

**Lend Lease Development Pty Ltd**

**PROPOSED HAYMARKET REDEVELOPMENT  
HAY STREET – LACKEY STREET, DARLING HARBOUR  
ASSESSMENT OF IMPACTS ON ADJACENT INFRASTRUCTURE**

**Report PSM1986-010R**

**March 2013**

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## **1. INTRODUCTION**

This report supports a State Significant Development Application (SSD 12\_5752) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Application seeks approval for the establishment of building envelopes and design parameters for a new neighbourhood and a community hub (referred to as The Haymarket) as part of the Sydney international convention, exhibition and entertainment precinct (SICEEP) Project at Darling Harbour.

The project will develop The Haymarket into one of Sydney's most innovative residential and working districts. Through the delivery of the overall project, Darling Harbour will also become home to Australia's largest convention and exhibition facilities, Sydney's largest red carpet entertainment venue, and a hotel complex of up to 900 rooms. The SICEEP Project importantly forms a critical element of the NSW Government's aspiration to "make NSW number one again".

### **1.1. Overview of proposed development**

The proposal relates to a staged development application and seeks to establish concept plan details for The Haymarket, located within the southern part of the SICEEP Site.

The Haymarket will include student housing, public car parking, a commercial office building, and four mixed use development blocks (retail/commercial/residential podium with residential towers above) centred around a new public square to be named Haymarket Square.

More specifically concept approval is sought for the following:

- Demolition of existing site improvements, including the existing Sydney Entertainment centre (SEC), Entertainment car park, and part of the pedestrian footbridge connected to the Entertainment car park and associated tree removal;
- North-west block – construction of a part public car park and part commercial/office building;
- North-east block – construction of a mixed use podium (comprising retail, commercial, above ground parking, and residential) with three residential buildings above;
- South-east block - construction of a mixed use podium (comprising retail, commercial, above ground parking, and residential) with three residential buildings above;
- South-west block - construction of a mixed use podium (comprising retail, commercial, above ground parking, and residential) with three residential buildings above;
- North block – construction of a mixed use building comprising retail, commercial and residential;
- Student housing – construction of two buildings providing for up to 1,000 beds;

- Public domain improvements including a new square, water features, new pedestrian streets and laneways, streetscape embellishments, and associated landscaping. (It is intended that a Stage 2 DA seeking approval for parts of the public domain (The Boulevard and Haymarket Square) will be lodged with the first residential stage);
- Reconfiguration and upgrade of Darling Drive (part);
- Remediation strategy; and
- Car parking rates.

## 1.2. **Background**

The existing convention, exhibition and entertainment centre facilities at Darling Harbour were constructed in the 1980s and have provided an excellent service for Sydney and NSW.

The facilities however have limitations in their ability to service the contemporary exhibition and convention industry which has led to a loss in events being held in Sydney.

The NSW Government considers that a precinct-wide renewal and expansion is necessary and is accordingly committed to Sydney reclaiming its position on centre stage for hosting world-class events with the creation of the Sydney international convention, exhibition and entertainment precinct.

Following an extensive and rigorous Expressions of Interest and Request for Proposals process, Darling Harbour Live (formerly known as 'Destination Sydney'- a consortium comprising AEG Ogden, Lend Lease, Capella Capital and Spotless) was announced by the NSW Government in December 2012 as the preferred proponent to transform Darling Harbour and create the new Sydney international convention, exhibition and entertainment Precinct.

Key features of the Darling Harbour Live Preferred Master Plan include:

- Delivering world-class convention, exhibition and entertainment facilities, including:
  - Up to 40,000m<sup>2</sup> exhibition space;
  - Over 8,000m<sup>2</sup> of meeting rooms space, across 40 rooms;
  - Overall convention space capacity for more than 12,000 people;
  - A ballroom capable of accommodating 2,000 people; and
  - A premium, red-carpet entertainment facility with a capacity of 8,000 persons.
- Providing up to 900 hotel rooms in a hotel complex at the northern end of the precinct.
- A vibrant and authentic new neighbourhood at the southern end of the precinct, called 'The Haymarket', home to an IQ Hub focused on the creative industries and high-tech businesses, apartments, student accommodation, shops, cafes and restaurants.

- Renewed and upgraded public domain, including an outdoor event space for up to 25,000 people at an expanded Tumbalong Park.
- Improved pedestrian connections linking to the proposed Ultimo Pedestrian Network drawing people between Central, Chinatown and Cockle Bay Wharf as well as east-west between Ultimo/Pyrmont and the City.

### **1.3. Site Description**

The SICEEP Site is located within Darling Harbour. Darling Harbour is a 60 hectare waterfront precinct on the south-western edge of the Sydney Central Business District that provides a mix of functions including recreational, tourist, entertainment and business.

With an area of approximately 20 hectares, the SICEEP Site is generally bound by the Light Rail Line to the west, Harbourside shopping centre and Cockle Bay to the north, Darling Quarter, the Chinese Garden and Harbour Street to the east, and Hay Street to the south.

The SICEEP Site has been divided into three distinct redevelopment areas (from north to south) – Bayside, Darling Central and The Haymarket. The Application Site area relates to The Haymarket as shown in the figure below.

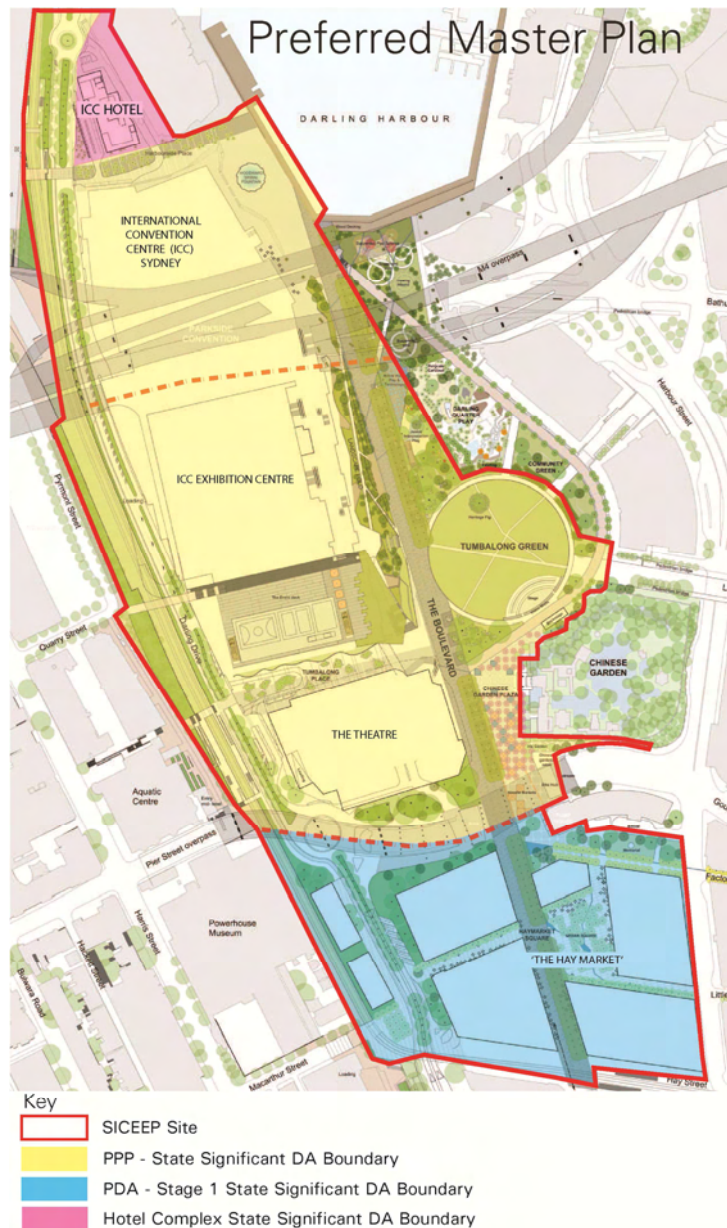


#### 1.4. Planning Approvals Strategy

In response to separate contractual agreements with the NSW Government and staging requirements Lend Lease (Haymarket) Pty Ltd is proposing to submit a number of separate development applications for key elements of the overall Project.

This staged development application involves the establishment of building envelopes and design parameters for a new neighbourhood and a community hub (The Haymarket) within the southern part of the SICEEP Site. Detailed development applications will accordingly follow seeking approval for specific aspects of The Haymarket in accordance with the approved staged development application.

Separate development applications will be lodged for the PPP component of the SICEEP Project (comprising the convention centre, exhibition centre, entertainment facility and associated public domain upgrades) and Hotel complex.



## 2. SCOPE OF WORK

This report has been prepared to support the State Significant Development Application (SSD 12\_5752) and presents a preliminary assessment of the impacts of the proposed Haymarket redevelopment on the following existing stormwater drainage structures which both run adjacent to and potentially underlie the proposed development:

- Historic Hay Street – Lackey Street stormwater channel (**Historic drain**), and
- Sydney Water Corporation (SWC) Hay Street – Lackey Street stormwater channel (**Sydney Water drain**)

This work was undertaken by Pells Sullivan Meynink (PSM) for Lend Lease Development Pty Ltd (Lend Lease) in accordance with a Professional Services Agreement executed on 21 February 2013 and our fee proposal dated 30 January 2013 (Ref. PSM1986-006L).

This work has been undertaken for the stage 1 development application of the project.

Documents provided by Lend Lease and relied upon in undertaking this work are included in the appendices.

## 3. PROPOSED HAYMARKET REDEVELOPMENT

Lend Lease are redeveloping The Haymarket, the southern portion of the Darling Harbour precinct, including the existing Entertainment Centre and surrounding area, as part of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) development.

The development is within the area currently occupied by the existing Sydney Entertainment Centre and associated multi-storey car park, as shown in Figure 1. The proposed buildings in this area generally comprise multi-storey residential apartments and commercial office buildings. No basement excavations are proposed.

An historic stormwater drain runs beneath Hay Street adjacent to the southern boundary of the development site. The alignment then turns north into former Lackey Street. Near the corner the original historic drain has gone and is replaced with a more modern structure (Sydney Water drain). The drain continues north and passes between and beneath new buildings within the proposed redevelopment. The drain eventually discharges into Darling Harbour.

SWC describe the Hay Street Stormwater Channel No.30P1 in their heritage register as follows:

*The Hay Street Stormwater Channel system is highly significant as it was one of the first five original combined sewers constructed in Sydney around the 1860 period. The other four sewers were; Blackwattle Bay (SHI 4570535), Woolloomooloo (SHI 4570813), Tank Stream (SHI 4573709) and Bennelong (SHI 4570854). These five sewers were responsible for greatly improving public health by diverting stormwater and sewage off the streets and discharging it out into the*

*Harbour. The five sewers are the first examples of sewerage and drainage services to be built in Sydney, and potentially Australia. The subsequent construction of the BOOS (Bondi Ocean Outfall Sewer) in 1889 and the connection of the Hay Street system in 1901 diverted sewer flow from the Harbour and into the ocean. Eventually the drain was used predominantly for stormwater, this further improved public health, hygiene and living standards for the city's residents. The channel is of technological significance as it provides an excellent example of the engineering and construction techniques of the late 1800's and of the city's early infrastructure. The numerous extensions and modifications made throughout the years provide and an archaeological record of the advancements made in drainage construction techniques. The operational curtilage for Hay Street SWC includes all original fabric and archaeological evidence including, but not limited to the channel bed, walls and coping. There is no visual curtilage associated with this structure as it is located predominantly underground. To formulate a specific curtilage statement that includes details of surrounding landuse and encroachment of various developments would require further investigations and is beyond the scope of this study.*

Robert Bird Group (RBG) have been engaged to provide structural engineering advice to Lend Lease. The RBG pile layouts represent the proposed development scheme piled foundation arrangements within the proposed development. The heritage drain is located within the Hay Street road reserve which is outside the footprint of the proposed development lots.

It is anticipated that suitable pile types may comprise bored piles, continuous flight auger piles, or screw displacement piles. Driven piles are unlikely to be suitable and have not been considered in this report.

#### **4. EXISTING STORMWATER INFRASTRUCTURE**

##### **4.1. Historic drain (SWC Ref : Hay Street Stormwater Channel No.30P1 No 4574216)**

The Hay Street – Lackey Street stormwater drain was constructed in 1863. It was originally for the drainage of both stormwater and sewage from the city into Darling Harbour. It follows Hay Street in a westerly direction from Sussex Street, then turns to the north along the former Lackey Street as shown in Figure 1. The historic section of the channel is 228 m in length, terminating at either end in a concrete chamber.

The drain was constructed on reclaimed land overlying relatively deep soft alluvial soils.

The drain is considered to be of high local heritage significance and is listed on the Sydney Water Section 170 Heritage and Conservation Register. It is one of the first five combined sewer channels built for Sydney. The completion of these five systems was significant in improving the standard of hygiene in the city. The commissioning of the Bondi Ocean Outfall Sewer in 1889 served to divert sewer flows from the city to the ocean at Malabar. The historic drain was retained solely to deal with stormwater flows.

The original drain comprises an elliptical arch structure, 2.1 m high and 3.0 m wide. Sandstone blocks were used in its construction. Each arch section consists of 21 blocks,

with ten blocks either side of a central keystone. The invert of the tunnel also consists of sandstone blocks formed in a shallow “vee” shape.

The invert level of the drain where it passes Dixon Street is RL 0.44 m (Ref. Lackey Street - Hay Street SWC amplification drawings, Appendix G). Assuming a longitudinal gradient of 0.22% (i.e. same as the adjacent drain), the invert level at the corner of Lackey Street would be about RL 0 m. The ground surface in this area is at about RL 2.5 m, which is consistent with the stated height of the structure and inferred invert level.

Note that mean sea level is RL -0.05 m (AHD), and therefore the invert of the drain would be underwater about half the time.

Criteria in regards to the magnitude of physical impacts which are acceptable for the historic portion of the channel have not been provided to PSM. Lend Lease has asked PSM to consider and nominate suitable acceptance criteria for potential impacts arising from the proposed development.

Between 2004 and 2009 rehabilitation of a 102 m length of the historic drain was undertaken by Sydney Water. The section rehabilitated had suffered from significant deformation of the arch, and there was concern regarding sudden collapse.

The precise location of the rehabilitated section is not stated in the documents supplied to PSM. The Sydney Water statement of heritage impact (Appendix C) notes that the dilapidation had extended upstream into the Harbour Street/Hay Street intersection. The document also describes the most seriously dilapidated section occurring under Hay Street between Lackey Street and Harbour Street. From these descriptions it seems likely that the rehabilitated section coincides with the portion of the historic drain which adjoins the Haymarket redevelopment site.

Rygate & Company Pty Ltd (project surveyors) have provided Lend Lease with information regarding the location of the drains. It is understood that this has been compiled from various sources, including works as executed drawings and “dial before you dig” drawings. This information shows that where the heritage drain runs beneath Hay Street that the edge of the drain is located about 4.2 m from the site boundary of the redevelopment site. The preliminary pile layout produced by RBG indicates that the closest pile is located 5.1 m from the heritage drain.

To mitigate further damage the sandstone block structure was lined with marine grade sulphate resistant concrete reinforced with Grade 304L stainless steel. This was placed around an elliptical liner.

#### **4.2. Sydney Water drain**

The drain originally ran along Lackey Street. Because of ongoing maintenance problems associated with poor hydraulics, the original drain was replaced with a covered concrete structure in the mid 1930s.

The newer structure is roughly rectangular in section, with an internal width of 3.7 m and a height of 2.2 m.

Further details of the structure are unknown at present.

## 5. GEOTECHNICAL CONDITIONS

A geotechnical model has been prepared for the site based on twelve boreholes drilled by others including Coffey for INSW, as well as from a range of geotechnical data provided by Lend Lease (from INSW data room). The location of these boreholes is shown in Figure 1, and relevant borehole logs are included in Appendix K.

The geotechnical units, levels, and thicknesses are shown in Table 1 and Table 2 below. Table 1 represents the historic drain along Hay Street, and Table 2 represents the northern section of the Sydney Water drain.

**TABLE 1  
GEOTECHNICAL MODEL  
HISTORIC DRAIN**

<b>GEOTECHNICAL UNIT</b>	<b>REDUCED LEVEL OF TOP OF UNIT RL (m) AHD</b>	<b>THICKNESS (m)</b>
FILL, ALLUVIUM	2.5 to 3.2	9 to 11
CLASS III SANDSTONE	-7 to -10	5 to 7
CLASS II SANDSTONE	-9 to -13	> 20

**TABLE 2  
GEOTECHNICAL MODEL  
NORTHERN END OF SYDNEY WATER DRAIN**

<b>GEOTECHNICAL UNIT</b>	<b>REDUCED LEVEL OF TOP OF UNIT RL (m) AHD</b>	<b>THICKNESS (m)</b>
FILL, ALLUVIUM	2.8 to 3.2	14 to 17
CLASS III SANDSTONE	-14 to -16.5	7 to 12
CLASS II SANDSTONE	-18 to -21	> 20

Note: 1. Rock classification is in accordance with Reference 1.

Inferred bedrock surface contours are shown in Figure 1. These indicate that the rock levels drop from the south to the north by about 7 m over a distance of roughly 180 m.

The Sydney Water drain passes over the Great Sydney dyke, though as the dyke will terminate at rock head level, it will have no effect on the geotechnical conditions immediately beneath the drain.

Groundwater levels encountered in the borehole investigations near the site were measured (by others) to be at about RL 0.8 m (AHD).

## **6. IMPACTS ON HISTORIC DRAIN**

### **6.1. Adverse mechanisms**

As noted in Section 4.1, the historic drain passes within about 4 m of the redevelopment site, and no basement excavation is proposed. Potential adverse impacts are therefore likely to be limited to the construction of bored piles, demolition works and possibly new and augmented utilities and infrastructure services works. Impacts due to piling are discussed in the following sections. The assessment of the latter two potential impacts is beyond the scope of this report.

The following potential adverse mechanisms have been identified during piling related works:

1. Pile hole collapse during excavation, potentially undermining or loosening soil supporting the historic structure.
2. Vibration from pile excavation, in particular during rock excavation.

Downdrag effects from pile settlement under load are not considered to present a risk to the historic drain structure. This is because of the significant distance (at least 5 m) between the proposed piles and the drain.

### **6.2. Pile hole collapse**

Pile hole stability can be readily addressed and controlled using a variety of techniques, including:

- Selection of pile type (e.g. continuous flight auger)
- Use of casing
- Trial piles located away from the drain

It is expected that collapse extending 5 m from a pile hole is highly unlikely, even in adverse ground conditions.

### **6.3. Vibration effects**

#### **6.3.1. Tolerable limits**

The drain beneath Hay Street will have experienced significant vibration over its life to date due to vehicular traffic and possibly from previous construction activity.

The published literature provides some guidance in regards to the tolerable vibration limits for various types of structure:

- 4 mm/s for structurally unsound structures under heritage protection (West German vibration criterion for blasting, Reference 4).
- 12 mm/s for old residential structures in very poor condition (Chae, Reference 3)
- 2 mm/s up to 30 mm/s for historic buildings in other countries (Reference 4).
- 30 mm/s for well-braced structures with heavy elements, structurally sound (West German vibration criterion for blasting, Reference 4).

As the historic drain has been strengthened with an internal reinforced concrete liner, the lower values for structurally unsound heritage structures in the above list are not considered appropriate. An acceptable vibration limit in the range of 20 mm/s or more is considered consistent with the likely condition of the existing structure.

Maintaining vibration magnitudes below this level should be readily achieved using the standard piling techniques (excluding driven piles).

### **6.3.2. Likely vibration magnitude**

Vibration magnitude for various construction activities are described in Reference 3. For bored pile construction in rock, the resulting vibration characteristics are considered to be represented by the pseudo-steady-state condition described in the reference.

Vibration data from pile excavation is not provided. This is likely to be because this type of vibration is typically negligible and does not result in adverse effects.

Vibration from other excavation activities, including “pavement breaker”, “caisson drilling”, and “jack hammers” are provided, and these are considered to be rough analogues for pile excavation using an auger fitted with tungsten points, as is often used in Sydney. For a distance of 4 m, vibration values (peak particle velocity) of between 4 mm/s and 18 mm/s are given for these three plant types.

It is noted that actual vibration effects will be dependent on piling plant and how it is used, as well as geotechnical conditions.

### **6.3.3. Vibration impact**

Based on the above discussion of vibration limits and likely magnitude, it is considered that vibration presents little risk to the historic drain.

Vibration effects can be managed by further assessment of the drain structure, as well as selection of appropriate plant and pile sizes, and monitoring of vibration during construction, as discussed below.

### **6.3.4. Vibration monitoring**

Typically prior to commencement of work in critical locations (i.e. near the heritage drain), trials are undertaken using the proposed plant, with vibration measured at varying distances. This is used to assess a ‘site law’ in regards to vibration magnitude and distance. Once it is demonstrated that vibration is within acceptable limits at the relevant distance, the work can commence at the critical location.

Vibration effects along the heritage drain can also be monitored during pile construction using instruments installed within or adjacent to the heritage drain. These are typically used in conjunction with data loggers and can be connected to alarm systems to alert construction personnel of excessive vibration (i.e. audible or visual signals).

#### **6.4. Impact on heritage drain**

Hole instability during pile excavation can be managed by selection of appropriate plant and employment of techniques appropriate to the encountered ground conditions (e.g. casing). The large separation distance proposed between the heritage drain and the piled foundations (in the order of 5 m) means that even if such instability were to occur, that it would be extremely unlikely to propagate as far as the drain.

Vibration is the main issue in regards to potential threats to the heritage drain. The use of a driven pile foundation system near the drain is therefore unsuitable. Conventional pile types such as bored piles, continuous flight augers, or screwed displacement piles are considered more appropriate.

Vibration can be managed using normal techniques, such as establishment of a 'site law' for piling plant, and undertaking of full-time monitoring of the drain during construction.

### **7. IMPACTS ON SYDNEY WATER DRAIN**

#### **7.1. Potential adverse impacts**

Four potential adverse impacts have been identified:

1. Physical conflict
2. Pile hole collapse
3. Vibration during pile construction
4. Pile downdrag

These potential impacts are discussed below.

#### **7.2. Physical conflict**

As shown in Figure 1, the current piling layout potentially intersects the Sydney Water drain in several locations at the northern end of the redevelopment site, such that the pile locations will either need to be adjusted or suitable bridging over the culvert structure will need to be provided (subject to the approval of SWC).

Such bridging will require the construction of piles in pairs, one on either side of the drainage structure with a bridging beam above from which the proposed structure columns will be supported. A structural bridging beam can be built between the two piles, on which the building columns can be constructed. All subject to the approval of SWC.

Conventional bored piles may need to be setback approximately 1 m from the sides of the Sydney Water drain. Closer positioning of piles may be possible where hole stability is provided during pile construction (e.g. casing).

### **7.3. Pile hole collapse**

Owing to the poor ground conditions, and the close proximity of pile footing to the existing drain, it is possible that pile hole instability could have an adverse effect on the drain.

This can be managed by appropriate selection and control of piling plant and pile sizes.

Careful use of casing may also provide a means of ensuring that the ground beneath the drain is not destabilised.

### **7.4. Vibration impact**

As noted in Section 6.3 above, vibration limits are relatively high for structurally sound structures. The concrete drain would seem to fit into this category, and therefore damage from vibration during pile installation is considered unlikely.

### **7.5. Pile downdrag**

The construction details of the drain are unclear, though it is likely the poor ground conditions underlying the drain mean that it has experienced significant movement and deformation in the 75 years since its construction. Downdrag effects from pile settlement under load are therefore likely to be insignificant by comparison.

Based on recent analysis undertaken for the nearby student accommodation towers, it is likely that a setback distance of about a metre between the pile shaft and the outside face of the drain wall will be sufficient to prevent adverse pile settlement effects on the drain.

## **8. CONCLUSION AND RECOMMENDATIONS**

The assessment described in this report demonstrates that the buildings proposed as part of the Haymarket redevelopment can be constructed so as to have negligible detrimental effects on the adjacent existing stormwater infrastructure, i.e.:

- Historic Hay Street – Lackey Street stormwater channel (**Historic drain**), and
- Sydney Water Corporation (SWC) Hay Street – Lackey Street stormwater channel (**Sydney Water drain**)

The main potential impact on the historic drain is vibration during adjacent pile excavation. Other impacts are unlikely due to the fact that the drain is located about 4 m from the site boundary along Hay Street, and 5 m from the closest proposed pile foundation. The historic drain has recently been rehabilitated and strengthened with an internal reinforced concrete liner. Vibration limits have been estimated based on the current condition. Vibration caused by pile excavation in soil and rock has been assessed and is less than the adopted limit.

To protect the Sydney Water drain, the pile layout will need to avoid the drain alignment, and also provide adequate horizontal separation distance between the pile shaft and the drain. Additionally, structural bridging beams may need to be constructed over the drain to support building columns. Such beams would be supported by piles on either side of

the drain. Any piles located adjacent to the drain will need to be detailed so as to limit the potential for creating instability in the soils beneath the drain.

In summary, PSM is satisfied that The Haymarket buildings as contemplated in Significant Development Application (SSD 12\_5752) can be developed adjacent to the existing heritage listed drain, and adjacent to and over the non-heritage SWC drainage infrastructure at the site.

Key risks to SWC's existing drainage infrastructure can be managed within acceptable limits utilising industry standard design and construction techniques and practices. Utilising such techniques, effects on the existing drainage infrastructure can be maintained within acceptable limits so as not to result in detrimental impacts.

It is recommended that once design developed building designs are sufficiently progressed, such as at the respective Stage 2 DA stages, and subsequent to further consultation with the respective utility providers, that the assessment undertaken to date be further refined to confirm the conclusions of this report.

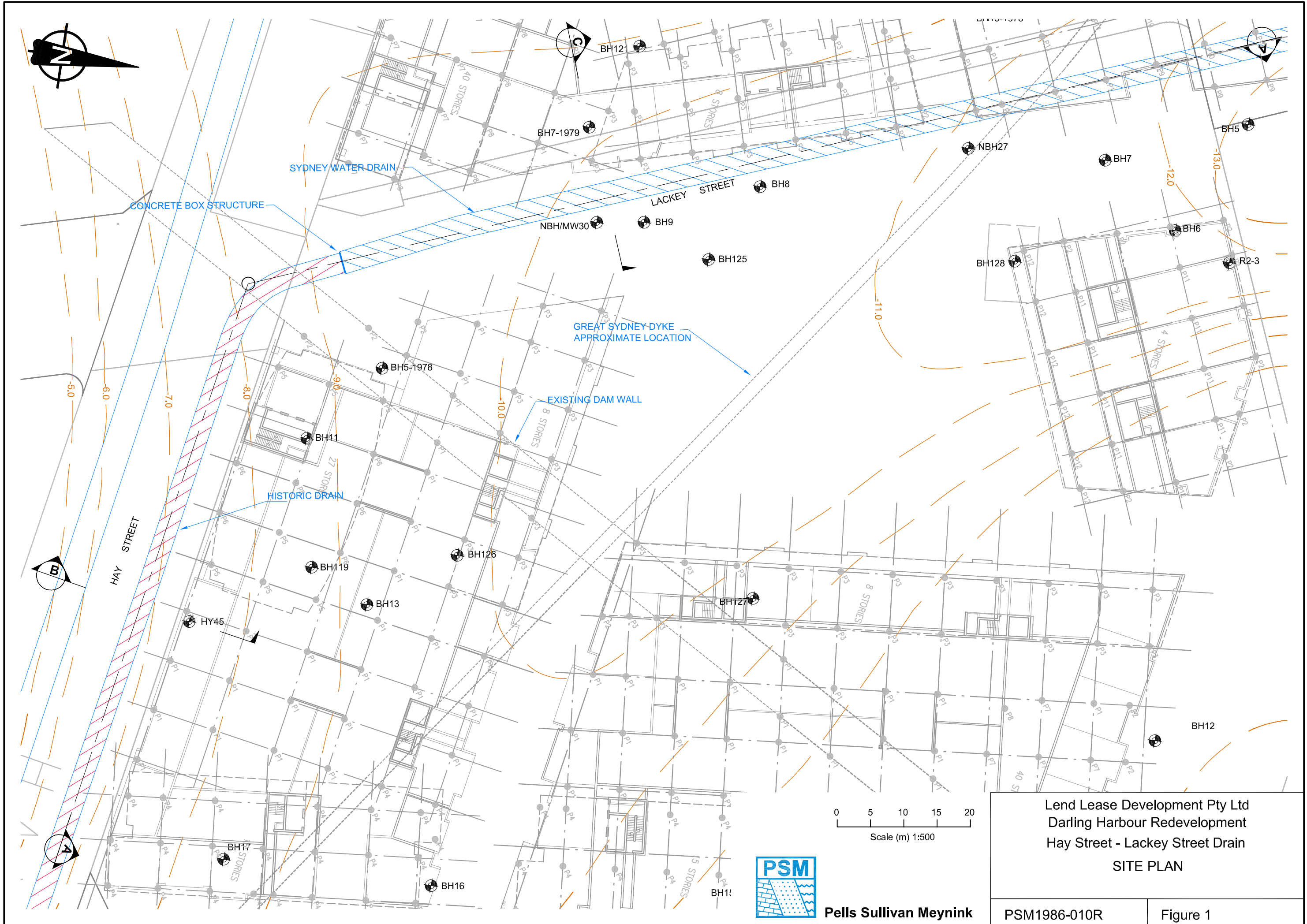
For and on behalf of  
PELLS SULLIVAN MEYNINK



STRATH CLARKE

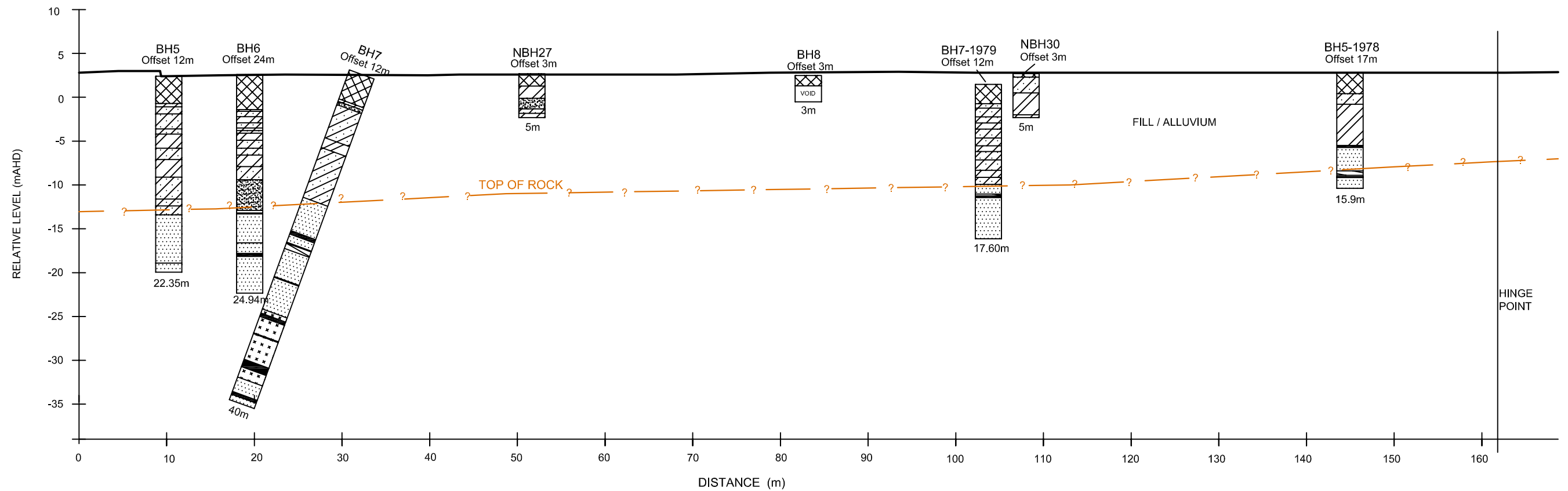
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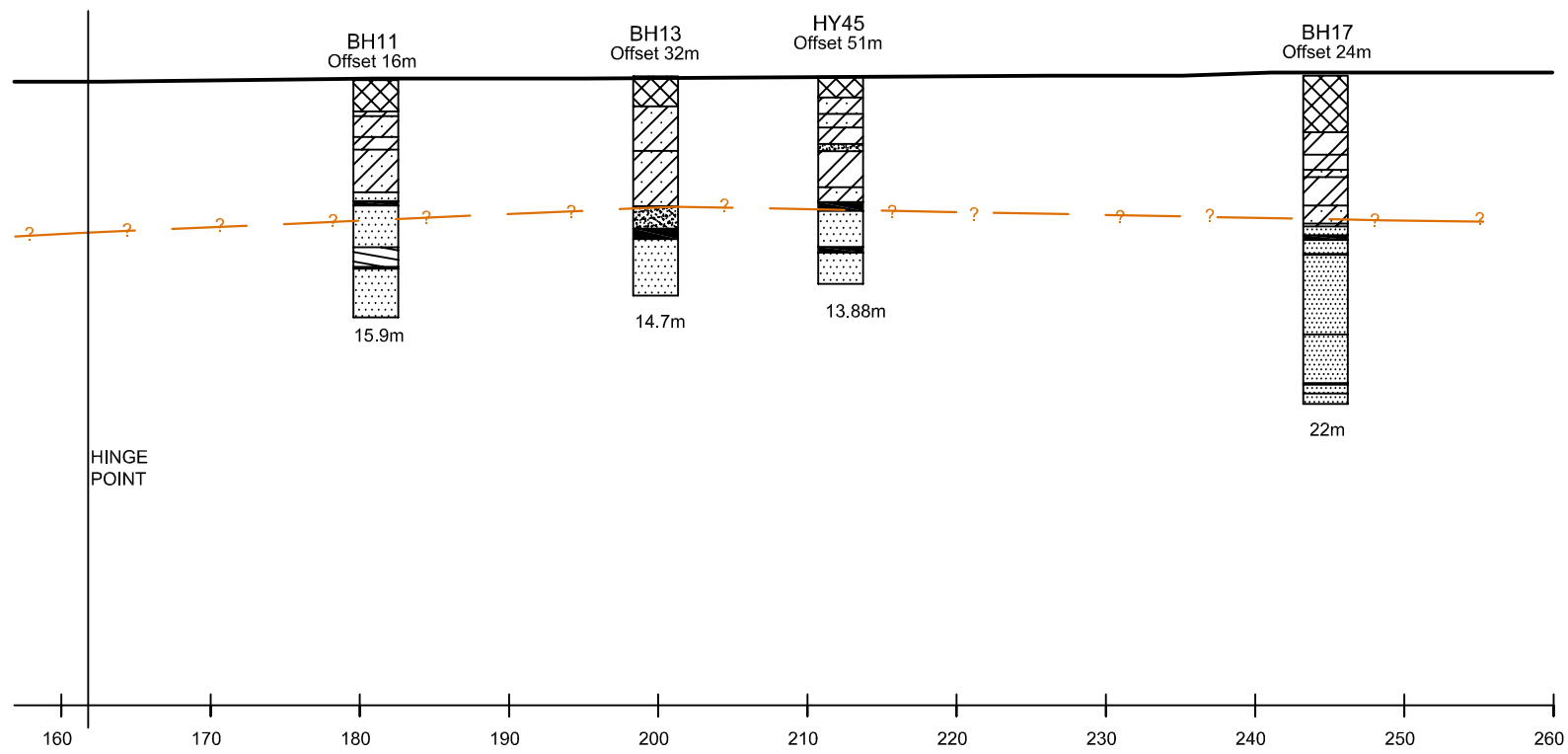


<p>Lend Lease Development Pty Ltd          Darling Harbour Redevelopment          Hay Street - Lackey Street Drain          SITE PLAN</p>	
<p>PSM1986-010R</p>	<p>Figure 1</p>


**Pells Sullivan Meynink**



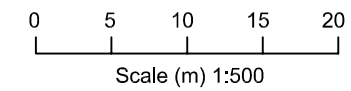
**A** SECTION  
SCALE 1:500



**A** SECTION  
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**LEGEND**

- Fill
- Alluvium
- Sand
- Sandy Clay / Clayey Sand
- Clay
- Shale
- Igneous
- Sandstone
- Core Loss

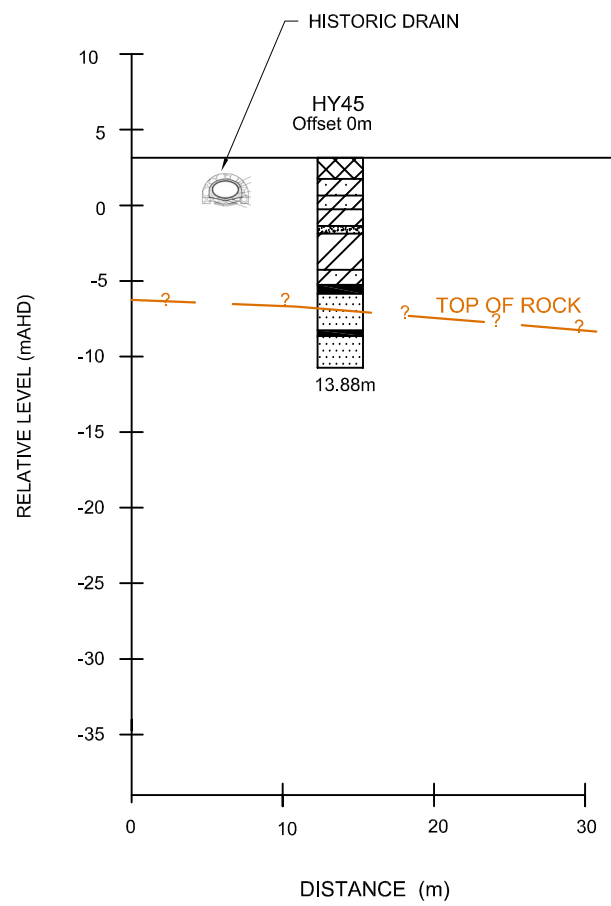


**Pells Sullivan Meynink**

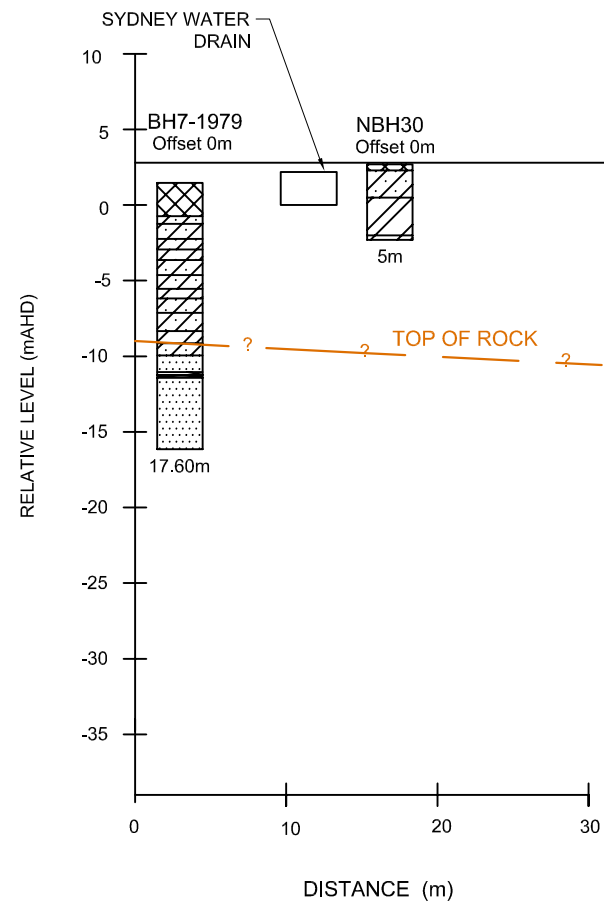
Lend Lease Development Pty Ltd  
Darling Harbour Redevelopment  
Hay Street - Lackey Street Drain  
**GEOTECHNICAL SECTIONS**  
**SHEET 1 OF 2**

PSM1986-010R

FIGURE 2



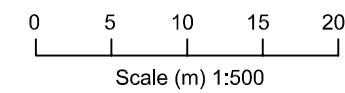
**B** SECTION  
SCALE 1:500



**C** SECTION  
SCALE 1:500

**LEGEND**

- Fill
- Alluvium
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- Sandstone
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Darling Harbour Redevelopment  
Hay Street - Lackey Street Drain

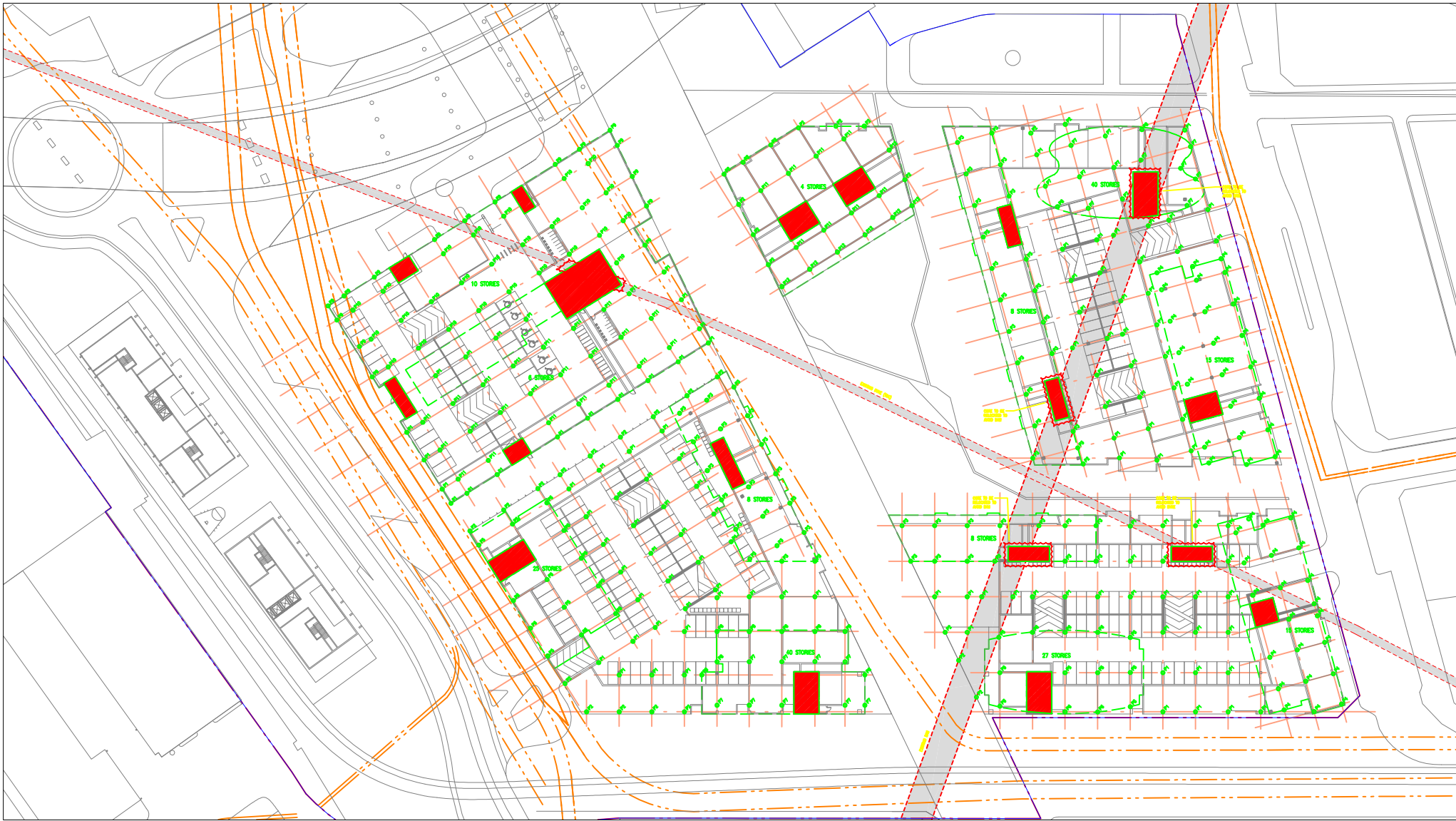
GEOTECHNICAL SECTIONS  
SHEET 2 OF 2

PSM1986-010R

FIGURE 3

**APPENDIX A**  
**PROPOSED BUILDING LAYOUT AND LOADS**





40 STORES		
LOAD	WIND (kN)	SEISMIC (kN)
WIND A	2000	200000
WIND B	2500	250000
IS	2000	200000
NONRESIDENT	4000	

15 STORES		
LOAD	WIND (kN)	SEISMIC (kN)
WIND A	2700	65000
WIND B	1100	21700
IS	4700	149000
NONRESIDENT	1800	

8 STORES		
LOAD	WIND (kN)	SEISMIC (kN)
WIND A	2700	11400
WIND B	500	1000
IS	4000	60000
NONRESIDENT	1000	

4 STORES		
LOAD	WIND (kN)	SEISMIC (kN)
WIND A	200	1100
WIND B	500	500
IS	900	2000
NONRESIDENT	300	

25/27 STORES		
LOAD	WIND (kN)	SEISMIC (kN)
WIND A	8000	220000
WIND B	2500	60000
IS	1800	70000
NONRESIDENT	1000	

10 STORES		
LOAD	WIND (kN)	SEISMIC (kN)
WIND A	2700	65000
WIND B	1100	21700
IS	4700	149000
NONRESIDENT	1800	

6 STORES		
LOAD	WIND (kN)	SEISMIC (kN)
WIND A	270	2800
WIND B	100	1000
IS	1400	18400
NONRESIDENT	300	

PILE LOAD SCHEDULE		
WIND	WIND LOAD (kN)	WIND LOAD (kN)
P1	300	1000
P2	3000	500
P3	4000	1300
P4	7000	1000
P5	13000	2000
P6	17000	2000
P7	20000	2000
P8	17000	2000
P9	5000	2000
P10	8000	2000
P11	2000	1000
P12	2500	1000

- NOTE:
1. THE LOAD SCHEDULES ABOVE ARE APPROXIMATE
  2. LOADS SHOULD BE REVIEWED AGAINST WIND AND SOIL TEST CAPABILITY
  3. DIMENSIONAL LOADS SHOULD USE GRADES, CLASS II (DC)
  4. ALL DIMENSIONS SHOULD BE CHECKED ON THE WORKING SET - 6 STORES ON THE NORTH
  5. GEOTECHNICAL PROVIDER SHOULD VERIFY LOADS AGAINST ALL SOIL TYPES
  6. ALL DIMENSIONS SHOULD BE CHECKED AGAINST ALL DIMENSIONS
  7. ALL DIMENSIONS SHOULD BE CHECKED AGAINST ALL DIMENSIONS
  8. ALL DIMENSIONS SHOULD BE CHECKED AGAINST ALL DIMENSIONS
  9. ALL DIMENSIONS SHOULD BE CHECKED AGAINST ALL DIMENSIONS
  10. ALL DIMENSIONS SHOULD BE CHECKED AGAINST ALL DIMENSIONS

**APPENDIX B**

**MWS&DB ENLARGEMENT OF LACKEY STREET DRAIN DRAWINGS**

**CITY STORMWATER DRAINAGE  
ENLARGEMENT OF LACKEY ST SECTION**

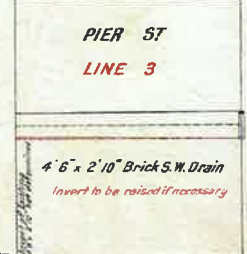
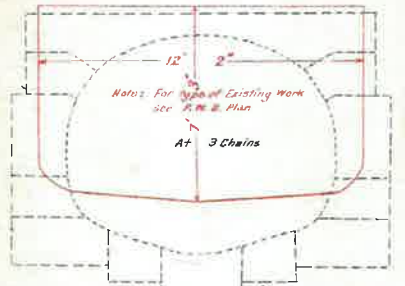
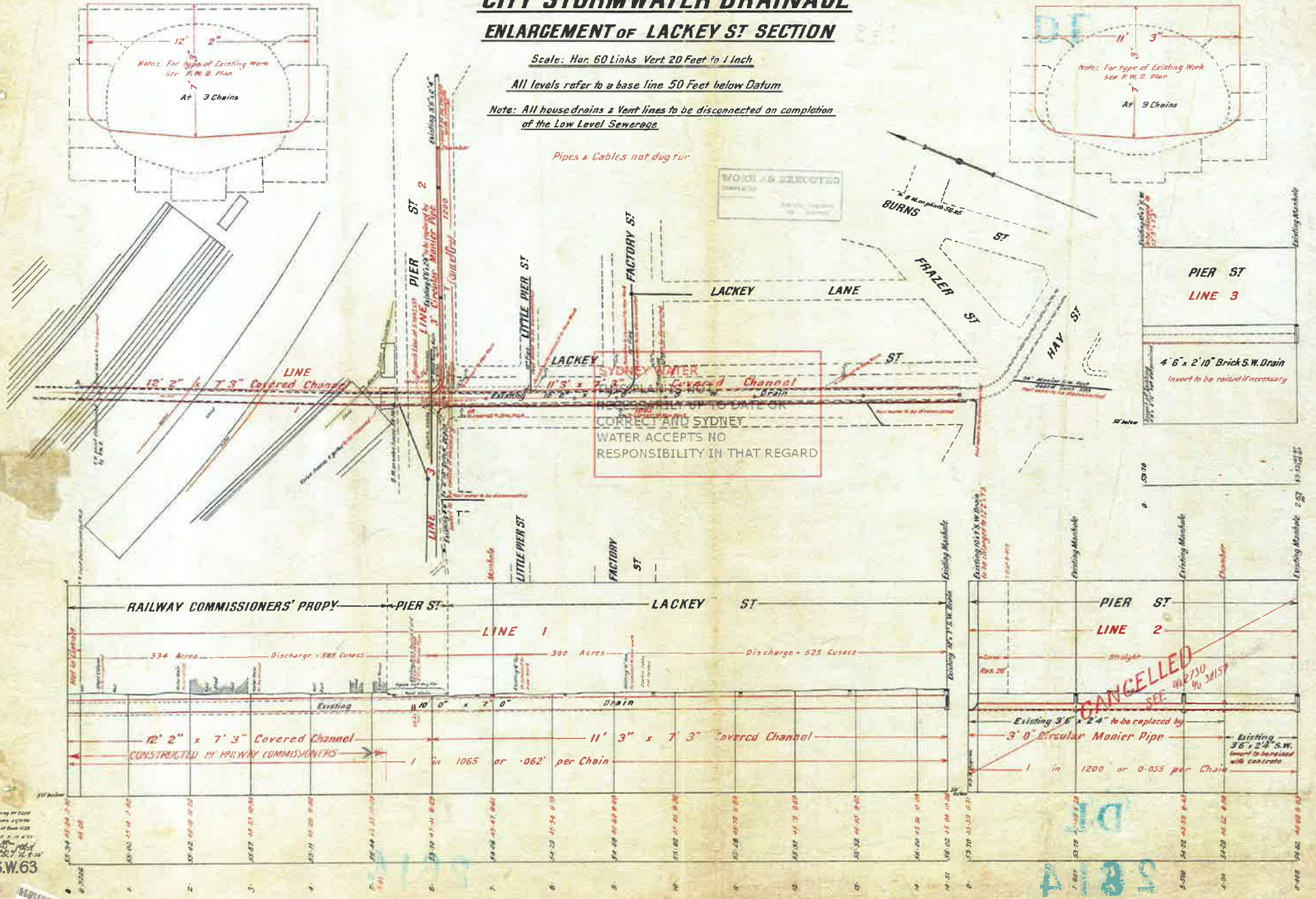
Scale: Hor. 60 Links Vert 20 Feet to 1 Inch

All levels refer to a base line 50 Feet below Datum

Note: All house drains & Vent lines to be disconnected on completion of the Low Level Sewerage

Pipes & Cables not dug for

CORRECT AND SYDNEY WATER ACCEPTS NO RESPONSIBILITY IN THAT REGARD



Survey No 2524  
Mains of 1910  
Level Bench 1129  
L.S. 20.11.05  
S.W.63

485

211  
10.8

# M. W. S. & D. B.

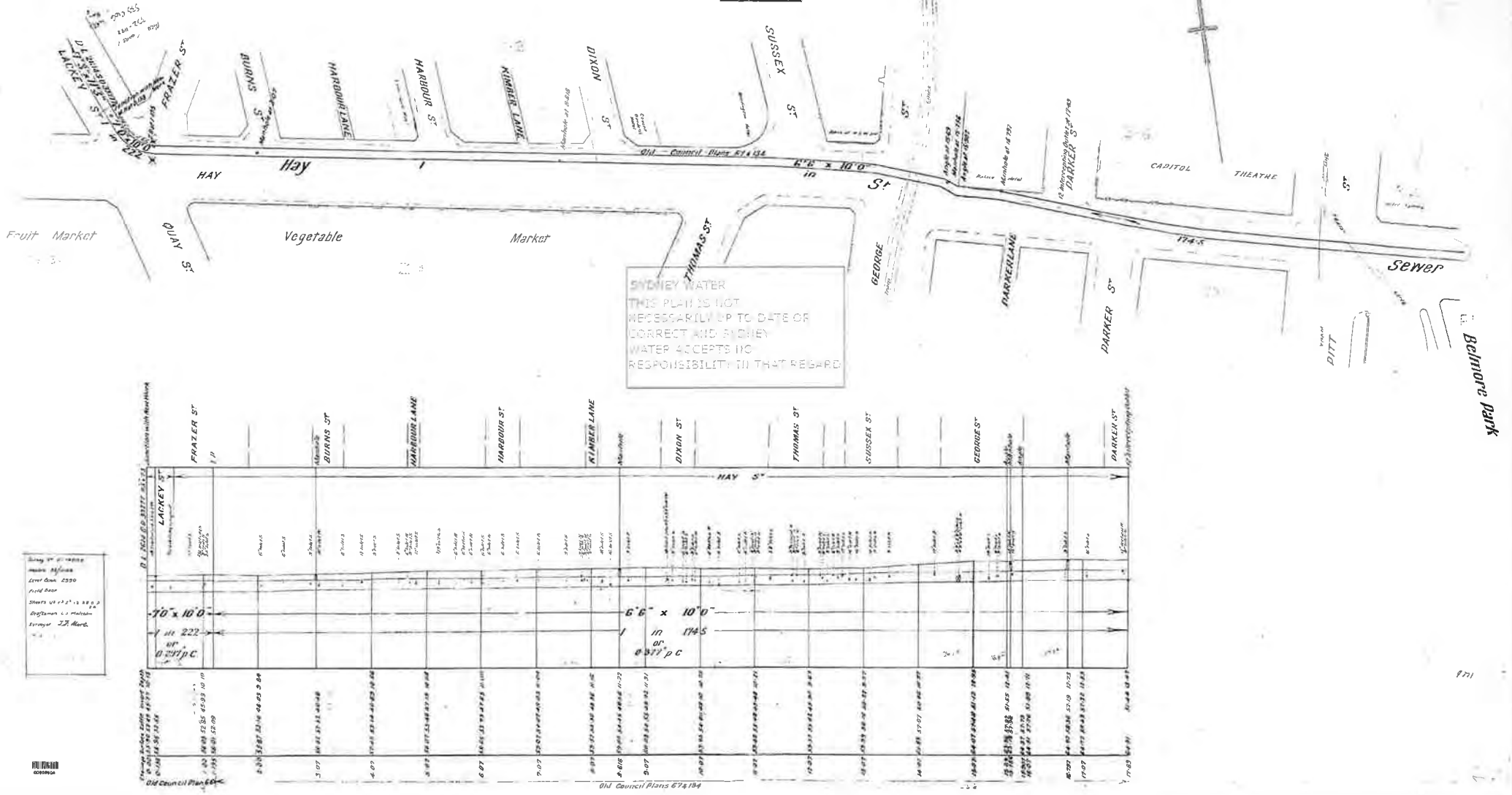
## CITY (LOW LEVEL) SEWERAGE

Scales Hor 60 Links, Ver 20 Feet to an Inch

All levels refer to a base line 50 feet below datum

Hay St Sewer as Executed condition as observed

June 1935



SYDNEY WATER  
 THIS PLAN IS NOT  
 NECESSARILY UP TO DATE OR  
 CORRECT AND SYDNEY  
 WATER ACCEPTS NO  
 RESPONSIBILITY IN THAT REGARD

Hay St 70' x 10'  
 Level 222  
 Field Base  
 Streets 1/2" = 100'  
 Prof. 1/4" = 100'  
 Survey 1/2" = 100'

Old Council Plans 674 194

Old Council Plans 674 194



**APPENDIX C**  
**SYDNEY WATER STATEMENT OF HERITAGE IMPACT**  
**HAY STREET STORMWATER CHANNEL**

## Statement of Heritage Impact

### Hay Street Stormwater Channel

(Former Hay Street Sewer)

**Sydney Water Corporation S170 Heritage & Conservation Register No. 4574216**

### Purpose

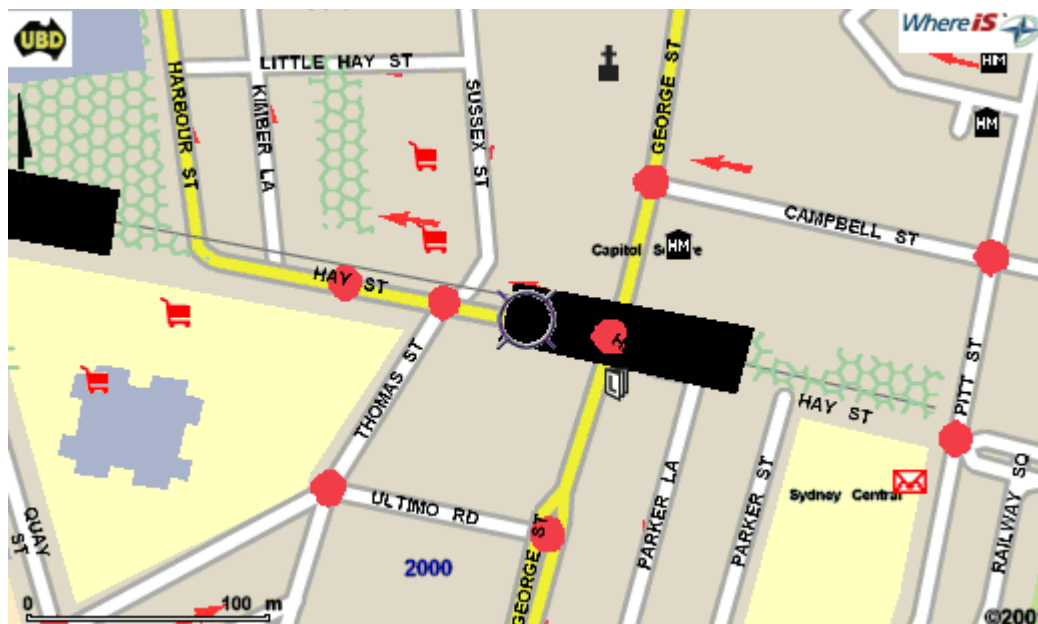
This document is prepared as supporting documentation for an application for an excavation permit, to impact a relic, under Section 140 of the *Heritage Act*. It discusses the heritage impacts and mitigation measures associated with the remedial works required to stabilise a damaged section of the stormwater channel and retain it in service.

### Prepared by

Phil Bennett, Sydney Water Heritage Adviser & Terence Simms, National Business Manager AWT, with advice from MacLaren North, Sydney Water Heritage Manager and Simon Wiltshire, Hughes Trueman, consultant heritage engineer.

### Address and Property Description

The Hay Street Storm Water Channel is located under Hay Street, Haymarket, Sydney. The channel follows a westerly direction from Sussex Street, then turns north along the former Lackey Street, discharging into Darling Harbour.



The Sydney City Council constructed the Hay Street sewage/storm water drainage system in 1863. The channel drained most of the south-eastern portion of the city and its original catchment was defined by Bourke Street to the north

## Statement of Heritage Impact

and Devonshire Street to the south (a catchment area of approximately 143 hectares).

The channel is constructed of sandstone blocks in a stretcher bond pattern and is an arch barrel construction creating a semi-elliptical structure, 2.1 metres high and 3.0 metres wide. The cross-section of the structure is symmetrical about the centre-line of the crown of the arch. Each cross section consists of 21 sandstone blocks. Ten blocks are located either side of the centre keystone. In most cases the sandstone blocks bear directly against each other, however occasionally mortar can be found in some joints. The base slab of the channel is also constructed of sandstone blocks. It has a 'vee-shape' profile, with a small scupper in the middle designed for low flows.

The structure itself is owned by Sydney Water Corporation, the land is owned by the Roads and Traffic Authority (RTA), and is under the planning control of the Sydney Harbour Foreshores Authority (SHFA). The light rail and monorail pass in close proximity to the channel.

### History and significance

The Hay Street Stormwater Channel was constructed in 1863 of sandstone blocks, originally for the drainage of both sewage and stormwater and is recognised as being of high *local* heritage significance. The channel is listed on the Sydney Water Section 170 Heritage and Conservation Register.

The Hay Street stormwater system is highly significant as it was one of the first five original combined sewers constructed in Sydney around the 1860s period. The other four sewers were; Blackwattle Bay, Woolloomooloo, the Tank Stream and Bennelong. These five sewers were responsible for greatly improving public health by diverting stormwater and sewage off the streets and discharging it out into the city's Harbour. The five sewers are the first examples of sewerage and drainage services to be built in Sydney, and potentially Australia. The subsequent construction of the BOOS (Bondi Ocean Outfall Sewer) in 1889 and the connection of the Hay Street system in 1901 diverted sewer flow from the harbour and into the ocean. Eventually the drain was used predominantly for stormwater, this further improved public health, hygiene and living standards for the city's residents. The channel is of technological significance as it provides an excellent example of the engineering and construction techniques of the late 1800s and of the city's early infrastructure. The numerous extensions and modifications made throughout the years provide a record of the advancements made in drainage construction techniques. The operational curtilage for Hay Street SWC includes all original fabric including, but not limited to the channel bed, walls and coping.

### Current situation and condition

The historic part of the channel is 228m in length and either end terminates in a 1980s vintage concrete chamber. Over the years some sections of the channel have suffered serious dilapidation. This is primarily due to the age of the structure, lack of deep footings and issues associated with the structure being built on

## Statement of Heritage Impact

reclaimed land, which has since shifted and subsided in places. The weight of traffic above one side of the arch, tidal movement within the channel, subsidence from ground water movements and tree root penetration have all contributed to its failure. This failure has taken the form of a significant deformation of the arch which threatens its structural stability as well as substantial cracking and damage to stone blocks.

Inspections undertaken in March 2004 identified significant worsening of the structure and the dilapidation has extended upstream into the Harbour Street/Hay Street road junction, presenting a major public safety risk. Engineering advice received from the Department of Commerce suggested that should a collapse happen, it would be sudden and without warning.



Sydney Water Corporation (SWC) proposes to undertake permanent remediation works to the damaged sections of the channel. These works entail the stabilisation of the sandstone block structure that forms the underground stormwater channel.

Following on-going condition monitoring by Sydney Water's engineers since 2002 the preferred method of repair is by slip-lining the most seriously dilapidated sections of the channel, which stabilises the existing structure, retains the historic fabric in situ (albeit in a concealed fashion) and allows the channel to continue in service as a part of the stormwater system.

## Statement of Heritage Impact

Due to its nature, the channel is considered to be a relic under the *Heritage Act* and thus approval is required under section 140 of the Act for these works.

### **The following aspects of the proposal respect or enhance the heritage significance of the item for the following reasons**

The Hay Street Stormwater Channel demonstrates different degrees of dilapidation over its length. The most seriously dilapidated section is that under Hay Street from Harbour Street to Lackey Street (refer drawing DILAP I, page 7 of the *Options Investigation Report*).

As illustrated by the drawing, some 100 metres of the channel have suffered only minor damage. This section will be subject to regular monitoring and minor local repairs in accordance with traditional sandstone block repair techniques. This will both conserve and enhance the heritage values of the item. The channel will be photographically recorded prior to any works commencing, with a copy of the record lodged in the Sydney Water Archives.

Over 20 repair/stabilisation options for the channel have been evaluated to address the seriously deteriorated section. These options have considered technical, cost and heritage implications, set out in detail in the *Options Investigation Report* (enclosed). The solutions proposed have been graded for their heritage conservation qualities by assessing retention of the historic fabric, maintenance of functionality and the reversibility of the remediation option. Importantly, all the significant elements of the heritage item will be kept and no demolition of the structure is required.

The proposed works to the channel involve the insertion of a large round/elliptical plastic pipe within the most badly damaged section of the channel for 102m of 228m total length (Chainages 34 to 136 on plan DILAP 1, page 7, *Options Investigation Report*). This pipe will be held in place through a soft grout which fills out the cavity between the new pipe and the walls of the original channel, with a 'bond breaker' membrane placed between the sandstone channel walls and the grout prior to construction (to be specified, but likely to be geotextile, plastic sheeting or similar). This will ensure that a separation layer exists between the sandstone arch and the lightweight grout, which will fill the annulus between the arch and the liner pipe. This allows for the slip-liner to be removed at any future date, rendering this solution reversible. A tapered funnel arrangement constructed in the same plastic as the pipe will be inserted at either end of the slip-lined section to facilitate the smooth flow of water into this section.

This solution has sufficient structural support to hold the damaged sections of the channel in place while keeping the channel in service. No fabric needs to be removed in this proposal and the works can be reversed in future if required. Minor spot repairs will be undertaken in other sections of the channel as required, using traditional masonry techniques.

The slip lining material will be brought into the channel in approximately 4m sections, slid into place and joined together. Entry into the channel will be by

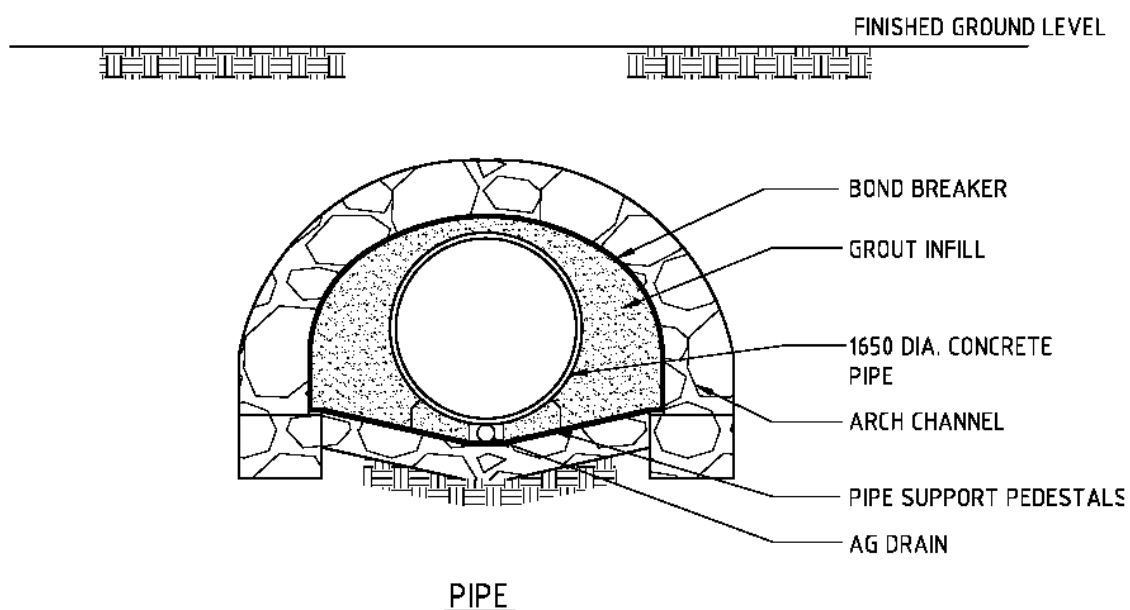
## Statement of Heritage Impact

creating an opening in the 1980s concrete transition chamber located at the east end of the channel (grid F-11 on plan DILAP 1, page 7, *Options Investigation Report*). This will entail no impact upon historic fabric and the access opening will be reinstated in reinforced concrete at the conclusion of works.

See the attached *Options Investigation Report* for a detailed analysis of the options considered and the scoring methodology used to rank the options. Through this analysis, it was determined that Option 3.6, Slip Lining, provided the optimum engineering, heritage and cost-based solution.

### The following aspects of the proposal could detrimentally impact on heritage significance

The proposed slip-lining of the arched sandstone channel will alter the form of the channel have a localised negative heritage impact, due to a section of the channel's fabric being concealed. This proposal will also require the insertion of a new oval formed pipe within the existing structure which adds new fabric and alters its original design. To minimise its impact the new pipe will be held in position using a soft, low density grout and a separation layer will be placed between the grout and the existing stone blocks. This allows for the removal of both grout and pipe if desired without damage to the stone.



## Statement of Heritage Impact

The decision to slip-line the channel was only made after considering the full range of remediation options available. These included considering the complete demolition of the structure to the full reconstruction of the structure, but many variables needed to be assessed before making the decision to slip-line. For instance, the large number of services located between the top of the channel and the road above made the reconstruction option unviable due to the excessive costs and disruption to vital services that would have resulted from digging up the channel.

Please refer to the *Options Investigation Report* for a detailed analysis of the different options that were considered. As stated, the conservation of the heritage values of the structure was an important determining factor when choosing the slip-lining option.

### Interpretation

Whilst, the proposal to slip-line the seriously dilapidated section of stone channel will alter its form and original design there are opportunities to interpret the underground channel to those above. It is located below a highly public place, the Sydney Entertainment Centre forecourt, and an interpretation of the channel is being proposed by Sydney Water Corporation. Details of this interpretation are yet to be finalised but some form of signage, mapping and photographic collage are being considered. Any interpretation works will be undertaken in conjunction with the Sydney Harbour Foreshore Authority, as managers of the public space, and the City of Sydney Council.

Due to very restricted access (access requires staff to be lowered by block and tackle through a manhole), the Hay Street channel is not suitable for any type of public access. Sydney Water does currently provide limited public access to the Tank Stream, a channel of State significance and similar vintage and construction.

### Archaeological issues

While the Hay Street Stormwater Channel is itself technically considered to be a relic, there will be no archaeological impacts from this proposal. Excavation for access into the tunnel will occur above the 1980s concrete transition junction at the east end of the tunnel, near the junction of Hay and Sussex Streets. Construction of the junction has removed any archaeological deposits in this area. Other access to the channel will be via existing manholes and no other excavation will be required.

'Stop work' protocols will be placed within the Construction Environmental Management Plan to ensure that Sydney Water's contractors halt work in the event of unexpected discovery and that Sydney Water heritage staff – MacLaren North (Heritage Manager) and Phil Bennett (Heritage Adviser) – are available to respond in the event of such a discovery.

## Statement of Heritage Impact

The channel will be photographically recorded by Phil Bennett (Heritage Adviser) prior to works commencing.

### **The following sympathetic solutions have been considered and discounted for the following reasons**

Actions that would prevent changes to the fabric of the channel were considered. One option was to do nothing to the channel but rather to limiting load on the channel by exclusion fencing and closing the roads above. This has occurred whilst the channel is undergoing monitoring to determine the rate of movement before a suitable remediation options was chosen. The monitoring determined that movement continues to occur without traffic above. Long-term function of the stormwater channel as well as risk to public safety through future structural failure discounted the do-nothing option.

The large number of services in the area (telecommunications, high pressure gas main, high voltage electricity, tram tracks, etc) made a solution which required the exposure of the top of the channel unviable (see attached *Services Plan*). Similarly, to suitably stabilise the channel without altering the sandstone construction would require extensive underpinning to compensate for the lack of good footings.

For a comprehensive analysis of solutions for the repair and stabilisation of the channel please refer to the *Options Investigation Report* attached.

### **Conclusion**

The proposed Option 3.6 – Slip-lining provides the best balance of technical, heritage and cost for addressing the structural failure of the channel. The slip lining will leave all historic fabric in place and the use of low density grout with a bond breaker membrane will allow the slip-lining to be removed in future if required. Less than half of the channel will be concealed by this technique and the exposed sections will be subject to localised stone repair using traditional techniques. Future monitoring programs will continue to assess the structural stability of the unlined sections of the channel. Importantly, this technique allows the channel to remain in service for its original purpose, albeit in a somewhat modified form.

### **Attachments**

Hay Street Storm Water Channel, Haymarket Sydney, *Options Investigation Report*.

Sydney Water Corporation S170 Register entry for this item.

Services Plan for Hay Street Channel area

Dilapidation Plan for Hay Street channel

**APPENDIX D**

**ARTICLE FROM “WATER”, JUNE 2009  
ENGINEERING HERITAGE AWARD**

in any application, from channel regulation to a modulating structure within a wastewater treatment facility.

The WLF is a wedge sealing design suited to large penstocks. Innovative hydrostatic testing has seen this penstock withstand up to 18m head pressure and is being utilised in the design of the \$1.9 billion Sydney Desalination Plant.

The DLF is a decant penstock for downwards opening weir-style gates. Recently used in various sewage treatment plant upgrades around Australia, the DLF features the single stem model for your standard applications and a dual stem model to accommodate the widest of open water ways, whilst still maintaining smooth operation with minimal deflexion.

The LF series complements AWMA's selection of purpose-designed control gates such as the LayFlat, SideWinder, Head and Discharge Gate and Segmented Stopboards.

For further information, contact AWMA on 1800 664 852 or visit [www.awma.au.com](http://www.awma.au.com)

## ENGINEERING HERITAGE AWARD

A Water Infrastructure Group pipeline rehabilitation project for Sydney Water has received an engineering excellence award from the Institute of Public Works Engineering Australia.

The \$4.1 million project involved relining the Hay Street stormwater channel and was awarded the Streets Opening Conference Engineering Heritage Award at the Institute's NSW Division Excellence Awards in Sydney. The channel runs under the busy intersection of Hay and Harbour Streets near the Sydney Entertainment Centre forecourt in Haymarket.



The channel was constructed by the Sydney City Council in 1863 and is a semi-elliptical structure built from sandstone blocks. It was one of the first combined sewers constructed in Sydney and was designed to improve public health by diverting stormwater and sewage off the streets and discharging it into the harbour.

It provides an excellent snapshot of infrastructure in early Sydney and is a fine example of late nineteenth century engineering and construction techniques. Kallard Ross, Water Infrastructure Group manager for the project, said that his team developed specific methods for the unique conditions in the Hay Street Channel.



"The new liner is made from marine grade N60 sulphate resisting concrete reinforced with SS304L stainless steel bars to provide a minimum design life of 100 years and maintenance free period of 50 years.



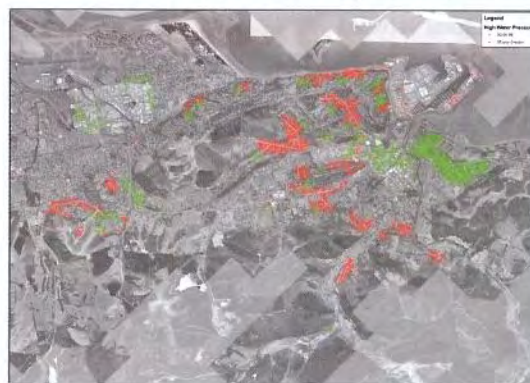
From left to right: Janssen Chan (SW), David Grasby (SW), David Stramandinoli (wigroup), Kerry Schott (SW), Kallard Ross (wigroup), Peter Van Breeda (SW), Arasan Arasaratnam (SW).

Contact: 03 9863 3535, [peverist@wigroup.com.au](mailto:peverist@wigroup.com.au)

## REDUCING WATER PRESSURES

Using InfoWorks WS has allowed Nelson City Council (NCC), in the South Island of New Zealand, to develop and prioritise strategies for reducing water pressures in selected parts of its supply network.

The model assists in prioritising the infrastructure renewals and ensures that any new pipes will be sized to take account of planned pressure strategies so that flows will remain sufficient to meet customer and fire flow requirements.



More than 5% of customers in Nelson receive water with a head in excess of 90m (295 feet) and NCC aims to reduce values in these parts of its network without dropping the pressure too low elsewhere. One of the prime reasons is water conservation, as lower pressures reduce usage, cut leakage and lead to fewer pipe failures. There are also energy savings in pumping and treatment.

**APPENDIX E**  
**PHOTOS OF LINING OF HERITAGE DRAIN**

