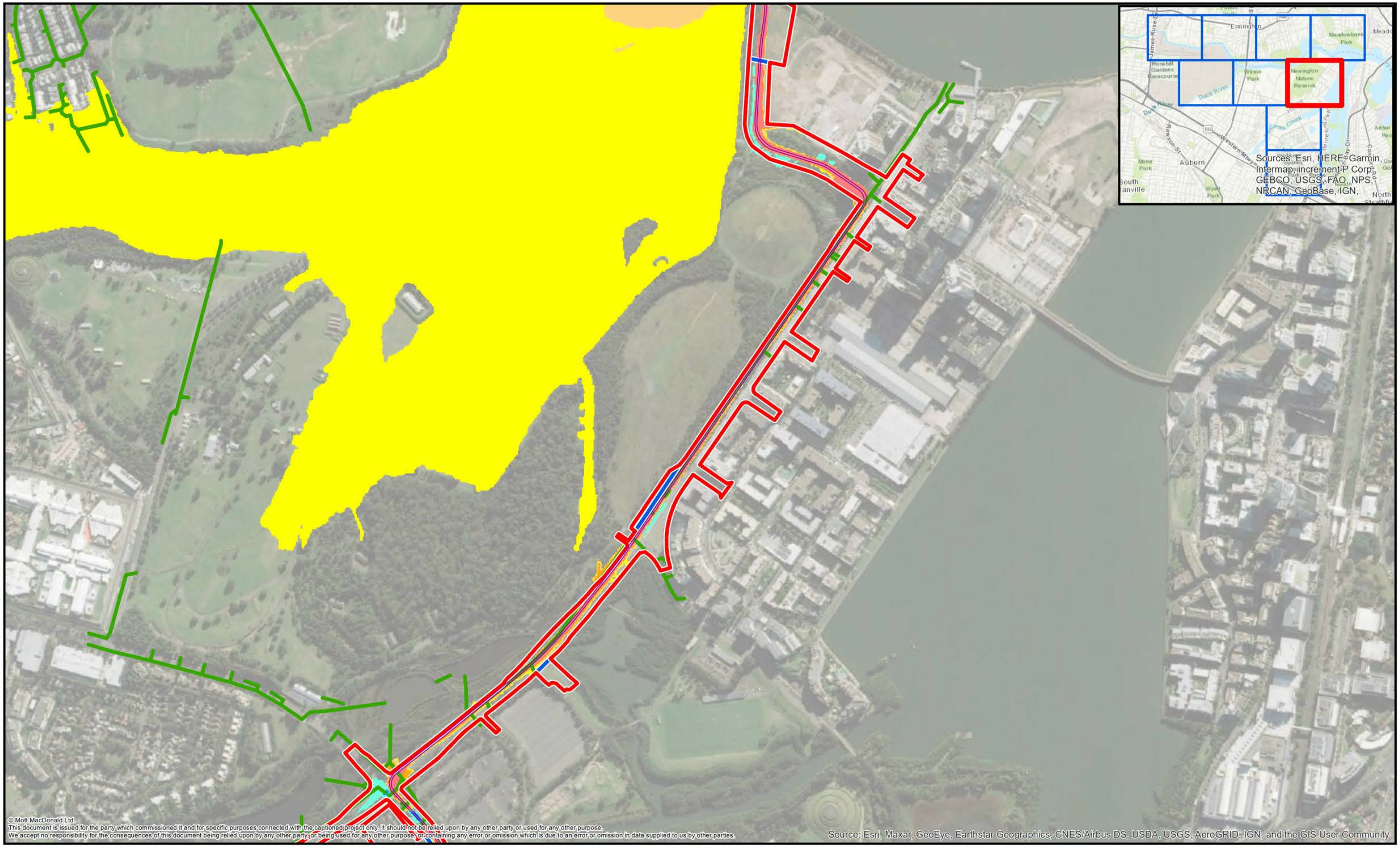
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 6 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 7 of 9

N

Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

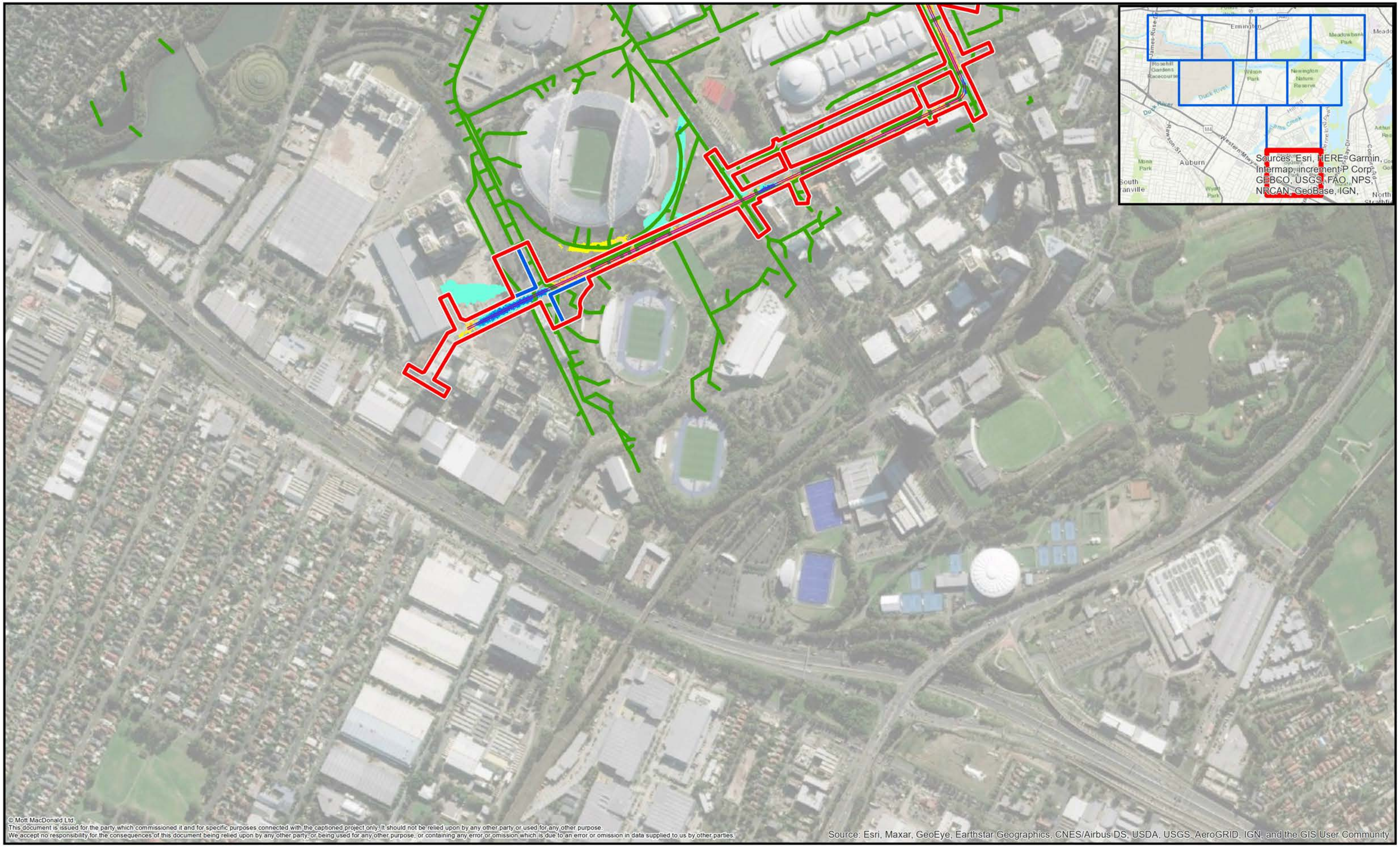
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 8 of 9

N



Legend

- Project Alignment
- Stormwater Pipes
- Construction Compounds
- Project Site

1%CC Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Climate Change Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

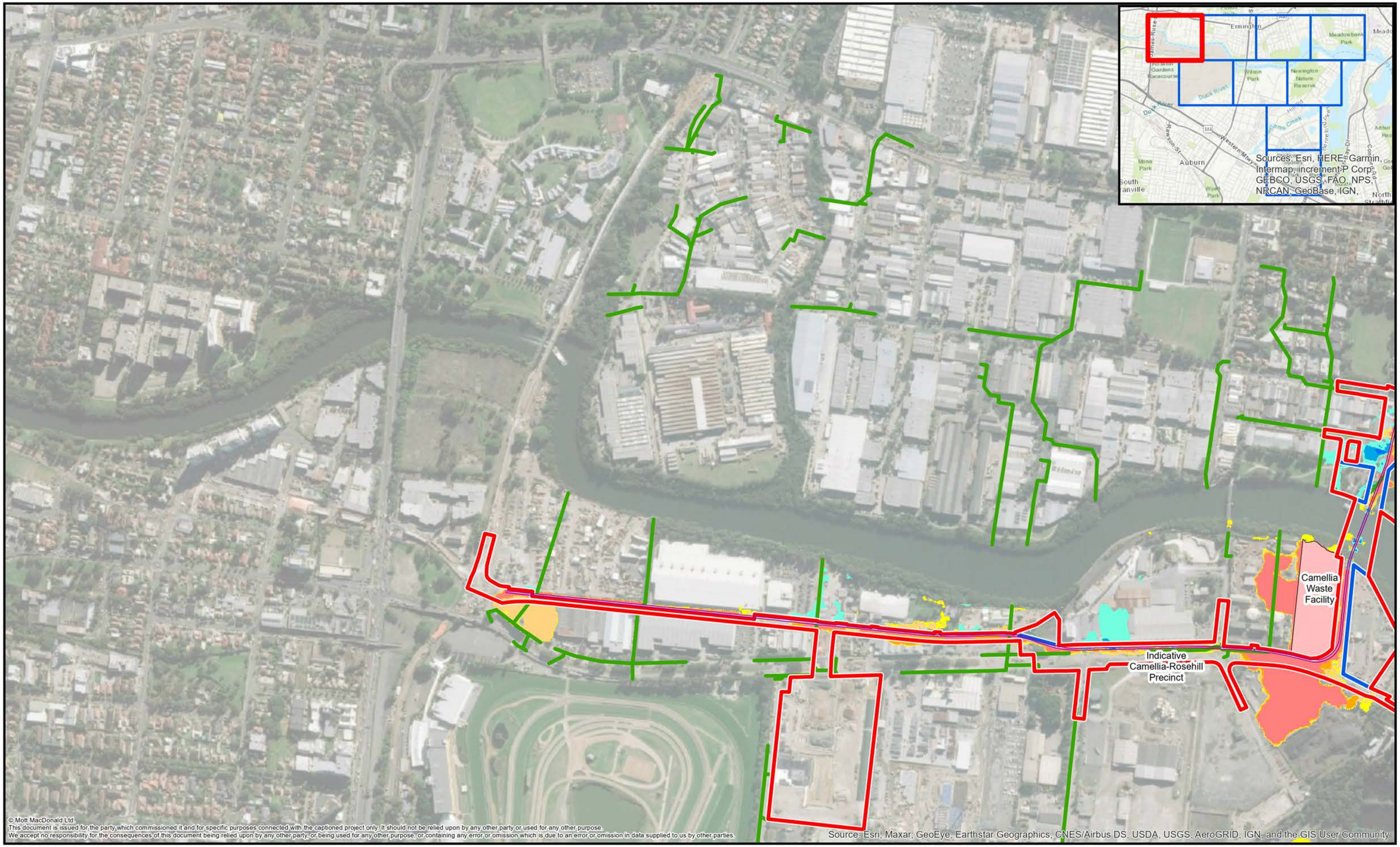
MOTT MACDONALD

Map Number

Sheet No 9 of 9

N

Appendix D Flood Modelling Figures – Cumulative Development Flood Level Difference



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Potential Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

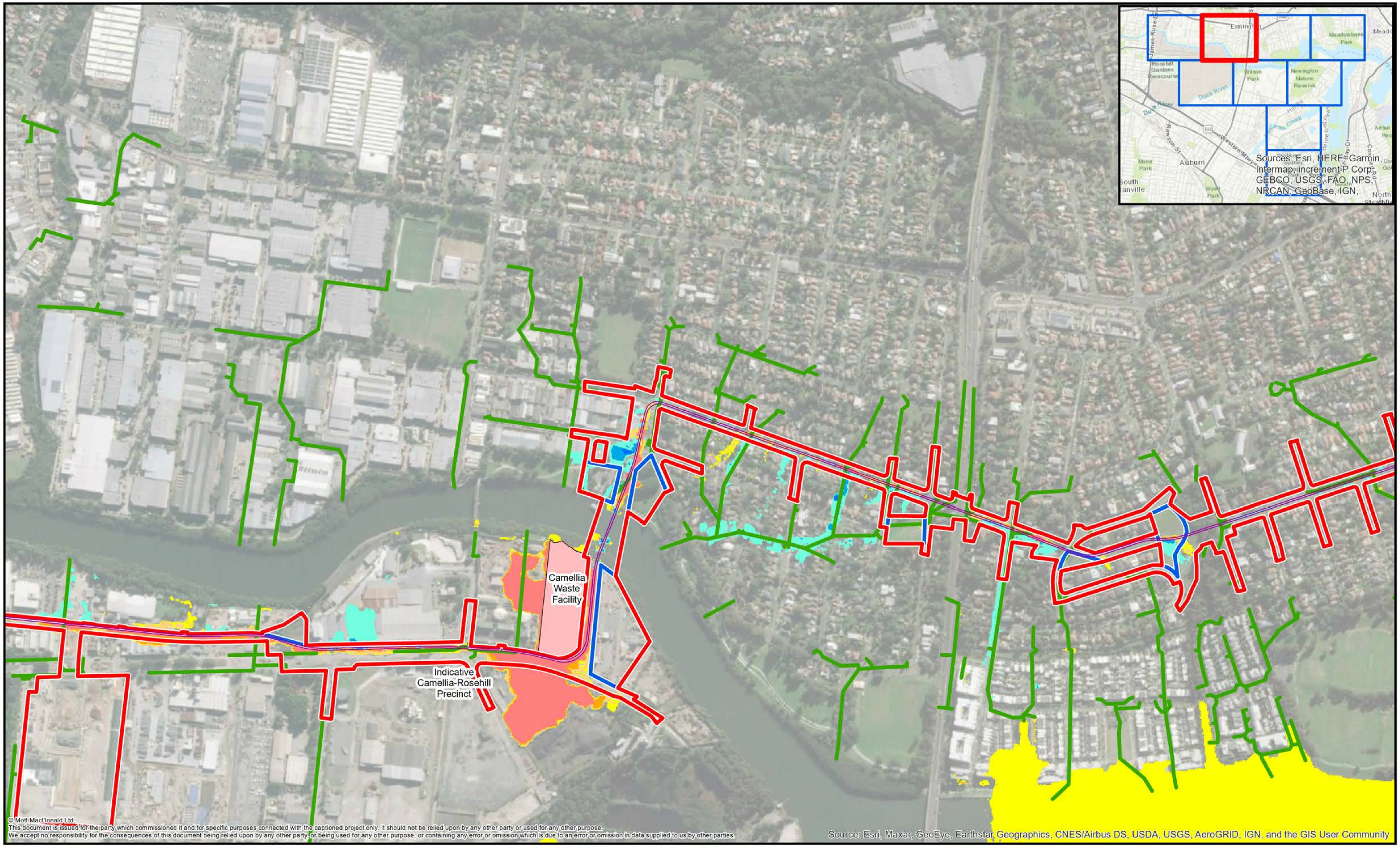
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 1 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Potential Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

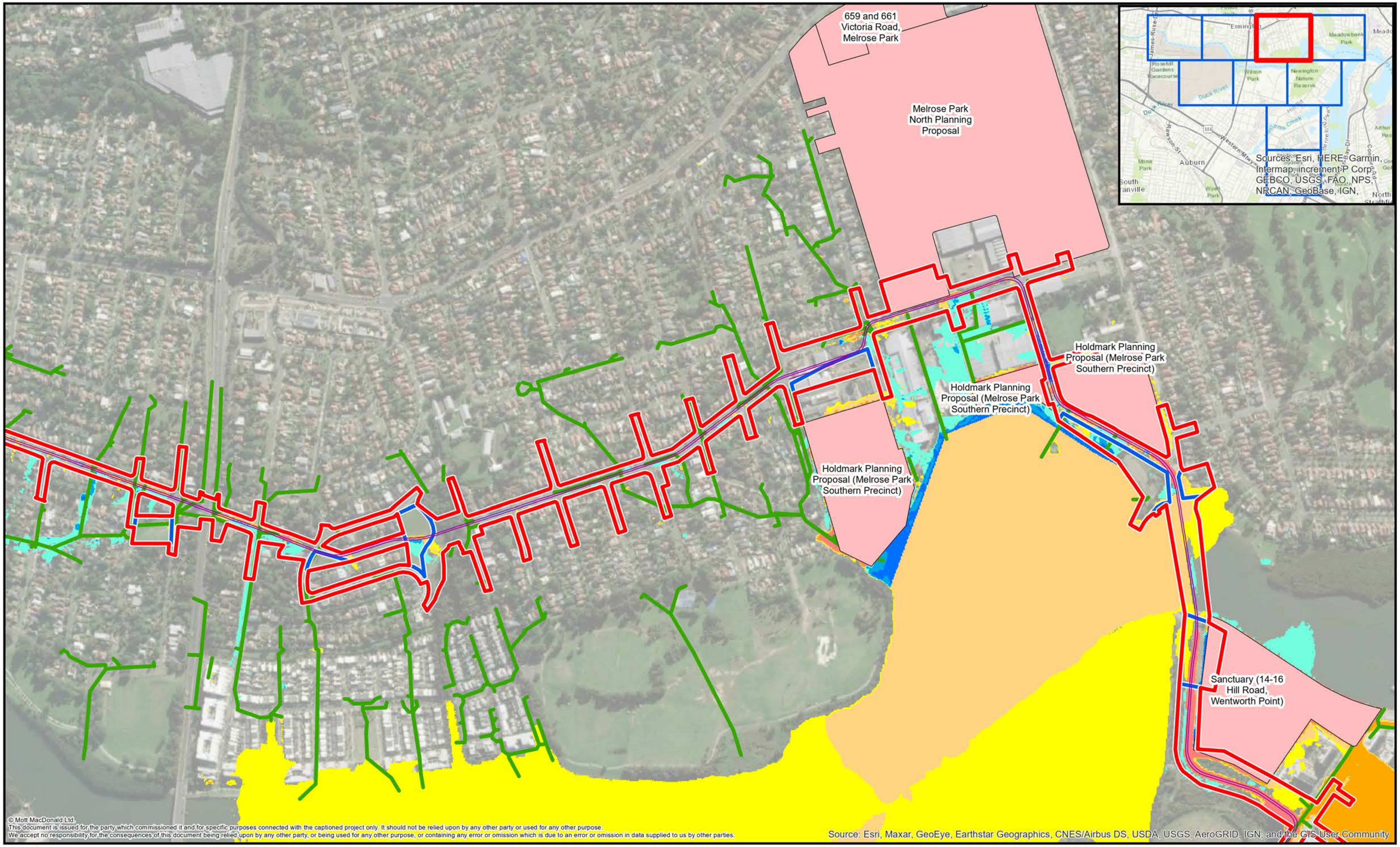
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 2 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Potential Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

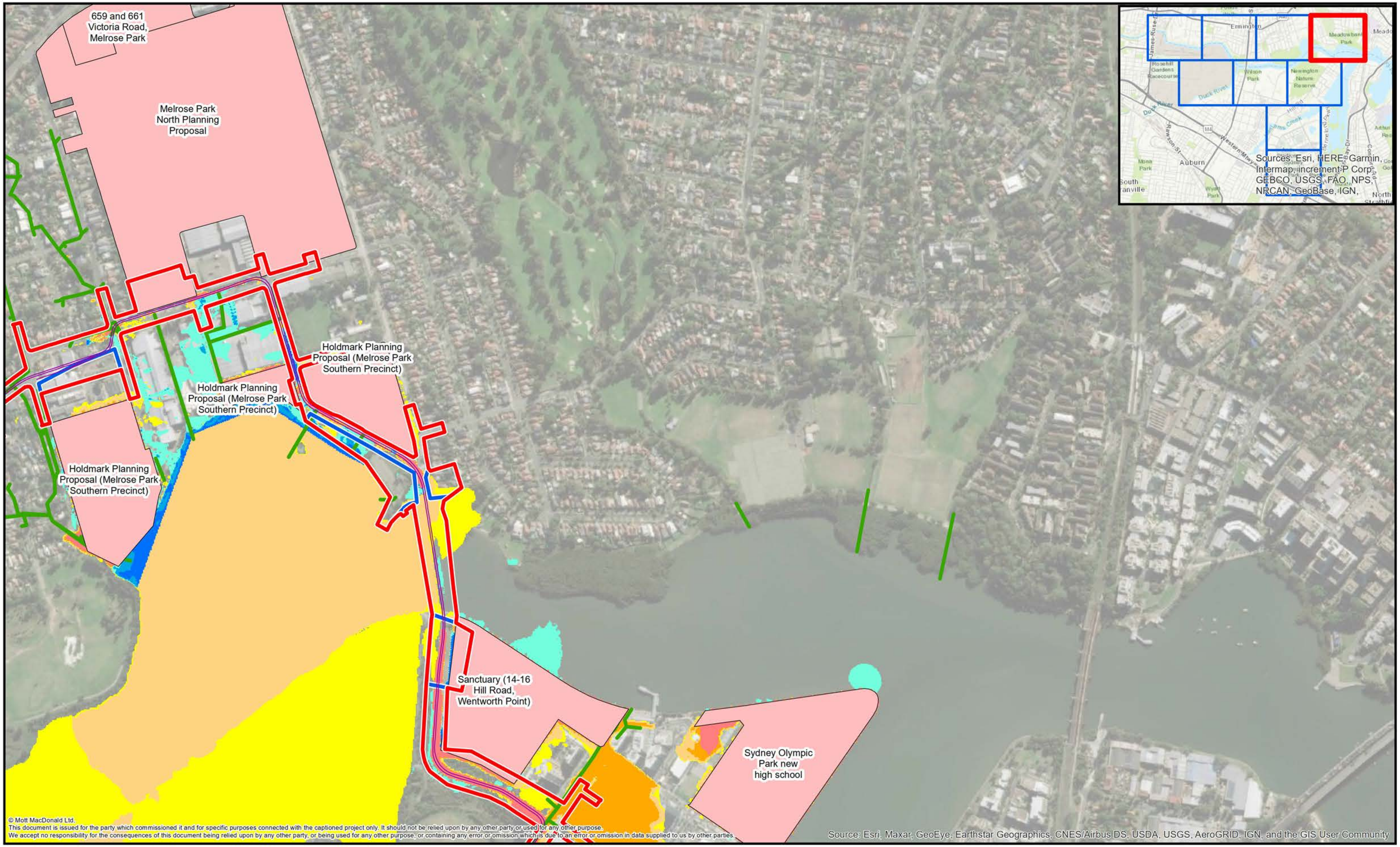
Scale at A3

MOTT MACDONALD

Map Number

Sheet No 3 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Potential Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

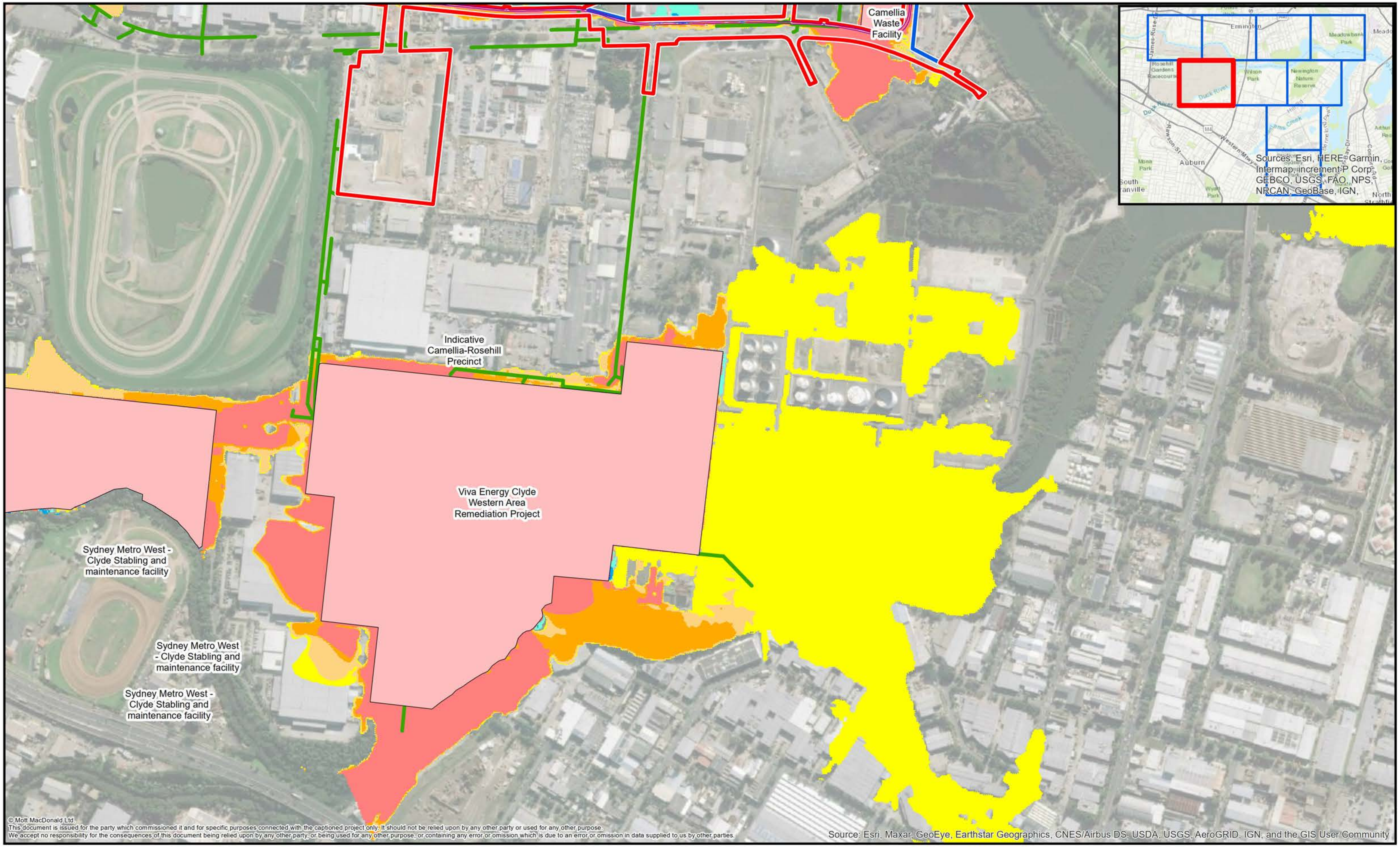
1:7,000

Scale at A3

MOTT MACDONALD

Map Number

N



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Potential Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

MOTT MACDONALD

Map Number

Sheet No 5 of 9

N

Legend

- Project Alignment
- Construction Compounds
- Project Site
- Potential Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

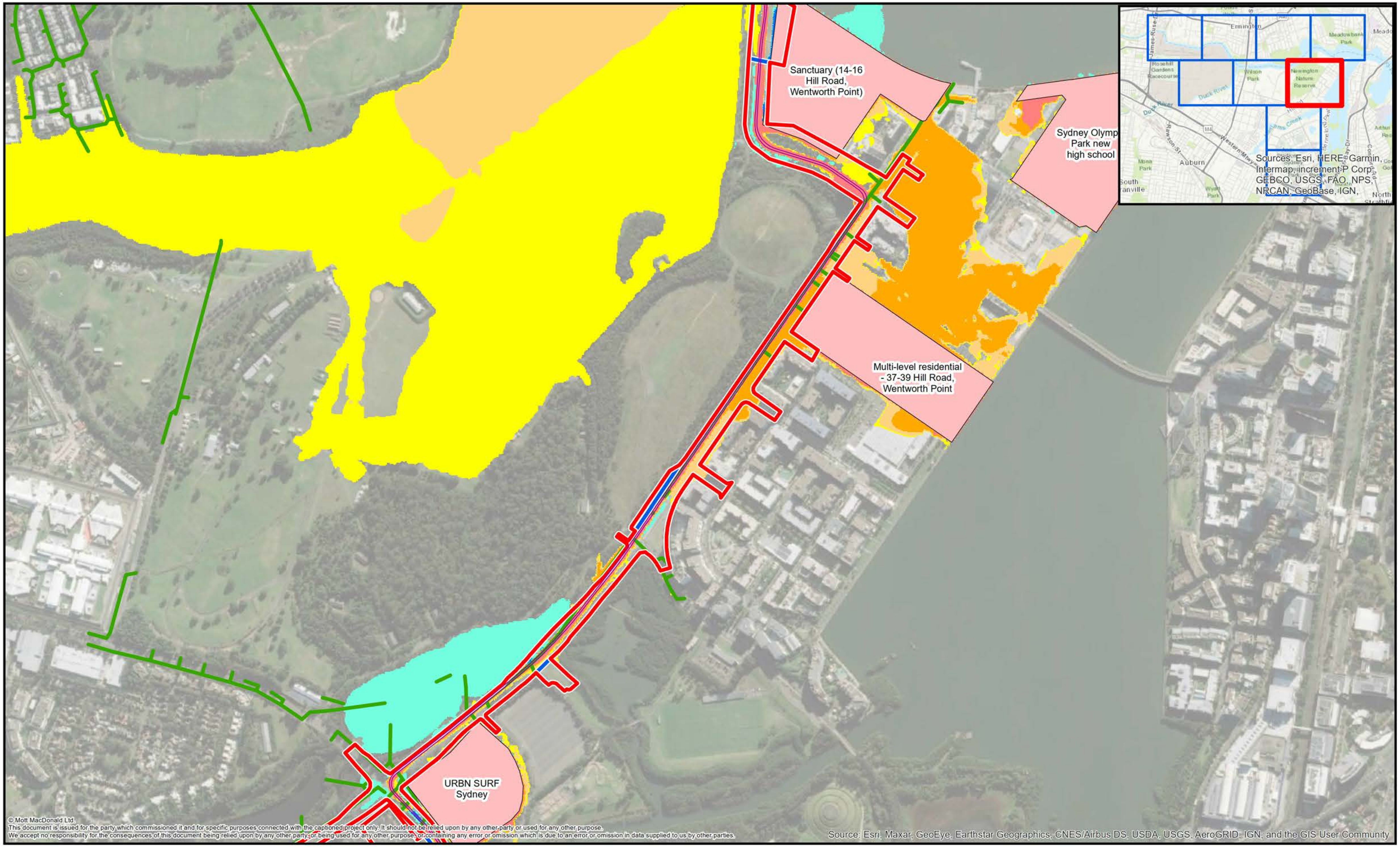
0 0.05 0.1 0.2 Kilometers

1:7,000
Scale at A3

MOTT MACDONALD

Map Number
Sheet No 6 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Potential Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

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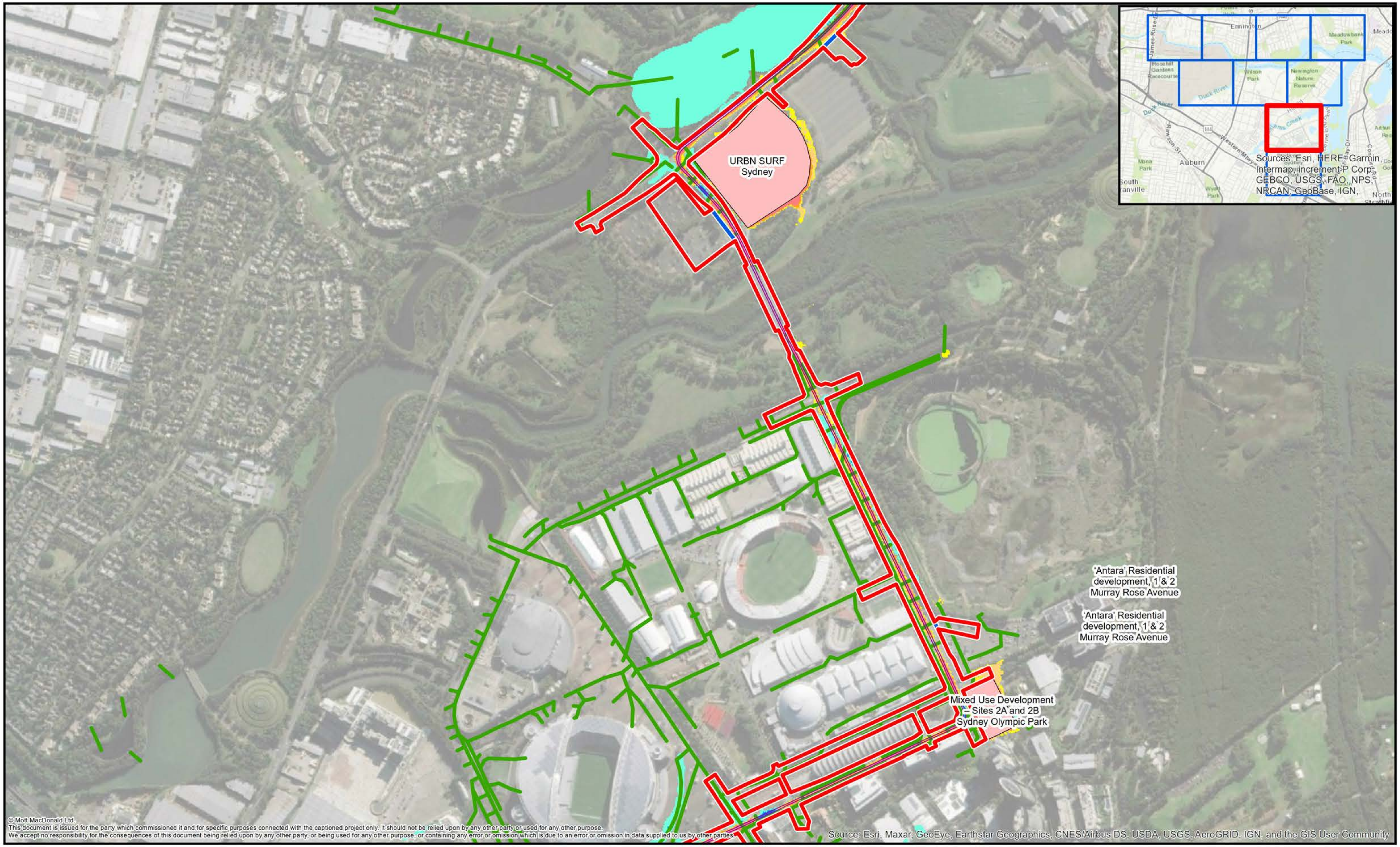
Map Number

Sheet No 7 of 9

N



Legend

- Project Alignment
- Construction Compounds
- Project Site
- Development
- Stormwater Pits
- Stormwater Pipes

1% Flood Level Difference (m)

- < -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- > 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000

Scale at A3

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Map Number
Sheet No 8 of 9

N

Legend

Project Alignment
Construction Compounds
Project Site
Potential Development
Stormwater Pits
Stormwater Pipes

1% Flood Level Difference (m)

< -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.02
0.02 - 0.05
0.05 - 0.1
> 0.1

Title

1% AEP Cumulative Projects Flood Level Difference (Afflux)

0 0.05 0.1 0.2 Kilometers

1:7,000
Scale at A3

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Map Number
Sheet No 9 of 9

N