POD VOLUME 3
ATTACHMENT K:
HYDRAULIC ASSESSMENT REPORT

PREPARED BY: ARUP

DESTINATION BRISBANE CONSORTIUM

PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL

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Queens Wharf Brisbane

PoD Volume 3, Attachment K – Hydraulic Assessment Report

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Abbreviations and Definitions

Acronym	Description
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AEP	Annual Exceedance Probability
AS	Australian Standard
BCC	Brisbane City Council
BRCFS	Brisbane River Catchment Flood Study
DBC	Destination Brisbane Consortium
DFE	Defined Flood Event
DFL	Defined Flood Level
DILGP	Department of Infrastructure, Local Government and Planning
DMT	Disaster Management Tool
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
PoD	Plan of Development
PDA	Priority Development Area
QWBIRD	Queens Wharf Brisbane Integrated Resort Development
SLR	Sea Level Rise
SLS	Serviceability Limit State
ULS	Ultimate Limit State

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1 Introduction

1.1 Development Precincts

The project name for the proposed development is the Queens Wharf Brisbane Integrated Resort Development (QWBIRD). In line with the PoD application terminology, each element of the development has been categorised into four precincts and associated sub-precinct as shown in Figure 2 and Figure 3 respectively.

1. Integrated Resort Development (IRD) Precinct, comprising:
    a. Resort Sub-Precinct;
    b. North West Sub-Precinct;
    c. North Quay Sub-Precinct;
    d. Queen's Wharf Plaza Sub-Precinct;
    e. The Landing Sub-Precinct;
    f. Waterline Park Sub-Precinct;
    g. Goodwill Extension Sub-Precinct;
    h. IRD Heritage Sub-Precinct;
    i. Miller Park Sub-Precinct;

2. Treasury Hotel and Casino Repurposing Precinct, comprising:
    a. Treasury Building Sub-Precinct;
    b. Lands Administration Building Sub-Precinct;
    c. Old State Library Sub-Precinct;

3. Residential Precinct

4. PDA Associated Development
    a. Bridge Sub-Precinct;
    b. Queen Street Interface Sub-Precinct;
    c. Turbot Street Sewer Upgrade Sub-Precinct.

Figure 1: QWBIRD Architectural Vision

Source: Grimshaw Architects

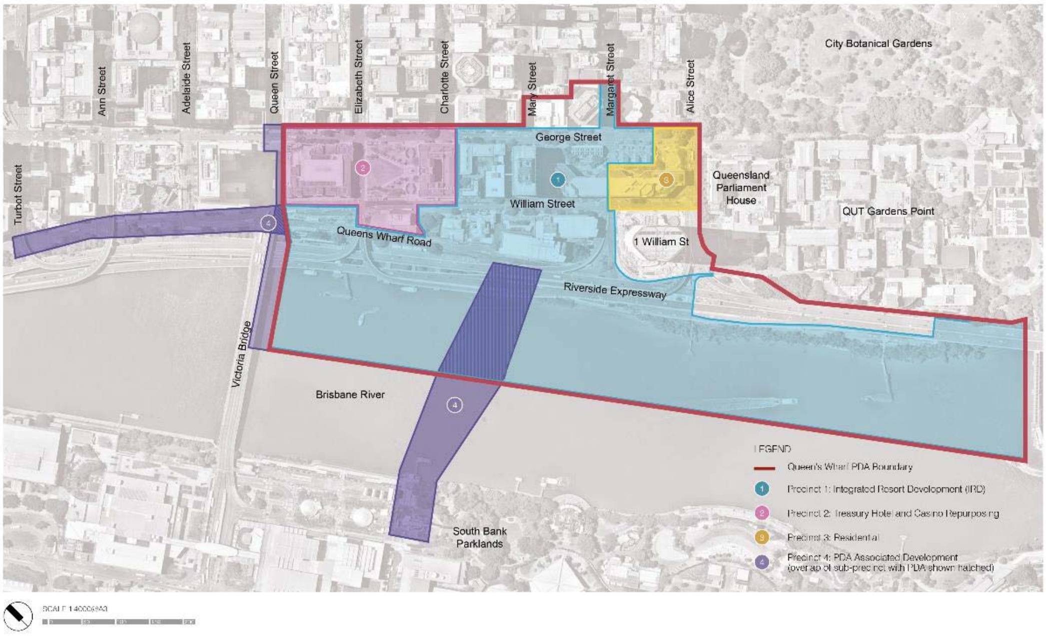

Figure 2: QWBIRD precincts

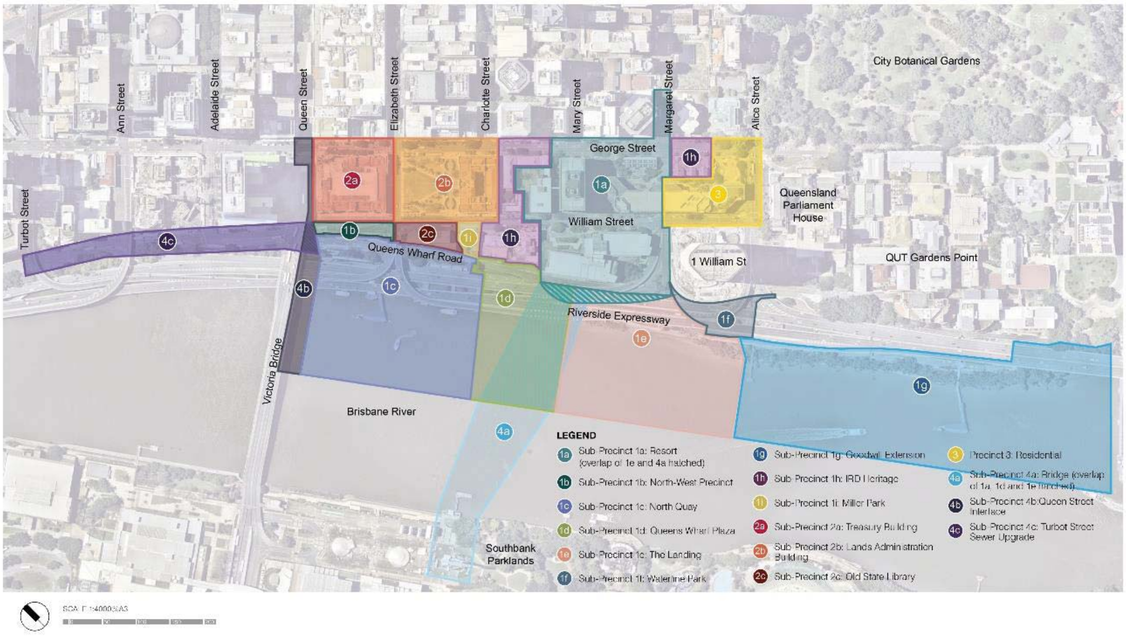

Figure 3: QWBIRD sub-precincts

1.2 Purpose of PoD Hydraulic Component

The development comprises a number of foreshore elements directly interacting with the Brisbane River. These include jetties, cut and fill earthworks, a boardwalk and a pedestrian bridge. As part of this study scope, a hydraulic analysis is required to inform the following:

1. Hydrodynamic forces (generally referred as ‘flood load’) estimate for input into the foreshore design works;
2. Flood Impact Assessment (the optimum design including mitigation shall lead to *no adverse flood impact* in accordance with the QWB PDA Development Scheme); and
3. Flood Planning levels, flood hazard, risk assessment and emergency management planning in relation to QWB (i.e. emergency management planning of the Brisbane CBD is outside this study scope).

For compliance with standard technical terminology, the analysis performed as part of the report will be referred as ‘hydraulic assessment’ or ‘hydraulic modelling’ rather than hydrology.

1.3 Precincts Considered for this Assessment

With regards to the hydraulic assessment, only the sub-precincts directly interacting with the Brisbane River and/or with the potential to change the flooding behaviour of the Brisbane River have been represented. These include:

1. Integrated Resort Development (IRD) Precinct:
   a. Resort Sub-Precinct;
   c. North Quay Sub-Precinct;
   d. Queen's Wharf Plaza Sub-Precinct;
   e. The Landing Sub-Precinct;
   g. Goodwill Extension Sub-Precinct; and

4. PDA Associated Development
   a. Bridge Sub-Precinct.

1.4 Disclaimer

When developing conceptual hydraulic models, there is always a degree of simplification required in order to simulate the complex nature of the physical system's behaviour. A model is a representation of a system and may not reflect the exact flood behaviour at all points in time and space that would relate to a given storm event. The model developed by Arup has been rigorously tested and it provides consistent results; it is therefore considered suitable for this assessment.

2 Legislation and Assessment Criteria

The development is part of the Queens Wharf Priority Development Area (PDA) Development Scheme which refers to the following guidelines:

- State Planning Policy (SPP) and Development Assessment (DA) mapping
- Brisbane City Council (BCC) Plan 2014
- Handbook 7, Australian Emergency Management Handbook Series and SDAP Module 10: Coastal protection.

The PDA development scheme also refers to the Brisbane River Catchment Flood Study (BRCFS) however this study was not available at the time of writing (ongoing).

In line with industry standard practice, the site has been assessed against (i) risk of catchment flooding and (ii) coastal hazard separately. The results of these assessments are presented in sections 2.1 and 2.2 respectively.

2.1 Catchment Flood Risk Policies

The development is subject to the BCC City Plan 2014 (City Plan) which refers to the BCC flood overlay code. The development is also required to comply with the overarching State Planning Policy (SPP) ‘Natural Hazards risk and resilience, Part D — Model Codes and Provisions (April 2016)’. The guidelines set out by the SPP generally refer to local planning instruments. In this particular instance, compliance with the BCC flood overlay code also means that the SPP policies are complied with. Therefore, only the BCC flood overlay code policies are presented in this document.

The City Plan flood overlay map indicates that QWBIRD is included within sub-categories 1 to 5 of Brisbane River flood planning area, shown in Figure 4. Section 8.2.11.3 of the flood overlay code sets out the assessment criteria and required performance outcomes for QWBIRD depending on these sub-categories.

Refer to Table 1 for details of the required performance outcomes in accordance with the City Plan flood overlay code.

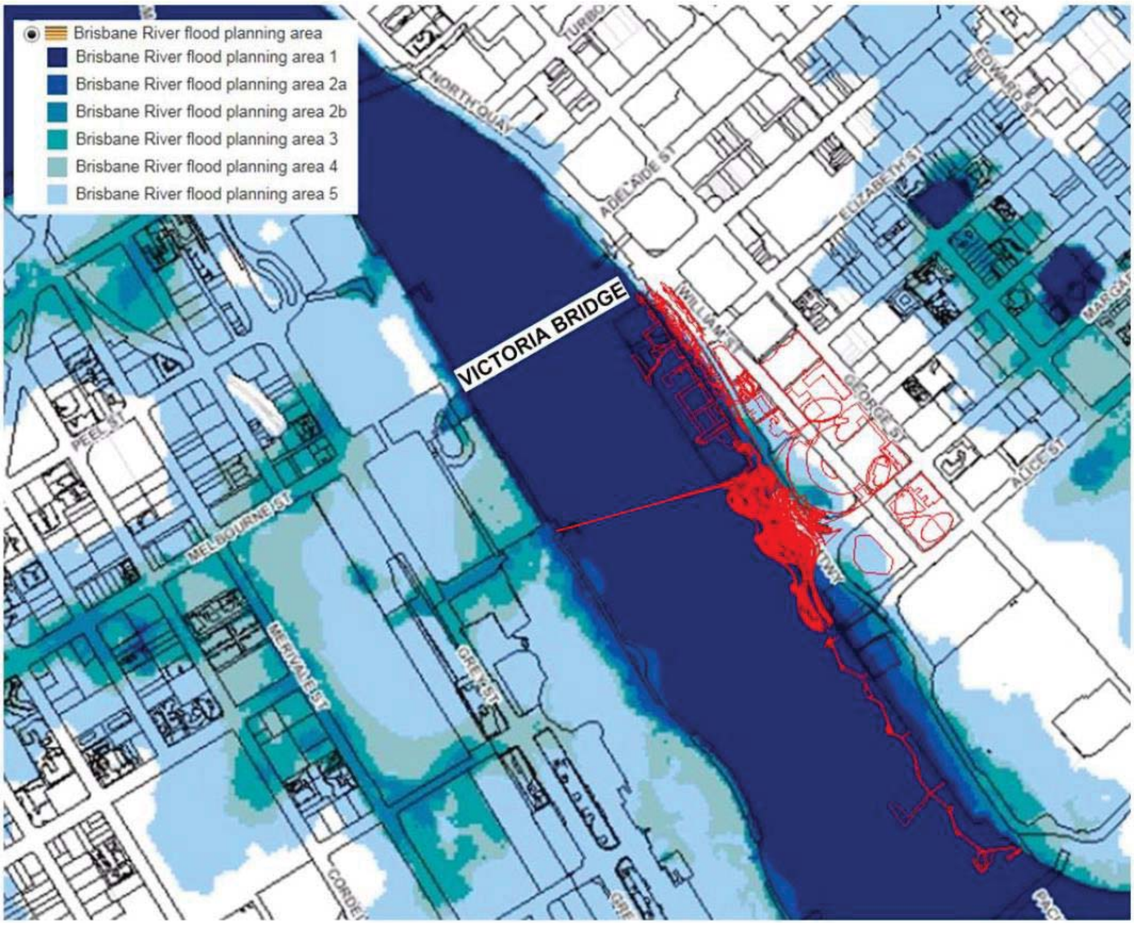

Figure 4: City Plan Flood overlay and QWBIRD (in Red)

Flood Impact Criteria

There is no formal criteria in the current legislation that defines what an ‘acceptable flood impact’ is for QWBIRD. Flood impact is generally expressed as a comparison of the predevelopment flood behaviour and the predicted post-development flood behaviour. This difference is presented in the form of flood impact maps, representing the change in flood levels or change in flood velocities from a development. Maps include a range for which the impact is considered tolerable, for instance a 0.015m change in flood levels. This means any increase within this range is considered acceptable and/or is considered a limitation of the model results accuracy with regards to impact quantification.

For the approving authorities, the impact of a flood is determined in consideration of the development location and the modelling results.

2.2 Coastal Hazard Policies

The development is subject to the BCC City Plan 2014 which refers to the BCC coastal overlay code. The City Plan Coastal Hazard overlay map shown in Figure 5 indicates that the proposed QWBIRD foreshore works are located in (i) an erosion prone area and (ii) a high to medium storm-tide inundation area; all proposed buildings are located outside the coastal hazard overlay (i.e. not affected by storm tide inundation).

Section 8.2.11.3 of the Coastal Hazard overlay code sets out the assessment criteria for the QWBIRD.

The development is also subject to the State Development Assessment Provisions (SDAP) Module 10: Coastal Protection. Refer to Table 2 and Table 3 for the required performance outcomes.

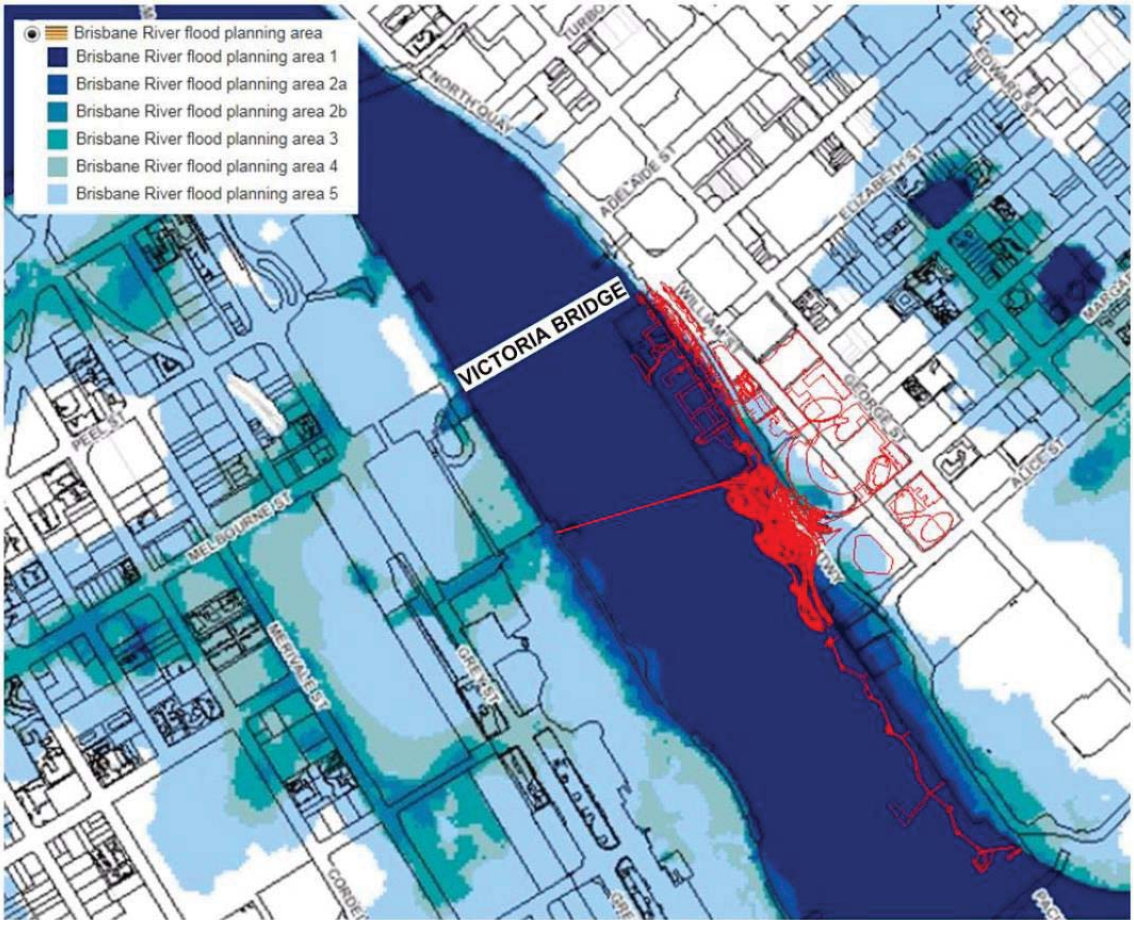

Figure 5: City Plan Coastal Hazard overlay and QWBIRD (in Red)

3 Compliance Against Legislation

3.1 Flood Hazard Overlay Code

The performance outcomes from the BCC Flood overlay code that are relevant to the project development are listed in Table 1.

Response column key:
☑ Achieved
P/S Performance solution
N/A Not applicable

Table 1: Performance Outcomes - BCC City Plan (2014) - Flood Hazard Overlay Compliance Matrix, Section B Criteria

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO3 Development: (a) is compatible with flood hazard in a defined flood event; (b) minimises the risk to people from flood hazard; (c) does not reduce the ability of evacuation resources including emergency services to access and evacuate the site in a flood emergency, with consideration to the scale of the development; (d) minimises impacts on property from flooding; (e) minimises disruption to residents, business or site operations and recovery time due to flooding; (f) minimises the need to rebuild structures after a flood event greater than the defined flood event. Note—Where Table 8.2.11.3.C identifies that a flood risk assessment is required, compliance with this performance outcome can be achieved by submitting a flood risk assessment, which may be included within a flood study, addressing the criteria within this performance solution. Preparing flood risk assessments and flood studies is required to be in accordance with the Flood planning scheme policy. Note—An emergency management plan prepared in accordance with the Flood planning scheme policy, which sets out procedures for evacuation due to flooding may be used to demonstrate compliance with this performance outcome.	**AO3** Development for a material change of use is identified in Table 8.2.11.3.C as compatible with the flood hazard in the relevant flood planning area.	✓	**PO assessment criteria** Definitions: Defined Flood Level (DFL) = Residential Flood Level (RFL) = 2011 Flood Level; This level is 5.4m AHD at the IRD. Note: The flood levels vary along the Brisbane River and the 5.4m AHD value should not be applied to other sites within the PDA without inspection of the flood model. a) Flood Hazard Compatibility The QWB development is included within sub-categories 1 to 5 of the "Brisbane River flood planning area". Much of the proposed shoreline of the site is designated community parklands or walkways. This is compatible with the flood hazard across the site (park use being compatible with all flood planning area sub-categories). The IRD main building falls into the flood hazard overlay, Brisbane River Flood Planning Category 3. The design details are as follows with regards to flooding considerations. o Essential Services above 5.9m AHD (this is 5.4m AHD RFL + 500mm freeboard). Refer to Appendix B. o All levels from basement and above protected to a minimum level of 5.4m AHD RFL via food barrier protection - refer to Appendix C The entire QWBIRD is compatible with the flood hazard. b) Flood Risk Assessment Refer to a), c) and d) of this section table

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
			c) Evacuation and Emergency A site specific emergency management plan will be developed in the next detailed design phase of the QWBIRD to assess the pre and post flood management operations at the site scale. It is noted that the Brisbane River Catchment Flood Study currently being commissioned by the State will provide information that underpins this plan, in particular flood warning times. Considering the large upstream catchment and long-time of concentration, the flood warning times are expected to be sufficient for evacuation planning in line with the 2011 flood event experience. This consideration also covers Handbook 7, Australian Emergency Management Handbook (State and Local authorities' responsibility). d) Flood Impact Assessment A specific flood risk assessment has been performed and results are presented in this document. The QWBIRD design development was performed in conjunction with the hydraulic modelling to develop an optimum design that results in minimal flood impact within and outside of the PDA, whilst still maintaining the architectural vision and structural requirements. For all the events modelled, the QWBIRD development results in less than 15mm flood impact outside the PDA boundary, except along Montague Road where a 17mm impact is locally observed. A 17mm impact is also observed locally in the river in a 1% Annual Exceedance Probability (AEP) event which remains within river banks. e) Disruption and Recovery Times Refer to c) and d) of this table, PO3 section. f) Flood Resilience All foreshore structures are designed for a 1000 year ULS (extreme case).

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO4 Development for a park ensures that the design of a park and location of structures and facilities responds to the flood hazard and balances the safety of intended users with: (a) maintaining continuity of operations; (b) impacts of flooding on asset life and ongoing maintenance costs; (c) efficient recovery after flood events; (d) recreational benefits to the city; (e) availability of suitable land within the park.	**AO4.1** Development involving a building or structure in a park complies with the flood planning levels specified in Table 8.2.11.3.D	✓	All the elements and facilities built on ‘The Landing' and 'Queens Wharf Plaza' are 'pop-up' elements, i.e. these are not proper buildings as specified in Table 8.2.11.3.D. These facilities can easily be removed during of a flood event situation, considering the long warning times; this means that there will be negligible impacts upon the assets in the case of a flood. Also refer to PO3.
PO5 Development is located and designed to: (a) minimise the risk to people from flood hazard on the site; (b) minimise flood damage to the development and contents of buildings up to the defined flood event; (c) provide suitable amenity; (d) minimise disruption to residents, recovery time and the need to rebuild structures after a flood event up to and including the defined flood event	**AO5** Development complies with the flood planning levels specified in Table 8.2.11.3.D. Note—If located in an area with no Council-derived flood levels such as an overland flow path, a Registered Professional Engineer Queensland with expertise in undertaking flood studies is to derive the applicable flood level and certify that the development meets the required flood planning levels in Table 8.2.11.3.D. The study is to demonstrate that the development and engineering design methods conform to the principles within the Flood planning scheme policy and the Infrastructure design planning scheme policy.	✓	Refer to PO3.

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO6 Development involving essential electrical services or a basement storage area is suitably located and designed to ensure public safety and minimise flood recovery and economic consequences of damage during a flood.	**AO6.1** Development ensures that: (a) all areas containing essential electrical services comply with the flood planning levels in Table 8.2.11.3.D; or (b) if a basement contains essential electrical services or a private basement storage area, the basement is a waterproof structure with walls and floors impermeable to the passage of water with all entry points and services located at or above the relevant flood planning level in Table 8.2.11.3.D. Note—A basement storage area does not include a bike storage room, change room, building maintenance storage and non-critical electrical services.	✓	Refer to PO3. <u>IRD Main Building</u> Essential electric Services above 5.9m AHD (this is 5.4m AHD RFL + 500mm freeboard). Refer to Appendix B. The electrical equipment is classified as essential for the building only.

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO7 Development does not directly or indirectly create a material adverse impact on flood behaviour or drainage on properties that are upstream, downstream or adjacent to the development.	**AO7.1** Development: (a) does not block, or divert floodwaters for any area affected by creek/waterway or overland flow flooding, excluding storm-tide flooding and Brisbane River flooding sources; or (b) does not result in a material increase in flood level or hydraulic hazard on upstream, downstream or adjacent properties. Note—Compliance with this acceptable solution can be demonstrated by the submission of a flood study by a Registered Professional Engineer of Queensland with expertise in undertaking flood studies demonstrating that the development and engineering design methods conform to the principles within the Flood planning scheme policy and the Infrastructure design planning scheme policy.	✓	Refer to PO3.

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3.2 Coastal Hazard Overlay Code

The performance outcomes from BCC Coastal overlay code that are relevant to the project development are listed in Table 2. An assessment against the State Development Assessment Provisions (SDAP) Module 10 is presented in Table 3.

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Response column key:
☑ Achieved
P/S Performance solution
N/A Not applicable

Table 2: Performance Outcomes - BCC City Plan (2014) - Coastal Hazard Overlay Compliance Matrix

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO2 Development other than for a park is located and designed to: (a) minimise the risk to all persons from coastal hazards; (b) minimise flood damages to the development and contents of buildings; (c) provide suitable amenity; (d) minimise disruption to residents, recovery time, and rebuilding or restoration costs after coastal hazard events.	**AO2** Development achieves minimum flood planning levels consistent with Table 8.2.6.3.C.	✓	All buildings in the QWB development are located outside the coastal hazard overlay.

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO3 Development for a park ensures that the design of the park and location of structures and facilities responds to coastal hazards and balances the safety of intended users with: (a) maintaining continuity of operations; (b) impacts of flooding on asset life and ongoing maintenance costs; (c) efficient recovery after flood events; (d) recreational benefits to the city; (e) availability of suitable land within the park. Note—The Infrastructure design planning scheme policy provides more detail on standards and specifications for public assets.	**A03** Development involving a building or structure in a park: (a) complies with the minimum flood planning levels in Table 8.2.6.3.C; or (b) is not located below the 20% AEP storm-tide level if Table 8.2.6.3.C does not apply to the type of structure.	✓	The foreshore public realm structures can be classified as Class 10b - Other Structures according to Table 8.2.6.3.D - Flood planning level categories for development types. The foreshore structures deck levels are located above the 20% AEP flood level in accordance with clause (b) of A03. A specific flood risk assessment has been performed and results are presented in this document. The QWBIRD design development was performed in conjunction with the hydraulic modelling to develop an optimum design that results in minimal flood impact, whilst still maintaining the architectural vision and structural requirements. Inundation from the upstream catchment, which has been assessed, is the predominant source of flooding for the area. A storm tide inundation would have lesser effect due to lower storm tide level and lower velocities. Flooding from storm tide event is also contained within the river banks. For these reasons a storm tide inundation impact assessment has not been performed as it would provide no additional information to the flood assessment presented in this document. Refer to Table 1, Performance Outcomes - BCC City Plan (2014) - Flood Hazard Overlay Compliance Matrix, PO3.
PO4 Development has access which provides for safe vehicular and pedestrian movement in the development, including emergency services access during and after a coastal hazard event.	**A04** Development locates access points and driveways in the flood free area (or the area of the lowest flood risk) of the site.	✓	Emergency vehicles can assess the foreshore from the north east between Alice Street to Elizabeth Street, noting that there are only a few physical access points at either end of the foreshore. This area is flood free (i.e. not subject to storm surge flooding) and outside both flood overlay and coastal overlay.

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO5 Development for pedestrian and cyclist paths: (a) provides a suitable level of trafficability; (b) manages the impacts of flooding on asset life and ongoing maintenance costs; (c) balances route availability with recreational and transport connectivity benefits to the city	**AO5.1** Development for off-road pedestrian and cyclist paths: (a) is not located in the Erosion prone area – coastal erosion subcategory; or (b) complies with the minimum flood planning levels in Table 8.2.6.3.H	✓	Pedestrian and cyclist paths complies with the minimum flood planning levels: above HAT + 0.3m.
PO6 Development does not: (a) impact adversely on the safety or amenity of an adjoining site; (b) impact adversely on the ability of others to implement future coastal hazard adaptation actions	**A06** Development does not concentrate, intensify or divert floodwater, erosion impacts or cause nuisance ponding onto other premises	✓	The development does not impede or divert floodwater flow. Refer to Table 1, Performance Outcomes - BCC City Plan (2014) - Flood Hazard Overlay Compliance Matrix, PO3. Inundation from the upstream catchment, which has been assessed, is the predominant source of flooding for the area. A storm tide inundation would have lesser effect due to lower storm tide level and lower velocities. Flooding from storm tide event is contained within the river banks. For these reasons a storm tide inundation impact assessment has not been performed as it would provide no additional information to the flood assessment presented in this document.

PERFORMANCE OUTCOMES	ACCEPTABLE OUTCOMES	RESPONSE	COMMENT
PO7 Development involving essential electrical services or a basement storage area is suitably located and designed to ensure public safety and minimise the need for flood recovery and economic consequences of damage during a flood.	**AO7.1** Development ensures that: (a) all essential electrical services comply with the flood planning levels in Table 8.2.6.3.C; or (b) if a basement contains essential electrical services or a private basement storage area, the basement is a waterproof structure with walls and floors impermeable to the passage of water and all entry points and services are located at or above the relevant flood immunity level in Table 8.2.6.3.C. Note—A basement storage area is a basement-level area for private storage, other than a bike storage room, change room, building maintenance storage and non-critical electrical services.	✓	All buildings in the development are located outside the coastal hazard overlay and are not subject to flooding from storm surge[1]. There is however a risk of flooding from the Brisbane River; this consideration has been assessed in Table 1, Performance Outcomes - BCC City Plan (2014) - Flood Hazard Overlay Compliance Matrix, PO3.
	AO7.2 Development involving a basement that relies on a pumping solution to manage floodwater ingress or for dewatering after a flood, provides an appropriately flood protected backup power source for those pumps.		

[1] The development is not subject to storm surge up to the probability of occurrence of the extreme events used in the BCC City Plan (2014)

Table 3: SDAP Module 10: Coastal Protection Compliance Verification

Performance outcomes	Acceptable outcomes	Response	Comment
PO1 Development in a coastal hazard area is compatible with the level of severity of the coastal hazard.	**AO1.1** Development is located outside a high coastal hazard area unless it is: 1) coastal-dependent development, or 2) compatible with inundation due to its nature or function, or 3) temporary, readily relocatable, or able to be abandoned, or 4) essential community service infrastructure, or 5) small- to-medium scale tourist development, or 6) redevelopment within an existing built-up urban area, or is redevelopment of built structures that cannot be relocated or abandoned. **And**	✓	The QWB PDA is located within coastal hazard areas for storm tide inundation and erosion prone areas. Much of the development in areas of coastal hazard risk can be considered coastal dependent development, including the jetties and boardwalks. Areas of public realm expansion along the foreshore of the river have also been designed to improve the access of the public to the river. The QWB PDA consists of redevelopment of an existing built-up urban area (the Brisbane CBD) and design considerations have been incorporated to ensure protection and mitigation from coastal hazards. This includes the location of areas of public open space and infrastructure that can be readily evacuated or abandoned. None of the QWB buildings are affected by storm tide events, including storm surge modelled for the area. The design of all structures within the erosion prone area have included appropriate measures to mitigate risk associated with erosion and have a 100 year design life.
	AO1.2 Development referred to in AO1.1(6) avoids being located within a high coastal hazard area, or where this is not practicable, minimises the exposure of people and permanent structures to coastal hazard impacts.	✓	The QWB PDA will ensure design minimises potential exposure of people and permanent structure to coastal hazard areas. Only areas of foreshore public open space are located within the mapped storm tide and erosion prone area hazards.
PO2 Development siting, layout and access in a coastal hazard area responds to potential inundation due to a defined storm tide event and minimises associated risks to personal safety and property.	**AO2.1** Development within a coastal hazard area is located, designed, constructed and operated to maintain or enhance the community's resilience to a defined storm tide event by limiting the exposure of people and structures to associated impacts. **And**	✓	Storm tide inundation will not result in any adverse effects to areas of public realm or buildings within the QWB PDA. Inundation from the upstream catchment, which has been assessed, is the predominant source of flooding for the area. A storm tide inundation would have lesser effect due to lower storm tide level and lower velocities. Flooding from storm tide event is also contained within the river banks.

Performance outcomes	Acceptable outcomes	Response	Comment
	AO2.2 Development mitigates any residual impacts from storm tide inundation in a coastal hazard area including by ensuring: 1) habitable rooms of built structures are located above the defined storm tide event level and any additional freeboard level that would ordinarily apply in a flood prone area under a relevant planning scheme standard, or 2) a safe refuge is available for people within the premises during a defined storm tide event, or 3) at least one evacuation route remains passable for emergency evacuations during a defined storm tide event, including consideration of the capacity of the route to support the evacuation of the entire local population within a reasonably short timeframe (for example, 12 hours). **And**	✓	There will be no habitable rooms located below the storm tide event level. Safe refuge and access from the foreshore areas, including the boardwalk have been provided, with easy egress out of foreshore development areas. As the storm tide events are not likely to be higher than the existing river bank level there are ample evacuation routes all along the foreshore frontage of the QWB PDA.
	AO2.3 Development within a coastal hazard area is located, designed and constructed to ensure exposed structures can sustain flooding from a defined storm tide event. **And**	✓	Structures within the coastal hazard area, that is all marine structures, will have a 100 year design life which includes resilience for flooding and storm tide inundation. The 100 year design life is related to the substructure and superstructure of all foreshore development.
	AO2.4 Essential community service infrastructure is: (1) located so that it is not inundated by a recommended storm tide event specified for that infrastructure, or (2) located and designed to ensure any components of the infrastructure that are likely to fail to function or may result in contamination when inundated by a storm tide (for example, electrical switch gear and motors, water supply pipeline air valves) are: (a) located above the peak water level for a recommended storm tide event, or	N/A	No essential community service infrastructure will be located in the area of mapped storm tide inundation hazards.

Performance outcomes	Acceptable outcomes	Response	Comment
	(b) designed and constructed to exclude storm tide intrusions or infiltration (including by being located in the ground), or (c) able to temporarily stop functioning during a recommended storm tide event without causing significant adverse impacts to the infrastructure or the community. **And**		
	AO2.5 Emergency services infrastructure and emergency shelters, police facilities, and hospitals and associated facilities have an emergency rescue area above the peak water level for a recommended storm tide event.	N/A	No emergency services infrastructure will be located in areas of mapped storm tide hazard.
PO3 Development directly, indirectly and cumulatively avoids an unacceptable increase in the severity of the coastal hazard, and does not significantly increase the potential for damage on the premises or to other premises.	**AO3.1** Development avoids increasing the number of premises from which people would need to be evacuated to prevent death or injury from a defined storm tide event.	✓	The QWB development will not increase the number of premises that will need evacuation in a storm tide event.
PO4 Development avoids the release of hazardous materials as a result of a natural hazard event.	**AO4.1** Development that involves the manufacture or storage of hazardous materials in bulk are designed to: 1) prevent the intrusion of waters from a defined storm tide event into structures or facilities containing the hazardous materials, or 2) ensure hazardous materials remain secured despite inundation, including secure from the effects of hydrodynamic forcing associated with wave action or flowing water.	✓	There will be no manufacturing or storage of hazardous materials in areas of storm tide inundation.
PO5 Natural processes and the protective function of landforms and vegetation are maintained in coastal hazard areas.	**AO5.1** Development in an erosion prone area within the coastal management district: 1) maintains vegetation on coastal landforms where its removal or damage may:	✓	The current foreshore area along the QWB PDA has been highly modified with rock revetment and constructed retaining walls forming the river edge. The natural coastal processes of sediment movement and channel morphology have been

Performance outcomes	Acceptable outcomes	Response	Comment
	(a) destabilise the area and increase the potential for erosion, or (b) interrupt natural sediment trapping processes or dune or land building processes 2) maintains sediment volumes of dunes and near-shore coastal landforms, or where a reduction in sediment volumes cannot be avoided, increased risks to development from coastal erosion are mitigated by location, design, construction and operating standards 3) minimises the need for erosion control structures or riverbank hardening through location, design and construction standards 4) maintains physical coastal processes outside the development footprint for the development, including longshore transport of sediment along the coast 5) reduces the risk of shoreline erosion for areas adjacent to the development footprint unless the development is an erosion control structure 6) reduces the risk of shoreline erosion for areas adjacent to the development footprint to the maximum extent feasible in the case of erosion control structures. **And**		previously impacted by the development along the river edge in this location. The proposed development of QWB site has been designed to current engineering standards to ensure impacts associated with erosion and bank stability are mitigated.
	AO5.2 Development in a <u>storm tide inundation area</u> is located, designed, constructed and operated to: 1) maintain dune crest heights, or where a reduction in crest heights cannot be avoided, mitigate risks to development from wave overtopping and storm tide inundation 2) maintain or enhance coastal ecosystems and natural features, such as mangroves and coastal wetlands,	N/A	The QWB PDA is not located in a coastal system that includes dunes. The relatively narrow fringe of mangroves and estuarine wetland in the PDA do not protect or buffer the adjacent land from sea-level rise impacts or storm tide inundation.

Performance outcomes	Acceptable outcomes	Response	Comment
	between the development and tidal waters, where the coastal ecosystems and natural features protect or buffer communities and infrastructure from sea-level rise and impacts from storm tide inundation. **And**		
	AO5.3 Redevelopment of built structures in the erosion prone area within a coastal management district: 1) avoids intensifying the use of the premises, or 2) demonstrates that any intensification of use will not result in an increase in the need for erosion control structures or riverbank hardening. **And**	PS	The riverbank within the QWB PDA is already completely developed and hardened with rock revetment and/or retaining wall structures. The natural protective function of landforms and vegetation have largely been removed from the site. The intensification of the use of the foreshore area as public open space areas will require erosion control and river bank protection measures to provide for the required design life of 100 years.
	AO5.4 Development that is coastal protection work involves, in order of priority: 1) beach nourishment undertaken in accordance with a program of beach nourishment works that source sediment of a suitable quality and type from outside the active beach system, or 2) the construction of an erosion control structure, where it is demonstrated that installing an erosion control structure is the only feasible option for protecting permanent structures from coastal erosion and those structures cannot be abandoned or relocated in the event of coastal erosion occurring. Editor's note: Applications for coastal protection work should be supported by a report certified by a Registered Professional Engineer of Queensland (RPEQ) that demonstrates how the engineering solution sought by the work will be achieved. Editor's note: Applications for erosion control structures should demonstrate the consideration of beach nourishment techniques, and include a statement of why nourishment (in whole or part) has not been adopted as the preferred means of controlling the erosion risk.	N/A	The QWB development is not for coastal protection works.

Performance outcomes	Acceptable outcomes	Response	Comment
	And		
	AO5.5 Development involving reclamation: 1) does not alter, or otherwise minimises impacts on, the physical characteristics of a waterway or the seabed near the reclamation, including flow regimes, hydrodynamic forces, tidal water and riverbank stability 2) is located outside the active sediment transport area, or otherwise maintains sediment transport processes as close as possible to their natural state 3) ensures activities associated with the operation of the development maintain the structure and condition of vegetation communities and avoid wind and water run-off erosion.	✓	The reclamation works will have negligible impacts on the adjacent bed of the river. The proposed methodology for the reclamation works includes the use of a double-sheet pile wall that will be driven down to the bedrock. This will provide a smaller excavation footprint that alternative solutions for rock revetment or bunding. The reclamation works will also have a negligible impact on the natural flow regimes within the rivers, maintaining a width of over 220m at the site of reclamation. The landform and shape of the reclamation area has also been designed to consider effects on flow velocities during flood events, with curves aligned to the direction of flow. The reclamation area will ultimately be an area of public open space with areas of hard and soft landscaping. The final design of this park will include stormwater and drainage infrastructure to manage surface water quality.
PO6 Erosion prone areas in a coastal management district are maintained as development free buffers, or where permanent buildings or structures exist, coastal erosion risks are avoided or mitigated.	**AO6.1** Development locates built structures outside the part of the coastal management district that is the erosion prone area unless the development is listed under AO1.1 (1) – (4). **And**	PS	The QWB development will require development within a CMD, however the majority of all permanent buildings will be located outside of the erosion prone area. Elements that are within the erosion prone area are tidal dependent structures, such as boardwalks and jetties. The reclamation area will also be located within the erosion prone area however, the location of this area will not result in increased coastal erosion risk.
	AO6.2 Small to medium scale tourist development is located outside the erosion prone area unless it is redevelopment. **And**	N/A	The QWB development is not a small to medium scale tourist development.
	AO6.3 Coastal-dependent development:	N/A	The QWB development is not coastal-dependent development.

Performance outcomes	Acceptable outcomes	Response	Comment
	1) locates, designs and constructs relevant buildings or structures to withstand coastal erosion impacts, including by use of appropriate foundations, or 2) installs and maintains coastal protection works to mitigate adverse impacts to people and permanent structures from coastal erosion at the location. **And**		
	AO6.4 Development that is temporary, readily relocatable or able to be abandoned, or essential community service infrastructure: 1) locates built structures landward of an applicable coastal building line, or 2) where there is no coastal building line, locates habitable built structures landward of the alignment of adjacent habitable buildings, or 3) locates lifesaver towers or beach access infrastructure to minimise its impacts on physical coastal processes, or 4) where it is demonstrated that (1) or (2) is not reasonable and (3) does not apply: (a) locates built structures as far landward as practicable (b) uses layout design to minimise the footprint of the development that remains within the erosion prone area. **And**	✓	There is not coastal building line in the location of the QWB PDA. The QWB development does not locate any new habitable buildings beyond the line of existing habitable buildings.
	AO6.5 Redevelopment of existing built structures not referred to in AO6.4, and excluding marine development: (1) relocates built structures outside that part of the erosion prone area that is within the coastal management district, or	PS	There is no coastal building line along the QWB PDA and development for public open space and infrastructure will be located within the erosion prone area. The foreshore elements of the project have been designed with a 100 year design life, which includes appropriate erosion control structures.

Performance outcomes	Acceptable outcomes	Response	Comment
	(2) relocates built structures as far landward as practicable, and landward of an applicable coastal building line, or (3) where there is no coastal building line: (a) relocates built structures landward of the alignment of adjacent habitable buildings, or (b) uses layout design to minimise the footprint of the development that remains within the erosion prone area, or (c) provides sufficient space seaward of the development within the premises to allow for the construction of erosion control structures. **And**		
	AO6.6 Redevelopment of built structures in the erosion prone area within a coastal management district, which results in an intensification of use, mitigates the erosion threat to the development, having regard to: 1) design and construction standards 2) installing and maintaining on-site erosion control structures within the premises if the development is not intended to be temporary.	✓	The redevelopment of the foreshore area within the QWB PDA will be designed by an RPEQ that specialises in marine infrastructure. Design life foreshore elements will be 100 years and this will include measures for mitigating any erosion.
PO7 Development avoids or minimises adverse impacts on coastal resources and their values, to the maximum extent reasonable.	**AO7.1** Coastal protection work that is in the form of beach nourishment uses methods of placement suitable for the location that do not interfere with the long-term use of the locality of, or natural values within or neighbouring, the proposed placement site. **And**	N/A	The QWB PDA does not consist of beach nourishment.
	AO7.2 Marine development is located and designed to expand on or redevelop existing marine infrastructure unless it is demonstrated that it is not practicable to co-locate the development with existing marine infrastructure.	PS	The marine development associated with QWB does not constitute an expansion or redevelopment of existing development. Despite this, the placement of the public realm elements of the project within the Brisbane River does not significantly impact on coastal resources.

Performance outcomes	Acceptable outcomes	Response	Comment
	And		The current condition of the coastal resources underneath the Riverside Expressway is limited and areas of significant value have largely been retained and protected.
	AO7.3 Marine development: 1) relies on a natural channel of a depth adequate for the intended vessels, or 2) where there are no feasible alternative locations for the facility in the local area that do not require dredging for navigation channel purposes, development is located, designed and operated to minimise the need for capital and maintenance dredging for navigation channel purposes. **And**	✓	No dredging is proposed to provide adequate channel depth for vessel mooring in the North Quay sub-precinct
	AO7.4 Development minimises dredging or the disposal of material in coastal waters during key biological events (such as fish aggregations or spawning) for species found in the area. **And**	N/A	No dredging is proposed as part of the QWB development
	AO7.5 Measures are to be incorporated as part of siting and design of the development to protect and retain identified ecological values and underlying ecosystem processes within or adjacent to the development site to the greatest extent practicable. This includes: 1) maintaining or restoring vegetated buffers between development and coastal waters to the extent practicable, unless the development is within ports or airports, or is marine development 2) maintaining or enhancing the connectivity of ecosystems in consideration of the cumulative effect of the development in addition to existing developed areas	✓	There is currently very limited riparian vegetation along the northern bank of the Brisbane River within the QWB. The landscape works within the parks proposed as part of the QWB development will provide an improved riparian vegetation. The QWB PDA is located within the highly developed reach of the Brisbane River that has very little habitat connectivity and low ecological corridor values. The majority of the estuarine wetland area associated with the patch of mangroves will be retained. Impacts will be limited to that required to construct the required boardwalk in the Goodwill Extension sub-precinct.

Performance outcomes	Acceptable outcomes	Response	Comment
	3) retaining coastal wetlands, seagrass beds and other locally important feeding, nesting or breeding sites for native wildlife. **And**		
	AO7.6 Measures are incorporated as part of siting and design of the development to maintain or enhance water quality to achieve the environmental values and water quality objectives outlined in the *Environmental Protection (Water) Policy 2009*. **And**	✓	Construction phase water quality management will be developed in accordance with the ESCF. For the operational phase of the development, WSUD will be incorporated into the drainage infrastructure. Initial MUSIC modelling prepared as part of the POD application indicates that runoff from the site can meet the required load based reductions specified in the State Planning Policy.
	AO7.7 Development avoids the disturbance of acid sulphate soils, or where it is demonstrated that this is not possible, the disturbance of acid sulphate soils is carefully managed to minimise and mitigate the adverse effects of the disturbance on coastal resources.	✓	Actual and potential acid sulphate soils have been identified within the project area and their disturbance cannot be avoided. As construction methodology is finalised, a detailed Acid Sulphate Soils Management Plan will be developed to ensure no discharge of acidic surface water into the Brisbane River.
PO8 Coastal protection work is undertaken only as a last resort where erosion presents an imminent threat to public safety or permanent structures.	**AO8.1** Coastal protection work is only undertaken to protect existing permanent structures from imminent adverse coastal erosion impacts, and the structures cannot reasonably be relocated or abandoned. **And**	N/A	The QWB development is not coastal protection work.
	AO8.2 Coastal protection work to protect private structures is undertaken on private land to the maximum extent reasonable. **And**	N/A	The QWB development is not coastal protection work.
	AO8.3 Coastal protection work does not increase the coastal hazard risk for adjacent areas or properties.	N/A	The QWB development is not coastal protection work.
PO9 Development avoids adverse impacts on matters of state environmental significance, or where this is not reasonably possible, impacts	**AO9.1** Development: 1) is set back from matters of state environmental significance	✓	Of the MSES identified in the State Planning Policy, only the wetlands of high ecological significance are mapped as occurring within the QWB PDA. The mapping indicates that the strip of retained mangroves around the Goodwill Extension area

Performance outcomes	Acceptable outcomes	Response	Comment
are minimised and an environmental offset is provided for any significant residual impacts to matters of state environmental significance that are prescribed environmental matters.	2) avoids interrupting, interfering or otherwise adversely impacting underlying natural ecosystem components or processes and interactions that affect or maintain the matters of state environmental significance, such as water quality, hydrology, geomorphology and biological processes, or 3) incorporates measures as part of its location and design to protect and retain matters of state environmental significance and underlying ecosystem processes within and adjacent to the development site to the greatest extent practicable. **And**		are considered to be high ecological significance wetlands under the EPP. The QWB development does not result in a significant residual impacts to any matters of state environmental significance.
	AO9.2 Where impacts cannot be reasonably avoided or minimised, an environmental offset is provided for any significant residual impact on matters of state environmental significance that are prescribed environmental matters caused by the development. .	✓	There is no residual significant impact to a MSES, when assessed against the Queensland *Significant Residual Impact Guidelines.* Under the SRI Guideline an action is unlikely to have a significant residual impact on a high ecological significance wetland if the mapped wetland in is determined as not having 'high' or 'very high' conservations values using AquaBAMM or an appropriate assessment technique agreed with the assessing department. The Aquatic Conservation Assessment Report prepared by the Queensland Government, which utilises the AquaBAMM methodology, maps the areas as having medium conservation values. Due to this conservation assessment any action that impacts on this area is unlikely to result in a significant residual impact for which an environmental offset could be conditioned.
PO10 Development maintains or enhances general public access to or along the foreshore, unless this is contrary to the protection of coastal resources or public safety.	**AO10.1** Development adjacent to state coastal land or tidal water: 1) demonstrates that restrictions to public access are necessary for: (a) the safe or secure operation of development, or (b) the maintenance of coastal landforms and coastal habitat	✓	The QWB development does not restrict public access to state coastal land. The foreshore and marine elements of the development will enhance opportunities for public access to the Brisbane River. The development improves access for a number of public uses, including pedestrians, recreational open space, dining areas, boat moorings and event spaces.

Performance outcomes	Acceptable outcomes	Response	Comment
	2) separates residential, tourist and retail development from tidal water with public areas or public access facilities, or 3) maintains existing public access (including public access infrastructure that is in the public interest) through the site to the foreshore for: (a) pedestrians, via access points including approved walking tracks, boardwalks and viewing platforms, or (b) vehicles, via access points including approved roads or tracks. **And**		
	AO10.2 Development adjacent to state coastal land, including land under tidal water: 1) is located and designed to: (a) allow safe and unimpeded access to, over, under or around built structures located on, over or along the foreshore (b) ensure emergency vehicles can access the area near the development, or 2) minimises and offsets any loss of access to and along the foreshore within two kilometres of the existing access points, and the access is located and designed to be consistent with (1)(a) and (b). **And**	✓	The aspects of the QWB development that are located over tidal water have been designed to allow for safe and unimpeded access. The design of the scheme has considered CPTED principles to meet the requirements of the Development Scheme. There is no loss of access along the foreshore, with improved access achieved through the development of North Quay, The Landing and the Goodwill Extension sub-precincts.
	AO10.3 Any parts of private development that extend over tidal water are to be designed, constructed and used for marine access purposes only.	N/A	There are no private developments located over tidal water.
PO11 Private marine development avoids structures attaching to, or extending across, non-tidal state coastal land abutting tidal waters.	**AO11.1** Private marine development and other structures such as decks or boardwalks for private use do not attach to, or extend across state coastal land that is situated above the high water mark.	N/A	The QWB PDA is not private marine development.

Performance outcomes	Acceptable outcomes	Response	Comment
	Editor's note: For occupation permits or allocations of State land, refer to the *Land Act 1994*.		
PO12 Further development of artificial waterways avoids or minimises adverse impacts on coastal resources and their values, and does not contribute to: (1) an increase in the risk of flooding or erosion (2) degradation of water quality (3) degradation and loss of matters of state environmental significance (including, but not limited to, coastal wetlands, fish habitat areas and migratory species habitat).	**AO12.1** The design, construction and operation of artificial tidal waterways maintains the tidal prism volume of the natural waterway to which it is connected. **And**	N/A	The QWB PDA does not consist of an artificial waterway
	AO12.2 The design, construction and operation of artificial tidal waterways does not increase risk from flooding. **And**		
	AO12.3 The design, construction and operation of an artificial waterway in connection with the reconfiguration of a lot ensures: (1) water inlet and outlets structures are of sufficient capacity to maintain the water quality within the waterway (2) water discharged from the artificial waterway protects the environmental values and water quality objectives of the receiving waters (3) dredged material is not disposed of to tidal water beyond the artificial waterway unless there is a beneficial reuse, e.g. beach nourishment. Editor's note: For more information on environmental values and water quality objectives see schedule 1 of the *Environment Protection (Water) Policy 2009*. **And**		
	AO12.4 The location of the artificial waterways avoids matters of state environmental significance, or does not result in any significant adverse impact on matters of state environmental significance.		

Performance outcomes	Acceptable outcomes	Response	Comment
PO13 Development does not involve reclamation of land below tidal water, other than for the purposes of: 1) coastal-dependent development, public marine development or community infrastructure 2) strategic ports, boat harbours or strategic airports and aviation facilities, in accordance with a statutory land use plan, where there is a demonstrated net benefit for the state or region and no feasible alternative exists 3) coastal protection work or work necessary to protect coastal resources or physical coastal processes.	No acceptable outcome is prescribed.	✓	The reclamation required for The Landing sub-precinct will be public open space and community infrastructure. I
Table 10.1.2: Operational work			
PO1 Tidal works that is private marine development does not result in adverse impacts to tidal land.	**AO1.1** The location and design of tidal works that is private marine development: 1) is on private land abutting tidal water and used for property access purposes 2) occupies the minimum area reasonably required for its designed purpose 3) is not to be roofed or otherwise covered 4) does not require the construction of coastal protection works, shoreline or riverbank hardening or dredging for marine access 5) does not adversely impact on public safety or public access and use of the foreshore.	N/A	The QWB PDA is not private marine development.

Performance outcomes	Acceptable outcomes	Response	Comment
PO2 Development does not result in the disposal of material dredged from an artificial waterway into coastal waters, with the exception of: 1) reclamation works, or 2) coastal protection works, or 3) the maintenance of an existing artificial waterway and the at-sea disposal of material that has previously been approved for the waterway.	**AO2.1** The design and construction of the artificial waterway includes onsite provisions for drying, re-handling and disposal of dredge material on site to facilitate the timely disposal to land or re-use.	N/A	The QWB development does not include an artificial waterway.
PO3 The design and construction of an artificial waterway maintains coastal landforms.	**AO3.1** The design and construction of the artificial waterway provides for sand bypassing where this is necessary to prevent erosion of adjacent coasts and minimise sedimentation of the waterway. **And**	N/A	The QWB development does not include an artificial waterway.
	AO3.2 Clean sand accumulating within an artificial waterway is returned to the active beach system, in preference to disposal on land.		
PO4 Development that involves dredging includes and complies with a management plan that demonstrates how environmental impacts will be managed and mitigated, and how the requirements of the *National assessment guidelines for dredging*, Australian Government Department of the Environment, Water, Heritage and the Arts, 2009, will be met.	**AO4.1** A management plan for the development: 1) directs the operation of the development 2) identifies disposal methods and disposal sites for the removed material for the construction and operational phases of the development 3) outlines how any adverse effects from extraction activities on sediment transport processes or adjacent coastal landforms will be mitigated or otherwise remediated by suitably planned and implemented beach nourishment and rehabilitation works. Editor's note: The suitability of the dredged sediment for ocean disposal is to follow the assessment of potential contaminants under the *National assessment guidelines for dredging*,	N/A	The QWB development does not involve dredging.

Performance outcomes	Acceptable outcomes	Response	Comment
	Australian Government Department of the Environment, Water, Heritage and the Arts, 2009. **And**		
	AO4.2 For land based disposal of dredged material, any area used for storing, dewatering, drying or rehandling dredged material as outlined in the dredge management plan is: 1) of sufficient size for the projected volume of dredged material from relevant capital or maintenance dredging 2) protected from future development that would compromise the use of the area for its intended purpose of material storage and dewatering. **And**	N/A	The QWB development does not involve dredging.
	AO4.3 For at-sea disposal of suitable dredged material, the dredge management plan specifies that material is placed at a dredged material disposal site only if it is demonstrated that it is not feasible to: 1) dispose of the material above the high water mark, if the material is from maintenance works for an existing artificial waterway for which at-sea disposal was previously approved, or 2) keep the dredged material within the active sediment transport system for the locality, or 3) use the material for beach nourishment or another beneficial purpose. **And**	N/A	The QWB development does not involve dredging.
	AO4.4 For at-sea disposal of dredged material where the marine spoil disposal site is a retentive (i.e. non-dispersive) site, the disposal site identified in the dredge management plan has the capacity to hold and retain the	N/A	The QWB development does not involve dredging.

Performance outcomes	Acceptable outcomes	Response	Comment
	material within its boundaries during construction and operation of the development. Editor's note: The use of dredged material for a beneficial purpose could include development of port or other marine facilities, use for construction or industrial purposes, or use to create or modify land or waters for an approved environmental outcome (such as creation of a bird roosting site). Further information about beneficial uses is contained in the *National assessment guidelines for dredging*, Australian Government Department of Environment, Water, Heritage and the Arts, 2009		
Within a strategic environmental area: riparian and wildlife corridor functions			
PO5 Natural regeneration of any cleared or work area is facilitated wherever possible.	**AO5.1** There is no impediments to the natural regeneration of native plant species in the area of clearing and works following completion of works.	N/A	The QWB PDA is not within a strategic environmental area.
Within a strategic environmental area: hydrological processes			
PO6 Development avoids or minimises impacts on natural drainage lines or flow paths, during both construction and operation.	No acceptable outcome is prescribed.	N/A	The QWB PDA is not within a strategic environmental area.
Within a strategic environmental area: water quality			
PO7 Development avoids or minimises any adverse impacts on environmental values and water quality objectives for receiving waters (surface and groundwater) from pollutants on site or leaving a site located in a strategic environmental area.	**AO7.1** Development demonstrates best practice environmental management to meet relevant environmental values and water quality objectives of the *Environmental Protection (Water) Policy 2009.* **Or** **AO7.2** All stormwater, wastewater, discharges and overflows leaving the site are: (1) treated to the quality of the receiving waters prior to discharge, or (2) reclaimed or re-used such that there is no export of pollutants to receiving waters.	N/A	The QWB PDA is not within a strategic environmental area.

4 Flood Impact Assessment

Hydraulic modelling has been undertaken to quantify the impact in terms of flood levels and velocities from the QWBIRD, in order to assess if the proposed development causes any unacceptable impact with regards to flooding conditions.

4.1 Methodology

A flood model was developed for the area based on industry best practice. The representation of the QWBIRD design within the flood model was rigorously verified, with changes in topography and landform directly included within the model topography and representation of structures confirmed against a range of sensitivity testing and calculations.

The flood analysis was performed for a range of storm events. These storm events are defined through their probability of occurrence, expressed as a percentage to occur or be exceeded annually (% Annual Exceedance Probability, or % AEP). To capture a broad range of potential flood level impacts from the proposed development, the following events were analysed:

- Tidal scenario (i.e. no rainfall or flood event)
- Design floods:
  - 5% AEP design flood (lesser rainfall event)
  - 2% AEP design flood
  - 1% AEP design flood
  - 0.2% AEP design flood
  - 0.05% AEP design flood (greater rainfall event)
- 2011 design modelled flood event

Details on the modelling methodology are included within Appendix A.

4.2 Impact on Peak Water Levels

The following maps (Figure 6 to Figure 19) show the impact from the proposed development on peak flood levels for each respective storm event. These maps depict the ‘difference’ between the peak flood levels of the ‘developed case’ (i.e. with the proposed QWBIRD development) and the ‘existing case’ (i.e. no development). The figures also indicate the maximum flood impact observed for the modelled event beyond the localised afflux from the bridge pier. The yellow to red colour range shows the increase in peak flood levels and the blue colour range shows the decrease in peak flood levels.

Note: the 2011 design modelled flood event includes the latest manual gate operations and hydraulic structures. It is representative of the 2011 hydrology with current situation.

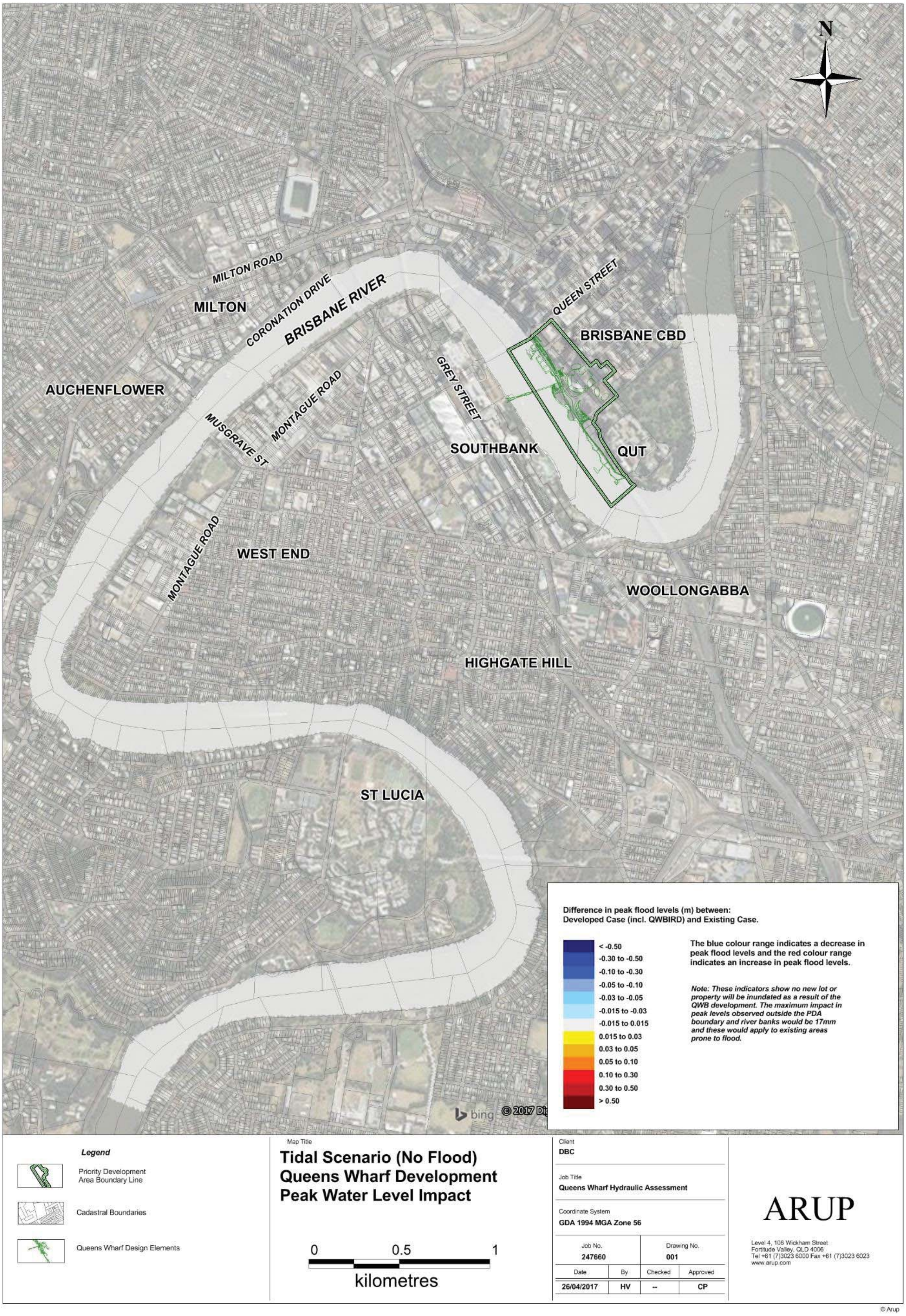

Figure 6: Tidal Scenario (No Flood) – QWB – Peak Water Level Impact (overview)

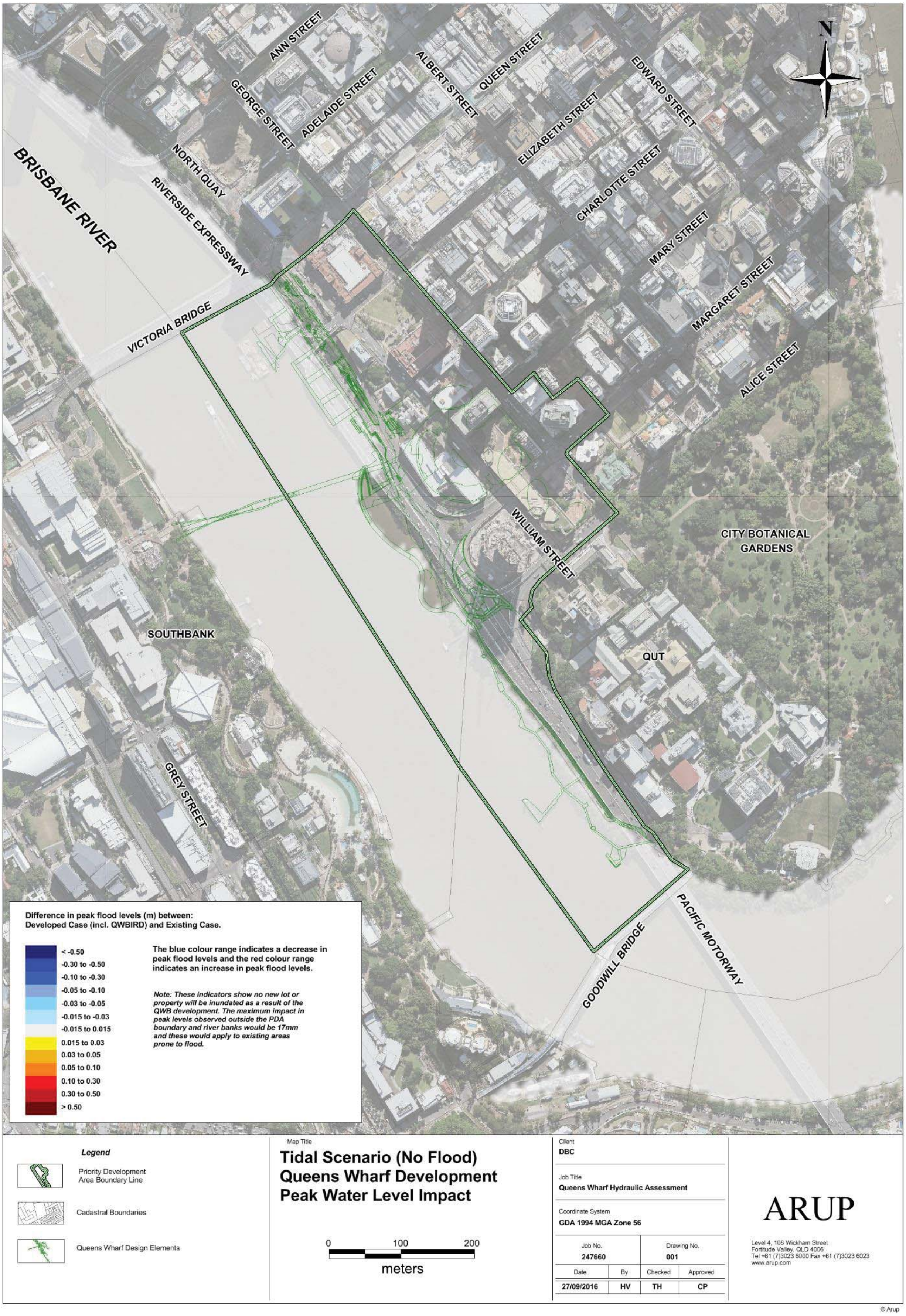

Figure 7: Tidal Scenario (No Flood) – QWB – Peak Water Level Impact

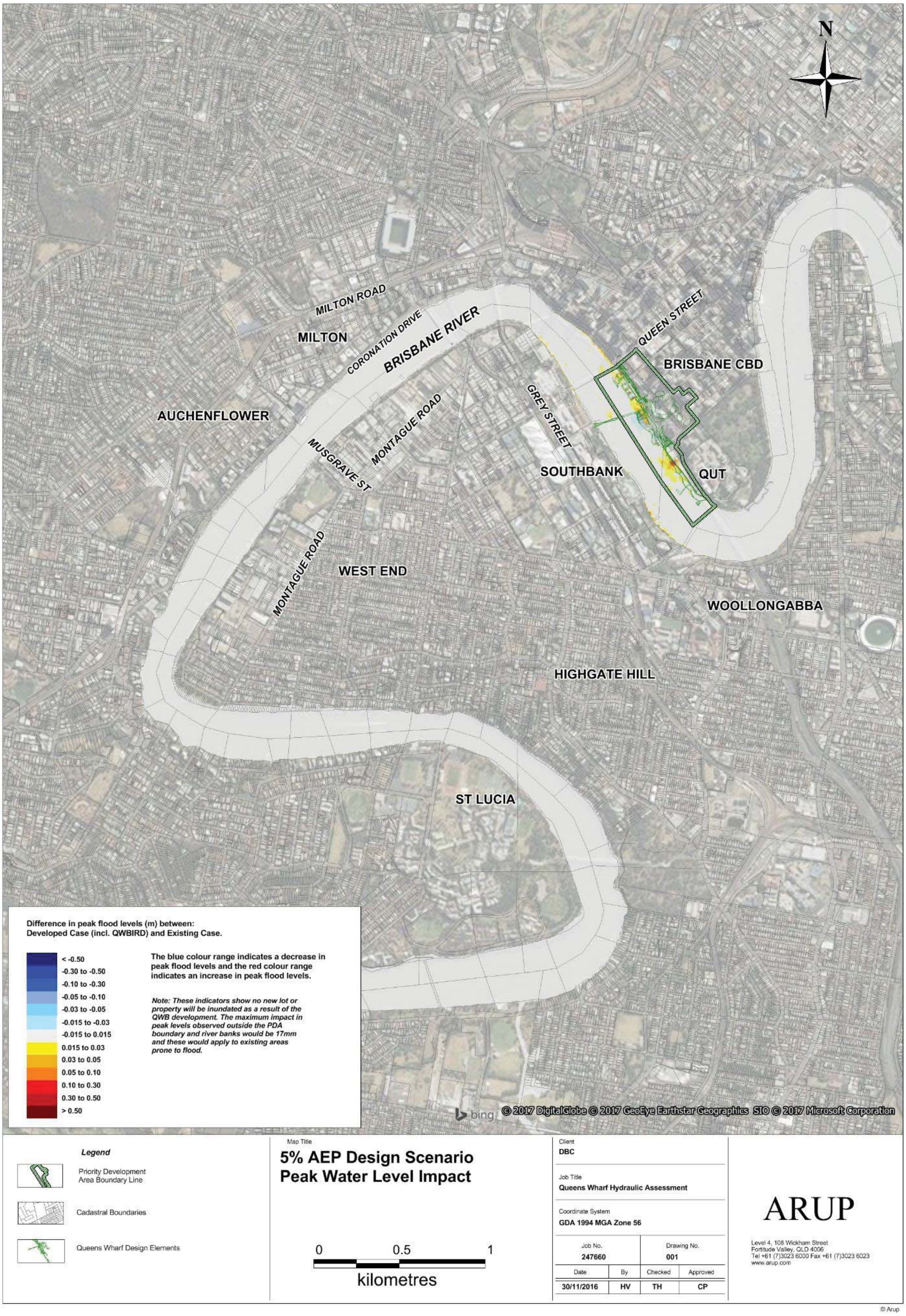

Figure 8: 5% AEP – QWB – Peak Water Level Impact (overview)

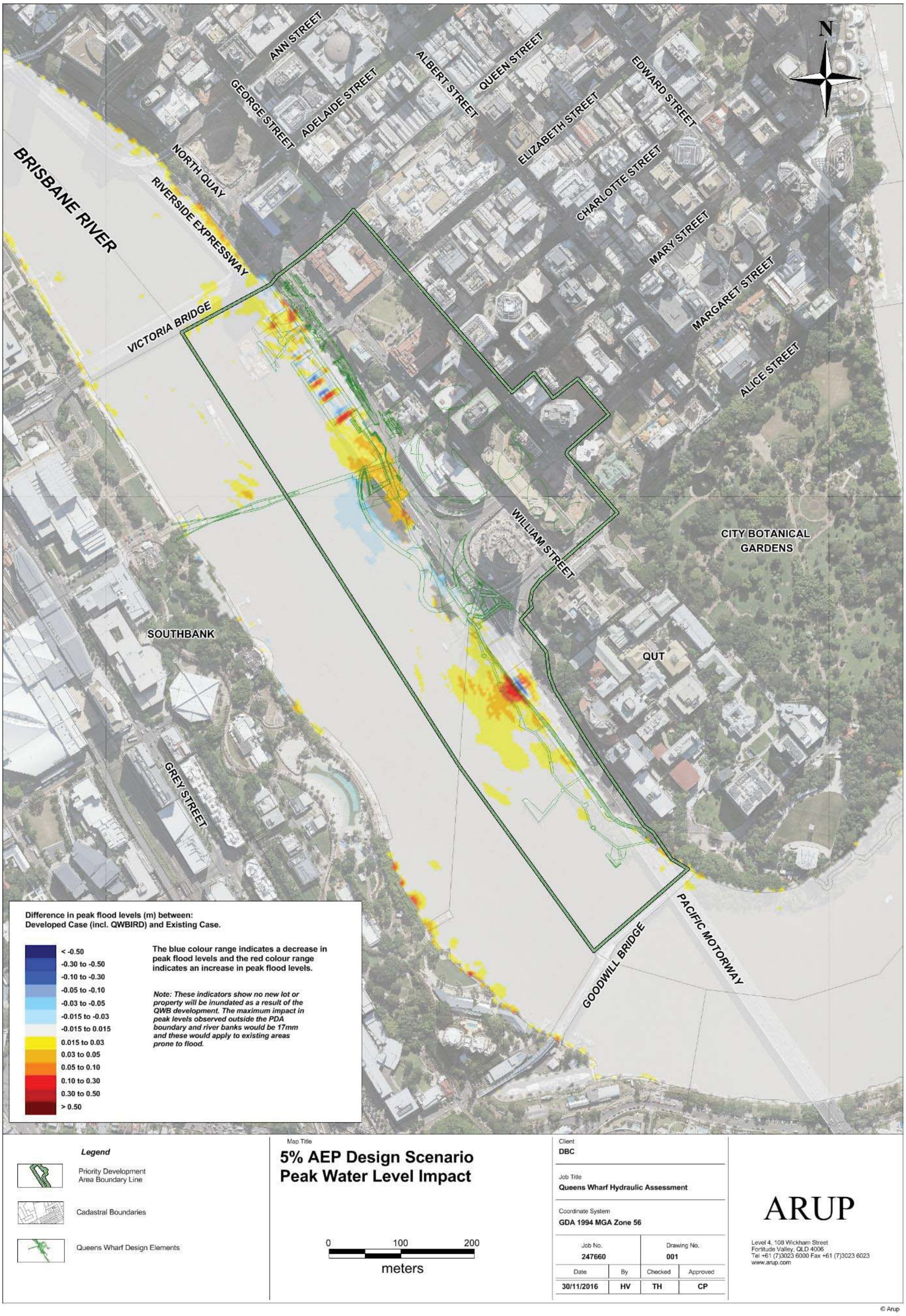

Figure 9: 5% AEP – QWB – Peak Water Level Impact

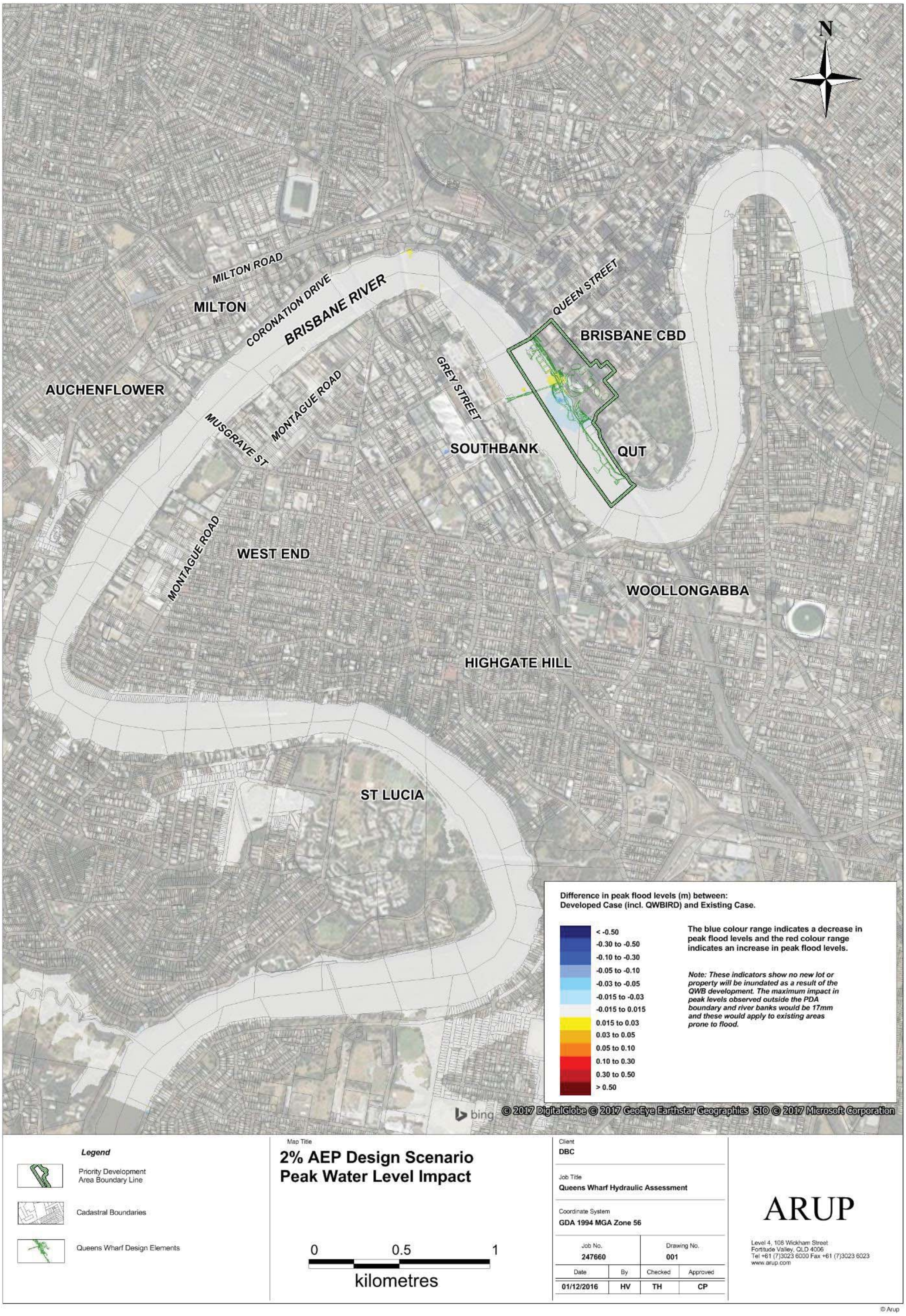

Figure 10: 2% AEP – QWB – Peak Water Level Impact (overview)

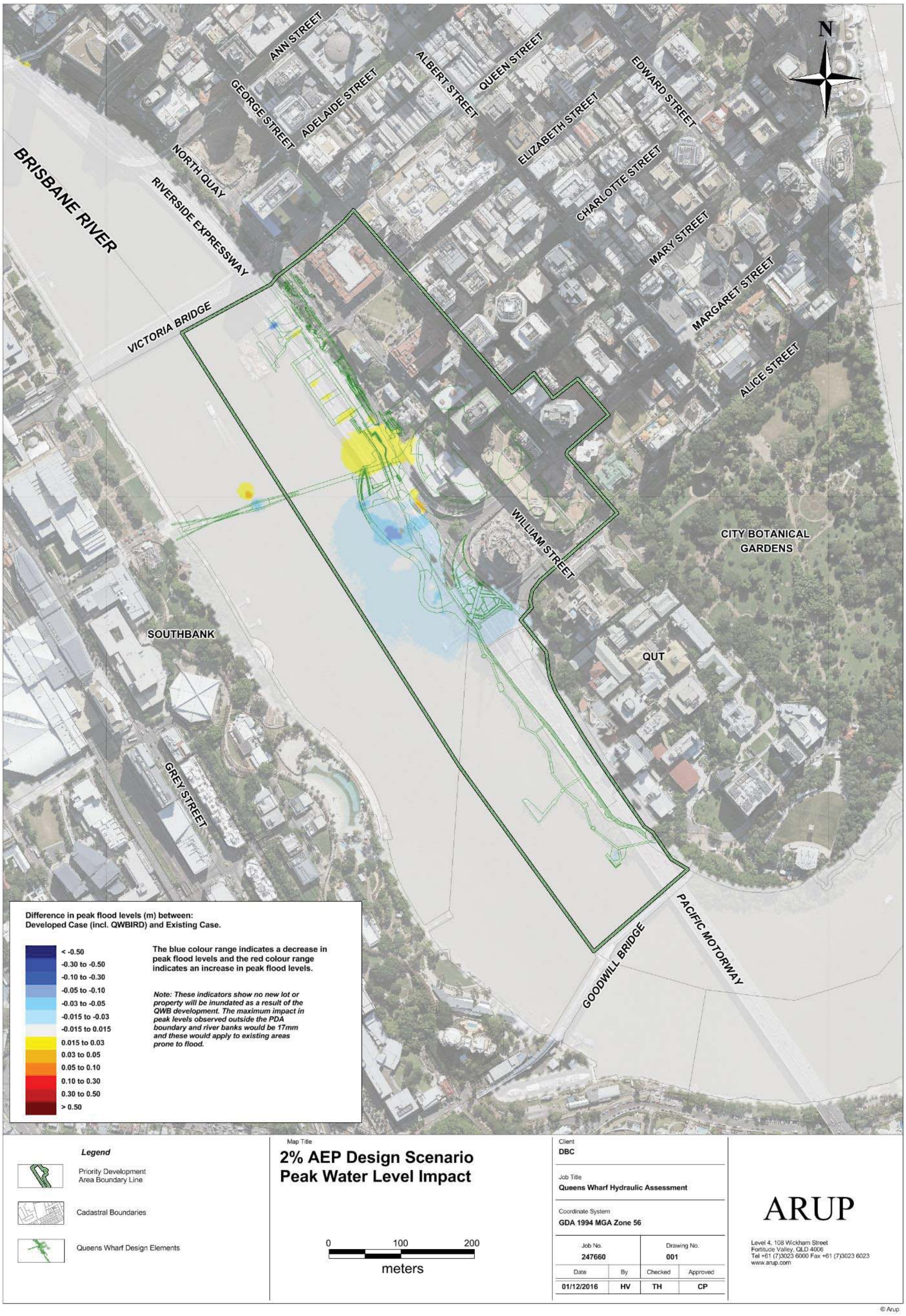

Figure 11: 2% AEP – QWB – Peak Water Level Impact

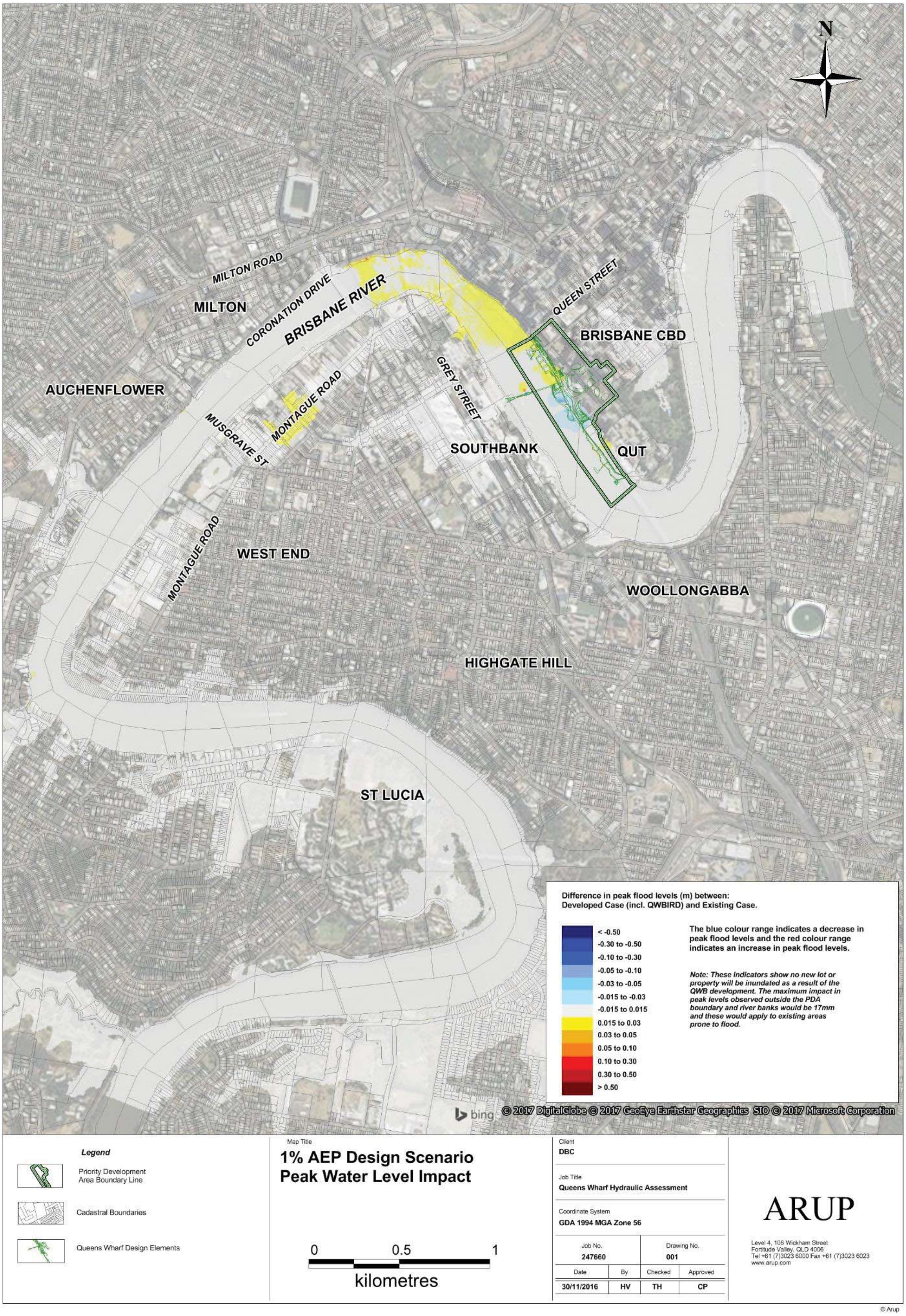

Figure 12: 1% AEP – QWB – Peak Water Level Impact (overview)

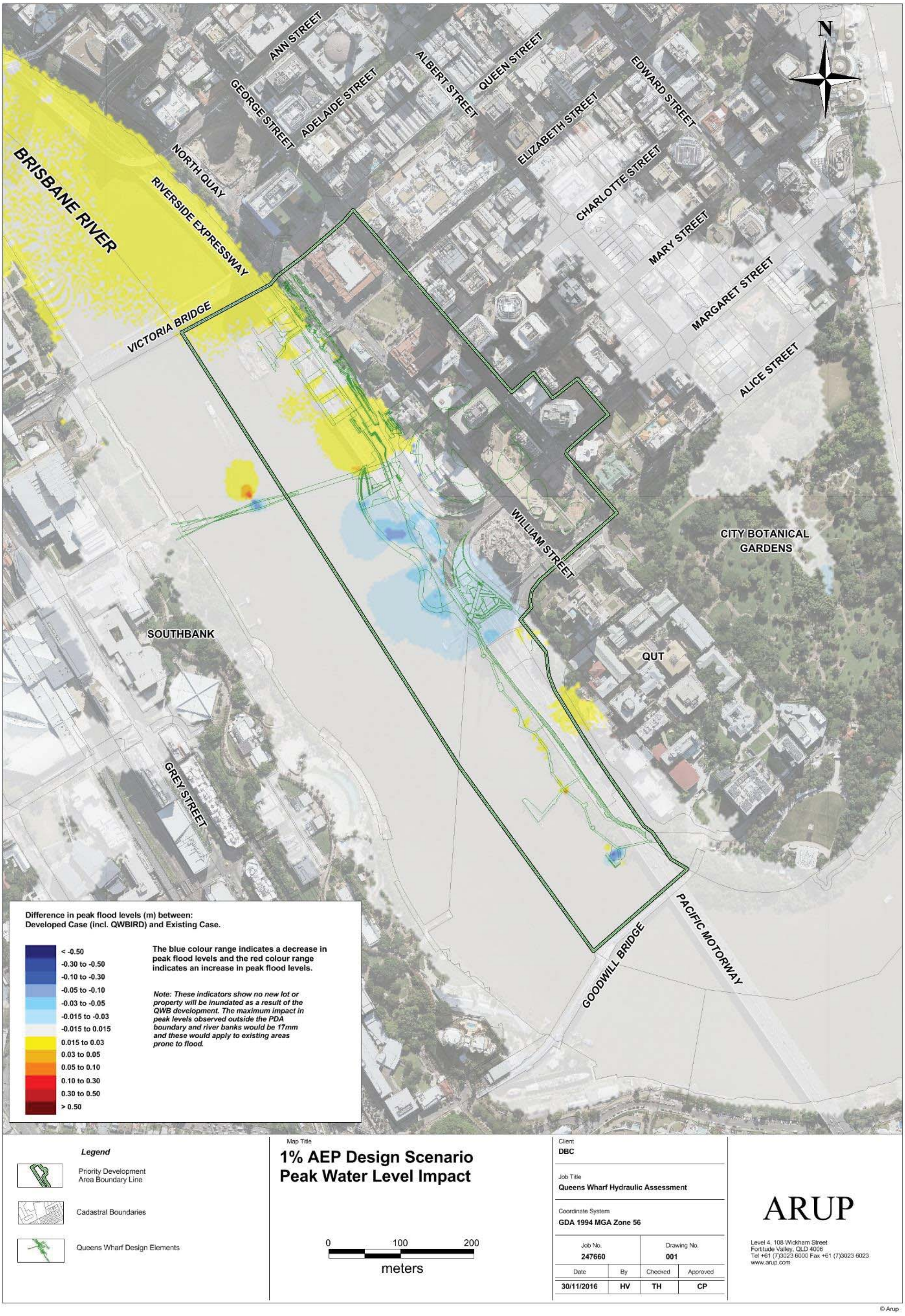

Figure 13: 1% AEP – QWB – Peak Water Level Impact

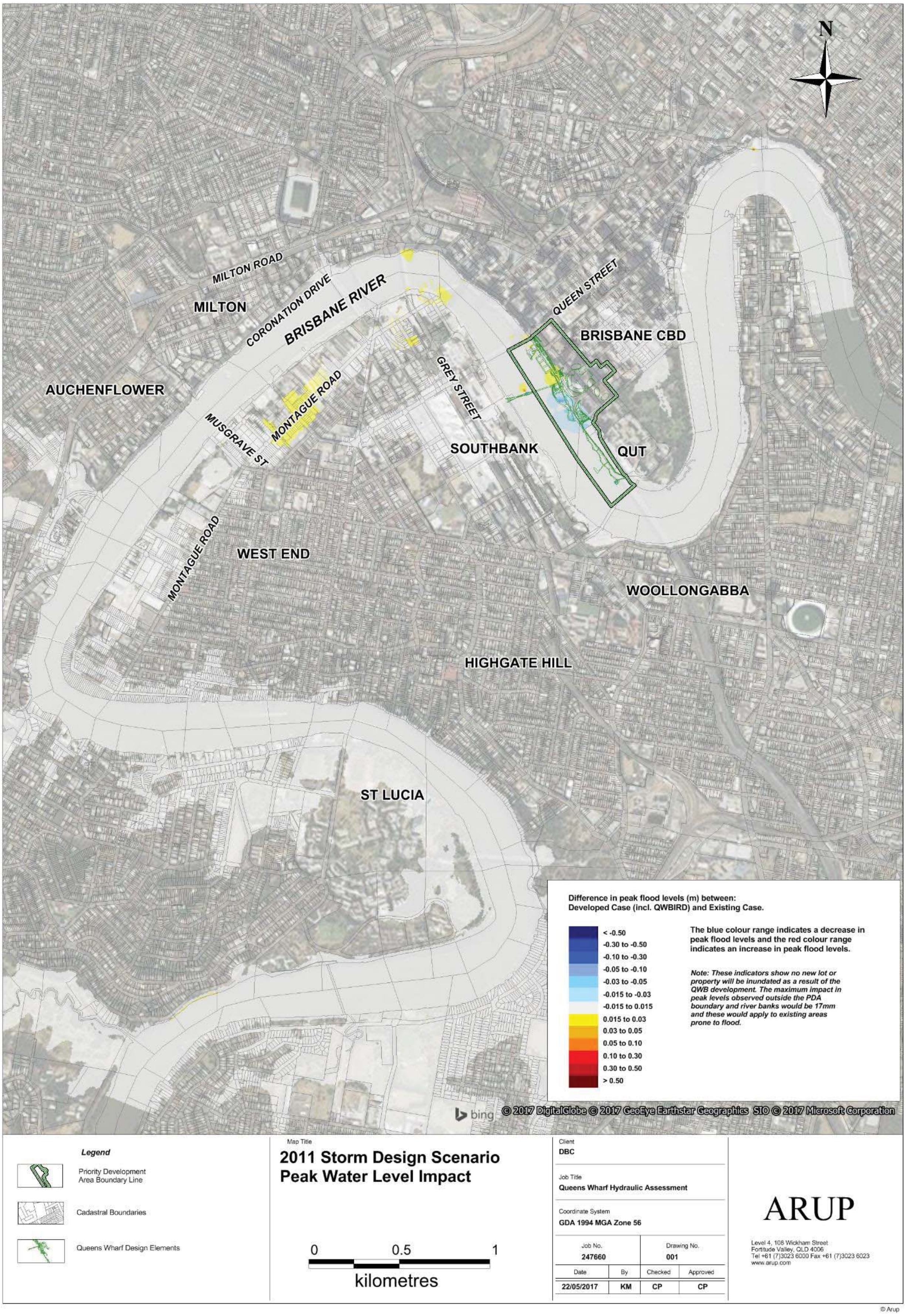

Figure 14: 2011 Modelled Flood Event – QWB – Peak Water Level Impact (overview)

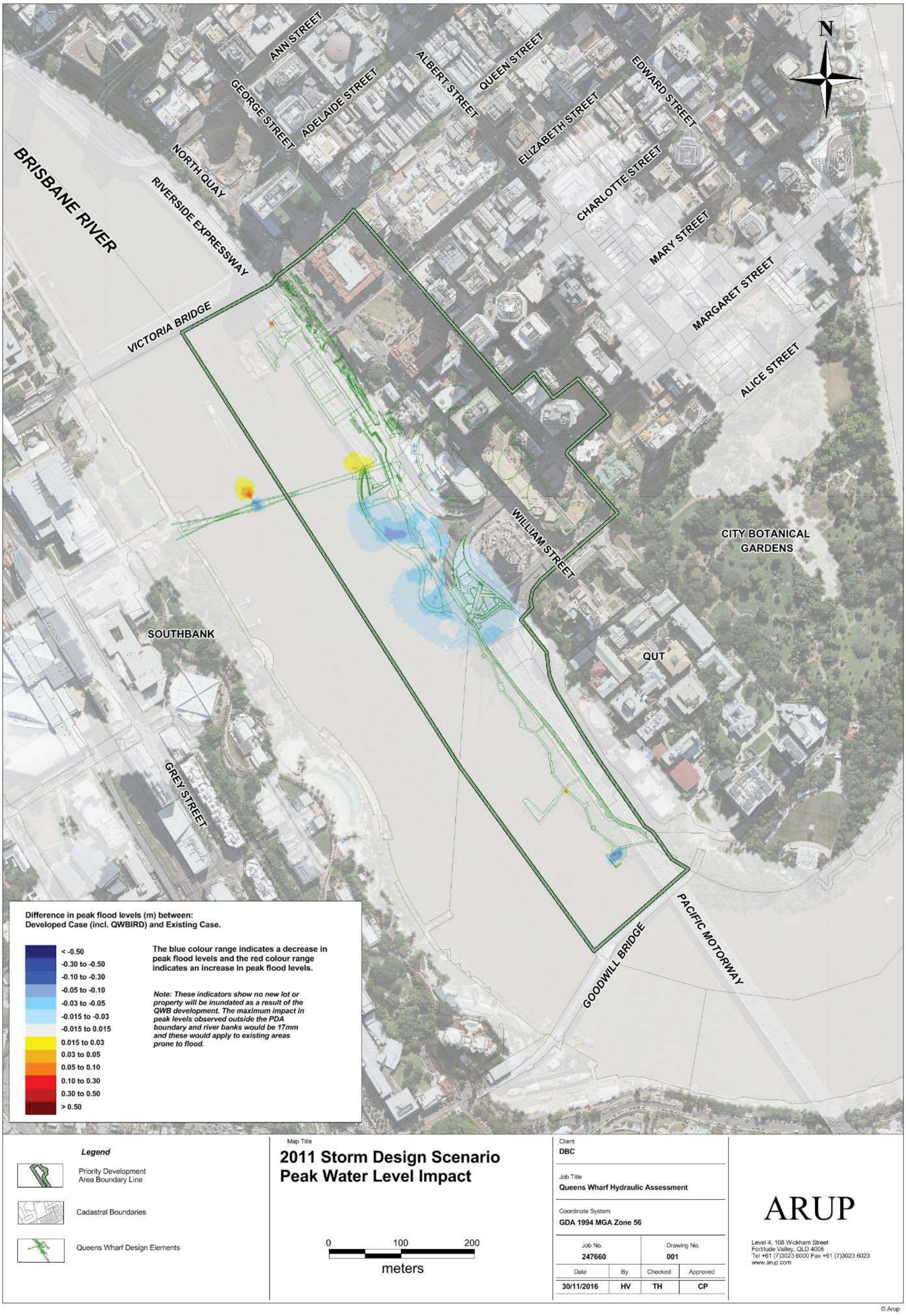

Figure 15: 2011 Modelled Flood Event – QWB – Peak Water Level Impact

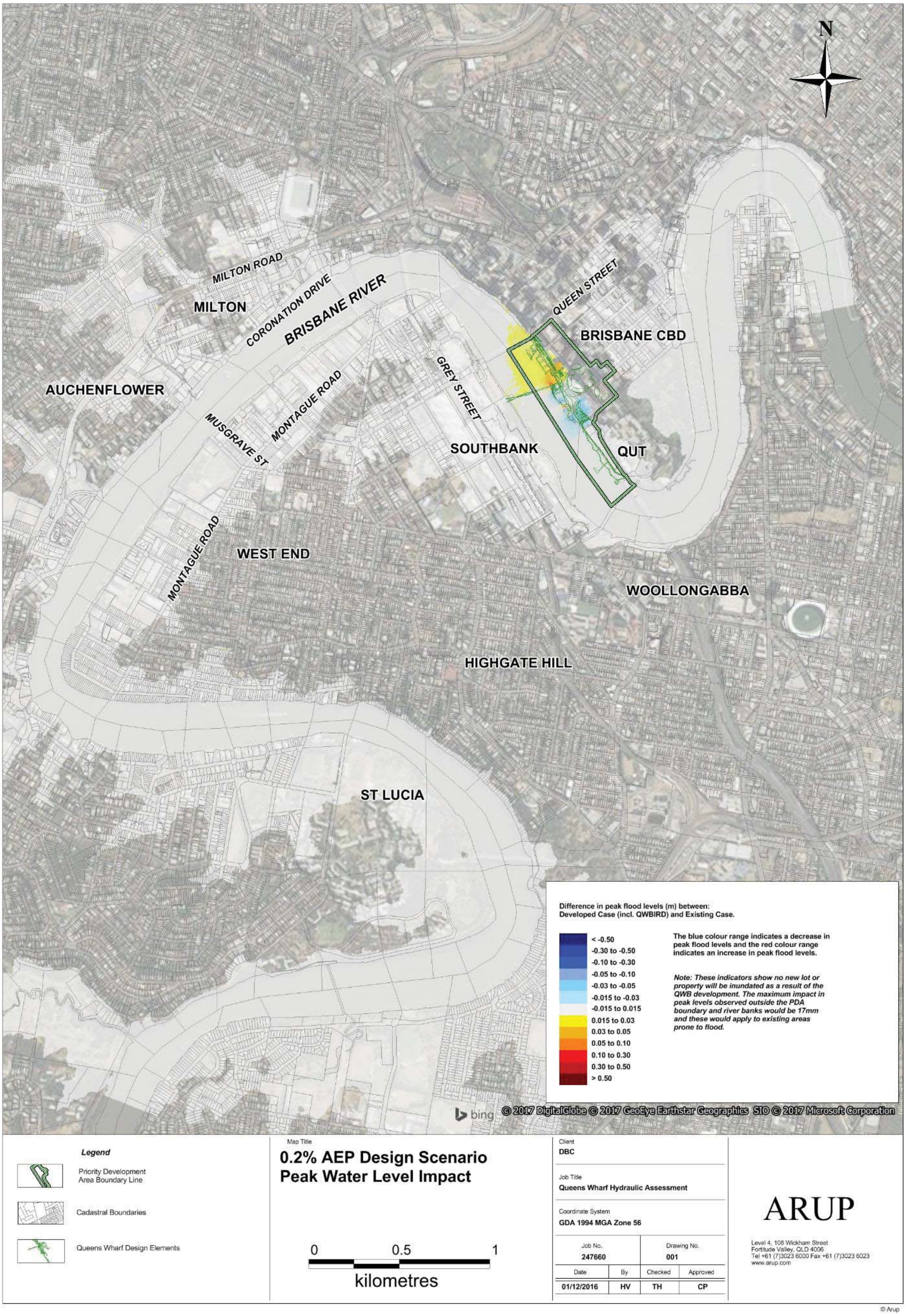

Figure 16: 0.2% AEP – QWB – Peak Water Level Impact (overview)

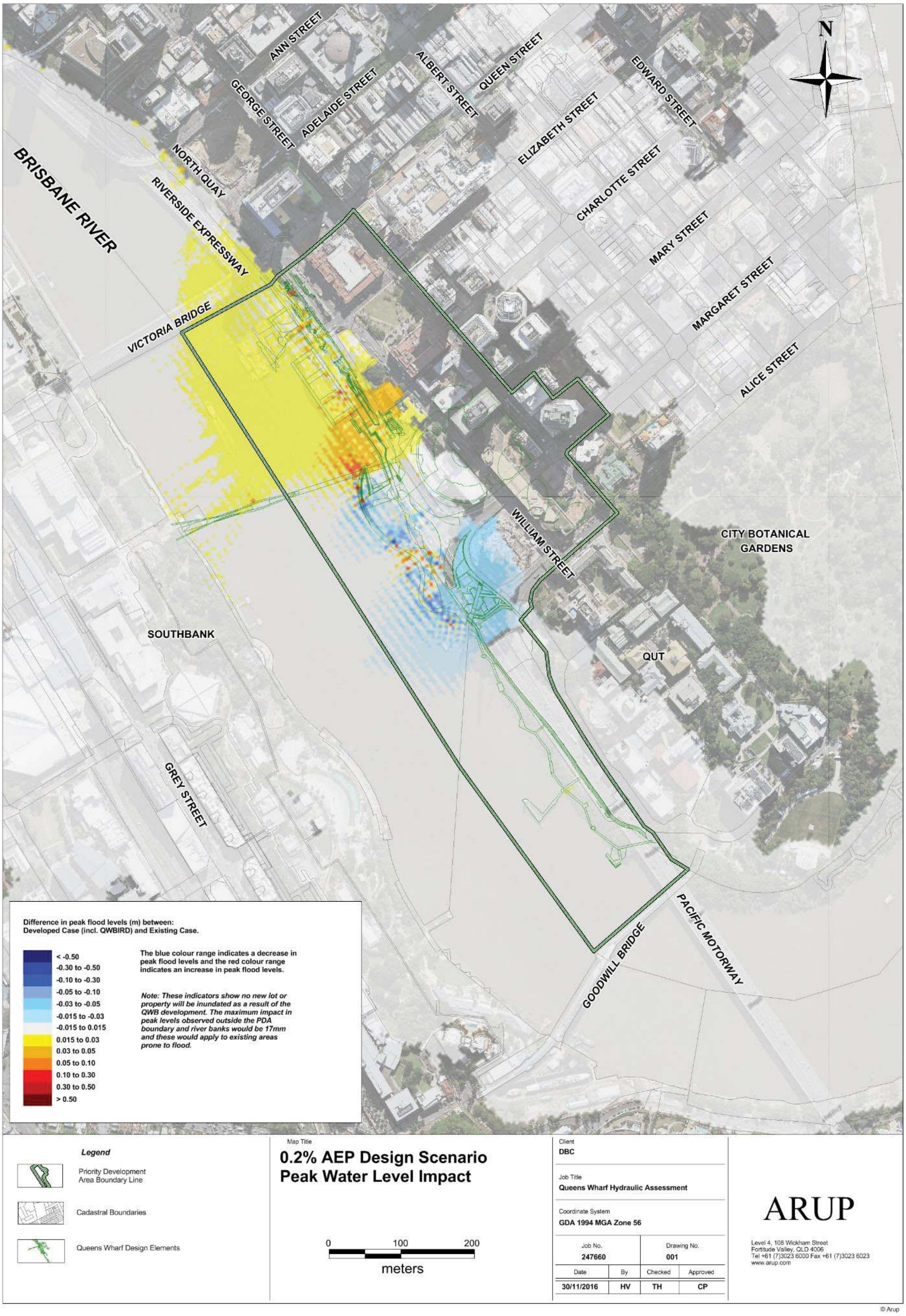

Figure 17: 0.2% AEP – QWB – Peak Water Level Impact

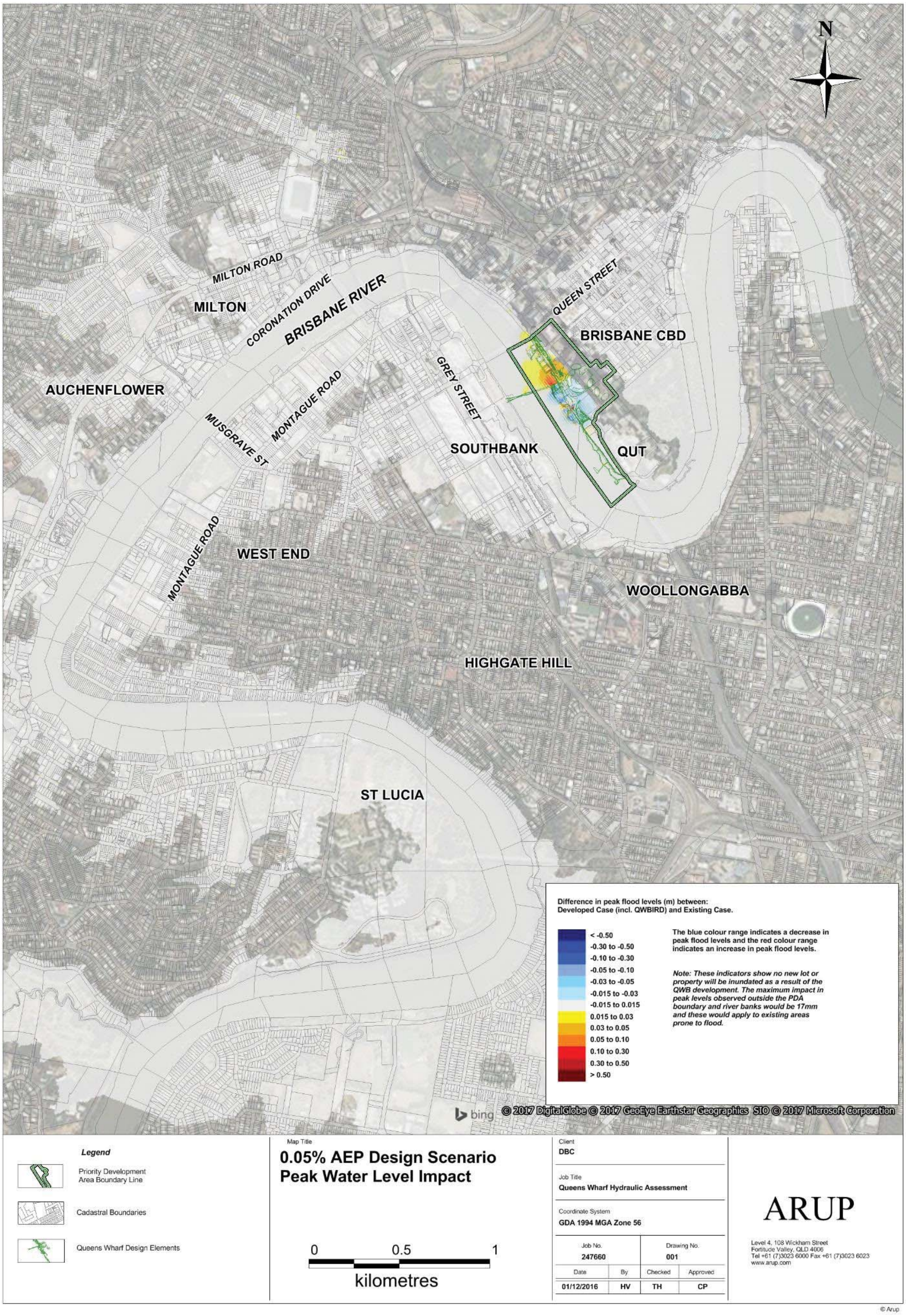

Figure 18: 0.05% AEP – QWB – Peak Water Level Impact (overview)

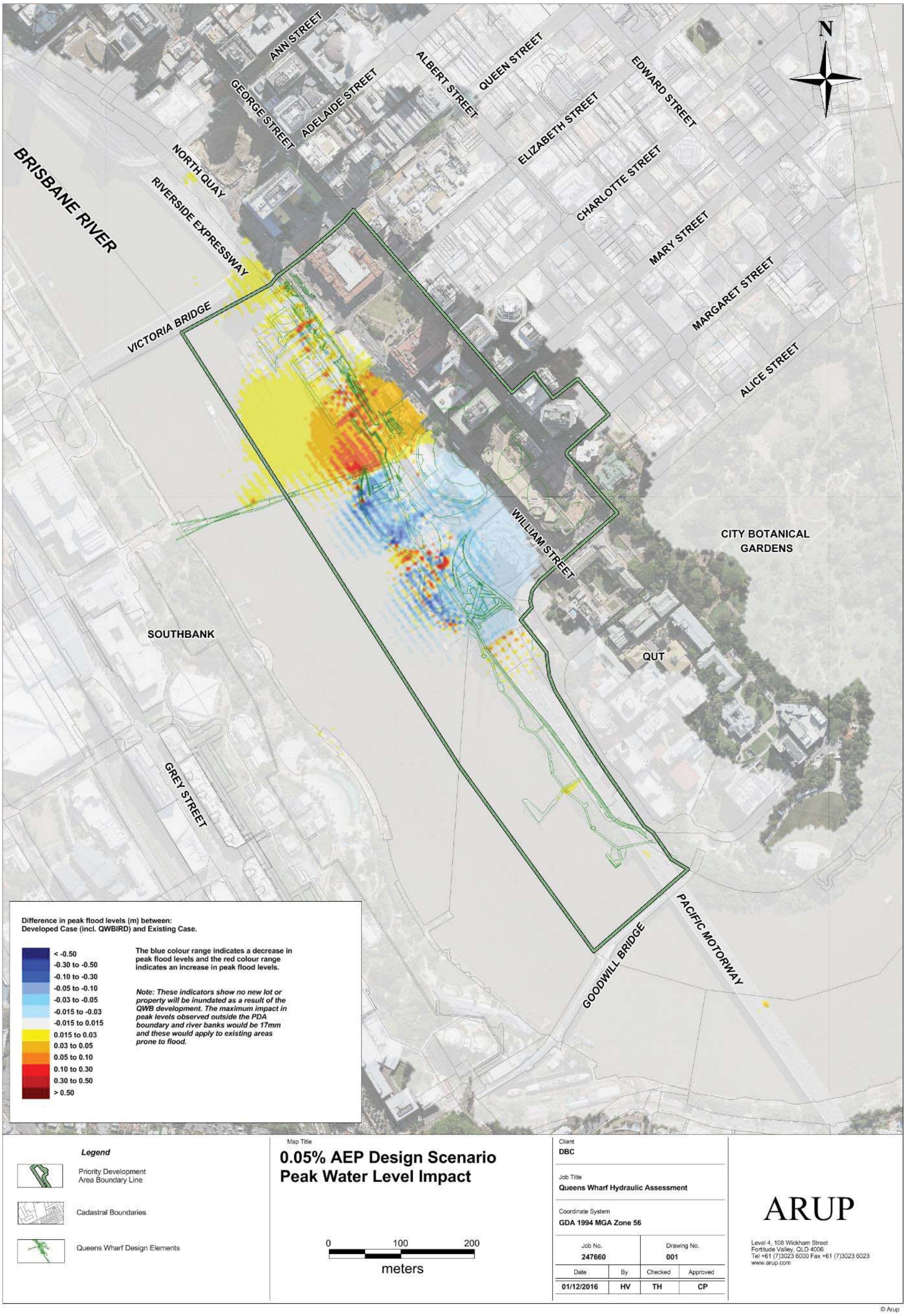

Figure 19: 0.05% AEP – QWB – Peak Water Level Impact

4.3 Impact on Peak Velocities

As mentioned in Section 4.1 the flood analysis was performed for a range of storm events. To capture a broad range of potential flood velocity impacts from the proposed development, the following events were analysed:

- Design floods
- 5% AEP design flood (lesser rainfall event)
- 2% AEP design flood
- 1% AEP design flood
- 0.2% AEP design flood
- 0.05% AEP design flood (greater rainfall event)
- Tidal scenario (i.e. no rainfall or flood event)
- 2011 design flood event

The following maps (Figure 20 to Figure 26) show the impact from the proposed development on peak flood velocities for each respective storm event. These maps depict the ‘difference’ between the peak flood velocities of the ‘developed case’ (i.e. with the proposed QWBIRD development) and the ‘existing case’ (i.e. no development). The yellow to red colour range shows the increase in peak flood velocities and the blue colour range shows the decrease in peak flood velocities. A small tolerance has been selected on purpose to better visualize the propagation of velocity impact as part of the modelling exercise; this means that high variation of colours are actually associated with a small impact value.

Note: the 2011 design modelled flood event includes the latest manual gate operations and hydraulic structures.

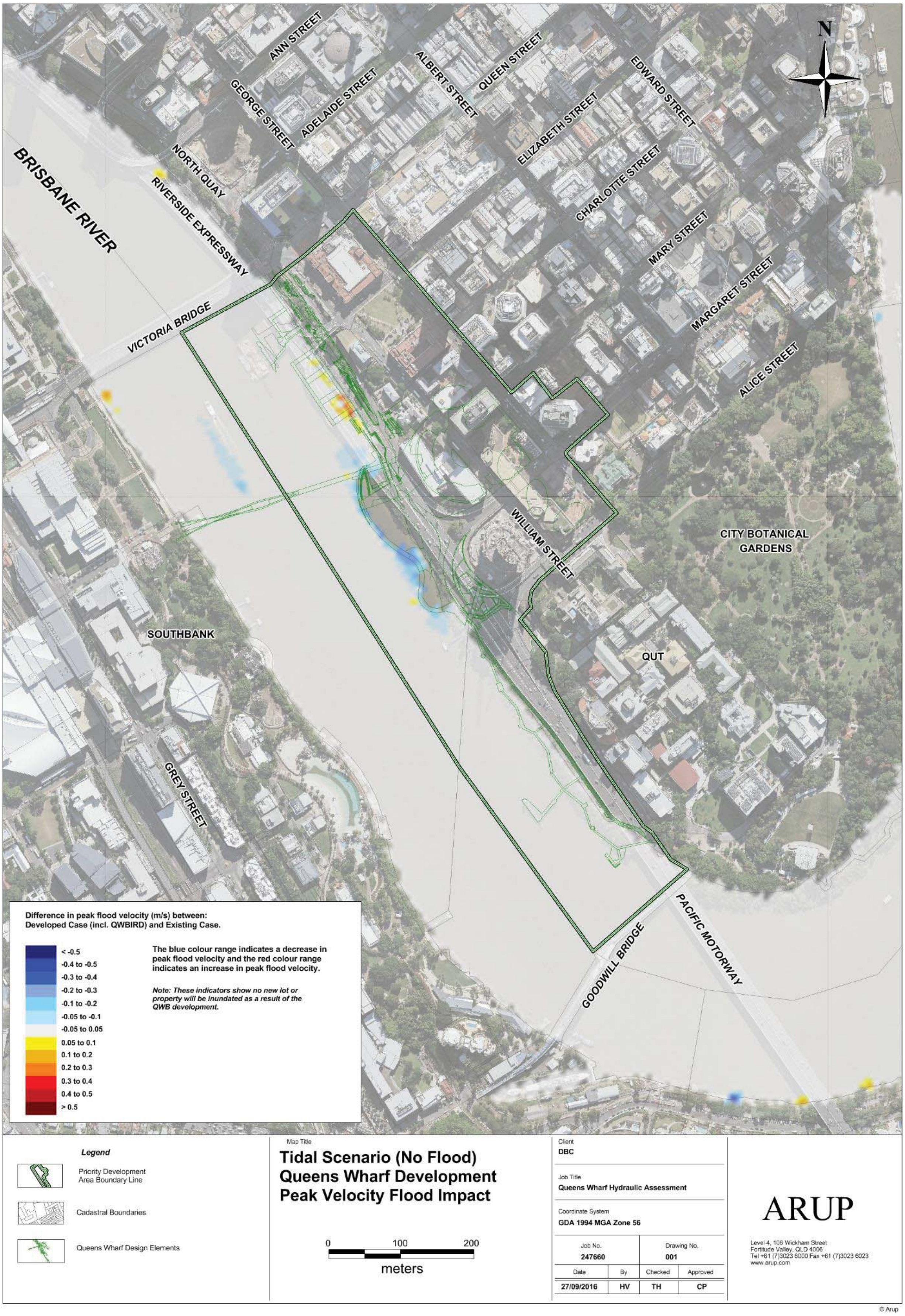

Figure 20: Tidal Scenario (no flood) – QWB – Peak Velocity Impact

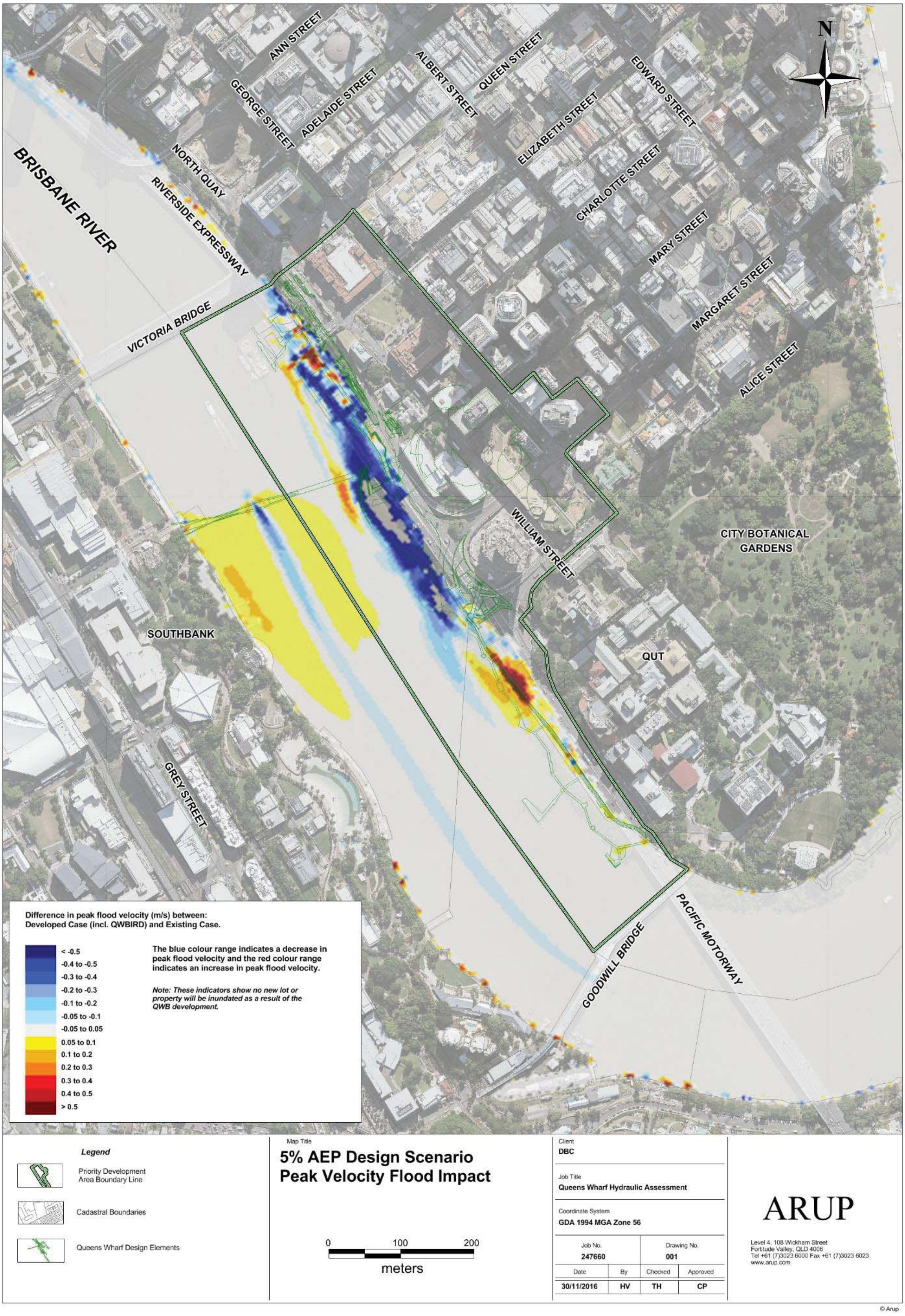

Figure 21: 5% AEP – QWB – Peak Velocity Impact

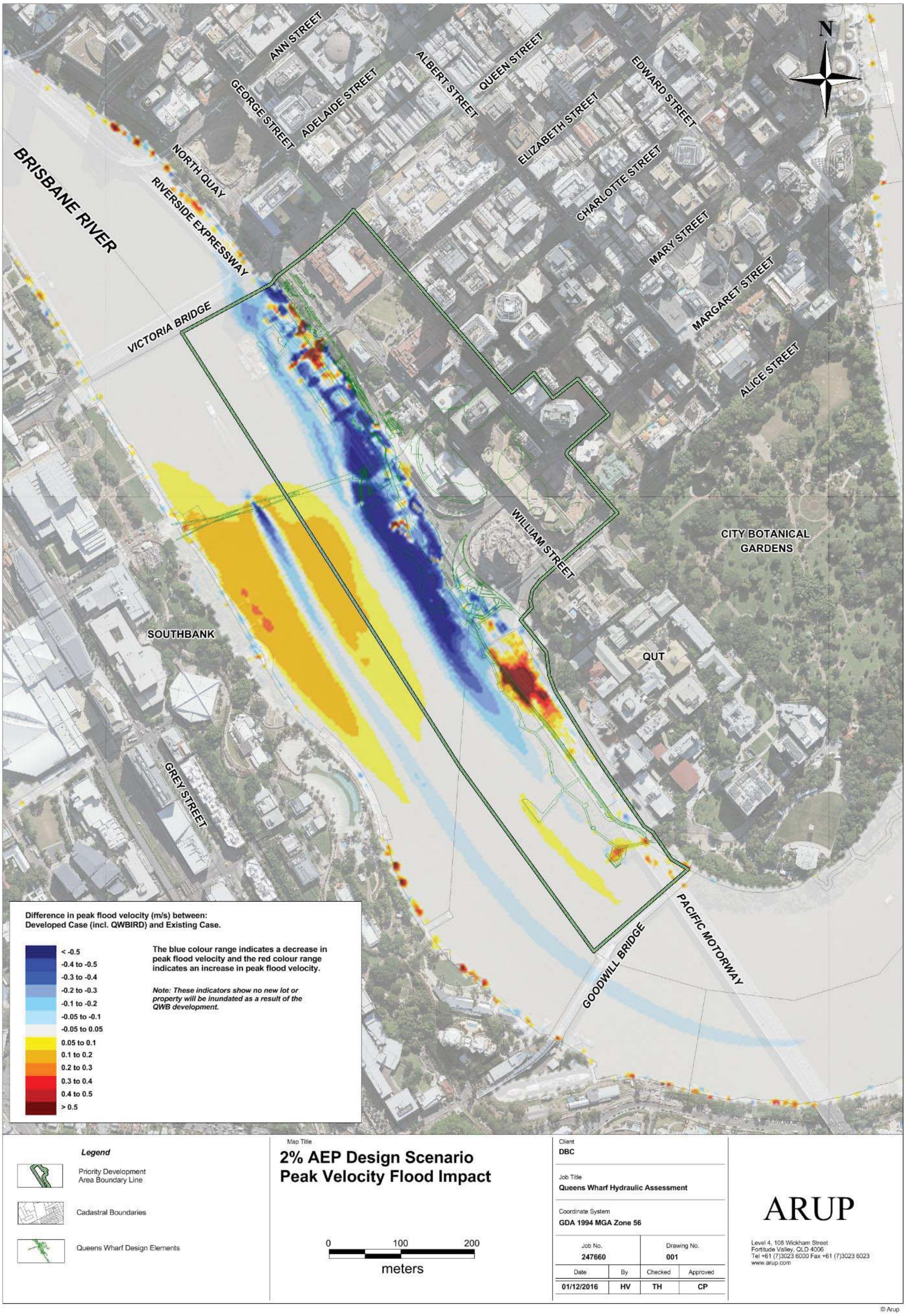

Figure 22: 2% AEP – QWB – Peak Velocity Impact

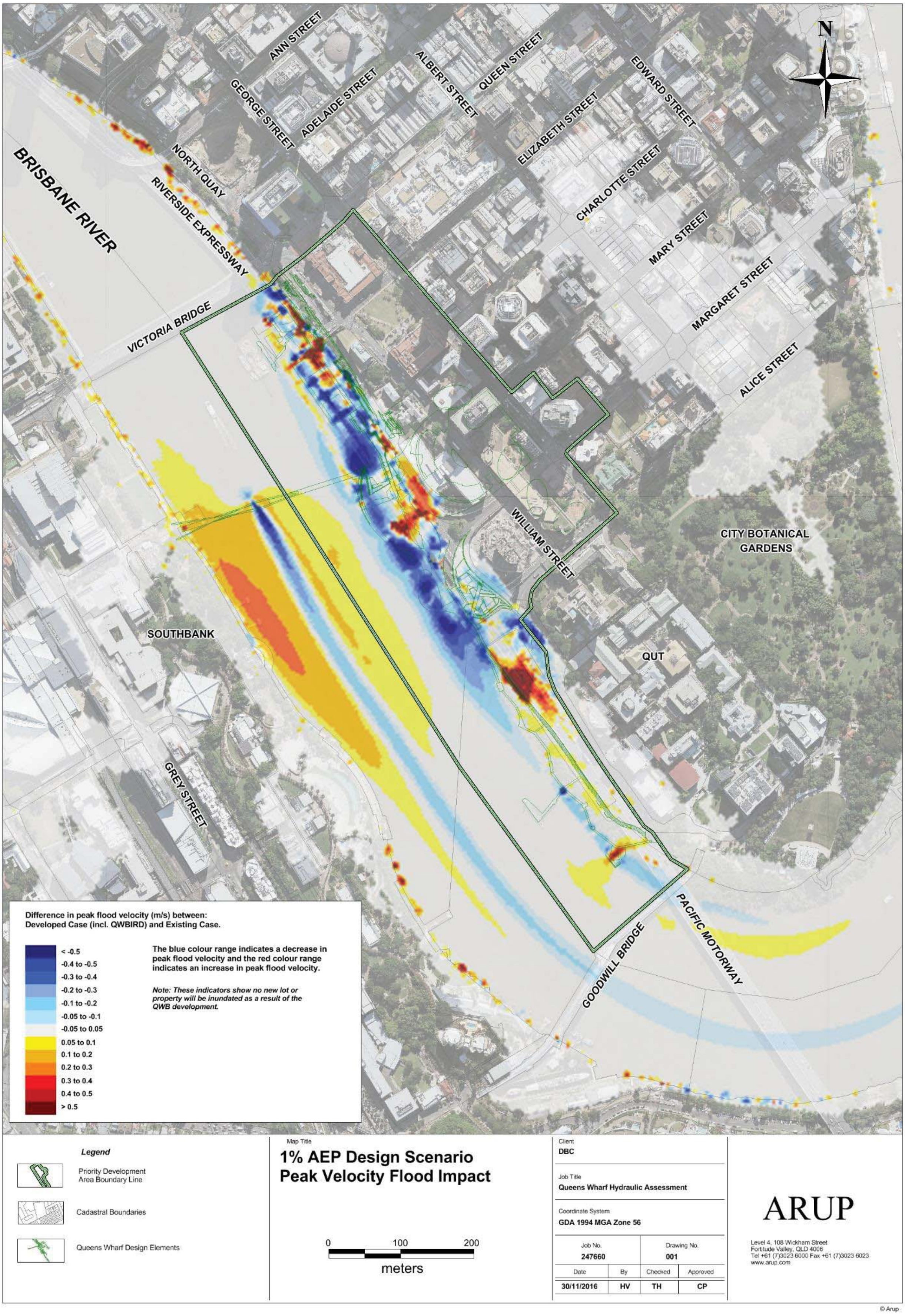

Figure 23: 1% AEP – QWB – Peak Velocity Impact

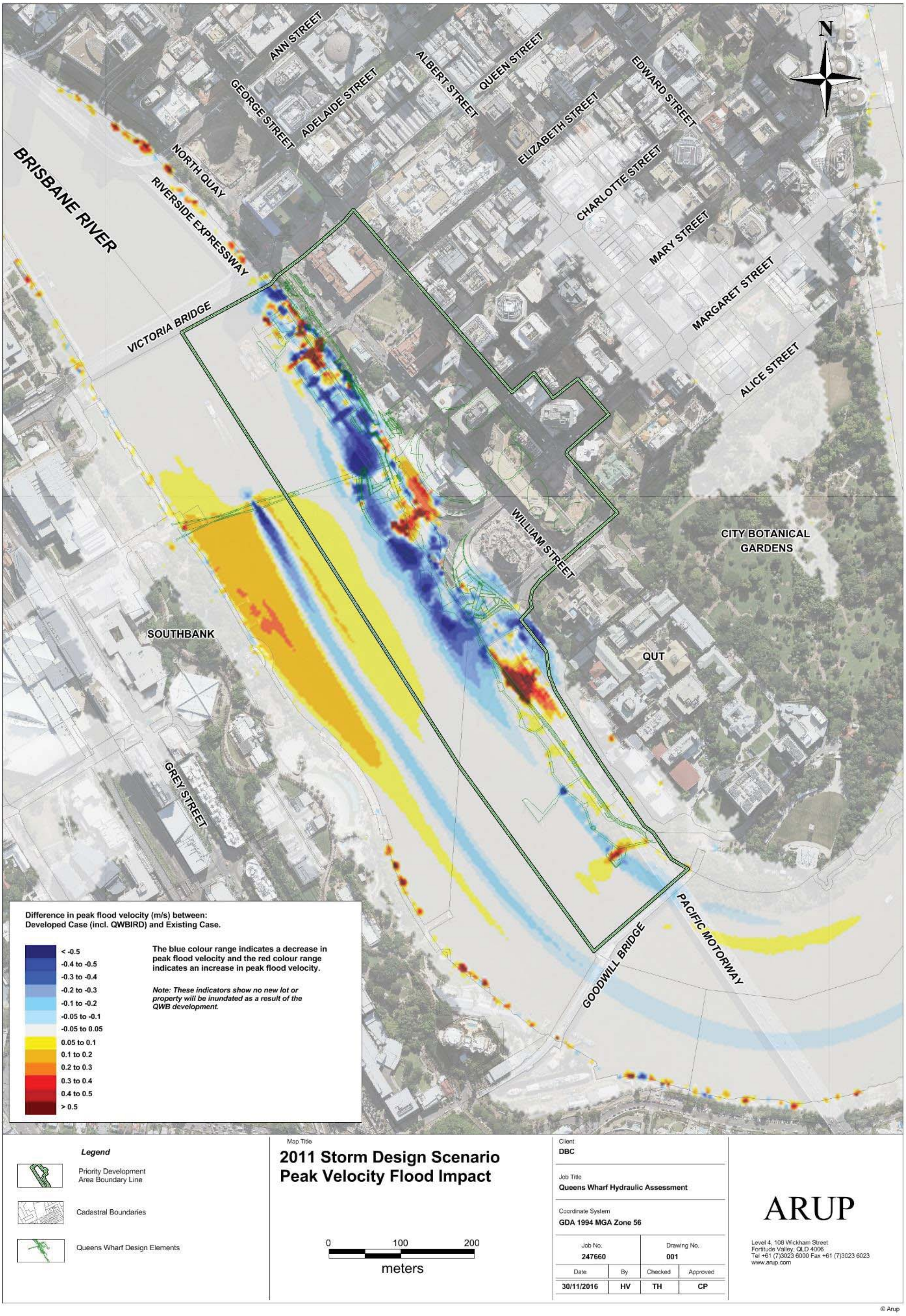

Figure 24: 2011 Modelled Storm Event – QWB – Peak Velocity Impact

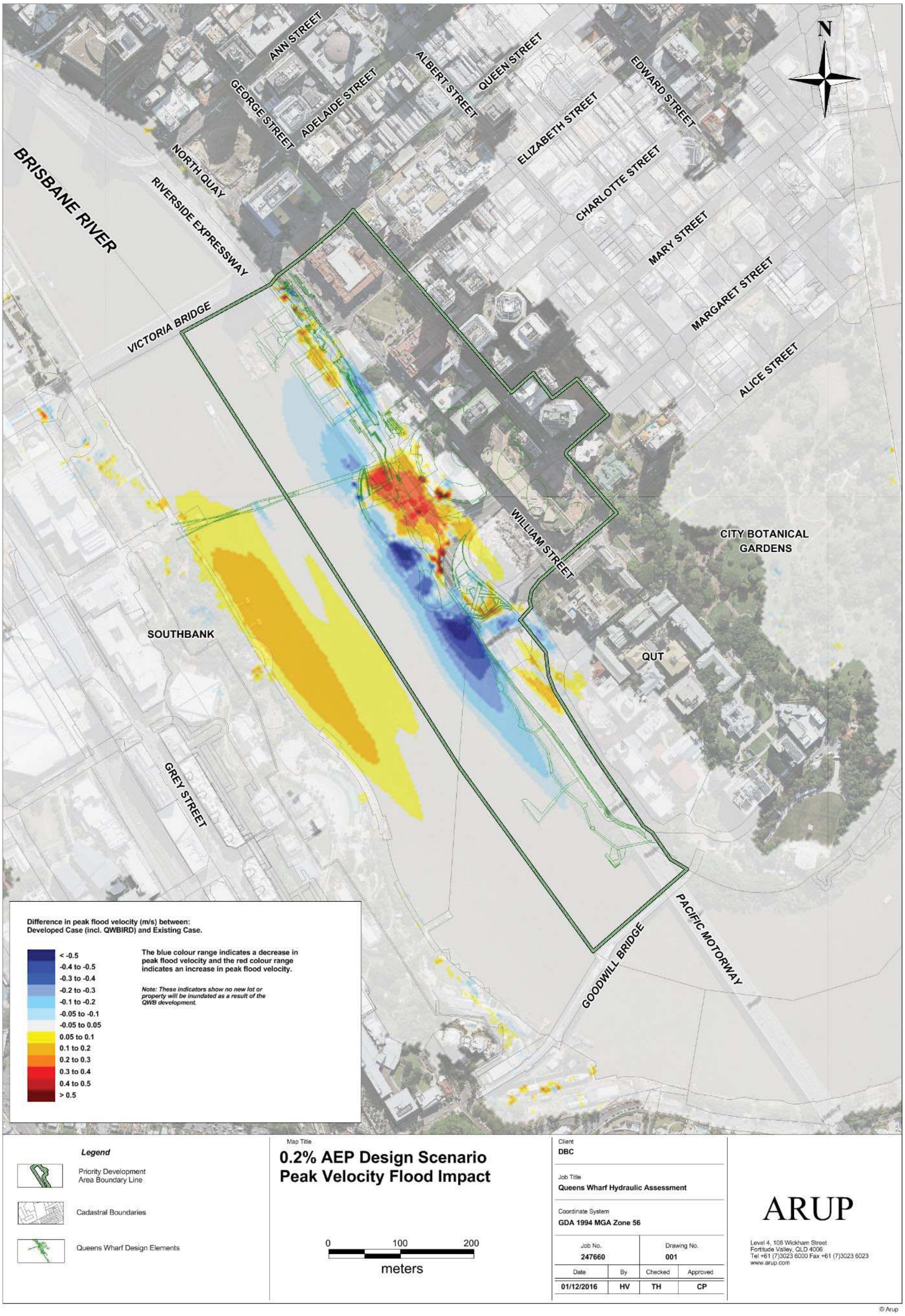

Figure 25: 0.2% AEP – QWB – Peak Velocity Impact

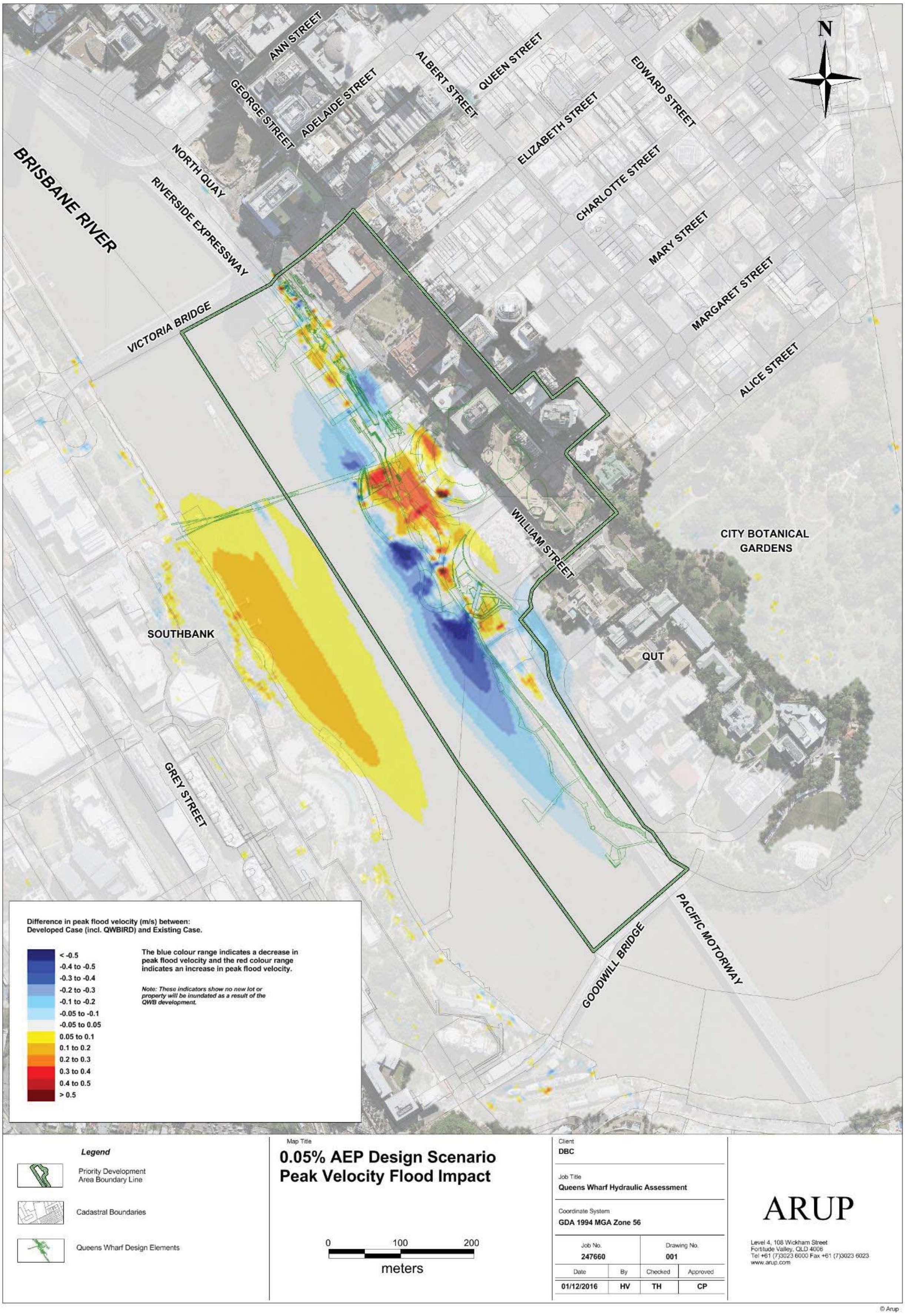

Figure 26: 0.05% AEP – QWB – Peak Velocity Impact

4.4 Results Analysis

For all the events modelled, the impacts in terms of peak flood level increases from the QWBIRD development remain localised, and less than 15mm outside of the PDA boundary. In a modelled 2011 design storm event and in a 1% AEP storm, a local increase in flood level of +17mm along Montague Road is observed. In a 1% AEP storm, a local increase upstream of the development is observed; the impact is +17mm and it remains within river banks. Local increases in flood levels up to 100mm are observed within the PDA in a 5% AEP storm (overtopping of the foreshore structures); these do not propagate outside of the PDA.

The impacts on peak flood velocities remain less than 0.5m/s outside the PDA. Local variations of velocities in the vicinity of the hydraulic structures are observed, in particular at the overtopping event(s); these remain localised and do not propagate on developed areas. A small tolerance has been selected on purpose to better visualize the propagation of velocity impact as part of the modelling exercise; this means that high variation of colours are actually associated with a small impact value.

Note: the 2011 design modelled flood event includes the latest manual gate operations and hydraulics structures. It is representative of the 2011 hydrology with current situation (i.e. flooding backup controlled by current manual gates).

The peak velocity magnitudes are presented in Figure 27 for the 2011 flood event. It can be seen from this Figure that the foreshore works are located in a low velocity zone (generally less than 1m/s in the 2011 event). Flood impacts are generally driven by velocities rather than storage in the Brisbane River system, therefore the QWBIRD results in minimal impacts. Note: as a maximum, the landing fill represents a 5% reduction in the overall channel conveyance cross-section (calculated at the Mean High Water Spring level).

For information, cross-section results are presented in Figure 28 for peak levels and Figure 29 for peak velocities. The results are taken from South Bank to The Landing (see Figure 30 for exact location).

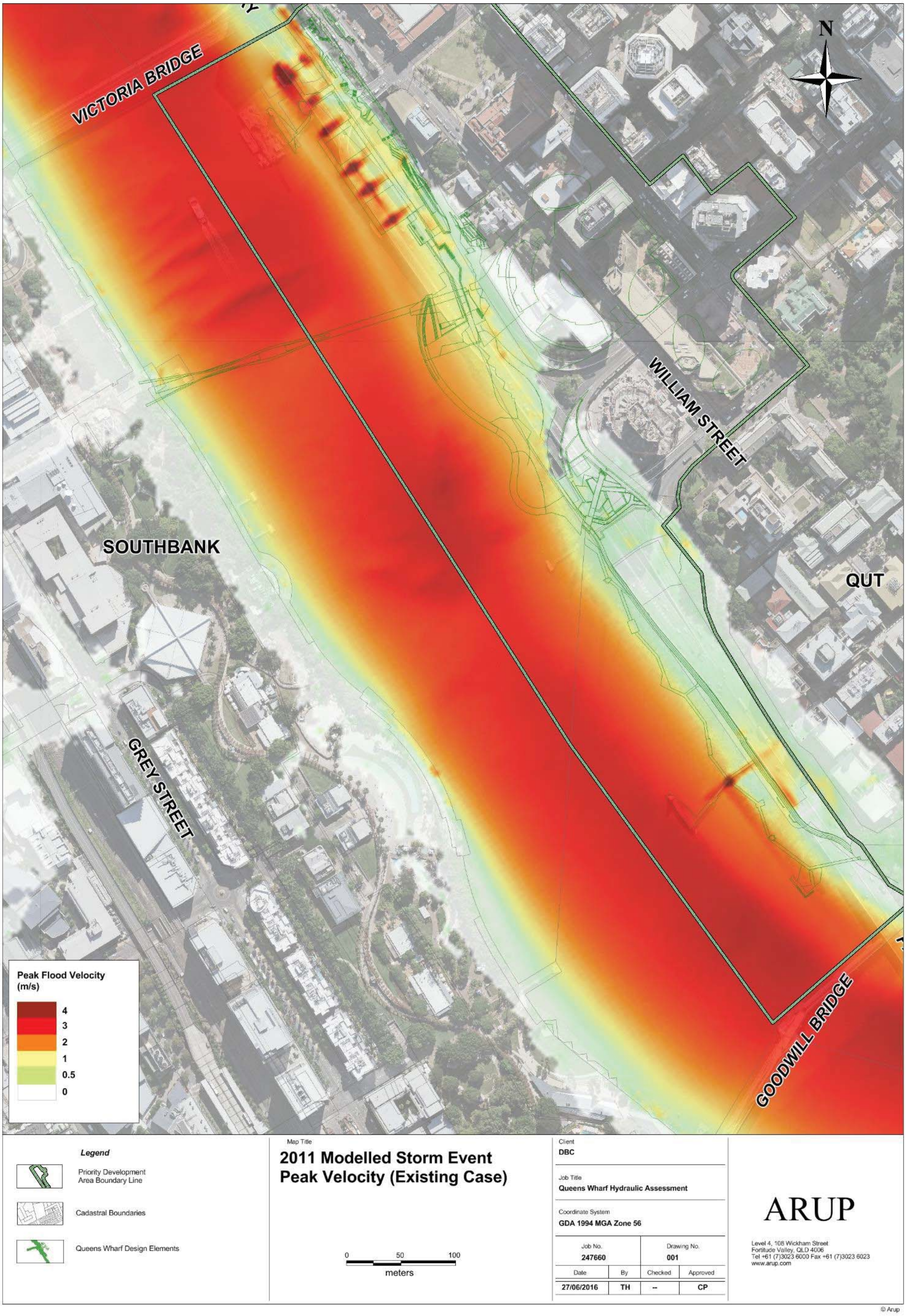

Figure 27: 2011 Modelled Storm Event - Peak Velocities (Existing Case)

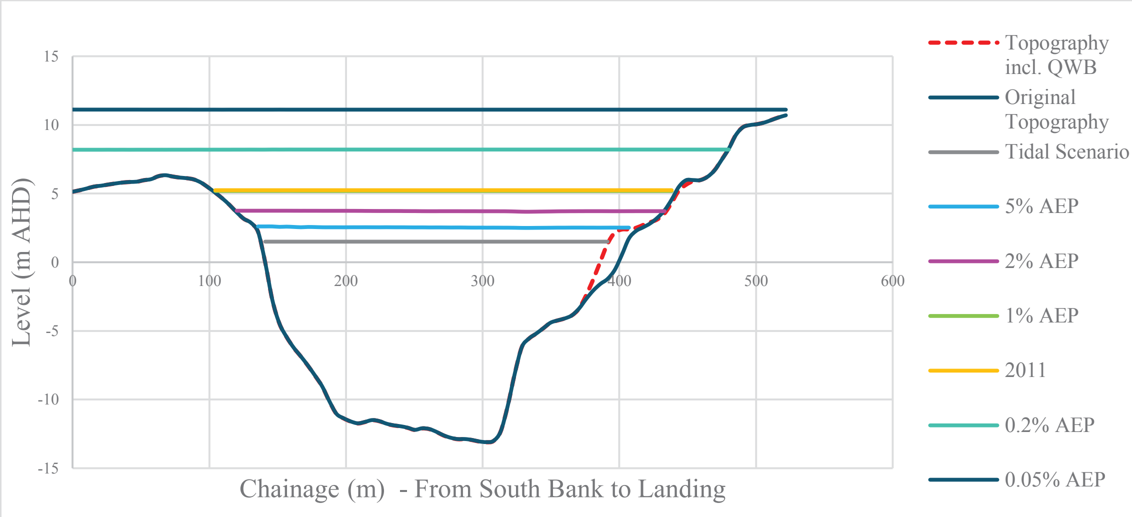

Figure 28: Cross Section Results (Peak Levels, including Development)

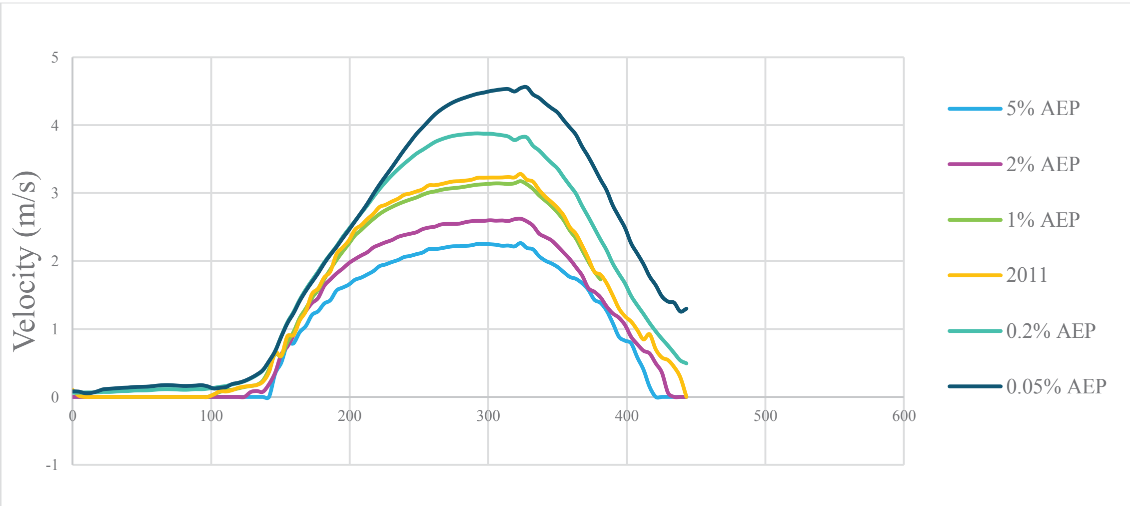

Figure 29: Cross Section Results (Peak Velocities, No Development)

Figure 30: Cross Section Location

4.5 Sensitivity Testing

4.5.1 Roughness Parameter

Sensitivity testing has been performed by decreasing the Manning's values by 10% and increasing the Manning's values by 10%. The results are presented in Figure 31 and Figure 32, showing the difference in peak flood level impact compared to the previous analysis with selected parameters, i.e. difference in flood impact results, or 'ddh' as generally referred to in the industry.

For both tests, the difference between the previous assessment's results is minimal and less than 15mm. The system is not sensitive to changes in Manning's n for the purpose of deriving flood impact[2].

2 Flood levels vary with a change in roughness, however the change is translated in both the existing case and the developed case; therefore the resulting flood impact remains consistent.

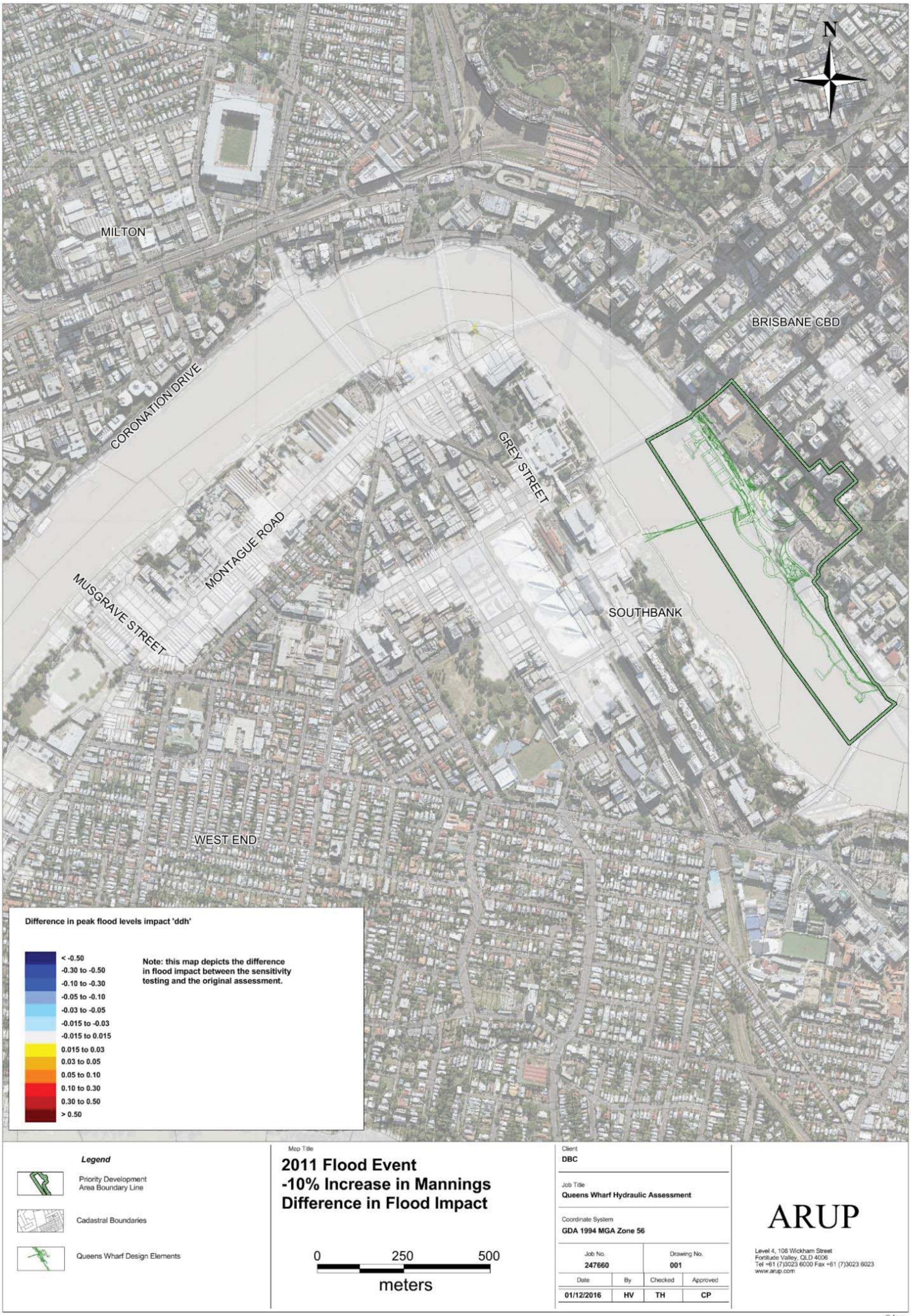

Figure 31: 1% AEP Event, -10% Manning's – Difference in Flood Level Impact

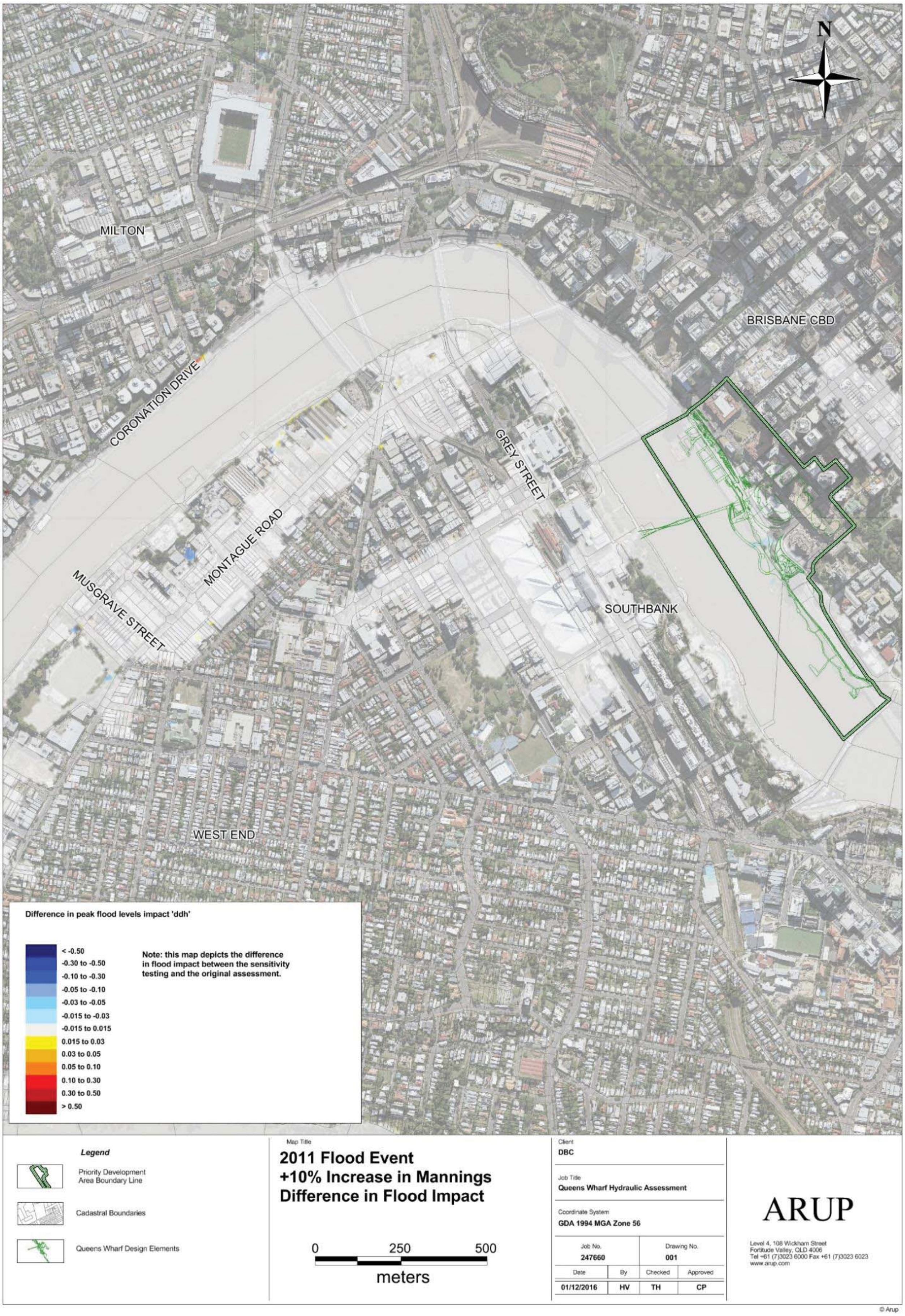

Figure 32: 1% AEP Event, +10% Manning's – Difference in Flood Level Impact

4.5.2 Bridge Representation Testing

Sensitivity testing has been performed on the bridge representation in the model:

- Case 1: form loss applied across the entire river section, via 'lfcsh' polyline (conventional method in the industry)
- Case 2: same form loss calculation, scaled onto pier location for a more realistic pattern of flood impact

Refer to Appendix A.5.2 for technical detail on the modelling approach.

The differences between the two approaches in terms of change in peak flood levels and peak flood velocities are shown in Figure 33 and Figure 34 respectively[3]. This testing was performed using the 2011 design flood hydrology. The change in results highly localised on the bridge pier and less than 3mm elsewhere overall. The velocity pattern is better represented with Case 2, where lower velocities are observed downstream of the pier (drag effect visible[4]), in comparison to Case 1 where form loss velocities are distributed across the river section (simplification of the system, drag effect not visible).

Case 2 approach was selected for this assessment as it provides a more realistic pattern of flood velocities impact[5].

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[3] Difference as follows: Case 1 minus Case 2

[4] Limitations of the physics represented by the model apply; refer to section A.1.7.

[5] Case 1 is generally more suitable for the representation of bridges supported with multiple, equally spaced piers.

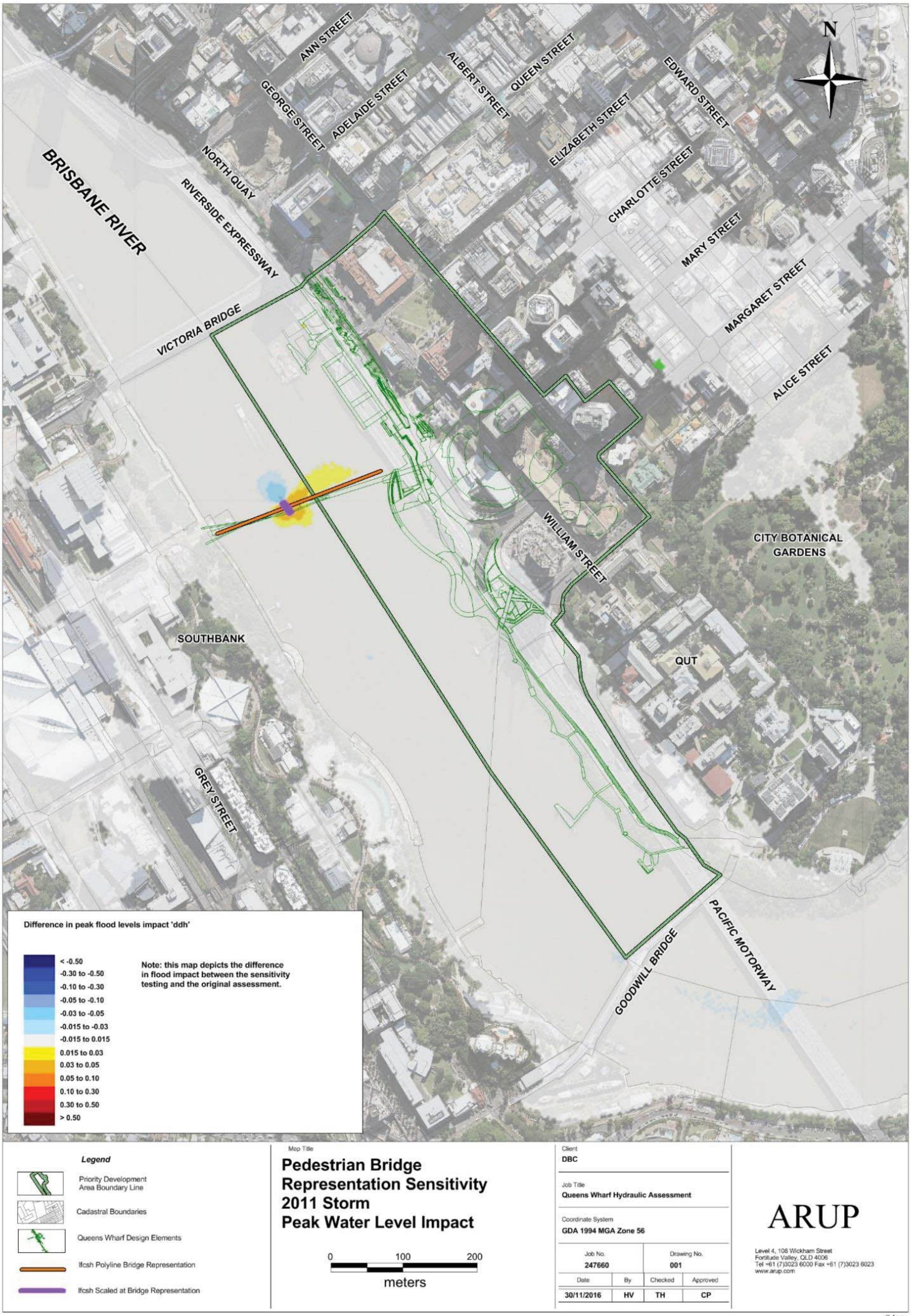

Figure 33: 2011 Modelled Storm Event – Pedestrian Bridge Representation Sensitivity on Levels

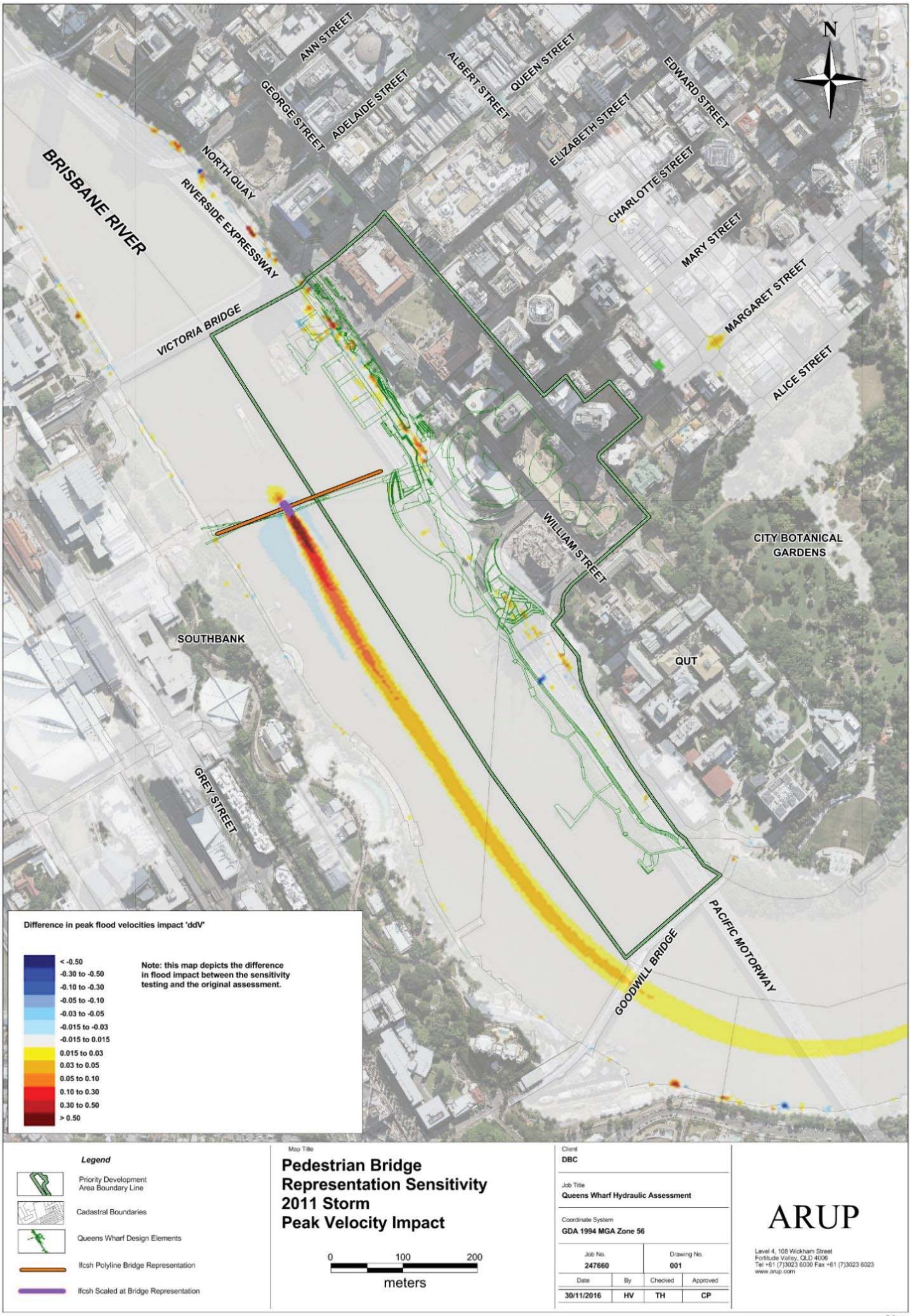

Figure 34: 2011 Modelled Storm Event – Pedestrian Bridge Representation Sensitivity on Velocities

:

4.5.3 Debris Accumulation Testing

Sensitivity testing has been performed on debris accumulation on structures, including:

- 3m debris mat at the pedestrian bridge pier
- 50% nominal blockage at all North Quay structures perpendicular to the flow
- 20% nominal blockage along the entire Goodwill Extension

The results are presented in Figure 35 showing the difference in peak flood level impact compared to the previous analysis (no debris accumulation), i.e. difference in flood impact results, or ‘ddh’ as generally referred to in the industry.

There are no visible changes in flood impact compared to a ‘no debris’ case. This is explained by the fact that additional debris blockage remains minimal compared to the overall channel conveyance.

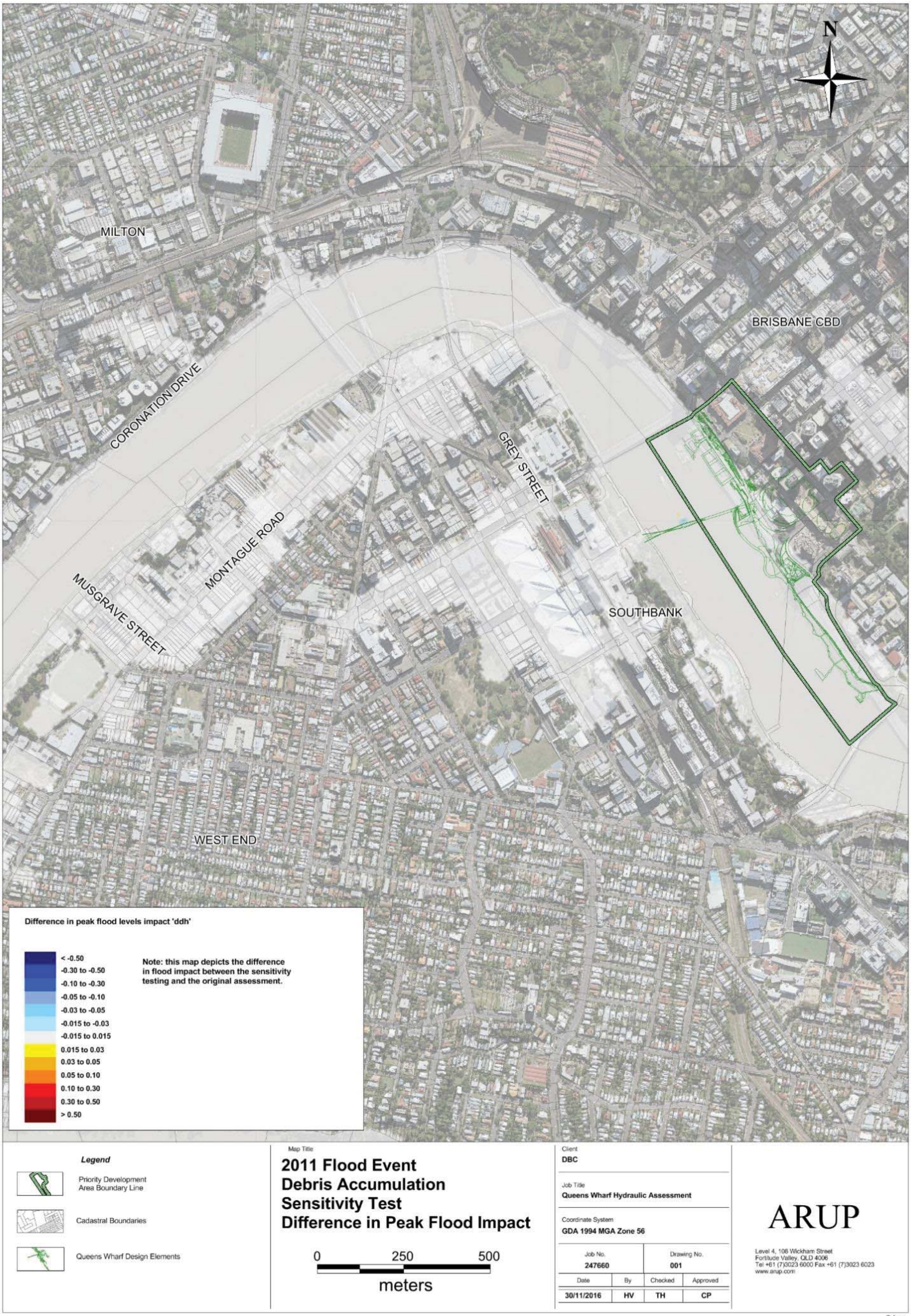

Figure 35: 2011 Design Storm Event – Debris Accumulation Testing

4.5.4 3m Debris Mat and Vessel Impact Testing

Sensitivity testing has been performed on both a debris accumulation and vessel impact at the bridge, including:

- 3m debris mat at the pedestrian bridge pier
- Vessel impact represented as 20% blockage over a 4m height, 6m width (i.e. in a direction perpendicular to the flow) on both sides of the bridge pier

The results are presented in Figure 36 showing the difference in peak flood level impact compared to the previous analysis (no debris mat, no vessel impact at the bridge), i.e. difference in flood impact results, or ‘ddh’ as generally referred to in the industry.

There are no visible changes in flood impact compared to a ‘no debris’ case. This is explained by the fact that additional debris blockage remains minimal compared to the overall channel conveyance.

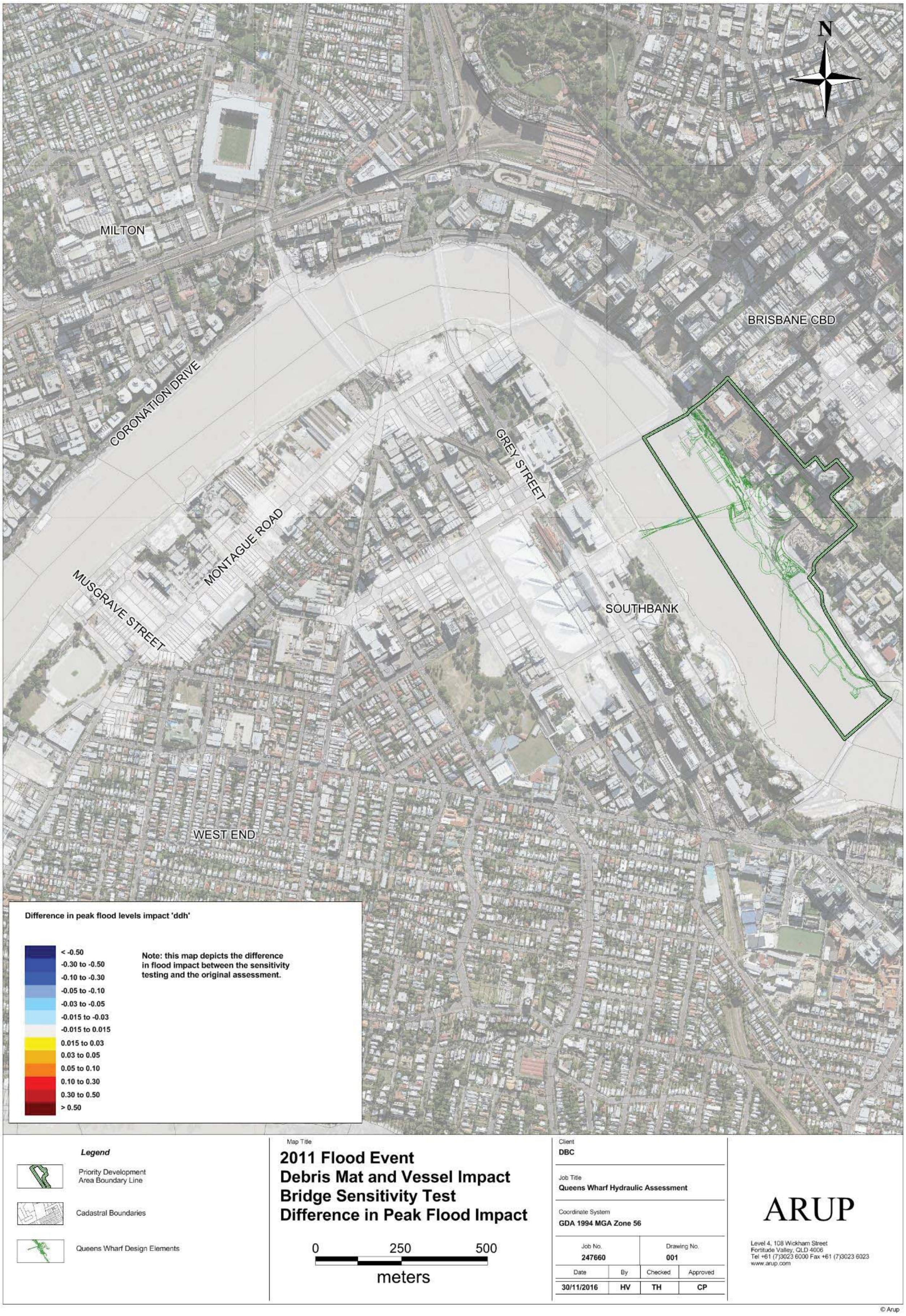

Figure 36: 2011 Design Storm Event – Debris Mat and Vessel Impact Testing

4.5.5 No Backflow Device Testing

Sensitivity testing has been performed on removing the backflow device installed after the 2011 flood event and results are presented in Figure 37. The map depicts the impact that QWBIRD would have had in a 2011 flood condition. It can be seen that the flood extent reflects the flood gates being removed (i.e. greatest flood extent); the impact is similar with or without the flood gates (i.e. compared to Figure 14).

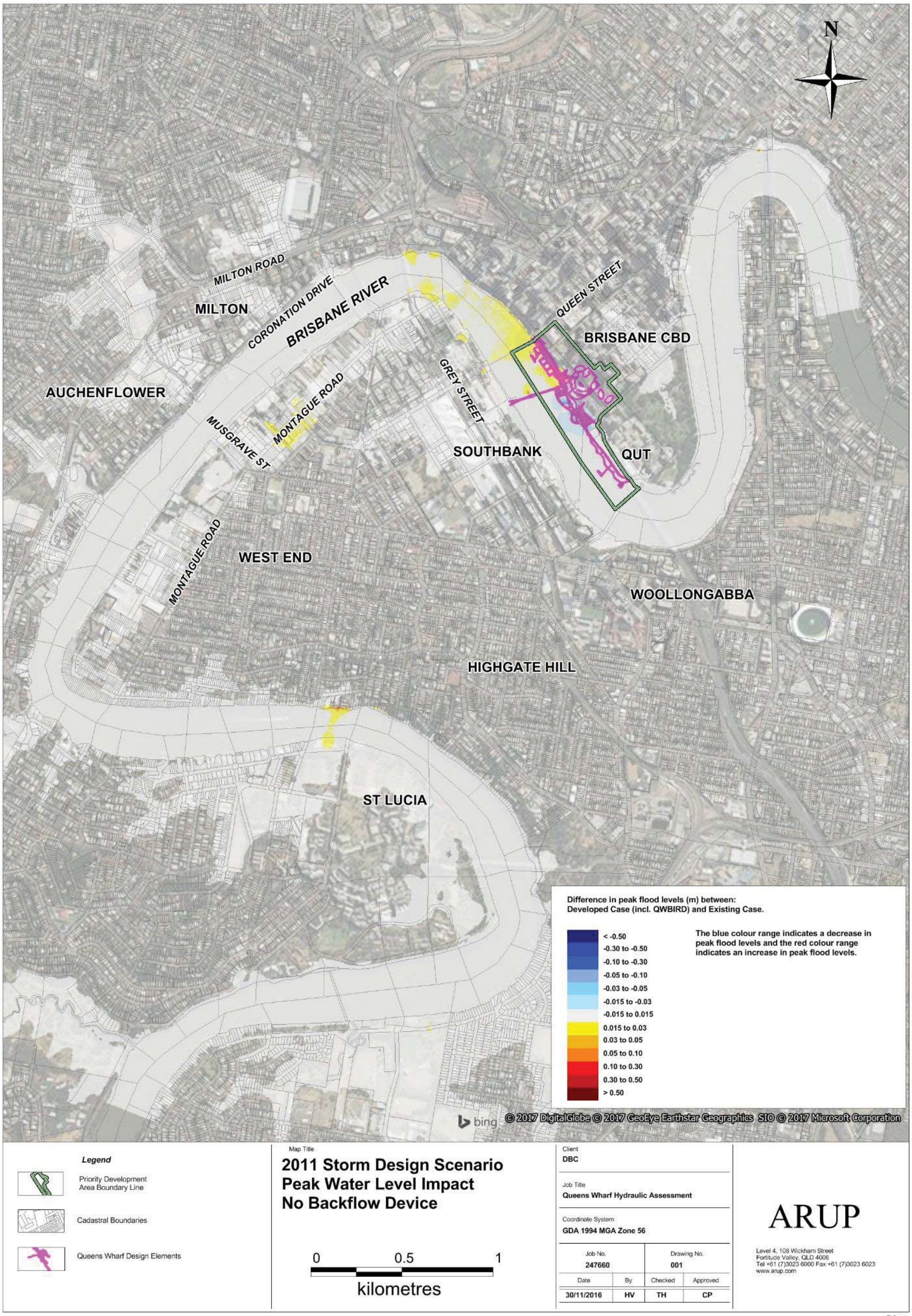

Figure 37: 2011 Design Storm Event – No Backflow Device Testing

4.6 Flood Impact Summary

The modelling indicates that the change in the flood characteristics as a result of the QWBIRD is less than 15mm in terms of increase in flood levels and less than 0.5m/s in terms of increase in velocities outside of the PDA boundary. In a modelled 2011 design storm event and in a 1% AEP storm, a local increase in flood level of +17mm along Montague Road is observed. In a 1% AEP storm, a local increase upstream of the development is observed; the impact is +17mm and it remains within the river banks.

There is no visible increase in flood extent[6] as a result of the QWBIRD. The modelling methodology is presented in Appendix A.

[6] The model is based on a 6m grid size; there may be change in flood extent within this 6m tolerance not captured by the model, specifically if the local topography varies over a 6m distance with vertical change in the order of the flood impact, so in this case varies over of a few millimetres (flat terrain).

5 Recommendations for Next Stages

5.1 Detailed Design Verification

The overall design of the QWB development is currently in progress and some element modifications may occur. It is recommended that ongoing verification of the flood impact be undertaken at various stages of the QWBIRD development using the Arup flood model or an updated version of this model.

5.2 Site Specific Emergency Management Plan

A site specific emergency management plan should be developed in the next detailed design phase if the QWBIRD, to assess the pre and post flood management operations at the site scale. It is noted that the Brisbane River Catchment Flood Study currently being commissioned by the State will provide information that underpins this plan, in particular flood warning times.

Considering the large upstream catchment and long-time of concentration, the flood warning times is expected to be sufficient for evacuation planning in line with the 2011 flood event experience. This consideration also covers Handbook 7, Australian Emergency Management Handbook (State and Local authorities' responsibility).

5.3 Construction Staging

The QWBIRD construction staging may have two effects:

1. Vulnerability of the design due to the intermediate stage not being modelled which may result in loads greater than the loads used in the design of elements of the works. For instance QWBIRD results in a decrease in velocities at the Goodwill Extension location; if the Goodwill Extension is constructed before the other elements it would be subject to higher flood velocities and higher flood loads than these being modelled in the 'developed' case. Arup has used the maximum peak flood levels and velocities between the existing case and developed case in the assessment of the flood load and debris mat load as inputs to the design to account for these circumstances.
2. Increase in flood impact due to temporary structures. This analysis can be performed at a later stage if deemed required using the Arup hydraulic model. It is anticipated that temporary structures would have negligible effects on flood behaviour.

5.4 Modelling Considerations

5.4.1 Tidal Condition Testing

Additional sensitivity testing could be performed on the coincidence effects of regional catchment flooding and tide levels (joint probability analysis), for instance using a coincident low tide level and peak flood inflow from the hydrology. Such model boundaries conditions could be obtained from a regional model, for instance the BRCFS hydraulic model when available and used in the Arup model developed for this study.

The recorded peak levels at City Alert Gauge in 2011, refer to A1.3.2, indicate a strong attenuation of the tidal influence (from 1.5m amplitude between low and high tide before the flood to about 0.25m amplitude during the peak of the flood event). This means that the flood behaviour is predominantly driven by the large inflows which are captured by the model rather than tidal conditions. It is therefore anticipated that this testing will not alter this assessment's findings.

5.4.2 Climate Change Testing

An additional Climate Change scenario could be performed using the Arup model; this testing would require inflows and associated tailwater levels based on an increase in rainfall intensities. Such conditions can be obtained from a regional model, for instance the BRCFS hydraulic model when available. It is anticipated that this testing will not alter this study findings, considering a range of design events has been tested for the assessment of impact.

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Appendix A

Modelling Methodology

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A1 Modelling Methodology

A1.1 Base Model Adopted

The TUFLOW model prepared by Venant Solutions as part of the tender phase of Queens Wharf Brisbane has been selected by EDQ, DIPLG and their technical advisors as being the most suitable base model for the analysis of the QWBIRD flood impact. For the remainder of this report, this model is referred to as the Jempson model (nomenclature set by EDQ and DILGP).The Jempson model has been supplied to Arup as a base of this assessment.

It is noted that a number of other hydraulic models are relevant to the project location, but have not been used for the following reasons:

- Brisbane River Catchment Flood Study (BRCFS) hydraulic model owned by DILGP. The model is currently being finalised and it is not available for engineering inputs into this assessment.
- Mike-21 model owned by BCC. The model is currently adopted by BCC for statistical design flood events. This model will be replaced by the BRCFS once released. The Brisbane River is represented in one Dimension (1D) and the model is not suitable for the detailed assessment of QWBIRD impact.
- The Disaster Management Tool (DTM) 'TUFLOW GPU' model developed by BCC for interim disaster management pending the completion of the BRCFS. The model is based upon a relatively new GPU technology which is still under development (e.g. no 1D component); the model is not suitable for the detailed assessment of QWBIRD impact.
- 3D TUFLOW-FV Model of the Brisbane River owned by BCC. The mesh elements are in the order of 30m therefore the model is deemed not suitable for the detailed assessment of QWBIRD impact.

It should be noted that the Jemspon model was developed as a tool to inform the proponents during bid phase of QWB. As noted by Venant Solutions in Section 1.3 of 'Queen's Wharf Brisbane Reference Hydraulic Model – Final Report (8 September 2014)':

"This model is to be used only during the procurement process of the Queens Wharf Brisbane Project to facilitate a comparative analysis of in-water infrastructure proposed in proponent submissions. This model will be used to provide an indicative assessment of potential flood impact from the proposals. The Development Approval process and any other approval process that this development may be subject to is a separate process and will require additional modelling and investigations".

Significant changes and refinements have been made to the Jempson model for the purpose of this assessment and the final model developed by Arup is referred to as the Arup model.

A1.2 Model Setup Refinements

A1.2.1 Software Platform

The model was developed using TUFLOW 2016-03-AA-Isp (64bits).

A1.2.2 Resolution and Multi-Domain Linking

The original Jempson Model was setup as a Multi-Domain (MD) TUFLOW model to optimize simulation runtimes, extending from Saint Lucia (Golf Links) to New Farm, approximately 850m downstream of the Story Bridge.

A desktop review of the model performance was undertaken by Arup. The velocities distribution was found to be inadequate, in particular at the multi-domain linking location (high-velocities field is artificially 'shifted' by the model). This is illustrated in Figure 38. As a result of this the model did not predict realistic impact patterns.

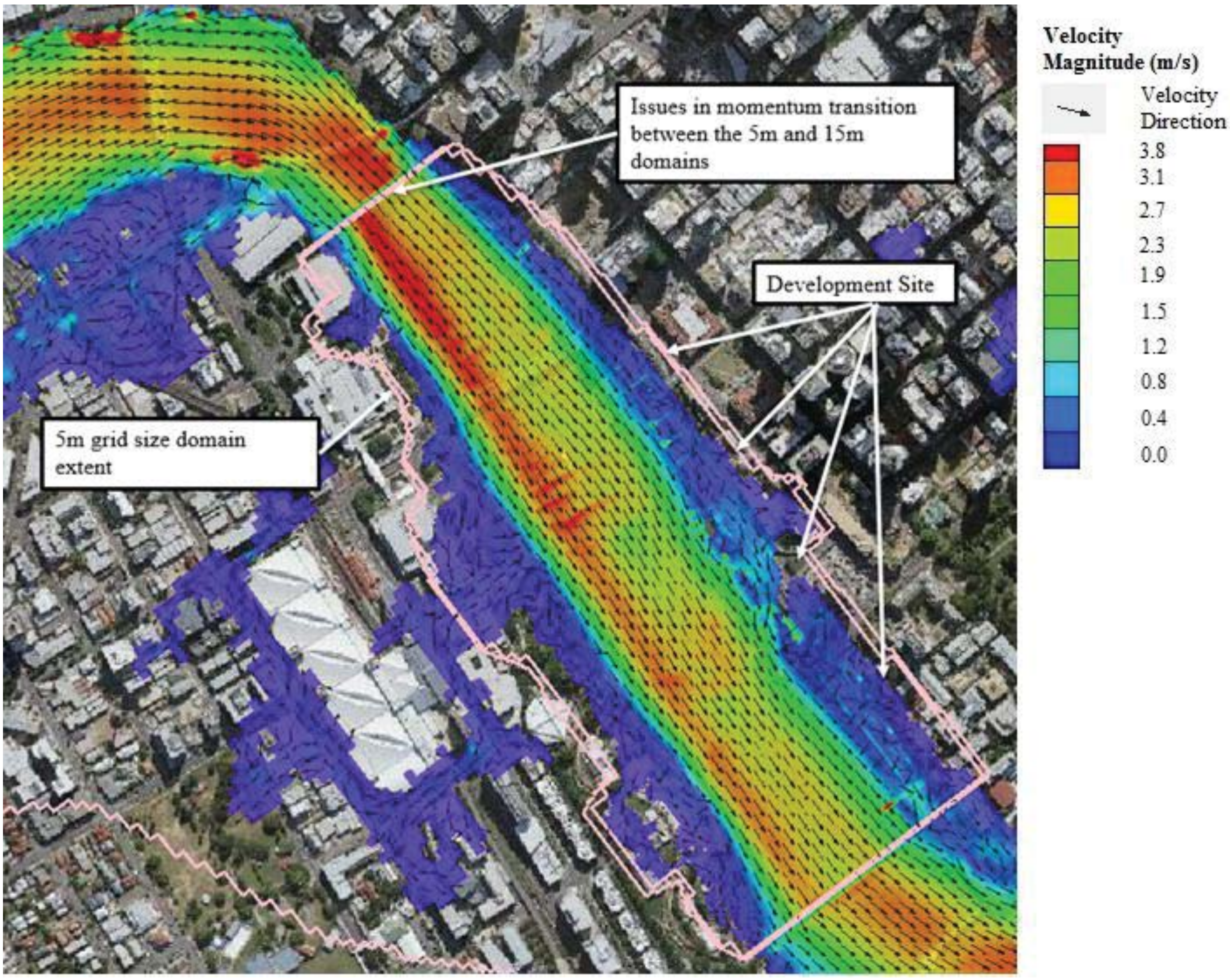


Figure 38: Jempson Model – Velocities Magnitude and Direction

Several tests on the 2d2d linking configuration have been performed by Arup, in an effort to model *realistic* velocity fields (and consequently momentum flux) whilst maintaining reasonable simulation runtimes; tests included:

- Varying the number and location of hidden 1d nodes for transfer;
- Smoothing the topography at the 2d2d linking location;
- Setting the linking location at the shallowest parts of the river; and
- Adjust the 'Link 2d2d Global Stability Factor' settings

The results did not provide satisfactory velocity fields. Arup attributes this to the fact that 2d2d linking does not perform well in deep channels where large volumes of water are transferred from one domain to another.

In order to resolve the momentum issue from the Jempson's model, the Arup model has been setup as a single grid size. As a general rule, a 'coarse' model grid size will tend to overestimate the impact from a design and its propagation compared to a 'small' model grid size; this is assuming that design representation is adapted to the grid itself (i.e. 'overrepresented' in the case of a 'coarse' model). In order to determine the *realistic* flood impacts associated with the design, three distinct grid sizes scenarios have been setup in the Arup model for specific purposes; these are:

- 8m model grid size was adopted during the development and refinement of the design as considered the optimum resolution between impact assessment and simulation runtimes. Associated timestep was set to 3 seconds[7]. This is also the resolution selected to extract the hydraulic parameters for the design of foreshore structures (refer to Appendix D).
- 6m grid size for presentation of final results and impact maps in this document (simulation runtimes range from 13hrs to 30hrs CPU time). Associated timestep was set of 2 seconds[7].
- 12m grid size for simulation of the sensitivity tests.

The orientation of the model was also modified to ensure the grid is well aligned with the flow of the Brisbane River along the proposed development.

[7] The resulting Courant Number is relatively high; sensitivity testing has been performed with a smaller timestep with no measurable change in results, therefore the selected timestep was considered appropriate.

A1.2.3 Topography and Hydrography

The Jempson model topography was based on a 2m Digital Terrain Model (DTM); this DTM was developed using Brisbane City Council 2009 LiDAR survey and 2011, 2012 and 2013 bathymetric survey. The latest hydrographic survey undertaken on 02 December 2015 provided by BENNETT & BENNETT was added onto the Arup model as illustrated in Figure 39. This is a Class A survey with a +/-0.5m specified accuracy. This also includes a ground survey undertaken by the same company in 2015. Other minor modifications have also been performed to the model such as topography smoothing and representation of local ridges and gullies, to ensure they are adequately represented with the new model resolution.

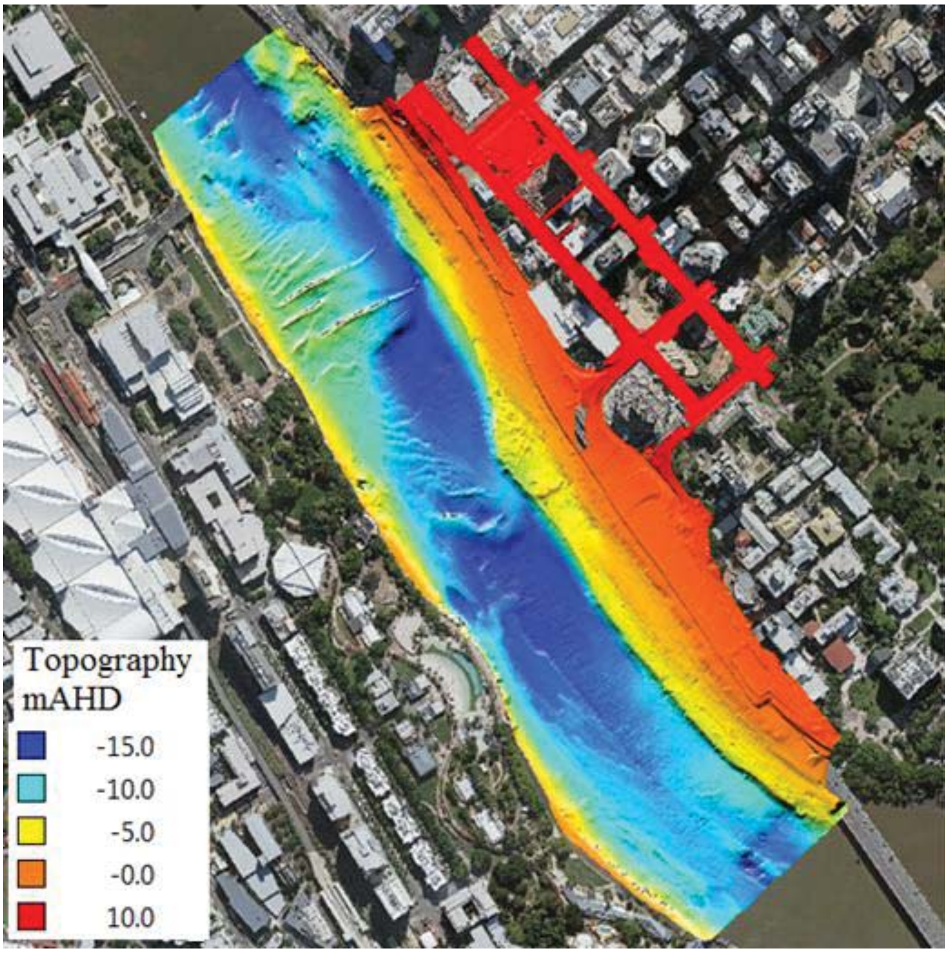


Figure 39: Brisbane River Hydrographic Survey undertaken 02 December 2015

The sand bars (ripples) are well captured by the survey. These are reflected in the model results and should not be interpreted as instabilities; this bathymetry is subject to change from year to year due to sediment transportation and is likely to change during a flood. It should be noted that changes to the river bathymetry during a flood have not been considered as part of this assessment.

A1.2.4 Additional Ground Survey

Additional ground survey was undertaken at specific locations in consultation with the State technical advisors, to confirm the topography representation in locations that were considered hydraulically sensitive and to confirm the accuracy of the LiDAR data. These areas included: Buchanan Street; Coronation Drive & Cribb Street; near the Ferris wheel at Southbank; Dixon Street underpass; Brisbane Street/ Gailey Street; Parmalat Processing Facility/Southbank Boardwalk; and Coronation Drive & Lang Parade to Graham Street. The additional survey was reviewed against the Brisbane City Council 2009 LiDAR data to verify the accuracy of the topography representation. Refer to Figure 40 for the plan view of the additional ground survey and Figure 41 to Figure 47 for the survey comparisons. The additional survey data was added to the Arup model.

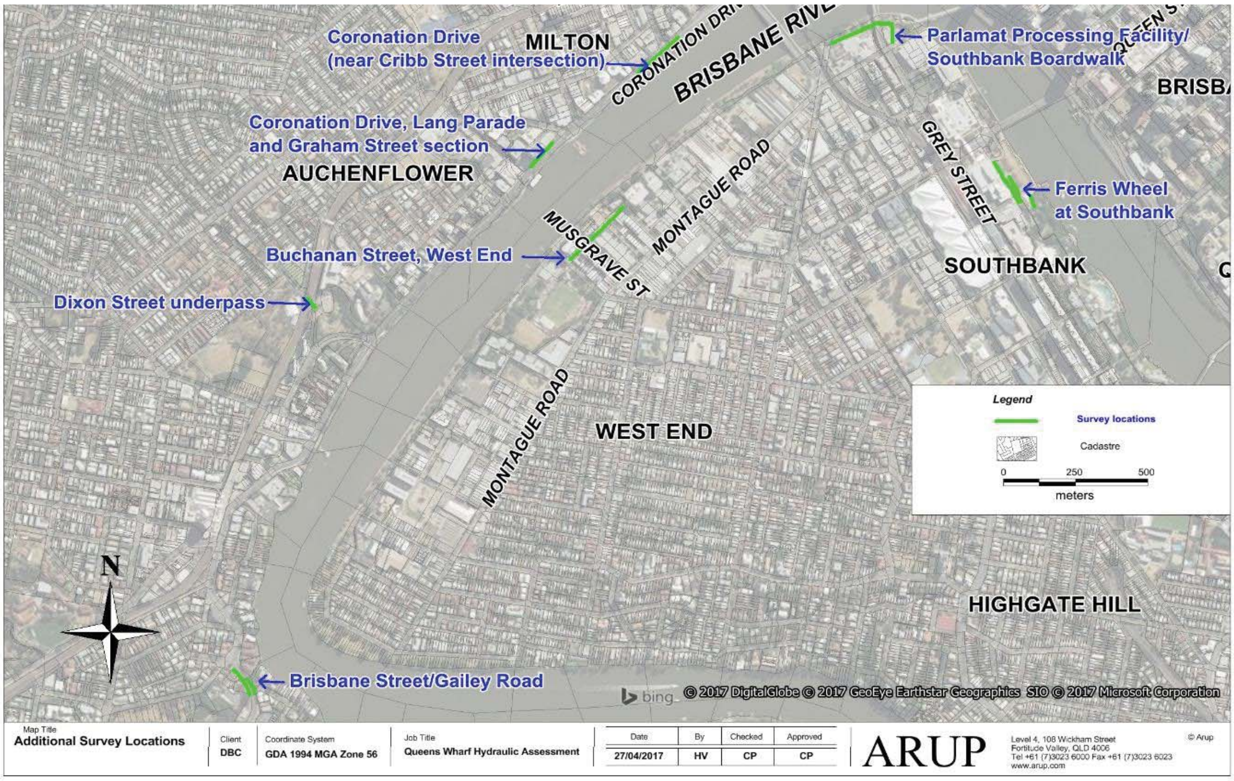


Figure 40: Plan view of additional ground survey

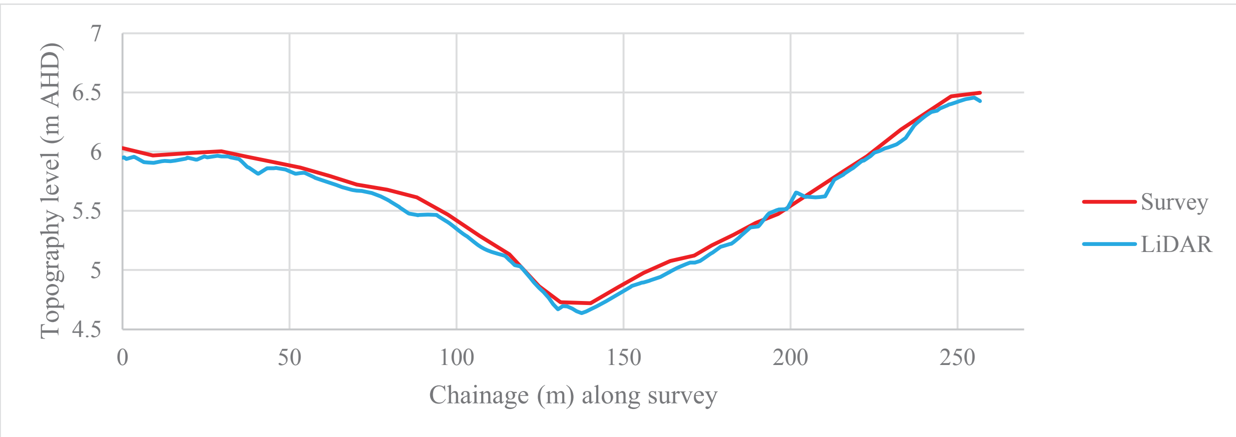


Figure 41: Comparison of survey and LiDAR data at Buchanan Street, West End.

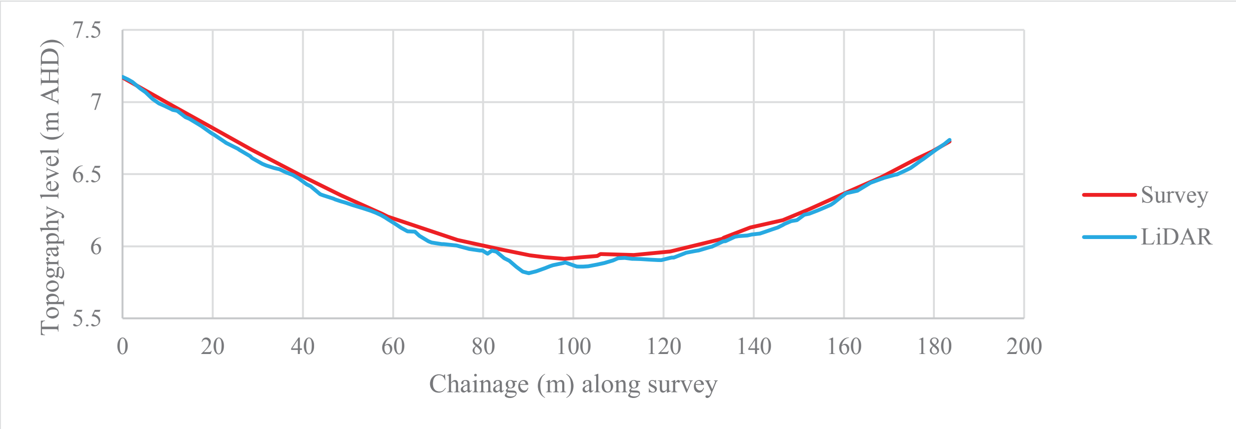


Figure 42: Comparison of survey and LiDAR data at Coronation Drive (near Cribb Street intersection), Milton.

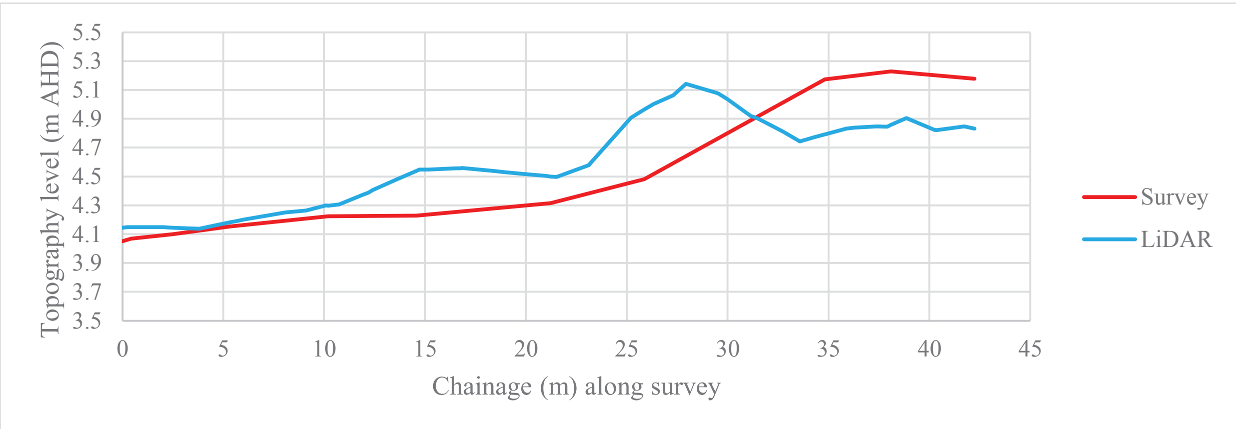


Figure 43: Comparison of survey and LiDAR data near the Wheel of Brisbane at Southbank.

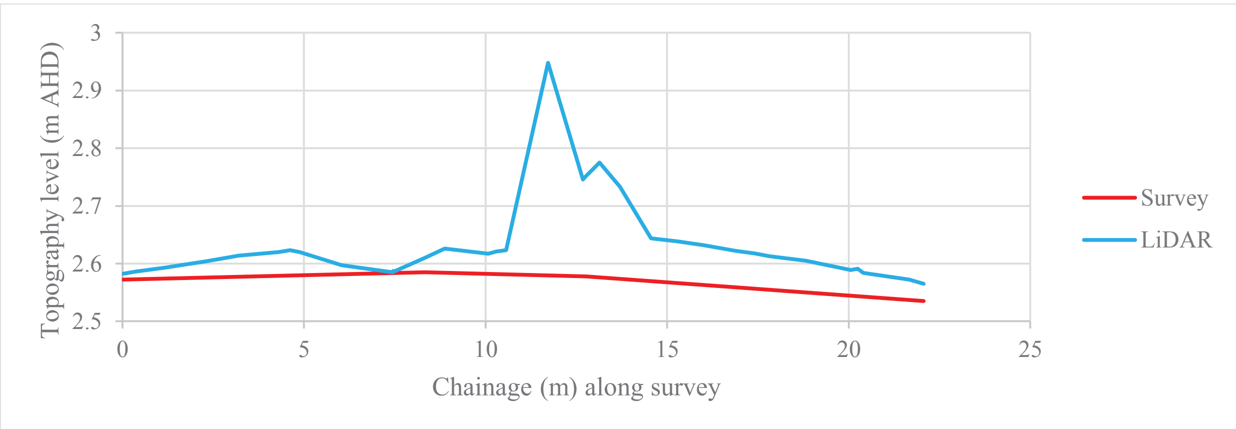


Figure 44: Comparison of survey and LiDAR data at Dixon Street underpass.

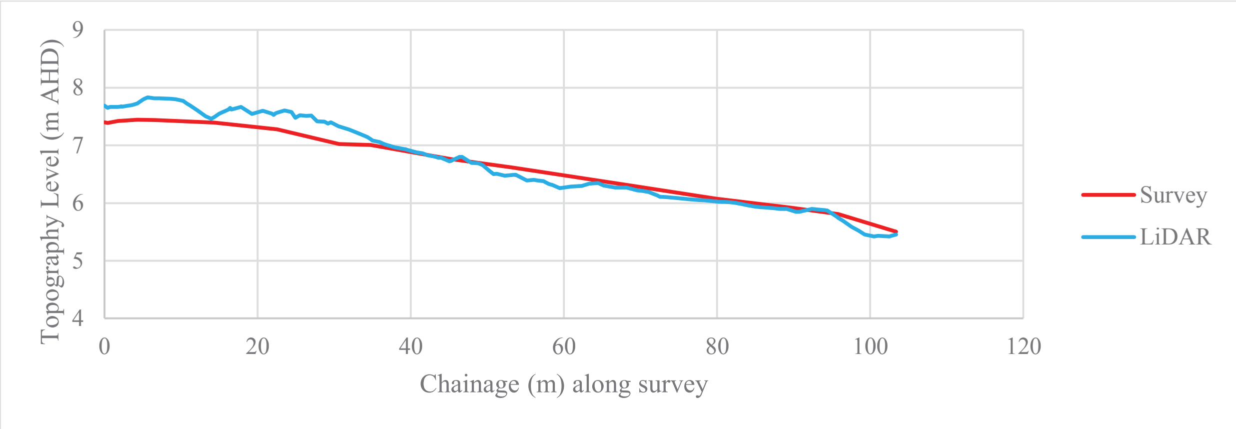


Figure 45: Comparison of survey and LiDAR data at Brisbane Street/Gailey Road.

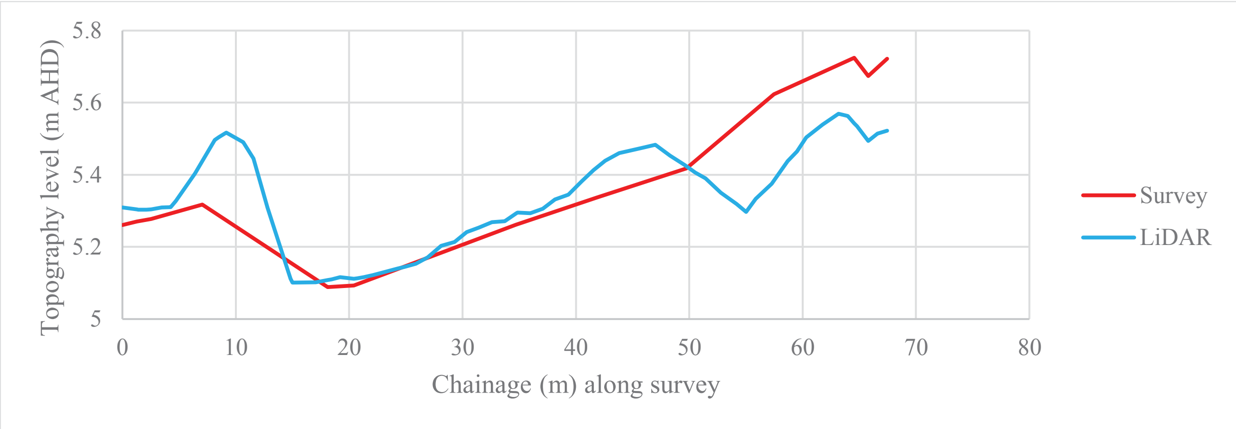


Figure 46: Comparison of survey and LiDAR data at Parmalat Processing Facility/Southbank Boardwalk.

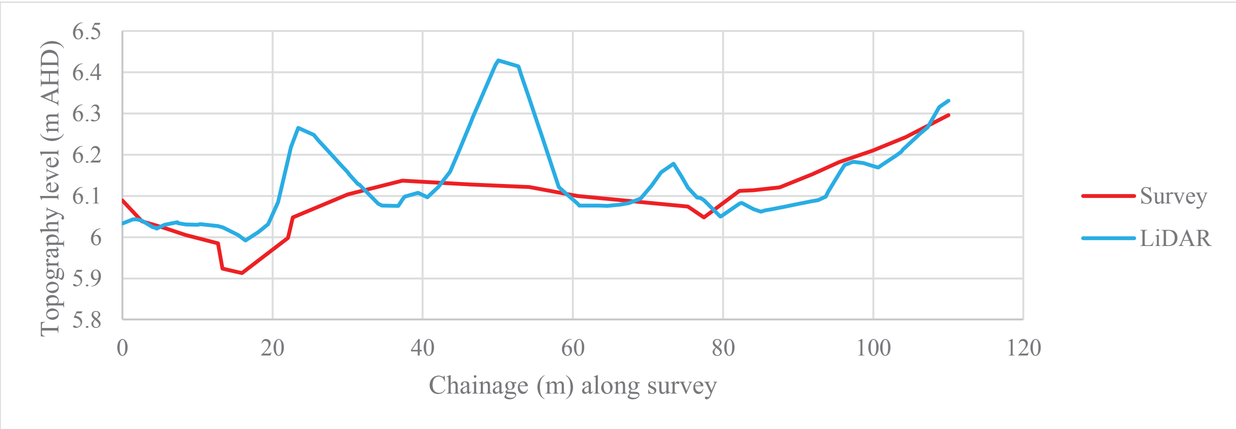


Figure 47: Comparison of survey and LiDAR data at Coronation Drive, Lang Parade and Graham Street.

The majority of the survey confirmed the accuracy of the LiDAR to +/- 130mm. With an exception of the survey taken near the Wheel of Brisbane at Southbank being a difference of +/- 350mm.

A1.2.5 Existing Foreshore Structures Representation

All bridges and CityCat terminals (including North Quay and QUT City Cat terminals) have been left unchanged from the Jempson model. These were modelled as a combination of (i) TUFLOW 'lfsch' features for the representation of losses and blockage and (ii) 'zshape' for topography.

A1.2.6 Drainage and Hydraulic Structures Representation

A number of stormwater pipes were included in the original Jempson model in 1D to allow backwater flooding from the river. As stated in the Venant Solution report: *"the dataset was not complete with regards to inverts and pipe diameters and so data was interpolated based on surrounding available information*".

A review of the 1D model results also indicated a number of instabilities. The 1D network was reviewed and modified using data information provided by BCC. The following logic was applied:

- Pipe greater than 600mm in diameter or width were added to the model (only major pipes represented)
- Network sections in the vicinity of the recorded 2011 flood extents were added to the model
- An invert level check was conducted of all pipes within network to address any 'nonsensical' invert levels

In some instances, the stormwater GIS data provided by BCC did not include invert levels. In these locations, unknown inverts levels were estimated based on the surrounding infrastructure grades and invert levels. Where no surrounding infrastructure was able to be used to interpolate the invert levels, an assumed pipe cover of 600mm minimum was applied. Stormwater inlet pits were placed based on the GIS data provided; in some instances the pit configuration was simplified. This included combining a number of smaller network links at one common location in order to provide an effective 1d link between the Brisbane River and the surrounding area.

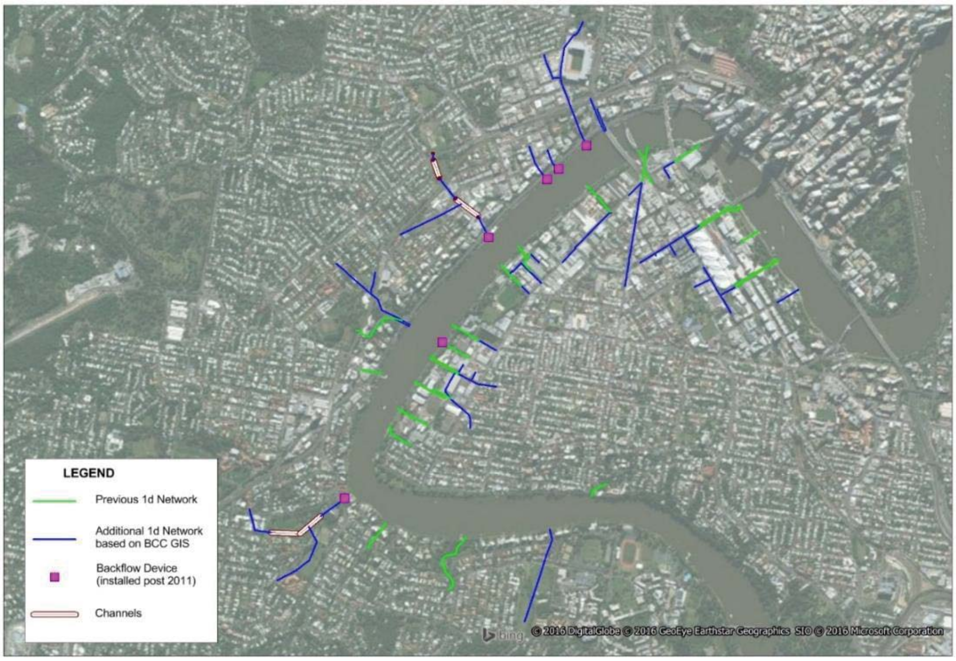


Figure 48: Updated stormwater network and backflow device in the Arup model.

Data provided by BCC also included information about backflow prevention devices (flood gates). Backflow prevention devices were installed after the 2011 flood event along Brisbane River. Data provided by BCC included GIS information showing the location of each backflow device, as-constructed drawings and design drawings. Locations of the backflow devices included:

- 1 outlet in Victoria St in West End (interpreted from the BCC drawings)
- Multiple outlets at Milton (interpreted from the BCC drawings and BCC GIS file for outlet structures)
- 1 outlet at Auchenflower/Milton area (interpreted from site investigations)
- 1 outlet at Gailey Road in St Lucia (interpreted from the BCC website)

It is noted that the backflow device located in the Milton/Auchenflower reach of Brisbane River was not included in any of the available information provided by BCC (refer to Figure 49). Through site investigations, it was found to be an operated gate structure which would be activated during a flood event.

Figure 49: Back and front of flood gate opening located at Milton/Auchenflower.

The backflow devices were represented into the model via the ‘Unidirectional Culvert’ feature in TUFLOW.

The Arup model was updated with the additional pipe and backflow information (refer to Figure 48). Two scenarios were set-up to determine the behaviour during the 2011 flood event (i.e. no backflow devices) and for a current day flood event (i.e. including the backflow devices).

A1.2.7 Roughness Parameters

The roughness values adopted in the Arup model are tabulated in Table 4:

Table 4: Roughness Parameter

TUFLOW Material ID	Roughness	Type
1	0.02	Primarily roadways, carparks and other smooth areas
2	0.03	Primarily Lower Brisbane River
3	0.028	Primarily Main Brisbane River Layer
4	0.040	Primarily Parklands and Reserves
6	0.100	Primarily Commercial and Business areas
7	0.150	Primarily Residential areas
8	0.200	Primarily Commercial and Business areas – zone 1
9	0.250	Primarily Commercial and Business areas – zone 2
10	0.100	Brisbane River Mangroves
13	0.028	Brisbane River 180Degree Bend Layer
30	0.500	Building Footprint
33	0.04	Landing – pop ups and Light Vegetation (Design)

A1.2.8 Arup Model Layout

The Arup TUFLOW model layout is presented in Figure 50 below.

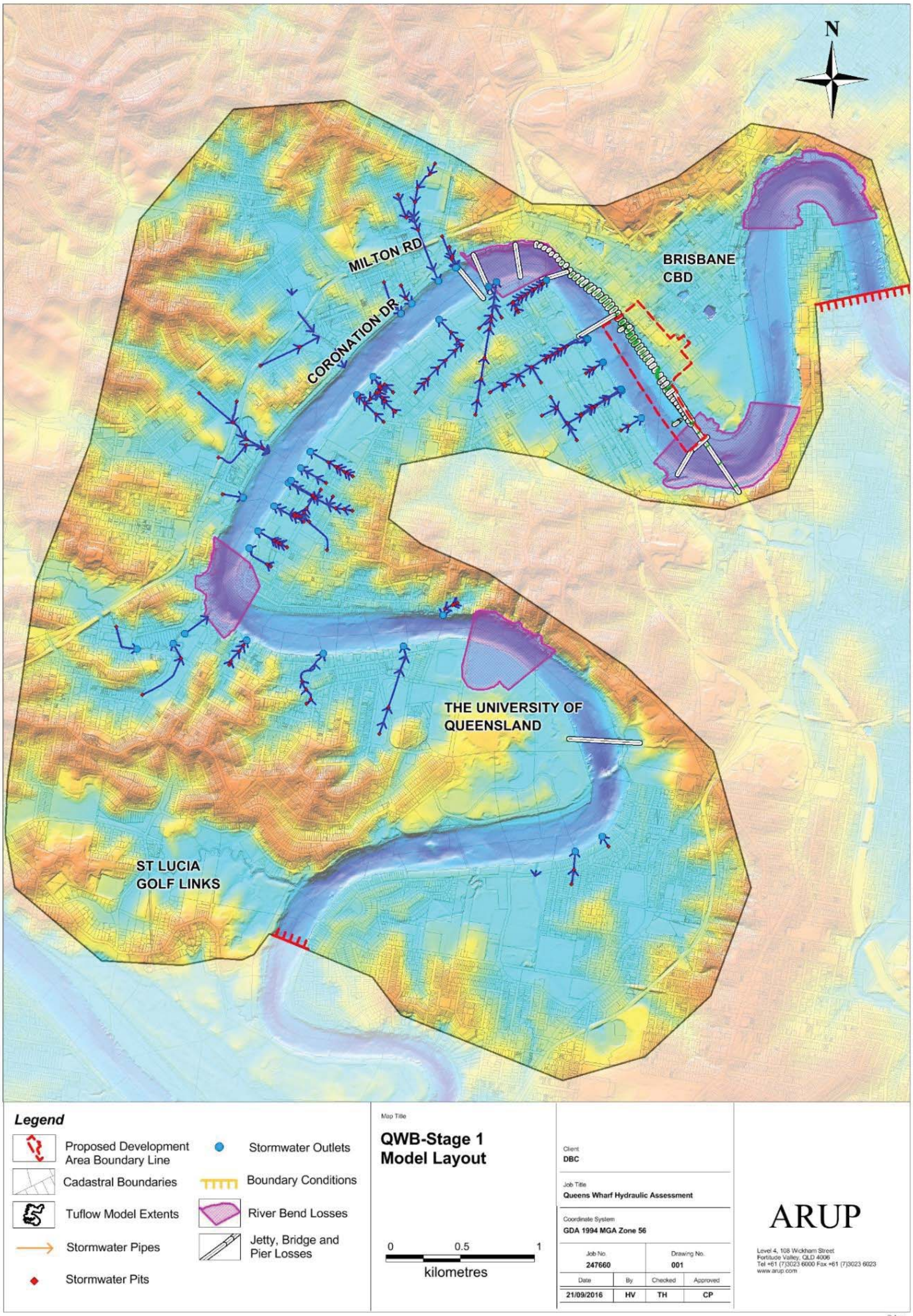


Figure 50: Arup Model Layout

A1.3 Model Calibration

A1.3.1 Flood Marks

The Arup model was calibrated to the January 2011 event. The inflow and associated tailwater boundaries were extracted from the BRCFS model; it was noted that the 2011 BRCFS inflow differs from the previous 2011 inflows setup in the Jemspon's model, which were derived from DTM calibrated TUFLOW model. The difference in peak flow is in the order of 5%, with the BRCFS 2011 inflows being lower.

Given the new inflows, increased model resolution, new survey and hydraulics structures, a re-calibration of the model was required.

Available calibration data included surveyed flood marks provided by the State and a flood extent available for download on the Department of Natural Resources and Mines (DNRM) website. Calibration was achieved by varying the river Manning's 'n' and the additional form loss applied to the bends.

The calibration results are presented in Figure 51 for the 2011 event, showing a good correlation between the model results and the observed flood event. At the surveyed flood marks the model is generally within ± 150 mm, which is considered to be a good calibration given the uncertainty associated with surveyed flood marks. At the IRD building, a ± 50 mm difference was achieved at the closest flood mark. Sensitivity testing has also been performed and the system was found to be not sensitive to refinements in the calibration.

A1.3.2 City Gauge

A good match between recorded and modelled data was achieved at the City Alert gauge as presented in Figure 51 below. The timing of the model replicates well this of the recorded event; the difference in peak flood level is 0.16m at the City Gauge.

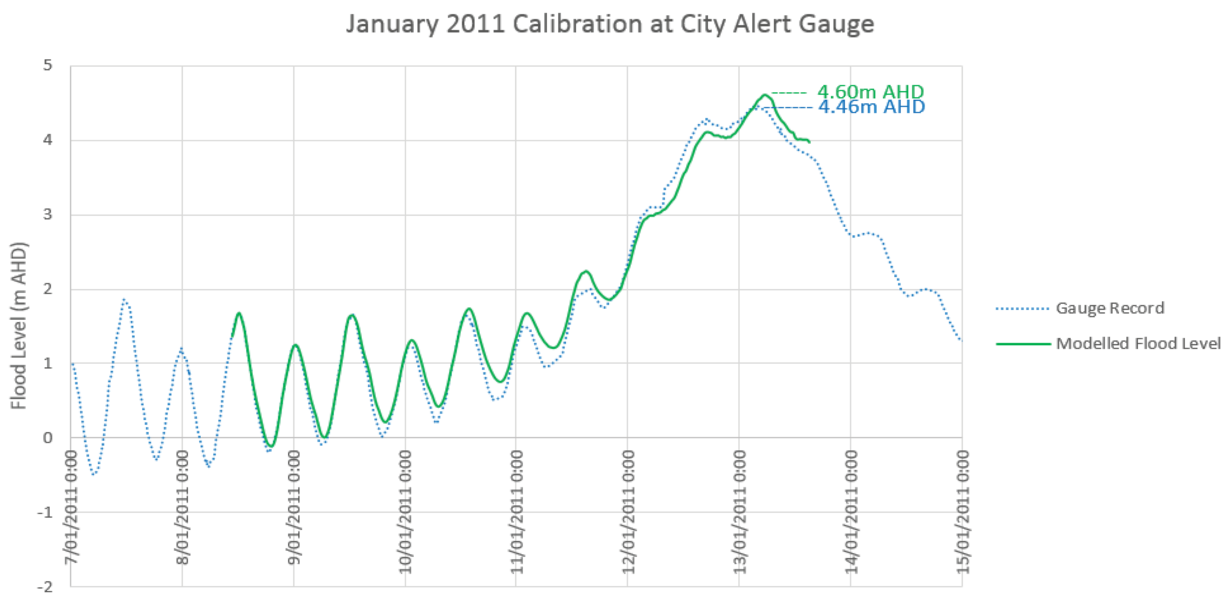


Figure 51: January 2011 Calibration at City Alert Gauge

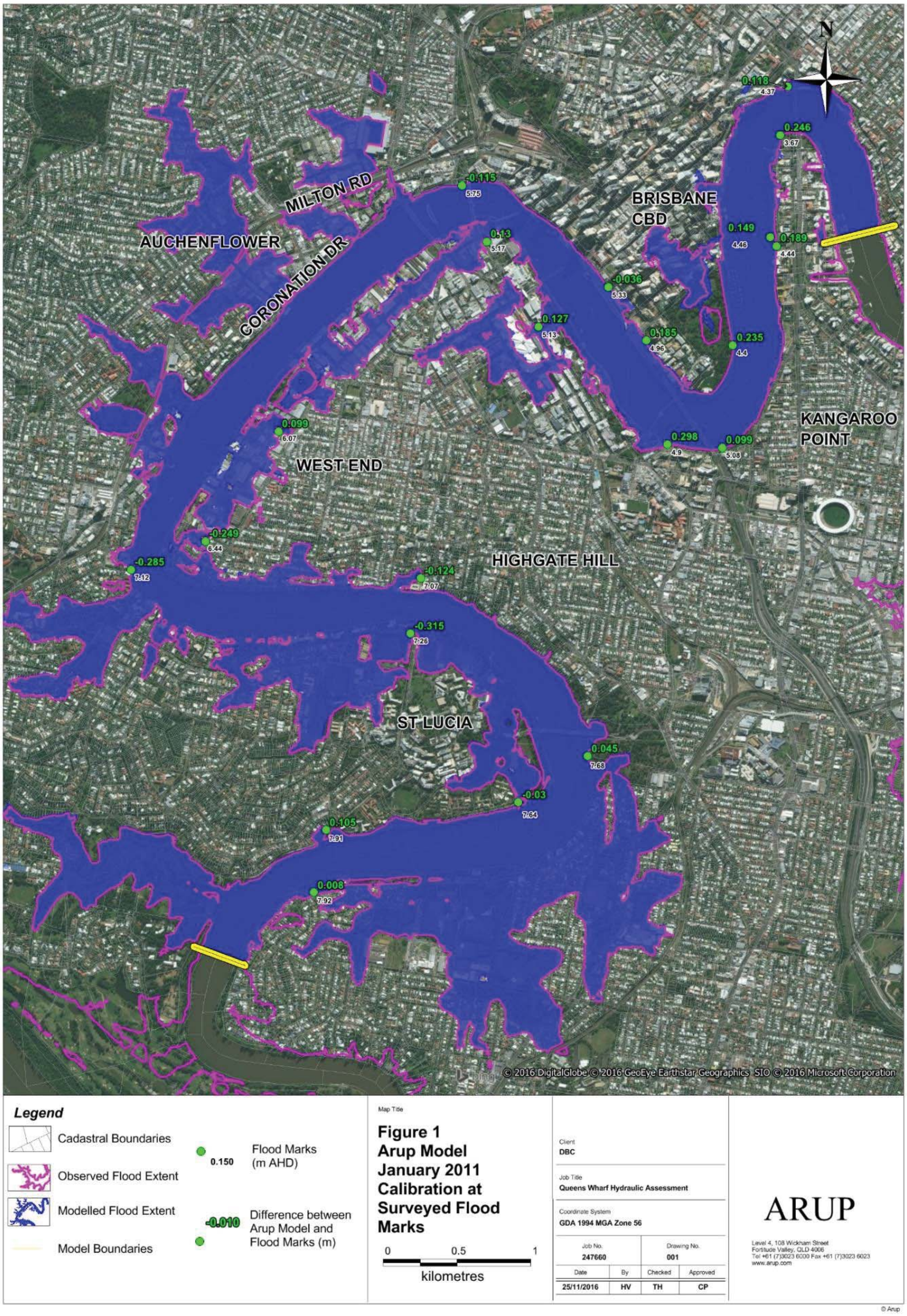


Figure 52: January 2011 Calibration at Flood Marks

A1.4 Hydrology

A1.4.1 Regional and Local Flooding Consideration

The Arup model have been setup for the analysis of riverine flooding only; there is no local flooding input into the model. This is suitable for this study as considered the worst case scenario for QWBIRD flood impact assessment. Any increase in levels from the development that translates in an increase in backup flooding from the drainage network into the floodplain will be identified with this approach; in the case of a combined regional-local flooding, it is anticipated that the impact from the development onto the floodplain would be less than the isolated regional case (in technical terms there would be less allowance for backup due to higher head at the pit inlets).

A1.4.2 Model Boundary Conditions

The 5% AEP, 2% AEP and 1% AEP (respectively 20yr, 50yr and 100yr ARI) design events were setup in the Jempson model based on BCC MIKE21 hydraulic model results of the Brisbane River. The upstream inflows and downstream levels time-series were extracted from the MIKE-21 model and scaled until the model approximated the design flood heights at the precinct.

More recent hydrological inflow data was provided to DBC for this assessment. This data consisted of flow and water level time series, extracted from the BRCFS model. The data represents the latest hydrological data for the following flood events: 5%, 2%, 1% AEP design storm and 2011 modelled flood event. It is noted that these updated boundary conditions supersede those provided in the Jempson Model. These results are subject to change as the BRCFS flood study has not been finalised.

Note: in reviewing the results, it was found that the story bridge location exhibits a strong lateral water surface gradient from left to right bank, in the order of half a metre, which cannot be modelled using a single time varying water level boundary as extracted from the regional BRCFS 1D model. For this reason, the downstream boundary spatial location has been moved 850m downstream to a location of flat lateral water surface gradient. The flood impact generated by the development was compared to this produced in earlier version of the Arup model, where the hydrology was applied at the exact sourced location; the difference in terms of flood impact in the river were generally around 1mm and at a maximum 2mm. Arup attributes this marginal difference to the change in the design and other hydraulic parameters between the two cases compared rather than the downstream boundary location effects, following a review of the flood gradient along the river from the site to the story bridge. This provide confidence that the downstream boundary setup in the Arup model is suitable for the purpose of this assessment and has no influence on it. That is, this assessment results are not sensitive to the downstream boundary levels (i.e. refining the model further in that aspect would not provide any change to the results presented in this report).

A1.4.3 Extreme Events

The Jempson model was not setup for extreme events as no hydrology could be sourced. The extreme events were required at this stage of the QWB development to inform the foreshore design works (i.e. estimate of flood forces, or flood load). For this assessment, preliminary boundary conditions were provided for the 0.2% AEP and the 0.05% AEP (respectively 500yr ARI and 2000yr ARI) extracted from the BRCFS model. These boundary conditions were extracted for the critical duration at the site and the time-series are presented in Figure 53). We note that the critical duration (or envelope of these) differ between the two events. These results are subject to change as the BRCFS flood study has not been finalised.

Note: the GPU solver, or TUFLOW GPU software, has been used to simulate the extreme events to ensure reasonable runtimes. It is noted that the TUFLOW GPU software cannot represent one dimensional elements, however the contribution of these is negligible in extreme events and the approach is therefore suitable.

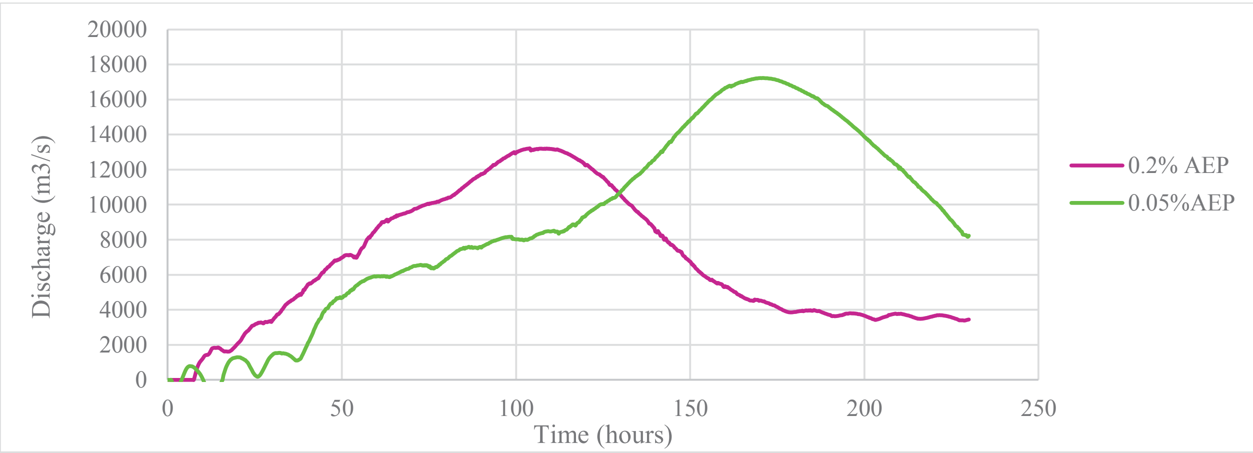


Figure 53: Extreme Events Inflows

A1.4.4 Tidal Event

A tidal event was simulated as part of this assessment as requested by stakeholders. Tailwater time-series were extracted at the Saint Lucia level gauge (applied at the upstream model boundary) and the Brisbane City Gauge and (applied at the downstream Model boundary) from the Bureau of Meteorology website. The record for the Brisbane City Gauge is presented in Figure 54.

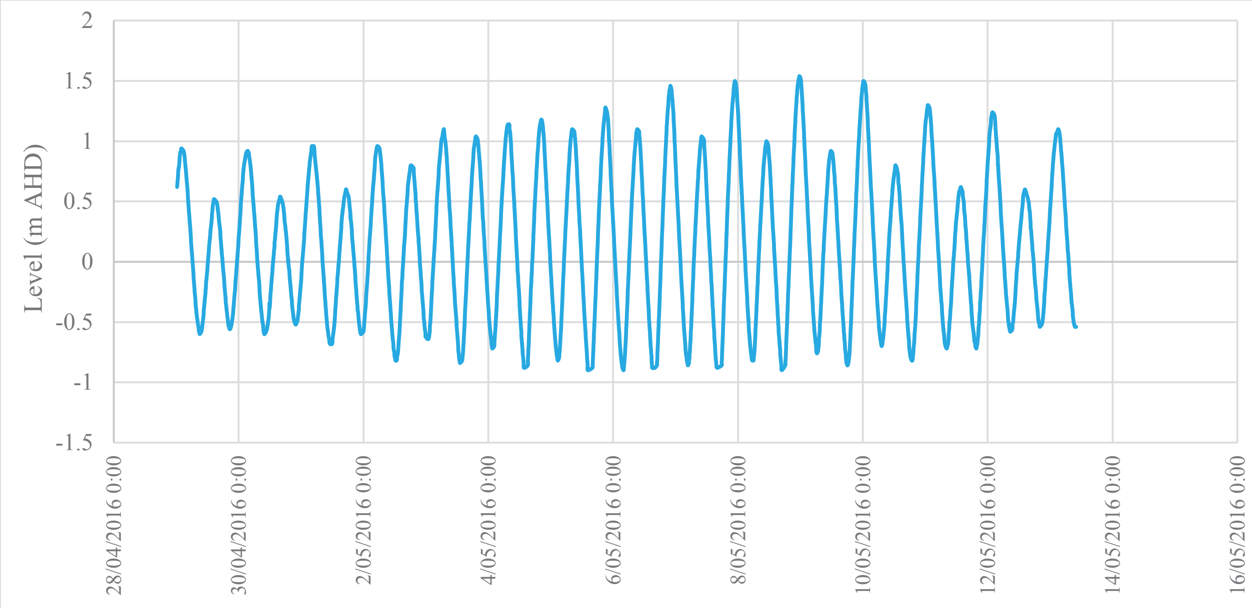


Figure 54: Tidal Event Scenario

It should be noted that this setup may not replicate tidal flows accurately (tailwater time series forcing at both upstream and downstream ends of a model is not industry standard recommended practice). This event has been setup mainly to visualize the varying water level extent under normal conditions (i.e. not during a flood) rather than to assess flood impact. It is recommended that this scenario be simulated using boundaries from a regional model extending from the bay to a non-tidal location of the river.

A1.4.5 Model Events Summary

Table 5: Model Events Summary

Event Nomenclature	Source
5% AEP	BRCFS[8]
2% AEP	BRCFS
1% AEP	BRCFS
0.2% AEP	BRCFS
0.05% AEP	BRCFS
2011[9]	BRCFS
Tidal	Brisbane City Gauge and Saint Lucia Gauge water level records[10]

[8] The BRCFS is ongoing and these inputs were provided as preliminary results
[9] The 2011 event is currently adopted for planning purposes
[10] It is recommended that this scenario be simulated using boundaries from a regional model extending from the bay to a non-tidal location of the river.

A1.5 Resulting Model Performance

A1.5.1 Mass Balance

The Mass Balance remains less than 0.02% for all events. The velocity distribution is presented in Figure 55 and appear realistic. The sand bars (ripples) are well captured by the survey and are reflected in the model results; these should not be interpreted as instabilities.

A1.5.2 Velocity Fields

The sand bars (ripples) are well captured by the survey and are reflected in the model results; these should not be interpreted as instabilities (refer to Section A1.2.3).

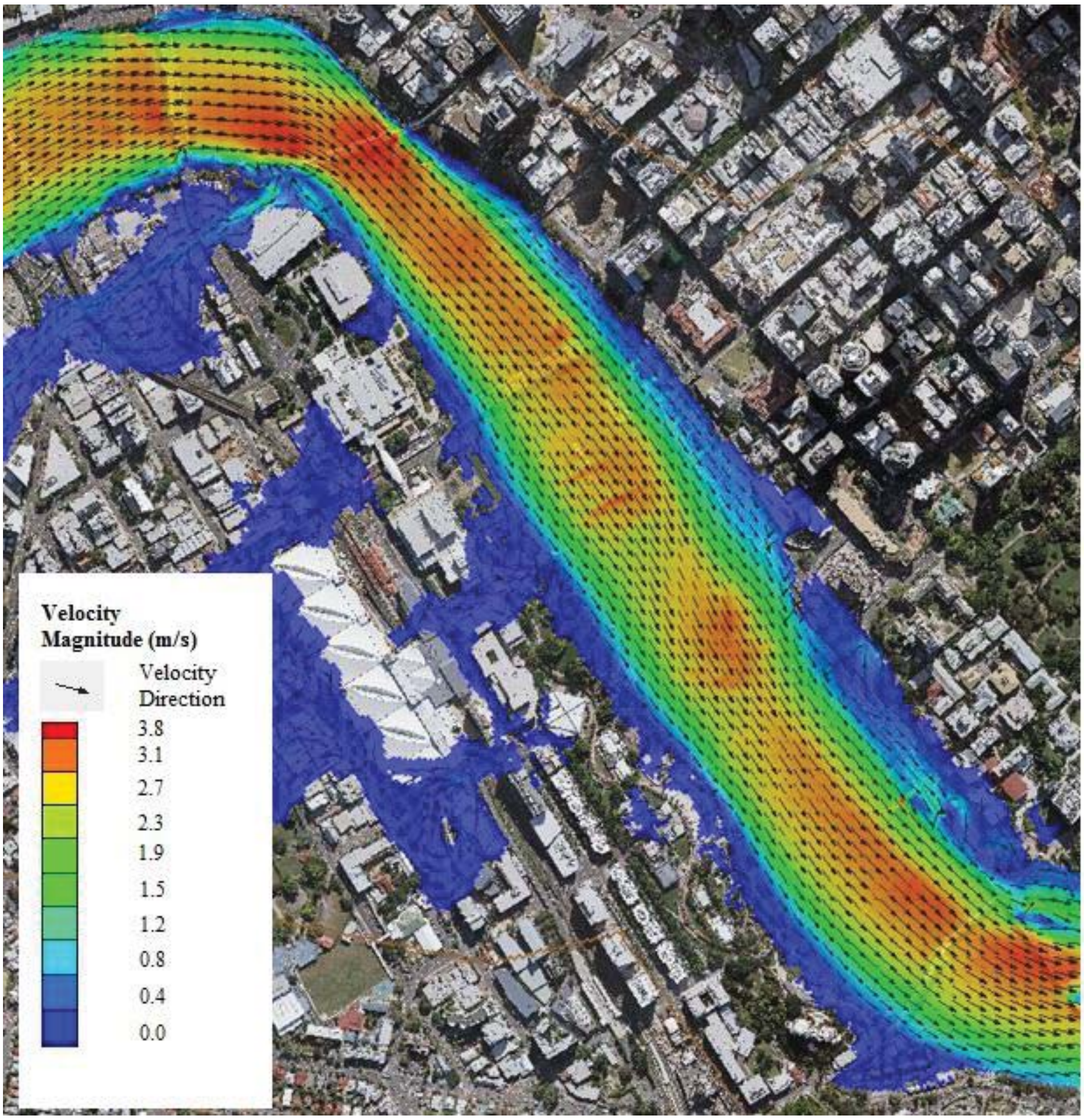


Figure 55: Arup Model Velocity Distribution

A1.6 Representation of the Design

With regards to the hydraulic assessment, only the sub-precincts directly interacting with the Brisbane River and/or with potential to impact on flooding have been represented in the model, namely (refer to Figure 3: QWBIRD sub-precincts

for locality map):

1. Integrated Resort Development (IRD) Precinct:

   a. Resort Sub-Precinct;
   c. North Quay Sub-Precinct;
   d. Queen's Wharf Plaza Sub-Precinct;
   e. The Landing Sub-Precinct;
   g. Goodwill Extension Sub-Precinct;

4. PDA Associated Development

   a. Bridge Sub-Precinct;

QWBIRD was subject to design development throughout this assessment phase. Some of these changes were performed in conjunction with the hydraulic modelling to develop an optimum design that results in minimal flood impact, whilst still maintaining the architectural vision and structural requirements. Only the latest version of the design is presented in this section (i.e. interim design and modelling iterations are not included).

A number of elements are sub-grid scale features of the model. These elements have been incorporated via 'form loss coefficient' to model the energy loss that these structure would incur to the flow. The form loss coefficient for each structure was calculated utilising the method set out in the *Hydraulics of Bridge Waterways, Bradley, 1978*. Particular attention has been given to the representation of these elements, with derivation of form loss coefficient adjusted and adapted to the model grid size and other existing features such as Riverside Expressway and existing jetties.

The latest 2016 release of TUFLOW has been used as it includes a revision of the form loss distribution across the water column, due to the previous approach producing inconsistent results where the bridge was substantially overtopped (drowned out) and the overall energy loss reducing with increasing water depth once the structure is submerged.

A1.6.1 North Quay sub-precinct 1.c

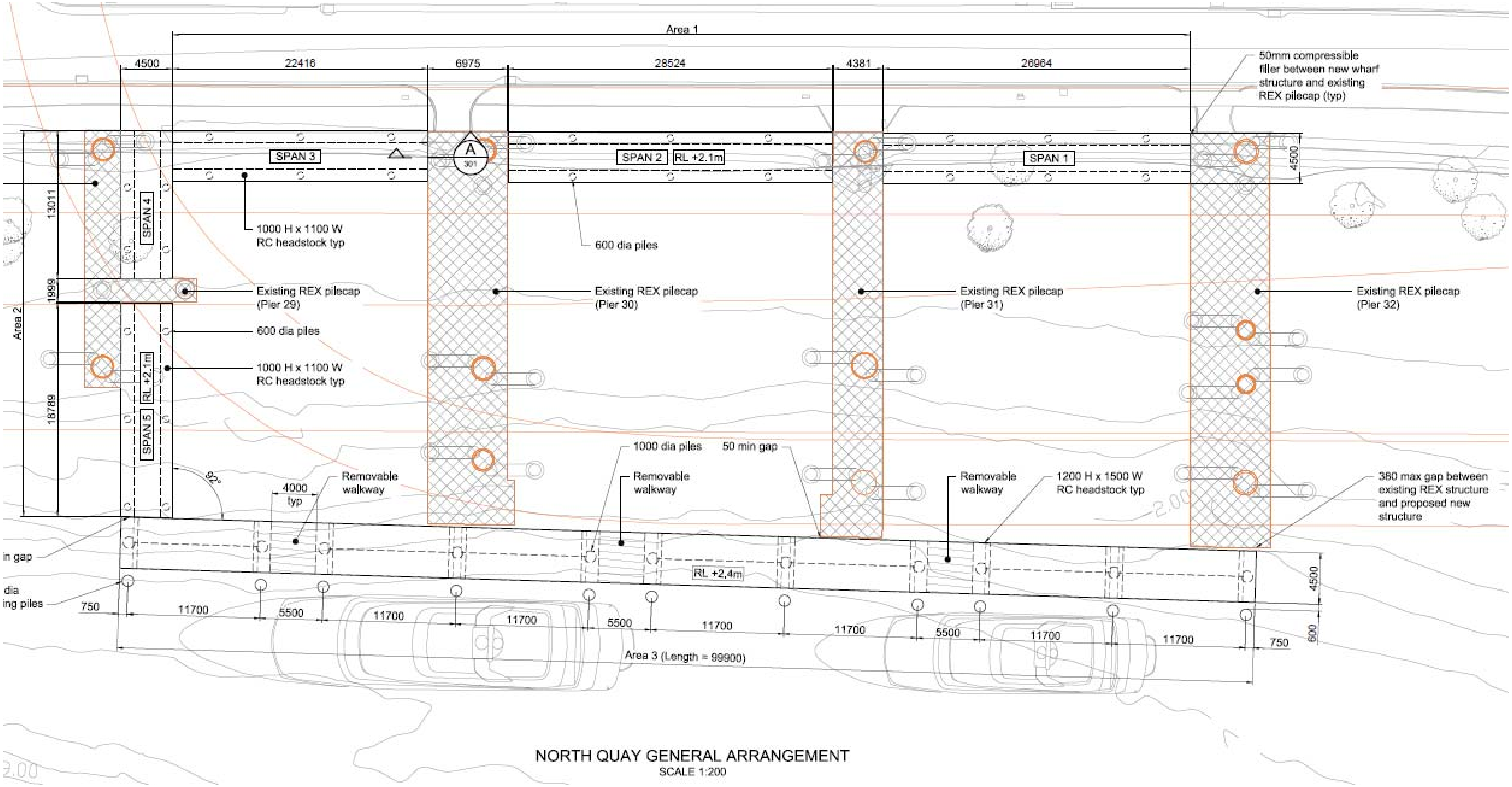
The North Quay precinct consists of two elements:

1. Maritime structures (deck on piles); and
2. Landscaping/extension of the existing Bicentennial Bikeway.

Maritime Structures

The maritime structures generally complement the existing piled deck structures; a plan view of the proposed structures at North Quay and the Cove is shown in

Figure 56 and Figure 57 with cadastre reference.



NORTH QUAY GENERAL ARRANGEMENT

SCALE 1:200

Figure 56: North Quay and the Cove – general arrangement

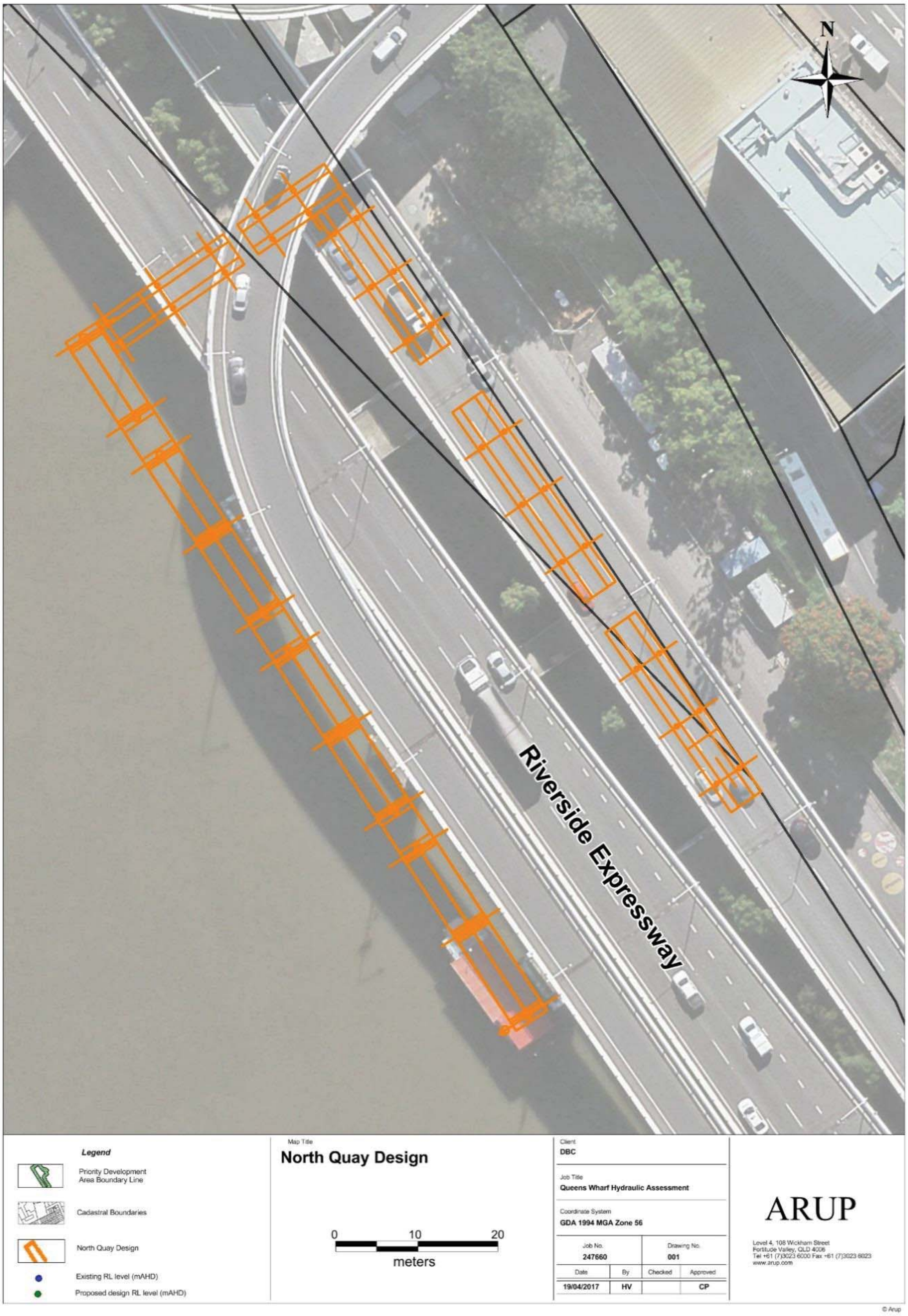


Figure 57: North Quay and the Cove with Cadastre Reference

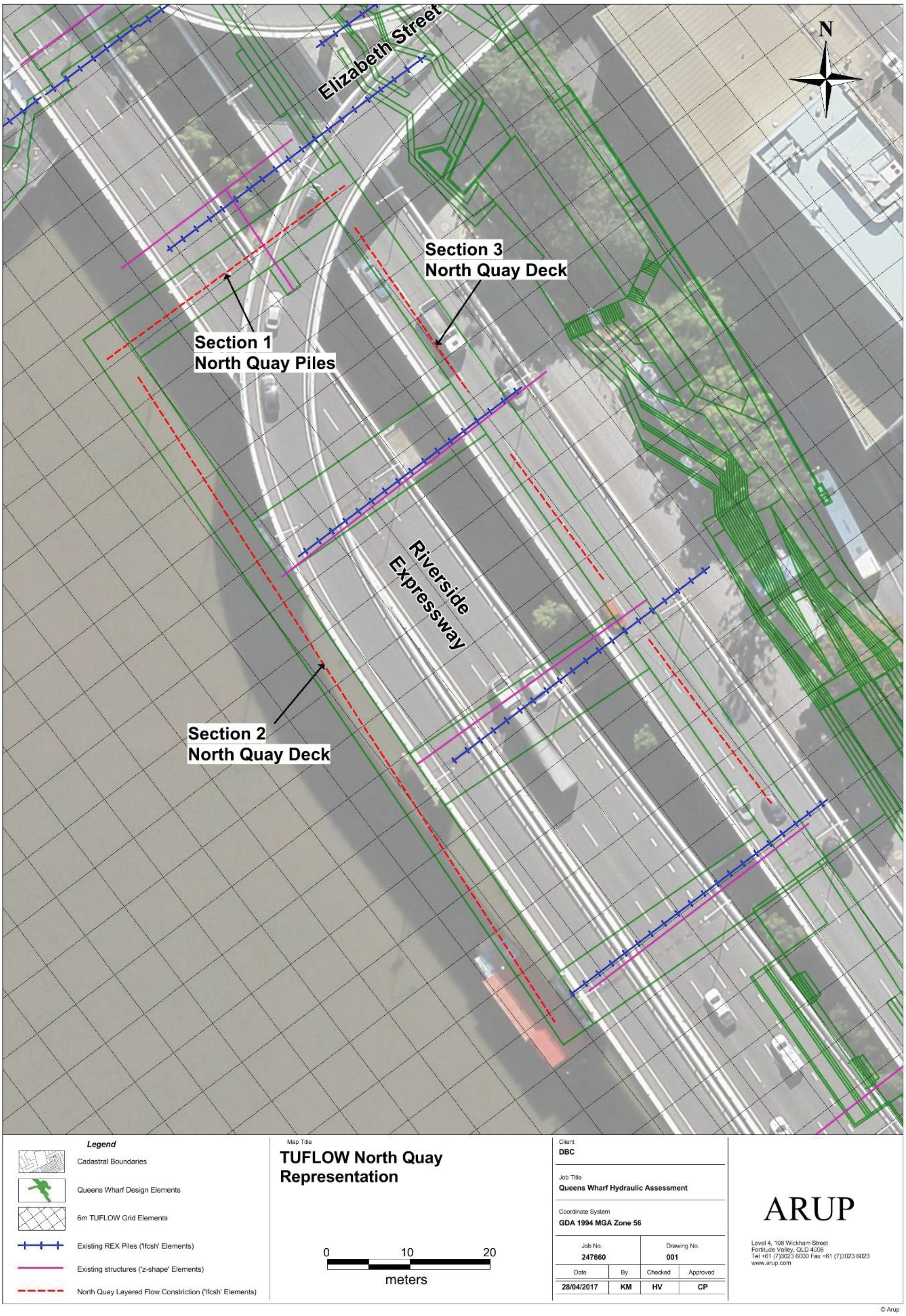


Figure 58: TUFLOW North Quay Representation

The structures have been represented in the TUFLOW model using layered flow constriction shapes ('lfcsh' elements). Figure 58 and Table 6 shows the North Quay representation in TUFLOW and the associated parameters.

A form loss coefficient was calculated for the entire arrangement with piles projected onto the most upstream jetty, based on the method set out in the *Hydraulics of Bridge Waterways, Bradley, 1978*. The partial blockage from the deck and piles has been input into the model for the entire arrangement. Note: sensitivity testing has been performed on increasing the blockage factor at the North Quay marine structures with no observable difference on results; refer to section 4.5.4.

Table 6: North Quay Representation Summary

	Section 1 (refer Fig 50)	**Section 2** (refer Fig 50)	**Section 3** (refer Fig 50)
Deck Soffit Level	0.85 m AHD	0.85 m AHD	0.85 m AHD
Deck Depth	1.25 m	1.25 m	1.25 m
Modelled Pier Losses	0.1	0	0
Modelled Pier Blockage	7%	7%	7%
Modelled Deck Blockage	100%	100%	100%

Topographic Modifications

Design files provided by CUSP landscape architects have been interrogated to develop a 3D surface of the proposed landform. The primary changes to the existing topography are summarised below:

1. The existing revetment wall has been raised to 2.1m AHD and extended further into the Brisbane River (2.4m AHD locally along the northern edge of the North Quay);
2. Some fill has been proposed along the northern edge of the Bicentennial Bikeway corresponding to stairs and landscaping (up to 3m fill).

The resulting Digital Elevation Model (DEM) is shown in

; this was directly input to the TUFLOW model. Refer to Figure 61 to Figure 63 for the DEM in plan and cross-sectional view.

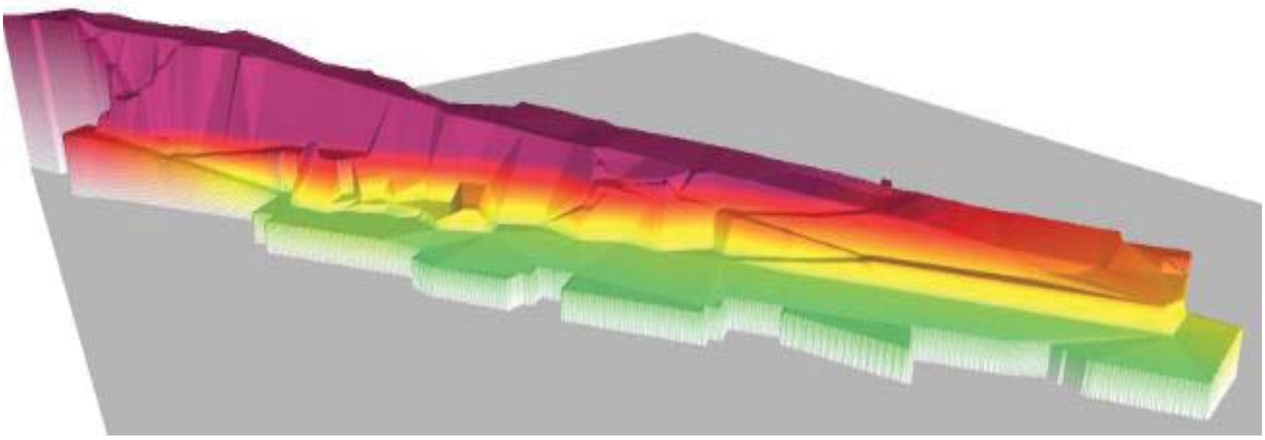


Figure 59: North Quay – DEM

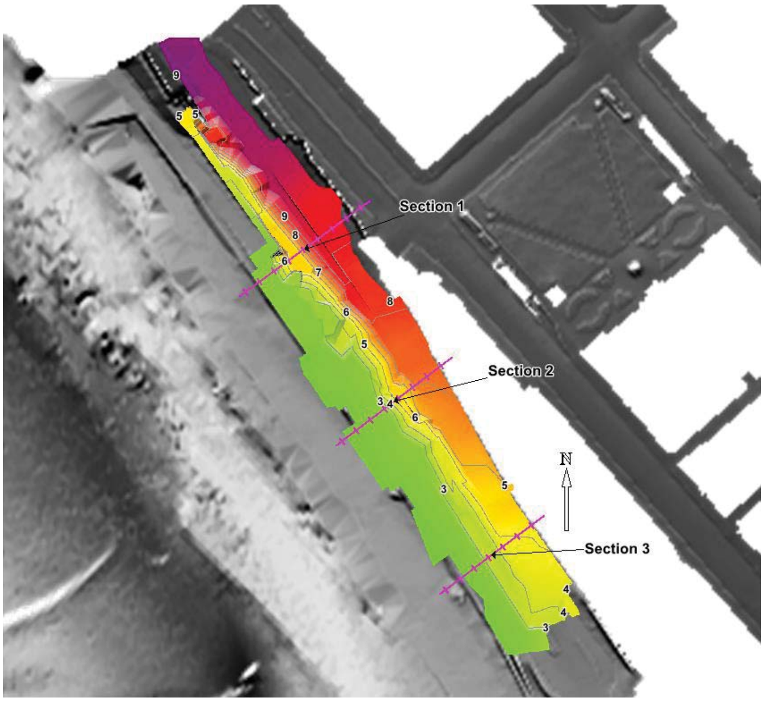


Figure 60: North Quay – Design DEM in plan with 1m contours

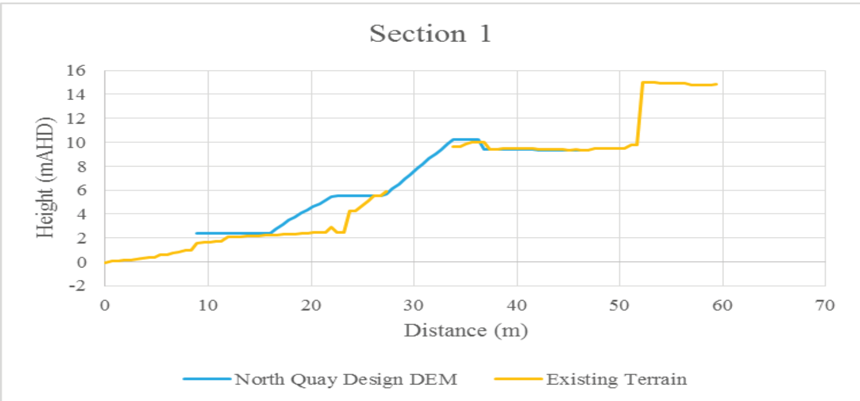


Figure 61: North Quay – Design DEM section 1 view (refer to Figure 60)

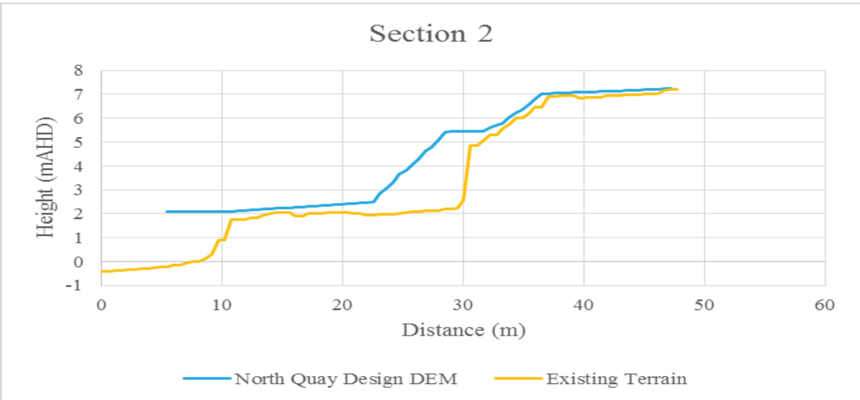


Figure 62: North Quay – Design DEM section 2 view (refer to Figure 60)

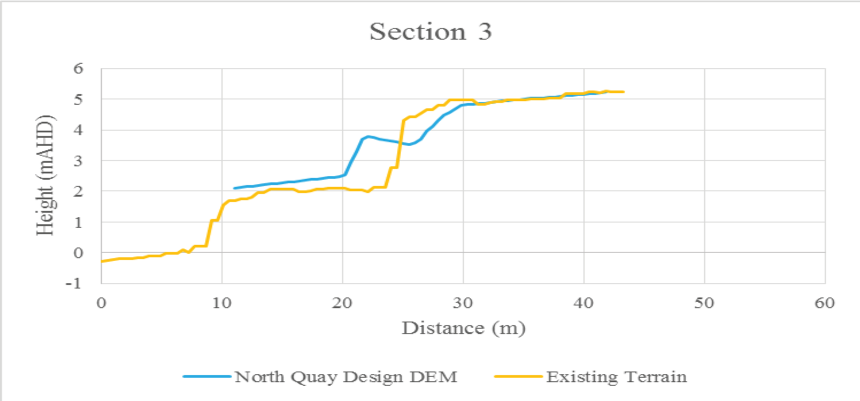


Figure 63: North Quay – Design DEM section 3 view (refer to Figure 60)

A1.6.2 Resort sub-precinct 1.a

The proposed bund and flood gates around the IRD main building have been represented into the flood model as a 'wall' set to a fixed level of 5.9m AHD (via "z-shape" features of the TUFLOW software). This is the current flood resilience measure proposed by Cottee Parker architects for the building, in particular for the utility plant equipment set at the basement.

A1.6.3 Queens Wharf Plaza sub-precinct 1.d

The Queens Wharf Plaza is the public space between the North Quay area and the Landing. The fill associated with Queens Wharf Plaza has been incorporated into the 'Landing' landform representation.

A1.6.4 The Landing sub-precinct 1.e

The Landing design consists of a fill extension of the landform into the Brisbane River. The alignment has been refined as part of this assessment.

Design files provided by CUSP landscape architects have been used to develop a 3D surface of the proposed landform. The primary changes to the existing topography are:

1. Fill extends towards the Brisbane River up to a 50m distance fill;
2. Some high landscaping variation within the landing, up to 3.0mAHD leading to a maximum fill of 5.4m along the banks of the Brisbane River.
3. Final elevation of the landing set up to 2.4mAHD where a vertical revetment wall is proposed;
4. The upstream edge of the landing is a deck structure with a 1 in 4 revetment slope underneath.

The general arrangement of the Landing Design is shown in Figure 64 and Figure 65 The resulting Digital Elevation Model (DEM) is shown in Figure 66 and was directly input to the TUFLOW model. Refer to Figure 67 to Figure 70 for the DEM in plan and cross-sectional view.

A higher roughness was also applied at the landing area to represent the pop-up facilities, from 0.02 Manning's parameter (existing case) to 0.04 (with landing).

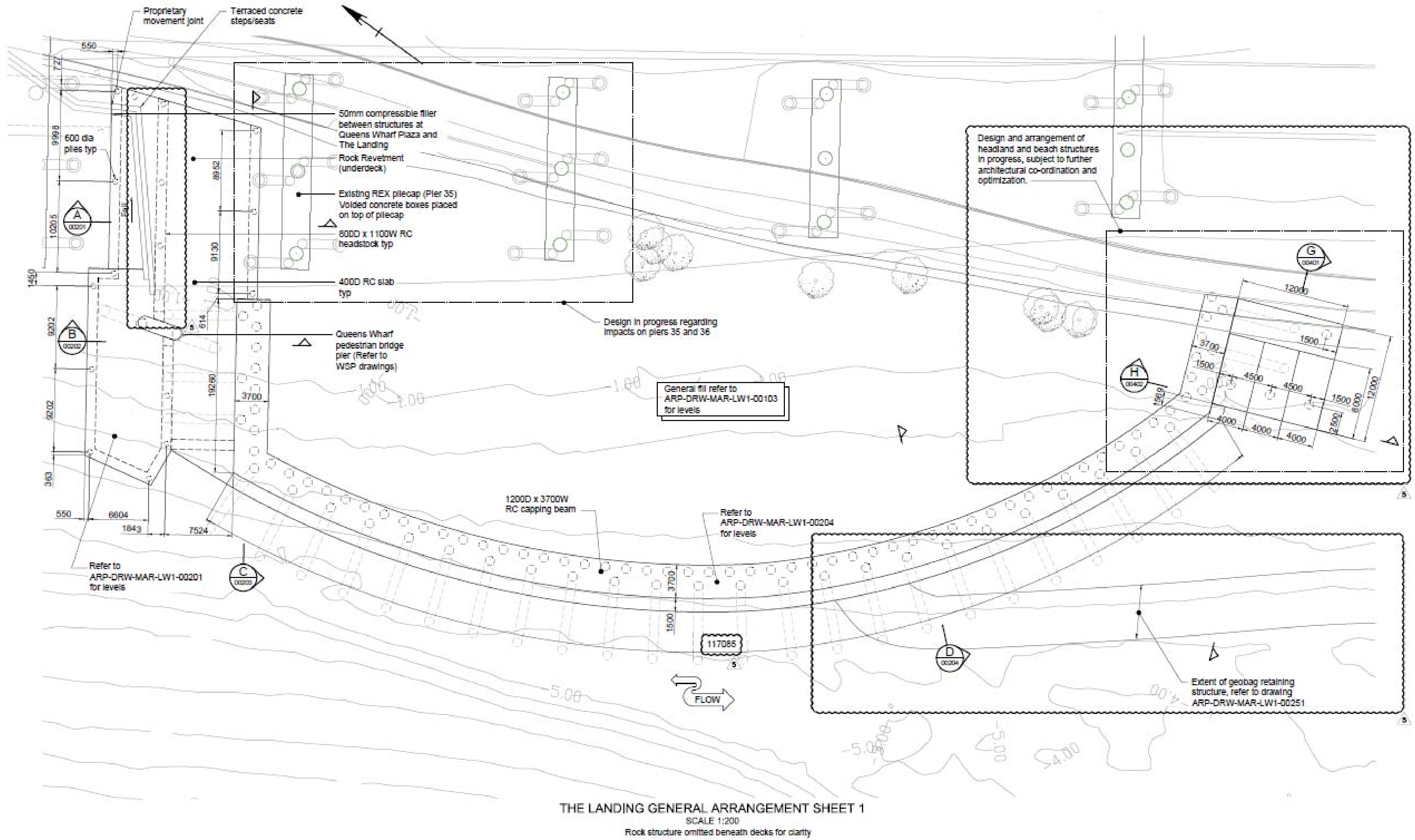


Figure 64: The Landing – General Arrangement

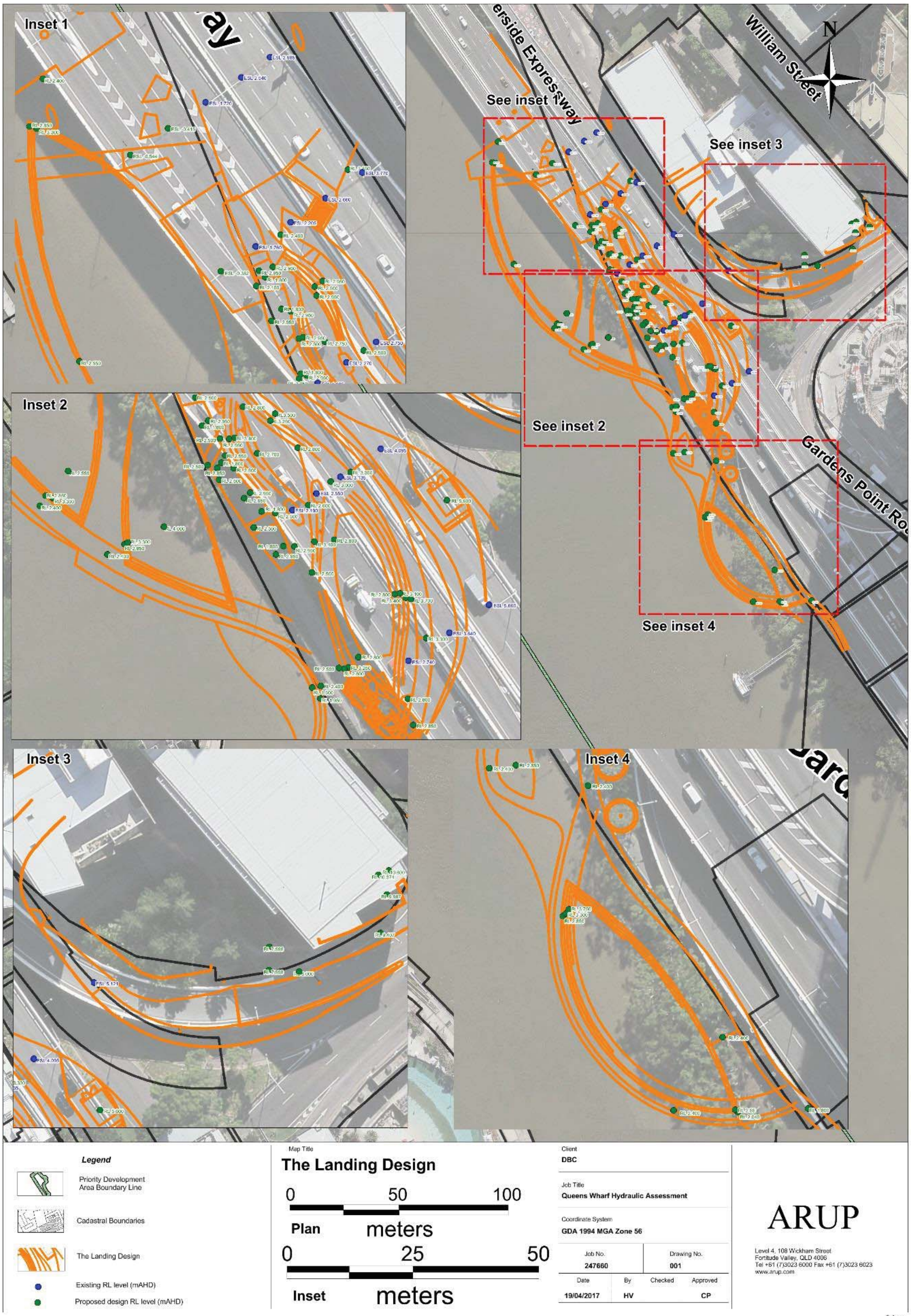


Figure 65: Landing with Cadastre Reference

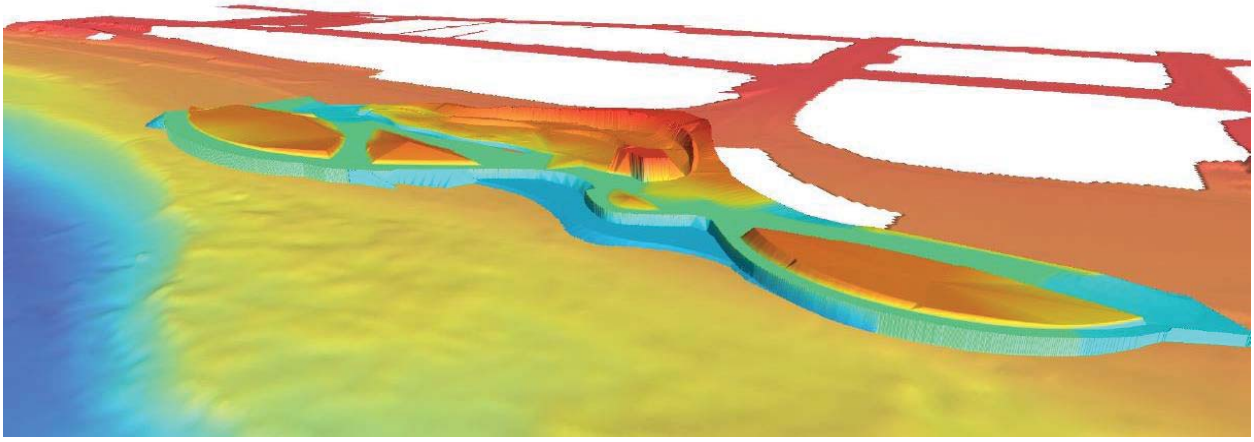


Figure 66: The Landing – Design DEM in 3D view

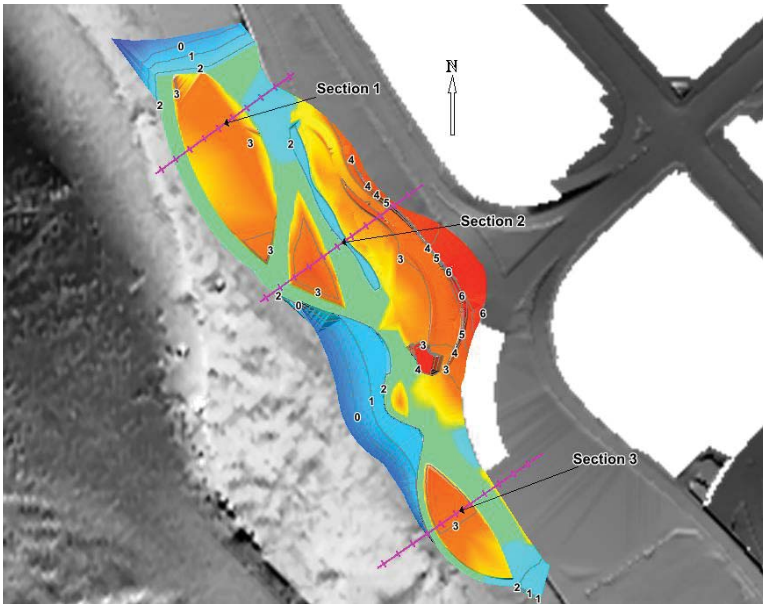


Figure 67: The Landing – Design DEM in plan with 1m contours

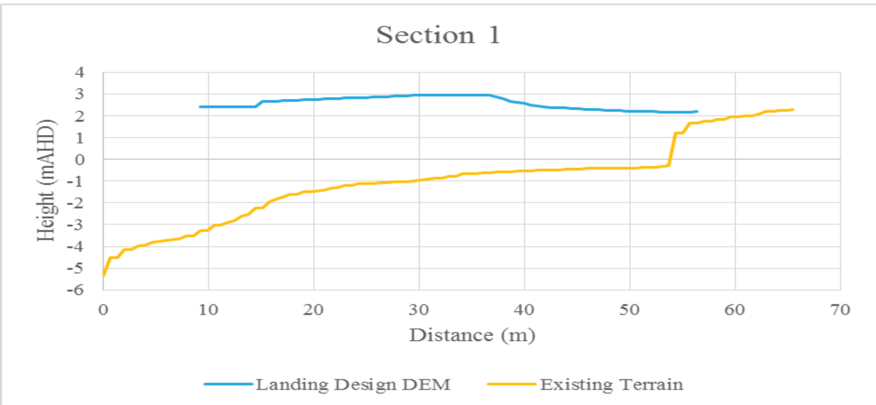


Figure 68: The Landing – Design DEM section 1 view (refer to Figure 67)

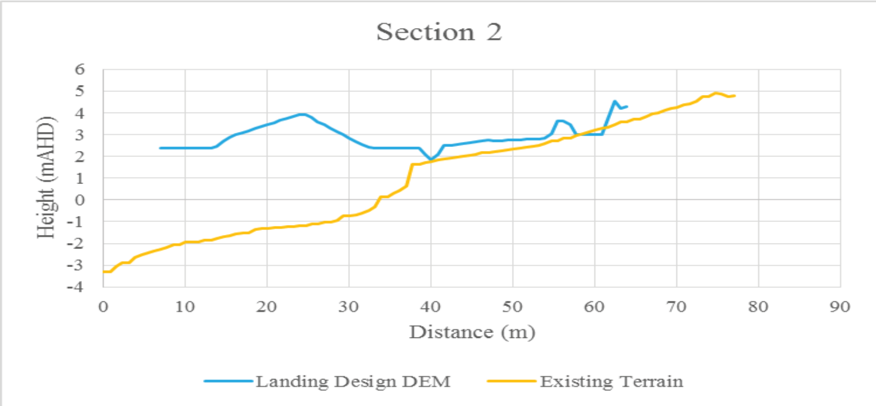


Figure 69: The Landing – Design DEM section 2 view (refer to Figure 67)

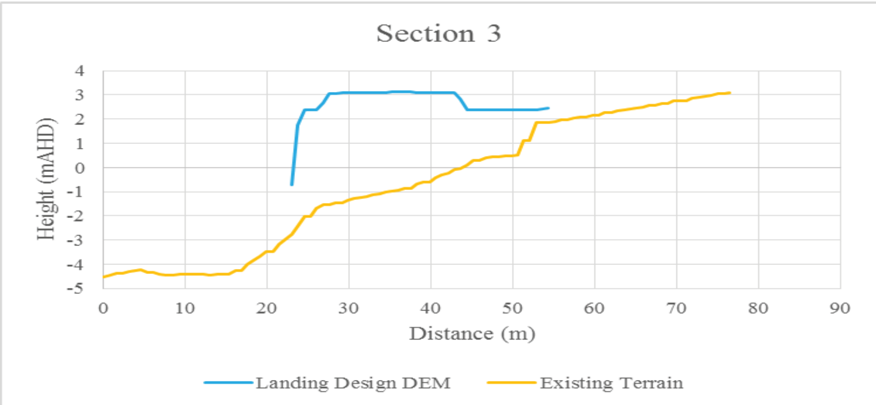


Figure 70: The Landing – Design DEM section 3 view (refer to Figure 67)

A1.6.5 Goodwill Extension Sub-Precinct 1.g

The Goodwill extension design consists of a piled boardwalk structure (precast deck units on piles) along the edge of the Brisbane River, extending from the Landing to Goodwill Bridge, as shown in Figure 71 and Figure 72.

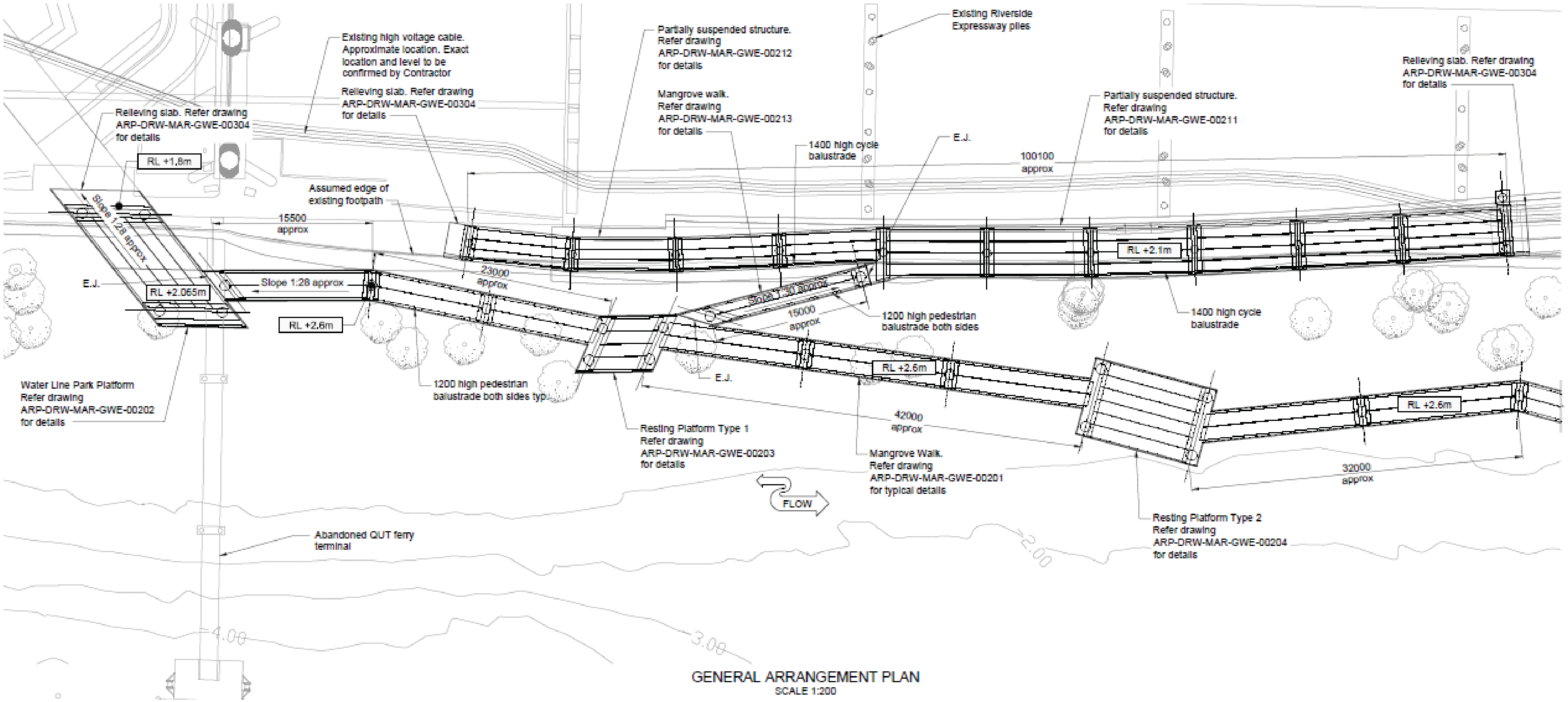


Figure 71: Mangrove Walk - Proposed Design Layout

Figure 72: Mangrove Walk with Cadastre Reference

As with the North Quay Maritime structures, the boardwalk has been represented using a Layered Flow Constriction Shape in TUFLOW. However, its alignment is 'complex' and the theory set out in the *Hydraulics of Bridge Waterways, Bradley, 1978* cannot be applied to the configuration.

Sensitivity testing has been performed on the representation of the boardwalk in the model – refer to A.1.6.7 - and ultimately a nominal form loss coefficient of 0.1 has been applied along the entire boardwalk. The alignment is shown in Figure 73 (in pink), with the TUFLOW 'lfcsh' representation (in blue) and the model grid resolution (in black). The boat house is sub-grid scale of the model and it has been represented via a nominal blockage factor and form loss applied over the entire pedestrian platform. The parameters applied in TUFLOW are shown in Table 7.

Overall the Goodwill Extension has been over-represented in the Arup model to ensure a conservative base for the assessment of impacts.

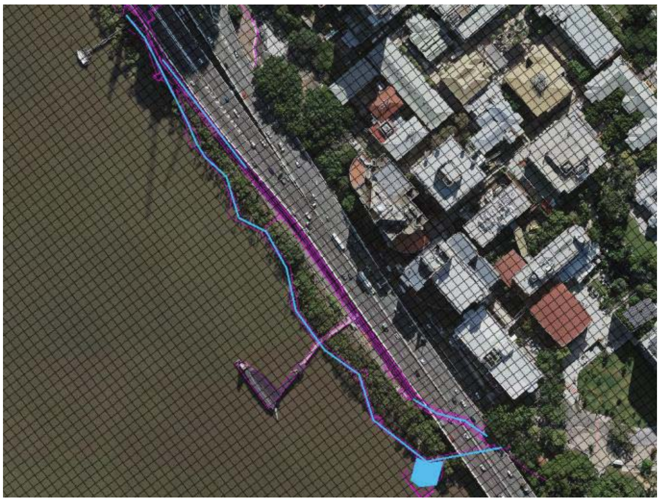


Figure 73: Goodwill Extension Representation

Table 7: Goodwill Extension Representation Summary

	Boardwalk	**Boat House**
Deck Soffit Level	1.88 m AHD	1.88 m AHD
Deck Depth	0.72 m	0.72 m
Modelled Pier Losses	0.1	0
Modelled Pier Blockage	7%	7%
Modelled Deck Blockage	100%	100%

Note: testing has been performed on the Goodwill Extension representation with no noticeable changes in the peak level results (hence flood impact), even in the case where the entire boardwalk is modelled as 'full blockage' via z-shape TUFLOW elements– refer to A.1.6.7. Overall the contribution of the Goodwill extension to the flood impact is negligible (less than 1mm) and considered as 'no impact'.

A1.6.6 Bridge sub-precinct 4.a

The QWBIRD includes a pedestrian bridge from the main tower to south bank. The indicative bridge design is shown in Figure 74.

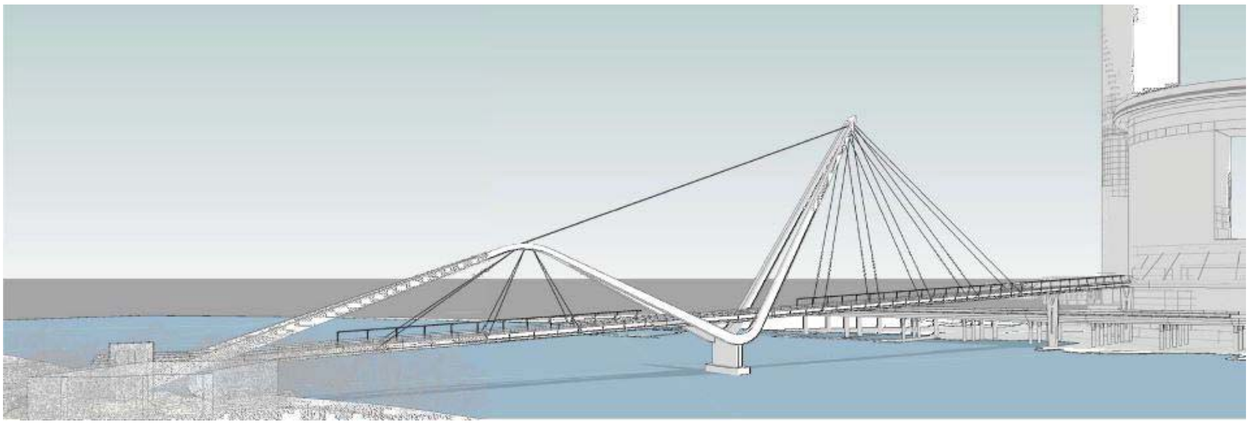


Figure 74: Indicative Pedestrian Bridge Layout

A plan view of the bridge with cadastre reference is presented in Figure 75

The soffit level of this bridge ranges from 27m AHD to 11m AHD at south bank and is well above the 0.05% AEP flood level. Therefore there is no flood impact from the bridge deck and bridge superstructure in all the events modelled as part of this assessment.

The pedestrian bridge in its indicative current configuration will be supported by a central pier which comprises of the following elements:

- Main supporting piles comprising 2 rows of 1.5m width piers, from the river bed level to approximately -1.5 m AHD, aligned with the flow;
- 3m high pile cap aligned with the flow (7.6m diameter); and
- Upper supporting pier, with an 18 degree skewed angle and 2.5m x 14m dimension.

Refer to Figure 76 and Figure 77 for schematic design.

Figure 75: Pedestrian Bridge with Cadastre Reference

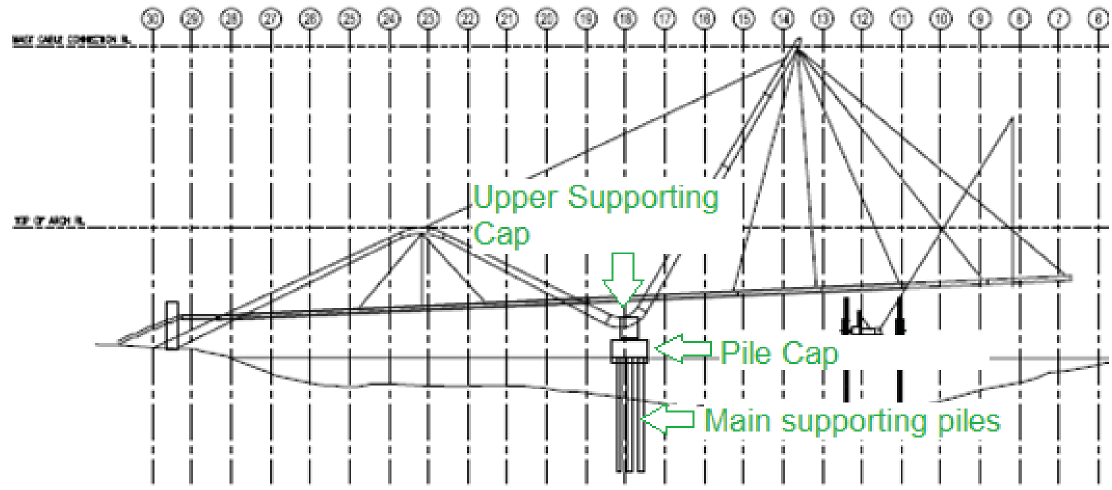


Figure 76: Section view of skewed mid river pile cap (central pier)

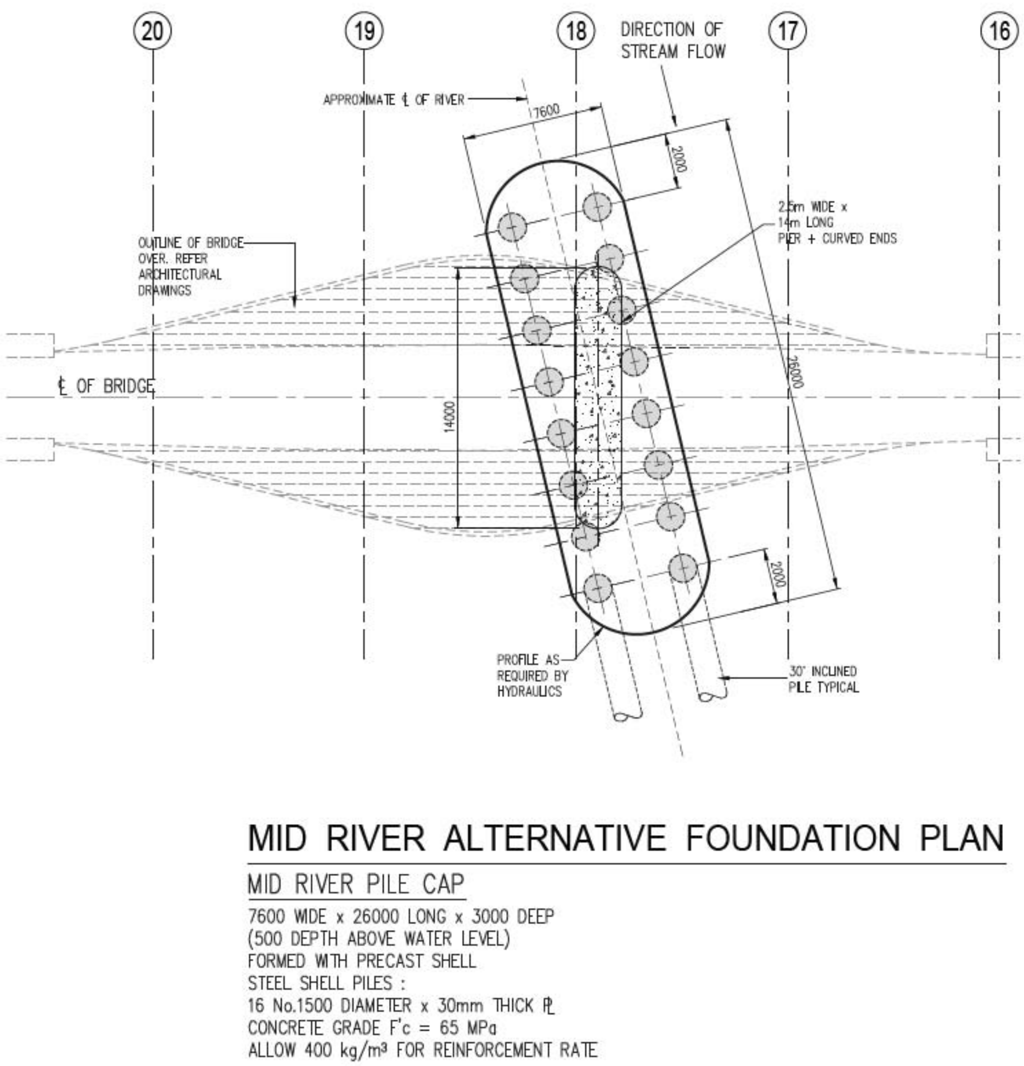


Figure 77: Plan view of skewed mid river pile cap (central pier)

The *Hydraulics of Bridge Waterways* predict an afflux of 9mm from the bridge pier, assuming the contributing loss from each pier element is proportional to its height. Note: this is in line with the default form loss method in TUFLOW in the 2016 release as shown in equation below (extract from 2016 TUFLOW manual):

$$\zeta_{total} = \frac{(y_1\zeta_1 + y_2\zeta_2 + y_3\zeta_3)}{y_{total}}$$

$$y_{total} = y_1 + y_2 + y_3 + y_4$$

$$\zeta_n = \text{Layer n FLC}$$

$$y_n = \text{Layer n water depth (set to zero if dry and cannot exceed depth of layer)}$$

$$\zeta_{total} = \text{Applied overall FLC}$$

The bridge pier has been modelled as a 'lfcsh' element onto the pier location, with the losses scaled to the pier dimension and adjusted to the model grid size. That is, the bridge has not been represented as a singular element across the entire Brisbane River width as would suggest the *Hydraulics of Bridge Waterways* theory. Instead it has been adjusted to replicate the theoretical far field afflux, with higher flood impact produced in the immediate vicinity of the pier, in order to model a more realistic pattern of impact. The percent blockage for each layer has also been applied to the model. A summary of the form loss calculation is presented in Figure 78, with lfcsh inputs highlighted.

Bridge Piles (lfcsh Layer 1)			Pile Cap (lfcsh Layer 2)			Upper pier (lfcsh Layer 3)		
Layer 1 level soffit	-1.5	m AHD	Layer 1 level soffit	1.5	m AHD	Flood Level	5.4	m AHD
Pile Diameter	1.5	m	Pile Diameter	7.6	m	Bottom pier level	1.5	m
Number of piles	2		Number of piles	1		contributing height	3.9	
Bed level	-10.5	m AHD	Bottom cap level	-1.5	m AHD	Length	14	m
Piles Height	9		Contributing height	3		Width	2.5	m
Ap (facing flow)	27.00	m2	Ap (facing flow)	22.80	m2	skew (degree)	18	degree
An2	2060.68	m2	An2	2862.73	m2	length (facing flow)	6.95	
J	0.013		An2 contributing	802.06		Ap (facing flow)	27.12	
ΔKp	0.03		J	0.028		An2	3861.75	
			ΔKp	0.039		An2 contributing	999.02	
						J	0.027	
						ΔKp	0.037	
River section length (at -6 m AHD):	234.3635	m	River section length (at 0m AHD):	261.6151	m	River section length (at 3.45m AHD)	321.5686	m
Grid Size:	6	m	Grid Size:	6	m	Grid Size:	6	m
FLC / grid size in direction of flow	1.1718175		FLC / grid size in direction of flow	1.70049815		FLC / grid size in direction of flow	1.983006367	
length pier	20	m	length pier	26	m	length pier	14	m
No. grid size required:	3		No. grid size required:	3		No. grid size required:	3	
FLC / m length (in direction of flow)	0.065100972		FLC / m length (in direction of flow)	0.094472119		FLC / m length (in direction of flow)	0.11016702	
% Blockage	26.16666667		% Blockage	100		% Blockage	32.40740741	

Figure 78: Pedestrian Bridge Form Loss Calculation Summary

A1.6.7 Mangrove Walk Representation Testing

The Goodwill Extension, or Mangrove walk boardwalk, has initially been represented in the QWB model via Layered Flow Constriction Shape in TUFLOW, using a nominal, high form loss coefficient of 0.1 considering its alignment is 'complex' and the theory set out in "*Hydraulics of Bridge Waterways, Bradley, 1978",* could not be applied to the configuration. The boat house is sub-grid scale of the model and it has been represented via a nominal blockage factor and form loss applied over the entire pedestrian platform.

A sensitivity test has been undertaken whereby the entire boardwalk was modelled as 'full blockage' (i.e. thick wall) via z-shape TUFLOW elements up to deck level, over the entre alignment. The 'thick wall' feature means that the entire grid element, which is 6m wide, is modelled as a wall. A screenshot of the design representation is included in Figure 79.

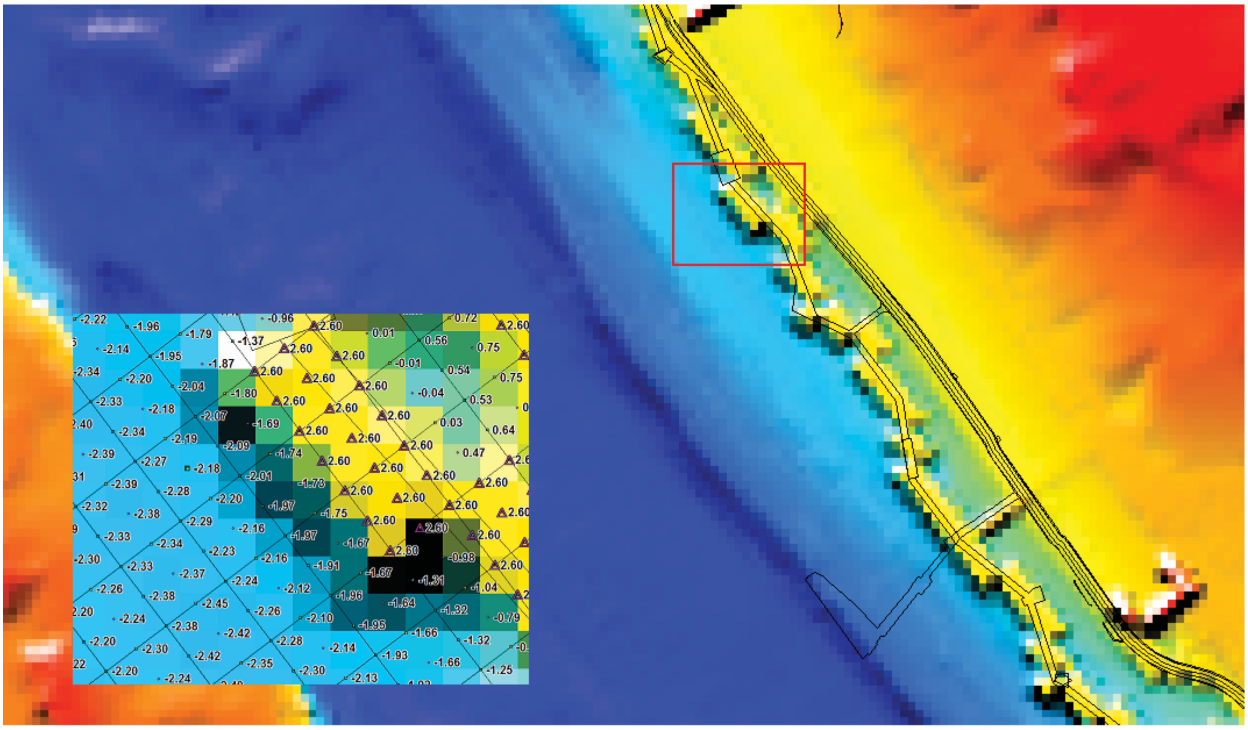


Figure 79: Mangrove Walk, Thick Wall testing representation

Results are presented in Figure 80 as follows. Note that the entire QWBIRD design has been modelled for this testing.

It can be seen from Figure 80 that representing the Mangrove Walk as a 'Thick Wall' does not result in any visible changes in terms of flood impact. In both cases the impact remained highly localised onto the Mangrove Walk. A closer review of the results indicated that the original Arup representation results in a greater impact (in the order of 1 millimetre) than the thick wall representation outside the localised impact area near the boardwalk; this is because the system is more sensitive to form loss factor than it is to blockage factor.

Therefore the approach selected by Arup was deemed conservative and appropriate for this assessment.

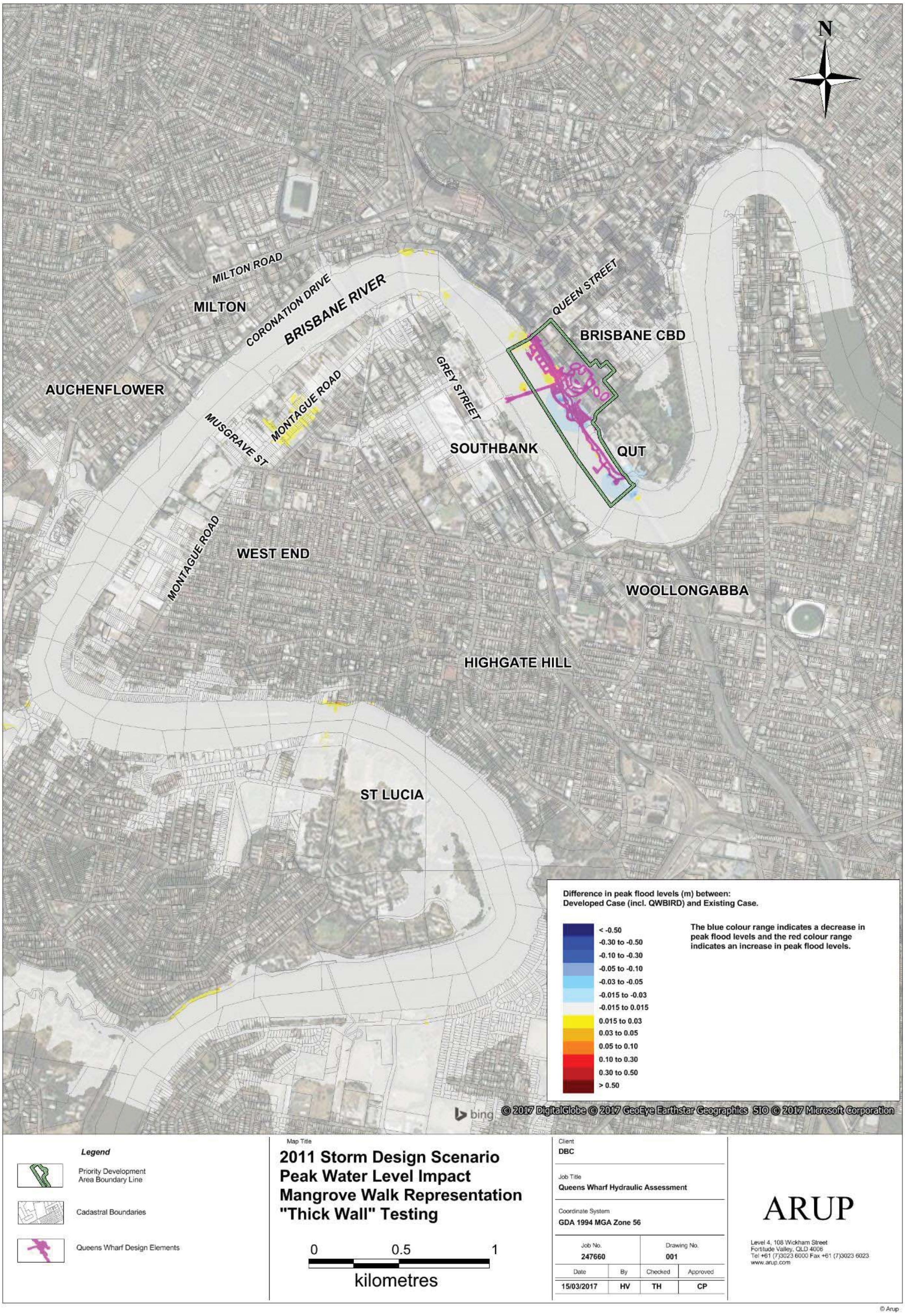


Figure 80: 2011 Design Storm Event – Mangrove Walk Representation “Thick Wall” Testing

A1.7 Numerical Modelling Limitations

The Arup model is a tool developed to assess the impacts from the Queens Wharf development using industry standards and industry best-practice modelling approaches.

When developing conceptual hydraulic models, there is always a degree of simplification required in order to simulate the complex nature of the physical system's behaviour. A model is a representation of a system and may not reflect the exact flood behaviour at all points in time and space that would relate to a given storm event. In particular, the following limitations are noted for the Arup model:

- No representation of the geomorphologic changes in river bed that would occur during a flood
- 2D depth-averaged computation
- Fixed roughness over the entire water column
- Horizontal turbulence approximated using eddy viscosity and vertical turbulence is modelled by the Manning's equation.
- Secondary flows excluded from the model (however these are estimated to be minimal compared to the main flow)
- Limitations in the representation of the QWBIRD design in particular with regards to three-dimensional and sub-grid scale variations (simplifications of design elements therefore apply)

The model developed by Arup for this assessment provides consistent results both in terms of flood impact and hydraulic results for the same design and is it therefore considered fit for purpose.

Appendix B

IRD Floor Plan

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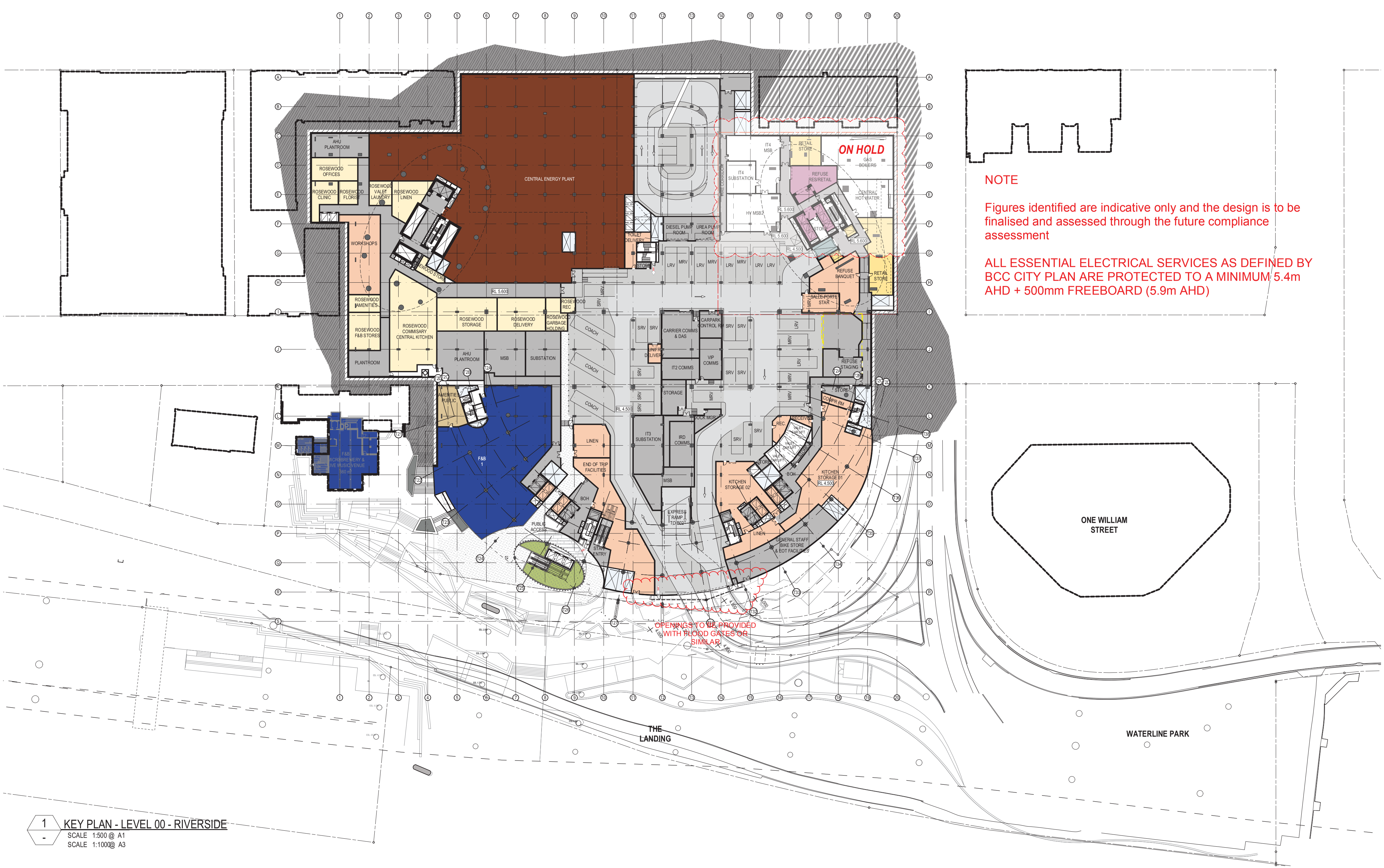

NOTE

Figures identified are indicative only and the design is to be finalised and assessed through the future compliance assessment

ALL ESSENTIAL ELECTRICAL SERVICES AS DEFINED BY BCC CITY PLAN ARE PROTECTED TO A MINIMUM 5.4m AHD + 500mm FREEBOARD (5.9m AHD)

1 KEY PLAN - LEVEL 00 - RIVERSIDE
SCALE 1:500 @ A1
SCALE 1:1000@ A3

CONSULTANT
201 MONTAGUE ROAD
WEST END QLD 4101 AUSTRALIA
TEL +61 7 3846 7422
FAX +61 7 3846 7433
www.cotteeparker.com.au
ABN 77 010 924 106
COTTEE PARKER

KEY PLAN

LEGEND

CLIENT
DESTINATION BRISBANE CONSORTIUM

REV	DESCRIPTION	DRW	CHK	DATE
13	WORK IN PROGRESS	DL	JH	20/09/16
12	WORK IN PROGRESS	DM	JH	09/09/16
11	WORK IN PROGRESS	DL	JH	25/08/16
10	WORK IN PROGRESS	DL	JH	15/07/16
9	WORK IN PROGRESS	SS	JH	05/07/16
8	WORK IN PROGRESS	DM	JH	24/06/16
7	WORK IN PROGRESS	DM	ND	16/06/2016
6	WORK IN PROGRESS	DM	JH	27/05/16
5	WORK IN PROGRESS	DM	JH	17/05/16
4	WORK IN PROGRESS	ZG	ND	06/05/2016
3	WORK IN PROGRESS	TVR	JH	05/05/2016
2	WORK IN PROGRESS	ZG	ND	21/04/2016

PROJECT
QUEENS WHARF BRISBANE
Integrated Resort Development

DRAWING TITLE
IRD - KEY PLAN
LEVEL 00

ISSUE
FOR INFORMATION

PROJECT NO.
4792A

SCALE 1:500 @ A1 1:1000 @ A3
0 10 20 30 40[m]

REVISION
13

DRAWING NO.
CPA-DRW-ARC-IRD-L00-02001

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Appendix C

IRD Flood Protection Strategy

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FLOODCONTROL INTERNATIONAL

DEMOUNTABLE BARRIERS

Demountable barriers are engineered to provide similar levels of protection to permanent flood defences, but with the distinct advantage of being fully removable when not required. They comprise aluminium panels that are inserted into steel channels. Bespoke clamps compress specialist seals to create a reliable barrier against flood water.

These barriers can be supplied for virtually any configuration including arcs, closed rectangles or circles and straight runs of any length. The system can be used on slopes up to 20° and can be stepped for steeper gradients. Each system is load calculated based on application and the prevailing flood conditions and can be configured for flood depths up to 4m. A four-sided detail is available for openings that may become fully submerged.

To facilitate installation in new builds, we can supply preformed ground plates with integral anchors for the demountable supports. The systems can be also retrospectively fitted to suitable existing foundations in which case load certified, chemically fixed sleeve anchors are used to attach the demountable supports.

This leaves only stainless steel bolt blanks at each post location. Due to the strength of our beams, this can be at 3m spacing.

Purpose designed seals that resist silt clogging and reform even after prolonged compression, together with vandal resistant covers and lockable clamps, make these systems ideal for locations where semi-permanent installation is a requirement.

The modular design facilitates storage and transportation and the ergonomically positioned carrying handles enable all but the higher systems to be erected without the need for mechanical lifting equipment.

Fully removable flush-finish perimeter defences - flood depths up to 4m, ideal for wide area defences.

USES

- Single building apertures.
- Openings in flood walls.
- Stainless / aluminium system for marine environments.
- Fully removable perimeter defence to buildings.
- A 'usually stored' system for erection when flood warnings received.

BENEFITS

- Low cost system.
- Lightweight - sections allow safe lifting of 3m beams by one person for rapid deployment.
- Flexibility – can be configured to any geometry.
- High strength – single beams can span up to 3m unsupported. Spans up to 6.5m possible with optional back-braces.
- Choice of bottom seals - allow barriers to sit on existing non-porous surfaces.
- Completely removable - leaving a totally flat ground surface.
- Vandal resistant - covers and padlockable clamps available.
- Able to be powder coated to any RAL colour.
- Long life - using galvanized and aluminium components.

FLOODCONTROL INTERNATIONAL

SIZES

- Unsupported spans possible up to 3m.
- Maximum spans of up to 6.5m possible with back bracing.
- Standard maximum flood control height of 4m, using 300mm standard beams.
- Beam weights of 8kg/m allow safe single person lifting of 2.5m beams.

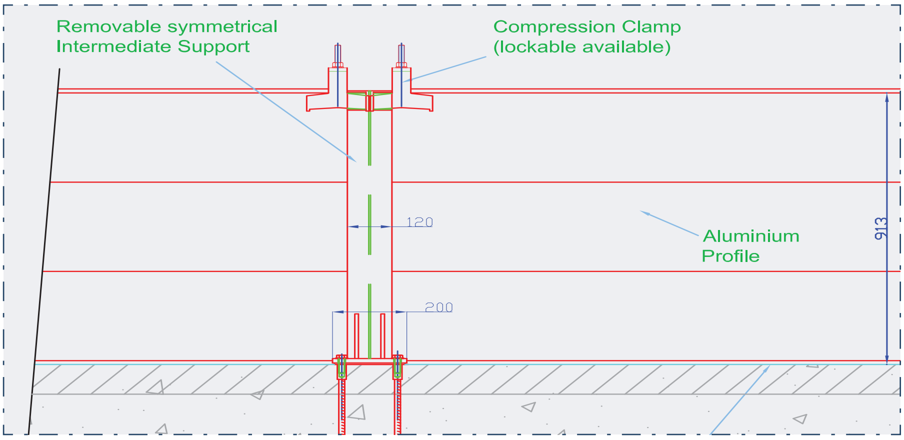
CONFIGURATIONS

- Any length or layout is achievable.
- Posts and beams can be tailored for any gradient.
- Posts can accommodate steps and changes in direction.

INSTALLATION

- End posts can be surface mounted or recess mounted. Architectural coverplates can be applied to match building finishes.
- Intermediate posts require RC beam foundation. This can be under final surfacing finish with drilled in stainless steel sockets, or with cast in baseplates.
- Systems can be retrospectively fitted to any suitable foundation.
- Every system is bespoke designed using CAD and drawings provided.

BESPOKE CAD DRAWINGS



Appendix D

Hydraulic Parameters

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Figure 1: Location of data points for the design of foreshore structures

Table 1: Current Flood Study Flood Velocities + 15% Increase

Point	Flood Velocities (m/s) - Current Flood Study + 15% - ADOPTED IN DESIGN						
	20YR ARI	50YR ARI	100YR ARI	2011	500YR ARI	2000YR ARI	
A	0.9	1.5	2.0	2.0	2.5	3.1	Goodwill Extension
B	1.3	2.0	2.5	2.5	3.2	4.0	
C	1.7	2.3	3.0	2.9	3.8	4.6	
D	0.3	0.7	1.2	1.2	1.3	2.2	
E0	0.8	1.0	1.2	1.2	2.1	3.3	North Quay
F	0.3	0.6	0.7	0.7	0.8	2.1	
X	0.7	0.9	1.0	1.0	1.5	2.9	
H	0.9	1.4	1.6	1.5	2.4	3.7	The Landing
I	0.8	1.2	1.8	1.8	2.9	4.0	
J	0.2	0.3	0.9	0.9	2.4	3.5	
K	0.3	0.9	1.6	1.6	2.3	3.3	
L	0.3	1.3	2.0	2.0	3.0	3.9	
BR1	2.2	2.8	3.3	3.2	3.9	4.0	Bridge Pier

Table 2: Current Flood Study Flood Levels

Point	Flood Level (m AHD) - Revised Flood Study - ADOPTED IN DESIGN						
	20YR ARI	50YR ARI	100YR ARI	2011	500YR ARI	2000YR ARI	
A	2.5	3.6	5.0	5.1	8.1	10.9	Goodwill Extension
B	2.4	3.6	4.9	5.0	7.9	10.8	
C	2.4	3.5	4.9	4.9	7.8	10.7	
D	2.4	3.5	4.9	4.9	7.8	10.7	
E	2.5	3.8	5.2	5.3	8.2	11.2	North Quay
F	2.5	3.8	5.2	5.3	8.3	11.3	
X	2.5	3.8	5.2	5.3	8.2	11.2	
H	2.5	3.7	5.2	5.2	8.2	11.2	The Landing
I	2.5	3.7	5.1	5.2	8.2	11.1	
J	2.5	3.7	5.1	5.2	8.1	11.1	
K	2.5	3.7	5.1	5.2	8.1	11.0	
L	2.5	3.8	5.1	5.1	8.2	11.2	
BR1	2.5	3.8	5.2	5.2	8.2	11.1	Bridge Pier

Note: It is noted that the 2011 flood level is 5.3m AHD in the latest model developed by Arup instead of 5.4m AHD previously advised. In practice the flood levels fluctuate around 5.35m AHD depending on the model parameterisation (this is the level of the closest flood mark captured in 2011). As results are rounded to the nearest 0.1m, this results in either 5.3m AHD or 5.4m AHD. For this reason, Arup previously recommended a flood level of 5.4m AHD for the IRD to ensure there would be no increase the other way around (i.e. from 5.3m AHD to 5.4m AHD) which has been adopted in the design.

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DESTINATION
BRISBANE
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