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Sydney Opera House Trust

Bennelong Drain Diversion Project

Hydrology and Drainage Assessment

January 2010

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Introduction

1.1 Purpose of this report

The Sydney Opera House Trust is proposing to divert the Bennelong Drain to a new route discharging at Farm Cove (referred to as 'the project' for the purposes of this document).

This report has been prepared by GHD Pty Ltd (GHD) as part of the environmental assessment of the project. The Sydney Opera House Trust is the proponent of the project, and the environmental assessment is being prepared by GHD in accordance with the requirements of Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

This report assesses the potential impacts of the project on hydrology and drainage.

1.2 Outline of the project

The project involves the construction of a new section of drain from the point where the Bennelong Drain enters the Sydney Opera House site, adjacent to the air intake structure for the Sydney Opera House car park. The Sydney Opera House Car Park is a separate entity owned by the State Property Authority and leased by the Trust Company of Australia.

The new section of drain would run in an easterly direction close to the Tarpeian Wall, around the southern side of the exhaust air shaft for the Sydney Opera House car park, extending to the proposed discharge point at Farm Cove.

Further details of the project are provided in Section 3.

1.3 Location of project

The site for the project is located within the forecourt area of Sydney Opera House, at the northern end of the Sydney CBD, on Bennelong Point. Bennelong Point is located between Sydney Cove and Farm Cove, both of which form part of Sydney Harbour. The project is located within the City of Sydney local government area (LGA).

The forecourt area is situated to the south of Sydney Opera House, between the Monumental Steps and the Tarpeian Wall.

The proposed outlet or discharge point for the proposed new section of drain would be located within the seawall at Farm Cove, immediately above the sea bed between the Royal Botanic Gardens Queen Elizabeth II gate and the Man O' War jetty.

The site location is shown in Figure 1-1.

1.4 Scope and structure of report

This report assesses the hydrological and drainage behaviour of the site under existing and proposed development conditions. Mitigation measures are also recommended, where necessary, to minimise any potential adverse impacts. The scope of work includes the following:

- Site visit and field reconnaissance;

- Consultation with Sydney Water Corporation (Sydney Water) as the owner of the asset;
- Collate and review available mapping data, including contour, cadastral, topographic and aerial photographs;
- Collate and review data from past studies, including Warren Smith and Partners (2005) design drawings, Sydney Water reports, catchment and drainage maps of the upstream drainage system, details of structures, pits and pipes, and flooding hotspots if known;
- Review available data on design and ocean water levels at Farm Cove;
- Review design criteria adopted for preliminary drainage design;
- Develop hydrology and stormwater drainage model of proposed diversion drain;
- Generate rainfall intensity frequency duration data for catchment, in accordance with Australian Rainfall and Runoff (1998);
- Estimate stormwater design inflows at strategic locations for 4 AEP (annual exceedance probability) design storm events;
- Assess hydraulic behaviour of proposed drainage system, taking into account catchment inflows, ocean water levels, flood and erosion potential;
- Interpret modelling results, including flow behaviour, diversion drain and outlet velocities, scouring potential, structures affected, storage capacities, and operational constraints;
- Estimate potential sediment yield in Bennelong Drain catchment. This involved discussions with Sydney Water;
- Assess sediment entrainment and sediment deposition characteristics at Bennelong Drain outlet;
- Provide recommendations for design; and
- Reporting.

The existing drainage system is briefly described in Section 2. In Section 3, the project is described. This is followed by an assessment of the potential impacts of the project in Section 4. The summary and recommendations are presented in Section 5.

Figure 1-1: Location of key site features and surrounds

2. Existing Drainage System

The Bennelong Drain catchment has an area of approximately 72 ha. It is bounded by Clarence Street to the west, Bathurst Street to the south, Macquarie Street to the east, and Sydney Harbour to the north (Figure 2-1).

The existing drainage system consists of a series of drains aligned in a north-south direction within the Sydney CBD area. Stormwater runoff generally flows in a northerly direction through these stormwater drains, until it reaches Alfred Street at Circular Quay.

At Alfred Street, the drainage system branches into three outlets. The primary outlet is the Bennelong Drain, which veers in a north-east direction towards Bennelong Point. This drain is rectangular in shape (3.05m wide by 1.22m high) and discharges into Sydney Harbour.

Two smaller drains also drain the catchment at Alfred Street, one at Loftus and the other at Philips Street. Both these drains have smaller capacities and overflow at Circular Quay directly into Sydney Cove.

Based on information provided by Sydney Water (City Drainage Area 29, Capacity Assessment, September 1996), it is estimated that the Bennelong Drain has a capacity of between the 12 to 15 year ARI storm event. By comparison, the Philips Street drain only has a capacity of between the 1 to 2 year ARI event, while the Loftus Street has a capacity of between the 0.5 to 1 year ARI event.

As noted earlier, discussions with Sydney Water indicated that a sediment sump presently exists in the drainage line discharging to the Bennelong Drain. It is understood that the amount of sediment collected in the sump has not been significant. Consultation with Sydney Water also indicated that there are no plans to upgrade the capacity of the existing stormwater drainage system upstream of the site.

Landuse within the catchment comprises of Commercial and Business Areas (78.2%), Open Space (18%), and Special Uses (3.8%). Overall, the catchment is estimated to have an impervious fraction of 86%.

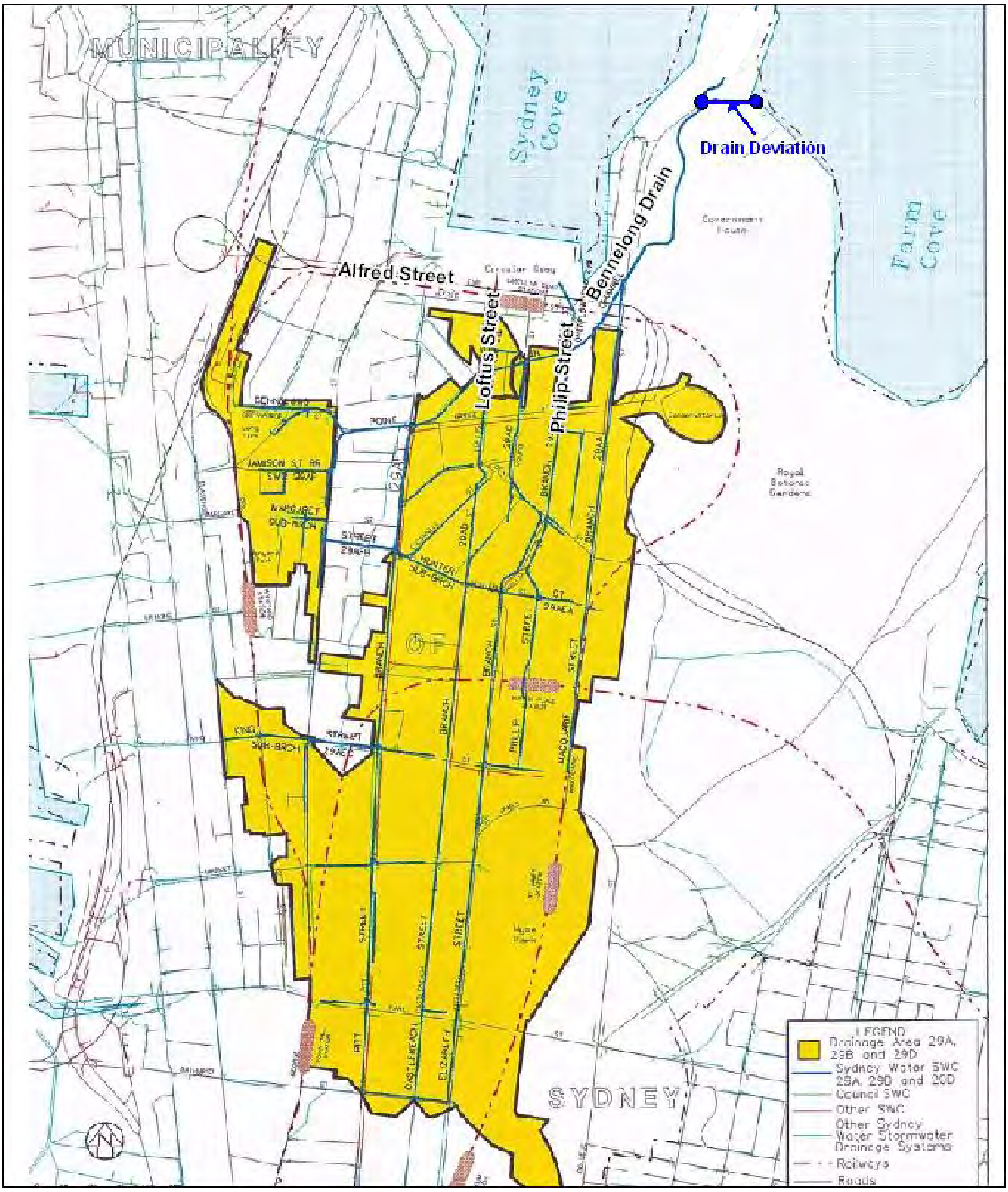


Figure 2-1: Bennelong Drain catchment

3. Proposed Drainage Works

3.1 Overview of the project

The following section describes the project which consists of a diversion drain discharging to the east to Farm Cove, with a capacity and outlet similar to that of the existing drain.

The existing Bennelong drain (3.05m wide x 1.22m high) has an open outlet, with no tidal gate to control backwater up along the drainage system during storm surges and elevated ocean water level conditions.

The proposed diversion drain (2.4m wide x 1.8m high) is similar to the existing drain, with an open outlet and no tidal gate. In terms of flow area capacity, the proposed drain is slightly larger, at $4.3m^2$, relative to the existing drain capacity of $3.7m^2$. These design parameters have been discussed with and agreed to by Sydney Water Corporation as the owner of the asset.

3.2 Need for the project

Sydney Opera House Trust proposes to divert the Bennelong Drain from its current route to a new route under the Sydney Opera House forecourt. At its current location, the drain discharges to Sydney Harbour. The proposed new discharge point would be to Farm Cove. The principal drivers for the project are discussed below and relate to future strategic building plan directions and operational flexibility.

The diversion of the drain is in line with its strategic building plan and would result in greater operational flexibility for future projects that are planned within the forecourt and beneath Sydney Opera House. Although these future projects are yet to be fully defined, they may include:

- The provision of a new loading dock area and associated access ramp. This would separate heavy vehicle deliveries from busy pedestrian areas and would increase public safety. It would also avoid the need for heavy vehicles to use the western and northern boardwalks; and
- New corridors and lifts to provide better access between different parts of Sydney Opera House.

Future projects such as these are likely to substantially improve the functionality of Sydney Opera House, but would not be able to proceed if the Bennelong Drain remains in its current position. As such, these projects would be contingent upon realignment of the Bennelong Drain.

3.3 New section of drain

The new section of drain would be a box culvert measuring approximately 1.5 m wide by 1.5 m high (internal dimensions) or 1.8 m wide by 1.9 m high (external dimensions) at the junction point, increasing to approximately 2.4 m wide by 1.8 m high (internal dimensions) or 2.7 m wide by 2.2 m high (external dimensions) along the majority of the diversion route. The drain would be constructed using prefabricated sections of concrete box culvert. A 4.39 m deep pit would be constructed at the junction between the existing drain and the new section of drain. The junction pit would include a cover to enable access for maintenance. The access cover would be located within a narrow strip of feature garden located at the southern extreme of the Sydney Opera House site against the base of the Tarpeian Wall. The new section of drain would be approximately 106 m long.

An area of approximately 8 m by 8 m would need to be excavated around the proposed new junction to construct and install the required infrastructure. Excavation would also be required along the route of the proposed diversion. The width and depth of the excavation would vary and would generally be between 2 m - 3.2 m wide to enable the drain to be installed.

An approximately 8 m long section of the original Bennelong Drain would need to be removed to allow construction of the junction between the Bennelong Drain and the new section.

The existing section of drain between the diversion point and at the obsolete outlet would be blocked off.

The location of the alignment is shown on Figure 3-1.

3.4 Outlet

The discharge point for the new section of box culvert drain would be located within the seawall at Farm Cove, immediately above the sea bed between the Royal Botanic Gardens Queen Elizabeth II gate and the Man O' War Jetty. The discharge point would involve a new outlet through the seawall approximately 2.4 m wide by 1.8 m high (internal dimensions), 2.7 m wide by 2.2 m high (external dimensions).

The majority of the outlet would be visible above the mean sea level, which in this location would be approximately 0.38 m above the bottom of the culvert. The mean high water level would be 0.93 m above the bottom, which means that just under half of the outlet would be visible at high tide.

The drain would be lined with sandstone to match the existing fabric of the seawall to approximately 1-1.5 m from the outlet.

3.5 Options considered during development of the project

The following section outlines options that were considered during development of the project, including:

- The do nothing option;
- Alignments;
- Design capacities;
- A flap valve at the outlet; and
- The need for sediment control.

3.5.1 Do nothing option

The do nothing option would involve leaving the existing alignment. This option is not considered appropriate as the existing alignment presents a site constraint that reduces the flexibility to accommodate future projects or developments at the site. This option does not align with the Strategic Building Plan directions for Sydney Opera House.

3.5.2 Alignment

Alignment to the west

Consideration was given to realigning the Bennelong drain to enter Sydney Cove to the west of Sydney Opera House. This option was rejected due to potential conflicts with existing infrastructure such as

Sydney Harbour Tunnel, carpark entrance and facilities including kitchens, air conditioning plant and sea water intake and boardwalk along the lower concourse. It may also conflict with future developments that may be undertaken in this area, such as the potential construction of a truck ramp to provide access to a new loading dock.

Alignment to the east (preferred option)

The preferred option is to realign the drain to the east so that it discharges into Farm Cove. Realigning the drain to the east was considered the preferred option as it avoids the potential conflicts with existing infrastructure. It also minimises conflicts with possible future projects that may occur within the Sydney Opera House precinct.

A route that winds south around the car park air vent was chosen. This was due to the route north of the air vent has a greater impact on existing in ground services. It was also observed that the area south of the air vent provides a more open marine area for the stormwater discharge compared to the area north of the air vent which is situated in a sheltered area between the seawall and the Man O'War steps.

3.5.3 Design capacity

The existing Bennelong Drain has capacity to accommodate a 10 year ARI storm event, and consideration was given to increasing this design capacity to accommodate larger events. Discussions with Sydney Water indicated that it is not considered appropriate to substantially increase the design capacity because the project involves retrofitting a section of drain at the downstream end of an existing system, and the project does not involve increasing the capacity of the remainder of the existing system.

It was considered that a substantially higher design capacity would only be justified if the existing upstream system was likely to be upgraded. Sydney Water advised it is highly unlikely the existing upstream system would be upgraded.

Based on the above reasons, the project has been designed to have hydraulic capacity to accommodate a storm event of approximately 15 year ARI which would be marginally greater than the existing drain. Sydney Water confirmed that this design capacity is appropriate.

3.5.4 Sediment trap

Consideration was given to provision of a sediment trap within the project. Discussions with Sydney Water indicated that a sediment trap is located within the Sydney Opera House Car Park, immediately upstream of the project, and that very little sediment has needed to be removed from this facility.

Sydney Water agreed that a sediment trap is not required as one is located immediately upstream and very little sediment has needed to be removed. It was also agreed that if a sediment trap is required, the forecourt of the Sydney Opera House is unlikely to be the optimal location. Based on this, a sediment trap has not been included in the project. However, as discussed in Section 4.2.5 of this report, sedimentation rates will be monitored and need for any additional sediment controls will be monitored and reviewed once the drain is operational.

3.5.5 Details of the seawall outlet

Outlet with flap valve

The original design undertaken by Warren Smith and Partners (2005) proposed the inclusion of a flap valve at the outlet point in Farm Cove. A preliminary review of this design was undertaken which indicated that the flap valve may result in some adverse hydrological impacts upstream along the drainage system. Therefore the inclusion of a flap was not considered to be a viable option.

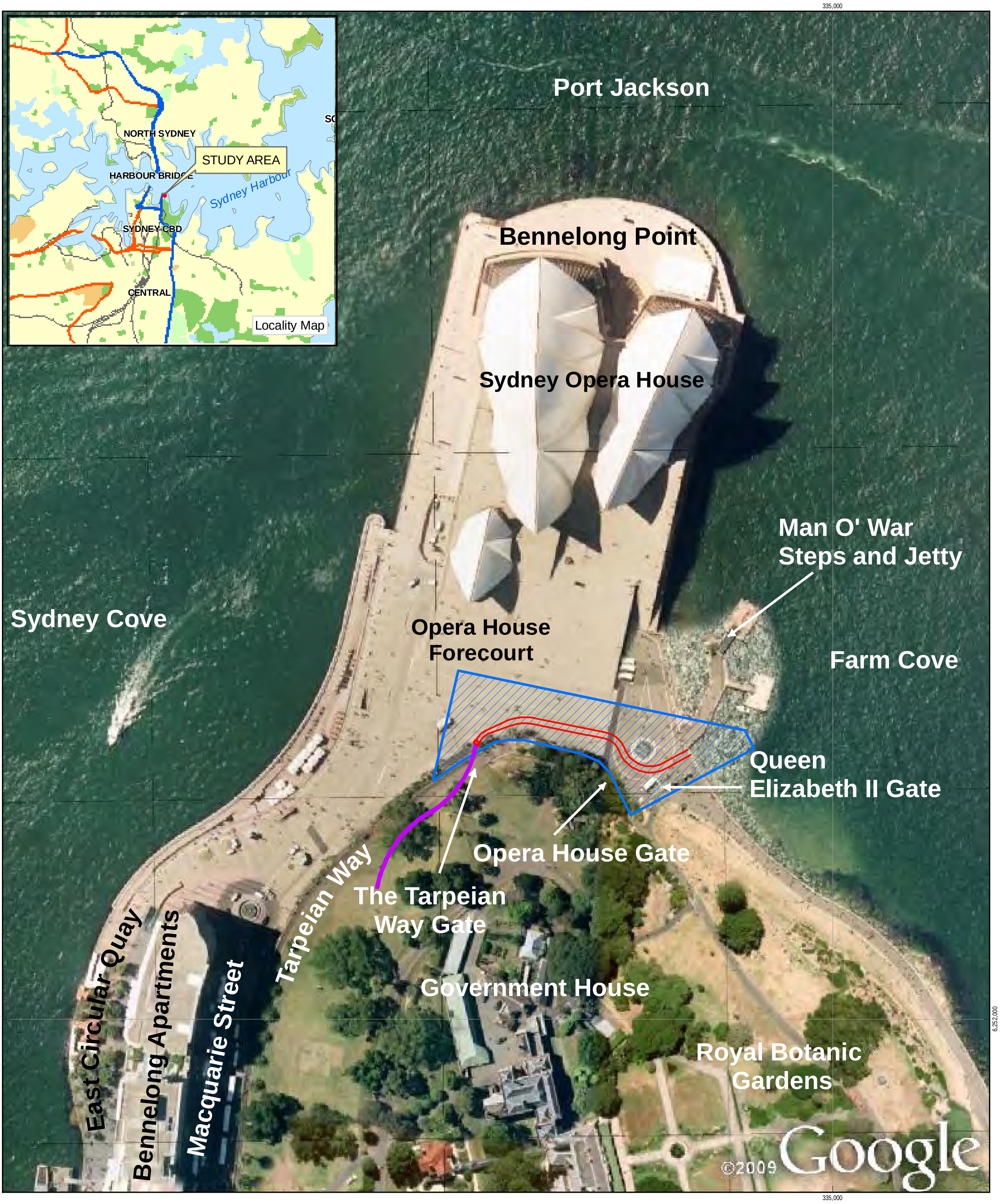
Outlet without flap valve

The design of the project as proposed involves an open discharge at the outlet. This option would operate in a similar manner to the existing drain outlet, which has no flap valve.

3.6 Operation activities

Following construction of the new section of drain, the Bennelong Drain would continue to provide drainage to the northern CBD catchment, with stormwater discharging to Farm Cove.

The drain would form part of Sydney Water's stormwater drainage system. As with the existing drain, it would be operated and maintained by Sydney Water.



Legend

Study Area — Upstream Drain Alignment — Proposed Drain Realignment

0 10 20 40 60
Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

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Bennelong Drain Diversion Project
Hydrology and Drainage Assessment

Location of Key Site Features and Surrounds

Job Number	21-18445
Revision	B
Date	Jan 2010

Figure 3.1

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10 Bond Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

Data source: Aerial Imagery from Google Earth Pro 2009; Locality Map Data, Navigate and Navteq, 2008.

4. Assessment of Hydrological and Drainage Impacts

Potential hydrological and drainage impacts of the project that need to be considered include the following:

- Impacts on upstream flooding;
- Impacts on sediment deposition and scour;
- Climate change impacts; and
- Construction impacts.

4.1 Impacts on Upstream Flooding

4.1.1 Hydrology

Design flows at the diversion outlet were estimated using the Rational Method, and in accordance with Australian Rainfall and Runoff (1998). The results are summarised in Table 1.

In Table 1, the 1 in 5 year ARI (average recurrence interval) flow at the Bennelong Drain is estimated to be 7.8 m^3/s. This is consistent with that estimated by Sydney Water (City Drainage Area 29, Capacity Assessment, September 1996) and adopted by Warren Smith and Partners (2005).

The design flows presented in Table 1 are for both existing and proposed drainage conditions. This is because the catchment areas and flow travel times are unchanged, with the net result that the design flows are not changed. In this regard, while the Sydney Opera House forecourt areas in the vicinity of the drain are slightly different under existing and proposed drainage conditions, the forecourt areas have their own drainage outlets. The forecourt areas do not discharge into either the existing or proposed Bennelong Drain and therefore do not impact on the drain catchment areas and design flows.

Table 1: Design flows

Design ARI (yrs)	Intensity (mm/hr)	Runoff Coefficient	Catchment Discharge (m^3/s)	Bennelong Drain Discharge (m^3/s)
1	52.1	0.68	7.1	0.9
2	67.3	0.73	9.7	3.5
5	87.0	0.81	14.0	7.8
10	98.7	0.85	16.7	10.6
20	114.3	0.89	20.3	14.2

Catchment Area = 71.1 ha, Impervious fraction = 85%, Time of concentration = 24.3min

Overall, the design flows at the Bennelong Drain are expected to remain the same under existing and proposed development conditions, for the full range of storm events. No adverse impacts on existing flow behaviour are expected on upstream flooding behaviour.

4.1.2 Flow hydraulics

The hydraulic capacities of the existing and proposed drains were estimated using the DRAINS model. This takes into account the tide levels at Farm Cove and the overflow level at the junction pit at the location of the diversion. The results are summarised in Table 2 and Table 3.

In Table 2, the hydraulic capacity of the existing drain is estimated to be about 10.6 m^3/s. This corresponds to a storm magnitude of about the 10-year ARI. By comparison, the hydraulic capacity of the proposed drain is estimated to be about 12.5 m^3/s (Table 3). This is estimated to equate to an ARI event of about 15 years.

Table 2: Hydraulic capacity of existing drain

Size	Opening Area (m^2)	Hydraulic Capacity (m^3/s)	Estimated ARI Event Capacity (yrs)
3.05m wide x 1.22m high	3.72	10.6	10

Table 3: Hydraulic capacity of proposed drain

ARI (yrs)	Discharge (m3/s)	Overflow from Pit	Drain Flow Depth[1] (m)	Comments
1	0.9	No	0.40 - 0.94	
2	3.5	No	0.42 - 0.94	
5	7.8	No	0.73 – 0.94	
10	10.6	No	0.90 – 0.94	
Approx 15	12.5	No	1.02	Drain Capacity
20	14.2	Yes	1.02	Drain Capacity Exceeded

Above is for Mean High Water Level = 0.503m AHD (note that Mean Sea Level = -0.046m AHD, Mean Low Water Level = -0.581m)

1: This is the depth of flow in the lower sections of the drain as well as the immediate vicinity of the drain outlet.

As the capacity of the proposed drain (12.5 m^3/s) is estimated to be greater than the existing drainage capacity (10.6 m^3/s), the project is not expected to have any adverse impacts on the upstream flooding behaviour.

It is noted that the proposed drain has a capacity equivalent to about the 15-year ARI flood. While this is relatively low for a trunk drainage system, Sydney Water has agreed that it would be adequate in this case because the project would be undertaken at the downstream end of an existing system and there are no plans to upgrade the upstream sections of the system.

Overall, the proposed drain diversion is not expected to have any adverse impacts on the existing upstream flooding behaviour.

4.2 Impacts on sediment deposition and scour

4.2.1 Sediment yield

Sediment yield data within the catchment is not available. However, based on typical export rates for urban catchments, it is estimated that the sediment yield for the Bennelong Drain catchment would be between 17,000 kg to 35,000 kg per year.

It should be noted that Sydney Water advised that there is a sediment trap within the Sydney Opera House Car Park which is immediately upstream of the subject section of drain. Relatively small volumes of sediment have accumulated in this trap and it requires emptying infrequently. This suggests that the sediment yield at the stormwater outlet is likely to be low.

4.2.2 Sediment Deposition and Flushing of Diversion Drain

Estimated discharge velocities at the proposed diversion drain outlet, for various storm ARI events, are estimated in Table 4. These velocities correspond to high tide conditions, and the exit velocities are therefore expected to be higher under low tide conditions.

Table 4: Discharge Velocities at Proposed Drain Outlet

ARI (yrs)	Discharge (m3/s)	Drain Flow Depth (m)	Outlet Velocities[1] (m/s)
1	0.9	0.40 - 0.94	0.4
2	3.5	0.42 - 0.94	1.6
5	7.8	0.73 – 0.94	3.5
10	10.6	0.90 – 0.94	4.7
Approx 15	12.5	1.02	5.1
20	14.2	1.02	5.1

1: Under high tide conditions

The above results indicate that for design storms between the 1-year to 20-year ARI events, the outlet discharge velocities would range from 0.4 m/s to 5.1 m/s. Velocities greater than 0.6 m/s are usually required to facilitate self flushing of drainage pipes. Flows at and above the 2-year ARI event are therefore expected to be sufficient for sediment entrainment and flushing to occur along the drainage line.

For lower flows up to the 1-year ARI event, some sediment deposition is expected to occur along the drainage system. The deposited sediment is expected to wash into the harbour during the larger storm events.

4.2.3 Scour and Sediment Deposition at Diversion Outlet

Potential scour and sediment deposition at the diversion outlet is a complex function of a large number of interacting variables, including the outlet velocities and shear stresses, flow alignment, sediment and bed characteristics, hydraulic structure design, time factors, regional factors, coastal currents, and tidal effects.

As noted in the previous section, design flows at and above the 2-year ARI event are expected to be sufficient for sediment entrainment and flushing to occur along the drainage line. The sediment is expected to wash into the harbour during the larger storm events.

At the existing drainage outlet to Sydney Harbour, sediment washed into the harbour is carried and redistributed by the river flows and coastal tides and currents. It is apparent that sediment washed into the harbour at the existing outlet has not posed any sedimentation issues. As indicated previously, effective operation of the sediment trap within the Sydney Opera House Car Park is likely to reduce the volume of sediment discharged by the Bennelong Drain. This is likely to be due to sufficient depths of water available between the drain invert and the seabed, which is estimated to be several metres. In addition, the location of the existing drain is where the river and tidal currents are likely to be relatively high, thus minimising the potential for sediment deposition to occur in that area.

By comparison, the proposed diversion outlet is located at the southern end of the Bennelong Point spur and on the leeward side of the tidal flows. At the outlet, the available flow depth is estimated to be about 0.5 to 1m under normal flow conditions.

Field observations at the vicinity of the proposed discharge outlet indicate that an area of limited circulation is likely to exist at the southern corner of the groyne structure (wharf) with the eastern seawall (

Figure 4-1). This is based on observations of the lateral flow currents, wind directions, flow depths, as well as past experience. This region is estimated to extend 10-30m along the seawall and 10-30m along the groyne structure. It is noted that this is an estimate based on visual observations.

At this area of limited circulation, the local flow velocities are likely to be low and not significantly affected by lateral currents along the shoreline, with the flow being due mostly to tidal fluctuations and turbulence. The significance of this region is that any sediment load derived from the upstream catchment and washed into the bay at this outlet is likely to accumulate within this region.

To further assist in understanding the sediment deposition behaviour at the vicinity of the diversion outlet, typical urban sediment particle distribution sizes, as well as the critical shear stresses and critical velocities for sediment entrainment, have been estimated. This approach is consistent with that applied to investigations in similar locations and the results are presented in Table 5.

In Table 5 the particle distribution data adopted is based on approximately 20 sets of data provided in Australian Runoff Quality Guidelines (2003) for urban catchments.

It is noted that, based on the typical urban particle distribution data adopted, the sediment may be classified as non-uniform (standard deviation greater than 1.35). Under this condition, armouring of the bed surface is expected to occur under low flow conditions. Armouring means that a top layer of coarser size sediment would develop through sediment sorting, which would protect and cover the finer sediment sizes underneath. It is expected that the armour layer may not be stable due to the tidal fluctuations and bursts of turbulence that would occur in the field. However, re-stabilisation of the armour layer is also expected to occur over time.

Table 5: Critical Shear Stresses and Velocities for Sediment Entrainment

Typical Urban Particle Size (mm)*	Tc (N/m^2)	Vc (m/s)
D_{84} = 2 mm	1.3	1
D_{50} = 0.4 mm	0.26	0.45
D_{16} = 0.1mm	0.065	0.22

* Particle size distribution derived from urban data presented in Australian Runoff Quality Guidelines (2003)
Tc = Critical Shear Stress based on Shields Entrainment Function
Vc – Critical Velocity based on critical shear stress for sediment entrainment

Comparison of the culvert discharge velocities in Table 4, with the critical velocities for sediment entrainment in Table 5, indicates that flow discharges smaller than the 1-year ARI event (high tide conditions) are unlikely to break up the armour layer or entrain more than 50% of the sediment sizes. Under these conditions, sediment deposition is expected to occur at the diversion outlet.

At higher discharges greater than the 1-year ARI event, however, the critical velocities for sediment entrainment are exceeded, and flushing of the sediment further out into the bay area is expected. The risk remains, however, that the tidal currents may carry and deposit the sediment in the area of limited circulation.

A potential issue is that the proposed diversion outlet is located within the area of limited circulation. At this location the transport of sediment further out into the bay area is generally more difficult, with any sediment deposited likely to remain trapped in this general area. As indicated previously, effective operation of the existing sediment trap upstream of the subject section would reduce the volume of sediment discharged at this point.

Overall, it is considered that sediment deposition or shoaling may potentially occur at the location of the proposed outlet over the long term. Much of this would depend on the sediment yield discharged from the drain, which is determined by the effectiveness of the upstream sediment trap. Recommended management measures are discussed in Section 4.

In terms of potential scour at the diversion outlet, the design flow velocities, while relatively high, are not considered to be an issue. This assumes that the vicinity of the proposed outlet is characterised by sandstone bedrock (as indicated in the design drawings), which would be fairly resistant to those flows. It is noted that loose rocks up to 1m in diameter would be unstable and subject to movement at velocities exceeding 5 m/s.

Legend

Proposed Drain Realignment

Area of Limited Circulation

0 1.5 3 6 9
Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

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Bennelong Drain Diversion Project
Hydrology and Drainage Assessment

Job Number 21-18445
Revision A
Date Sept 2009

Observed Area of Limited Circulation

Figure 4.1

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10 Bond Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Google Earth Image 2009, Sydney Water 2005. Created by: BAH

4.2.4 Observations at other sites

The actual sediment yield within the Bennelong drain catchment is not available. However, our estimates (Section 4.2.1) indicate that the yield may be between 17,000 to 35,000 kg per year. This order of magnitude would be typical for a catchment of this nature.

In order to assess sedimentation problems over stormwater drains along the harbour and Circular Quay, a visual inspection of a number of drain outlets was carried out along Farm Cove and Sydney Cove. No sedimentation was evident at any of the drains inspected. At Farm Cove, however, the local catchments were considered to be much smaller, while at Sydney Cove, the depths of water at the harbour were significant.

Three other regional locations were also inspected, these being Rushcutters Bay, Point Piper, and Rose Bay. These locations, while not identical to the proposed outlet location, have some similarities in terms of a spur, local jetties or groyne-like structures or a culvert outlet. At all these locations, shoaling or sediment deposition was clearly observed. The catchments of these areas differ from that of the Bennelong Drain in that there are higher proportions of pervious surfaces in the other catchments.

Consultation with Sydney Water indicated that the volume of sediment discharged from stormwater drains is heavily influenced by factors such as Council street cleaning programs.

The above observations suggest that any sediment deposition, over and above that which would occur naturally, would depend on the catchment yield and discharged through the diversion drain, as expected. The other drains at Farm Cove and Sydney Cove suggest that sediment yield in this area is not significant or problematic, though it must be qualified that the relatively large water depths in the Quay areas may have limited the issue.

4.2.5 Recommendations

On the basis of the above findings, it is recommended that a monitoring program be established to monitor the amount of sediment that may be deposited at the outlet once it has been commissioned. The quantity of sediment discharged from the outlet to the receiving environment would be further quantified post construction. This would be undertaken as part of Sydney Water's existing operational plan for the overall stormwater network and would involve six monthly inspections of the sediment trap immediately upstream of the project to ensure it is operating effectively.

If the sediment yield is found to be significant and significant sediment deposition problems are observed to be occurring, a potential mitigation strategy would be to upgrade the sediment sump that is currently located within the Sydney Opera House Car Park, immediately upstream of the project.

It is also recommended that a boom be temporarily installed at the proposed diversion outlet to monitor and capture any floating debris and gross pollutants that may be discharged into Farm Cove. This would provide an indication of the amount of floating debris discharged from the drain. If the amount of floating debris is found to be significant, a permanent boom could be designed, otherwise the temporary boom would be removed.

4.3 Climate change impacts

The NSW Government Draft Sea Level Rise Policy (February 2009) states that sea level rise along the NSW coast is expected to rise by up to 0.4m by year 2050 and 0.9m by year 2100.

The NSW Floodplain Risk Management Guidelines (2008) suggests that, in order to take into account climate change effects, the following impacts would need to be assessed:

- Rainfall intensities – increases of 10%, 20% and 30%; and
- Sea level rise – 0.18m (low level scenario), 0.55m (mid level) and 0.91m (high level).

Design flow estimates, assuming a 30% increase in rainfall intensities, are estimated in Table 6. These results indicate that, with a 30% increase in rainfall intensity, the 5-year ARI design flow would increase from 7.8 m^3/s to 12.8 m^3/s. Effectively, for this scenario, the climate change 5 year ARI flow would increase significantly and correspond to the existing 15-year ARI flow.

The performance of the proposed diversion channel is further assessed taking into account a 30% increase in rainfall intensity, and coupled with sea level rise. The results are summarised in Tables 7, 8, and 9.

Based on the results shown in Tables 7, 8, and 9, it is evident the overall effects of climate change are such that the hydraulic efficiency of the proposed diversion drain would be significantly reduced. From a proposed design capacity of about the 15-year ARI (Table 3), the climate-affected capacity would be reduced to only between the 2 and 5 year ARI event.

It is noted that the above findings are for a 30% increase in rainfall intensity. For less severe increases in rainfall intensities, the impacts are expected to be lower.

Table 6: Design Flow Estimates at Bennelong Drain for 30% Increase in Rainfall Intensities

Design ARI (yrs)	Intensity (mm/hr)	Runoff Coefficient	Catchment Discharge (m3/s)	Bennelong Drain Discharge (m^3/s)
1	67.7	0.71	9.6	3.4 (Existing 0.9)
2	87.5	0.76	13.1	7.0 (Existing 3.5)
5	113.1	0.85	19.0	12.8 (Existing 7.8)
10	128.3	0.89	22.7	16.5 (Existing 10.6)
20	148.6	0.94	27.6	21.4 (Existing 14.2)

Discharge values in brackets are those for existing conditions

Table 7: Flow Hydraulics with 30% Increase in Rainfall Intensity and Low Sea Level Rise

ARI (yrs)	Discharge (m3/s)	Overflow from Pit	Drain Flow Depth (m)	Comments
1	3.4	No	0.59 – 1.12	
2	7.0	No	0.67 – 1.12	
*	12.5	No	1.02 – 1.12	Hydraulic Capacity
5	12.8	Yes	1.02 – 1.12	

Low Sea Level Rise Scenario = + 0.18m increase

Table 8: Flow Hydraulics with 30% Increase in Rainfall Intensity and Medium Sea Level Rise

ARI (yrs)	Discharge (m3/s)	Overflow from Pit	Drain Flow Depth (m)	Comments
1	3.4	No	0.81 – 1.34	
2	7.0	No	0.81 – 1.34	
*	12.5	No	1.02 – 1.34	Hydraulic Capacity
5	12.8	Yes	1.02 – 1.34	

Medium Sea Level Rise Scenario = + 0.4m increase

Table 9: Flow Hydraulics with 30% Increase in Rainfall Intensity and High Sea Level Rise

ARI (yrs)	Discharge (m3/s)	Overflow from Pit	Drain Flow Depth (m)	Comments
1	3.4	No	1.32 – 1.85	
2	7.0	No	1.32 – 1.85	
*	12.5	No	1.32 – 1.85	Hydraulic Capacity
5	12.8	Yes	1.32 – 1.85	

Medium Sea Level Rise Scenario = + 0.91m increase

Under storm tide conditions, some backwater is expected upstream along the drainage system, which would result in a reduction in the drainage capacity. However, both the existing and proposed diversion drains would behave in a similar manner, hydraulically, under climate change conditions. On this basis, no adverse impacts are expected to occur, relative to existing conditions.

Sydney Water was consulted regarding the need to design the project to accommodate climate change scenarios. Sydney Water advised that it would not be appropriate for the project to accommodate these scenarios because it is located at the extreme downstream end of an existing system and there are no plans to upgrade the upstream sections of the system.

4.4 Construction Impacts

During construction of the proposal, it is expected that any land disturbance would be carried out in accordance to NSW Guidelines for Construction sites (NSW Landcom Blue Book, 2004).

An erosion and sediment control plan is expected to be prepared and implemented as part of the construction management plan. Under these considerations, any potentially adverse construction impacts are likely to be minimal and manageable.

5. Summary and Recommendations

An assessment of the hydrological and drainage impacts of the proposed Bennelong Drain Diversion project has been carried out. The results indicate that the hydraulic performance of the proposed design would remain similar to that under existing conditions, and no adverse impacts would occur. Consultation with Sydney Water indicates that it is appropriate that the proposed drain has a comparable design capacity to that of the existing drain.

Assessment of the sediment yield potential of the catchment, drainage outlet velocities, sediment entrainment characteristics, and the location of the discharge points, suggests that sediment deposition may become an issue at the new outlet location over time. In particular, sediment is expected to be deposited in an area of limited circulation at the corner of the groyne with the existing eastern seawall. However, much of this depends on the actual sediment yield in the Bennelong catchment and the effectiveness of the sediment trap that is located in the Sydney Opera House Car Park, immediately upstream of the project.

It is recommended that a monitoring program be established to monitor the amount of sediment that may be deposited at the outlet once it has been commissioned. The quantity of sediment discharged from the outlet to the receiving environment would be further quantified post construction. This would be undertaken as part of Sydney Water's existing operational plan for the overall stormwater network and would involve six monthly inspections of the sediment trap immediately upstream of the project to ensure it is operating effectively.

If the sediment yield is found to be significant and significant sediment deposition problems are observed to be occurring, a potential mitigation strategy would be to upgrade the sediment sump that is currently located within the Sydney Opera House Car Park, immediately upstream of the project.

It is also recommended that a boom be temporarily installed at the proposed diversion outlet to monitor and capture any floating debris and gross pollutants that may be discharged into Farm Cove. This would provide an indication of the amount of floating debris discharged from the drain. If the amount of floating debris is found to be significant, a permanent boom could be designed, otherwise the temporary boom would be removed.

Based on information provided in the design drawings, that the diversion outlet is founded on sandstone bedrock, potential scour at the outlet is not considered to be a problem. It is noted, however, that loose rocks up to 1m in diameter would be unstable and subject to movement at the outlet velocities, which are estimated to exceed 5 m/s during high flows.

Assessment of the climate change impacts indicates that the design capacity and hydraulic efficiency of the proposed diversion drain would be significantly reduced, particularly if the severe climate scenarios eventuate. However, climate change impacts would be similar for the both the existing and proposed drains, and no adverse impacts are expected, relative to the existing conditions. This approach has been confirmed in consultation with Sydney Water.

Land disturbance during construction is not expected to be an issue assuming that all construction activities would be carried out in accordance with the NSW 'Blue Book' (Landcom 2004) for Soils and Construction.

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