Health Infrastructure
c/- Savills Australia
Level 7, 50 Bridge Street
SYDNEY NSW 2001

Job No. EH423

Attn: Mr Nick Anderson

21 December 2017

Re: St Leonards Health Organisation Relocation Flooding Assessment

Dear Sir,

This letter sets out the findings of an investigation that has been undertaken by Lyall & Associates (**L&A**) to assess flooding behaviour in the vicinity of a new building that will be built on the eastern side of Reserve Road within the grounds of the Royal North Shore Hospital at St Leonards. The new building in combination with site clearing works form part of the larger St Leonards Health Organisation Relocation (**SHOR**) project. This letter also sets out the impact that the proposed development will have on flooding patterns.

1. Site Description

The area comprising the SHOR project, the extent of which is shown on **Figure 1**, is bounded by Reserve Road to its west, existing commercial development to its south (Lot 11 DP 1013030), Herbert Street to its east and existing hospital facilities to its north. **Figure 1** also shows the extent of Sites 4A and 4B which are located along the southern side of the SHOR project boundary and are the subject of this letter.

Figure 2 and the site survey plan (refer copy contained in **Annexure A**) show the footprint of a number of multi-storey brick buildings that are located entirely or partially within Sites 4A and 4B. The two sites are accessed from Reserve Road via a driveway that is located adjacent to the southern boundary of Site 4A. Plates contained in **Annexure B** show the key features of Sites 4A and 4B.

Reserve Road falls at a grade of about six per cent from an elevation of about RL 82.15 m AHD adjacent to the northern boundary of Site 4A, to about RL 79.69 m AHD adjacent to its southern boundary. Beyond this point the road continues to fall at a grade of less than one per cent toward the Pacific Highway.

Herbert Street falls at a grade of about 3 per cent from an elevation of about RL 75.84 m AHD adjacent to the northern boundary of Site 4B, to about RL 74.60 m AHD at the sag in the road that is located adjacent to its southern boundary.

A trapped low point is present in the north-eastern corner of Lot 11 DP 1013030. The trapped low point has a minimum elevation of about RL 73.96 m AHD, which is about 600 mm below the road level in Herbert Street. An existing solid concrete wall and a series of raised garden beds run along the eastern boundary of Lot 11 DP 1013030 adjacent to the trapped low point. The wall and the garden beds are set above the level of the road at an elevation of about RL 76.15 m AHD.

2. Existing Drainage System

Figure 1 shows the extent of the 18.9 ha catchment which contributes to flow in a trunk drainage line that runs in an easterly direction across Gore Hill Oval (**Gore Hill Oval Catchment**). **Figure 1** also shows the extent of the additional 1.9 ha catchment that contributes to flow in the trunk drainage line at Reserve Road (**Reserve Road Catchment**).

Figure 2 shows that the trunk drainage line comprises a single 900 mm diameter pipe where it runs through Sites 4A and 4B. A second drainage line comprising a single 525 mm diameter pipe which controls runoff from Reserve Road also runs parallel with the 900 mm diameter pipe through Sites 4A and 4B. There are a series of existing grated inlet pits located along the 900 mm diameter pipe in the vicinity of Sites 4A and 4B. These pits are denoted Pits 3, 4, 5, 6 and 7 on **Figure 2**.

The trapped low point in Lot 11 DP 1013030 is drained by 1500 mm and 2100 mm diameter pipes that run in a northerly direction along Herbert Street. The two pipes combine into a single drainage line about 70 m north of Site 4B, where the combined system turns and runs in an easterly direction under St Leonards Railway Station, eventually discharging to Flat Rock Creek about 1 km downstream of Herbert Street. **Figure 1** shows the extent of the 2.4 ha catchment that contributes to flow in the trunk drainage line at the trapped low point in Lot 11 DP 1013030 (**SHOR Catchment**).

Runoff from a 6.7 ha catchment, the extent of which is also shown on **Figure 1**, contributes to flow in the lateral pipes that connect to the trunk drainage line in Herbert Street (**Herbert Street Catchment**).

3. Gore Hill Park Redevelopment

Willoughby City Council (**WCC**) has advised that it intends to redevelop Gore Hill Oval in the near future as part of the proposed Gore Hill Park Redevelopment Project. In addition to the upgrade of the sporting facilities, the project will involve the construction of a 4000 m^3 on-site detention system beneath the surface of the oval. It is understood that the purpose of the on-site detention system is to reduce the impact of flooding downstream of the oval.

4. WCC's Technical Standard No. 3

In November 2009, WCC updated its *Attachment 22 Floodplain Management – Technical Standard No. 3* document which deals with flood-related planning controls in the Willoughby City LGA. Under the updated Technical Standard, the Royal North Shore Hospital site has been assigned a **Major Drainage** classification due to the presence of several overland flow paths that run through it. In the case where new hospital type developments are proposed, the key requirements of *Technical Standard No. 3* which are relevant to properties identified as being subject to a Major Drainage classification are as follows:

- No structure to impede flood flow.
- Redevelopment is to follow the footprint of the existing buildings.
- Habitable floor levels are to be located a minimum of 500 mm above the peak 1% Average Exceedance Probability (**AEP**) water surface elevation.
- A safe flood evacuation route is to be provided at the habitable floor level.

The following sections of this report set out the findings of an investigation that was carried out to determine the freeboard that is available to the minimum habitable floor level of the proposed development under post-developed conditions and how it relates to the above requirements.

5. Assessment of Flooding and Drainage Patterns – Present Day Conditions

5.1 Background

L&A undertook an investigation on behalf of WCC in 2009 which broadly defined patterns of overland flow across the whole of the Local Government Area. The investigation identified an overland flow path is present along the southern boundary of Sites 4A and 4B during storms which surcharge the existing trunk drainage line.

More recently L&A have been engaged to undertake the flood study for the Flat Rock Creek catchment (L&A, 2017). This study involves the update of the hydrologic (DRAINS) and hydraulic (TUFLOW) models that were originally developed as part of the 2009 study to more accurately define the nature of overland flow in the vicinity of the hospital. These updated models formed the basis of the current assessment.

5.2 Details Incorporated in the Existing Hydrologic and Hydraulic Models in the Vicinity of Sites 4A and 4B

The structure of the hydrologic (DRAINS) model that was developed as part of L&A, 2017 was updated to incorporate the additional sub-catchments shown on **Figure 3**,[1] the outlets of which correspond with the location of existing stormwater inlet pits. The surface roughness applied to each sub-catchment was also updated to reflect the findings of more recent studies that have been undertaken in the LGA.

The structure of the hydraulic (TUFLOW) model that was developed as part of L&A, 2017 and subsequently updated as part of the present investigation incorporates the following data:

- LiDAR survey data captured in June 2013.
- Detailed ground survey data (refer **Figure 3**) which was provided by the Applicant.
- Up-to-date details of the existing stormwater drainage system contained in WCC's asset database.
- Invert levels and pipe dimensions that were taken from survey, work-as-executed design drawings and field measurements where available.
- The inclusion of z-lines to represent the existing concrete wall and raised gardens beds which run along the Herbert Street frontage of Lot 11 DP 1013030.

5.3 Present Day Flooding Patterns

Figures 4 to **9** show the characteristics of overland flow in the vicinity of Sites 4A and 4B under present day conditions for design storm events with AEP's ranging from 20 to 0.2 per cent, as well as the Probable Maximum Flood (**PMF**). **Table 1** over the page sets out the peak flood levels in the vicinity of Site 4B for each storm event.

[1] Note that the extent of the internal sub-catchments within the SHOR project boundary were provided by Enstruct Group Pty Ltd.

TABLE 1
COMPARISON OF PEAK FLOOD LEVELS IN VICINITY OF SITE 4B
PRESENT DAY VERSUS POST-DEVELOPED CONDITIONS[1]

AEP (%)	Peak Flood Level (m AHD)				Change in Peak Flood Levels (m)[2]	
	Present Day Conditions		Post-Developed Conditions			
	PFL1	PFL2	PFL1	PFL2	PFL1	PFL2
20	74.25	75.25	74.30	75.23	0.05	-0.02
5	74.89	75.45	74.89	75.43	0	-0.02
1	75.41	75.63	75.39	75.63	-0.02	0
0.5[3]	75.69	75.71	75.63	75.68	-0.06	-0.02
0.2[4]	75.91	75.92	75.87	75.88	-0.04	-0.04
PMF	77.21	77.21	77.21	77.21	0	0

1. Refer **Figures 4** to **9** for location of peak flood level identifier.
2. A positive value represents an increase, and conversely a negative value represents a decrease in peak flood level which is attributable to the proposed development.
3. Analogous to a 10% increase in 1% AEP rainfall intensities.
4. Analogous to a 30% increase in 1% AEP rainfall intensities.

The key findings of the investigation as they relate to present day conditions were as follows:

- Gore Hill Oval operates as a sink point for overland flow which enters onto its surface for storm events with AEP's up to 0.2 per cent.
- Runoff generated from the Reserve Road Catchment will be contained within the road reserve for storm events with AEP's up to 0.2 per cent. In the PMF, stormwater will surcharge the eastern footpath of Reserve Road and flow in an easterly direction along the southern boundary of Sites 4A and 4B.
- In a 1% AEP storm event, a peak flow of about 1.3 m^3/s will surcharge the 900 mm trunk drainage line at Pit 4[2], where it will flow in an easterly direction toward the trapped low point in Lot 11 DP 1013030.
- Depths of overland flow in the south-eastern corner of Site 4A will generally be less than 300 mm in a 1% AEP storm event (refer **Figure 6**).
- The peak 1% AEP flood level in the trapped low point is RL 75.41 m AHD[3].
- The existing concrete wall and raised garden beds which are located along the eastern boundary of Lot 11 DP 1013030 prevent the equalisation of peak flood levels in Herbert Street with those in the trapped low point.

[2] Note that this finding assumes that the rate at which stormwater surcharges the drainage system is not constrained by the dimensions of the pit or its grate. While this flow rate represents ideal flow conditions, in reality, the rate at which stormwater will surcharge the pit will be less than under ideal flow conditions.

[3] Modelling undertaken as part of the L&A, 2017 shows that the on-site detention system that will form part of the Gore Hill Park Redevelopment Project will reduce the rate at which stormwater will surcharge the existing trunk drainage system at Pit 4 to about 0.3 m^3/s, thereby lowering the ponding level in the trapped low point in Lot 11 DP 1013030 by 290 mm to RL 75.12 m AHD in a 1% AEP storm event.

6. Flood Risk Assessment – Post Developed Conditions

6.1 Description of Current Development Proposal

Figure 10 shows the layout of the proposed development, including the footprint of the new building, while **Annexure C** contains a copy of the plans showing finished ground levels under post-developed conditions. The plan in **Annexure C** also shows the post-developed sub-catchment boundaries, as well as the layout of the proposed internal drainage system, all of which was prepared by Enstruct Group Pty Ltd.

Site 4B will be reshaped so that it falls at a grade of about eight per cent from an elevation of about RL 79.00 m AHD in its north-western corner to about RL 74.50 m AHD adjacent to Pit 6. There is no plan to construct a new building on Site 4B as part of the current project.

The proposed development will entail the demolition of five existing buildings and the construction of a new building in Site 4A. The footprint of the existing building will be extended by up to 30 m along its northern side and up to 10 m on its eastern side. The basement of the new building, which comprises the lowest habitable floor in the development, will be set at RL 76.00 m AHD. A loading dock will be located in the south-east corner of the basement and will be accessed via a driveway which will extend off Reserve Road along the southern side of the new building.

The aforementioned driveway will fall at a grade of about seven per cent from an elevation of about RL 79.90 m AHD at Reserve Road to about RL 76.00 m AHD adjacent to the loading dock. A 450 mm high retaining wall will be constructed at the eastern end of the driveway, with the finished level at its base set at RL 75.55 m AHD.

A low retaining wall will also be constructed along the southern boundary of Sites 4A and 4B. The purpose of the wall is account for the level difference in Site 4A and Lot 11 DP 1013030.

Pit 4 will be demolished and replaced by a new surcharge pit (denoted **Pit 4A** on **Figure 10**). The new pit will be located about 8 m to the east (down slope) of the existing pit that it replaces. **Annexure D** shows that the grate level of Pit 4A will be set at RL 75.55 m AHD, 300 mm above finished ground levels which will be set at RL 75.25 m AHD.

The existing concrete wall that runs along the Herbert Street frontage of Lot 11 DP 1013030 will be extended along the eastern boundary of Site 4B at an elevation of RL 76.15 m AHD where it will tie into high ground.

6.2 Hydrologic and Hydraulic Model Development

The hydrologic (DRAINS) model that was developed to represent present day conditions was updated to incorporate the post-developed sub-catchment boundaries within the boundary of the SHOR project to reflect the redistribution of surface runoff that will result from the proposed development.

The structure of the hydraulic (TUFLOW) model representing present day conditions was adjusted as follows:

- ground levels across the development site were adjusted based on finished surface levels shown on the drawings provided by Enstruct Group Pty Ltd (refer **Annexure C**);
- the existing buildings that will be demolished as part of the development were removed from the model and the new building added;
- Pit 4 was removed from the model and replaced by Pit 4A;

- the existing concrete wall along the Herbert Street frontage of Lot 11 DP 1013030 was extended approximately 20 m to the north where it will tie into high ground;
- ground levels were raised along the southern boundary of Site 4A to reflect the blocking effect of the proposed retaining wall; and
- hydraulic roughness values were adjusted to reflect the change in land-in Sites 4A and 4B.

The updated TUFLOW model was run for design storm events with AEP's ranging from 20 to 0.2 per cent, as well as the PMF.

A hydraulic model was also developed using the DRAINS software package to check the results of the TUFLOW model and to generate a hydraulic grade line along the existing piped drainage system where it runs between Pit 1 and Pit 6 under post-developed conditions. The 1% AEP discharge hydrograph in the pipe immediately downstream of Pit 1 was extracted from the TUFLOW model and used as the upstream boundary condition in the DRAINS model, while the peak 1% AEP flood level in the trapped low point in Lot 11 DP 1013030 (refer **Table 1**) was applied to its downstream boundary.

6.3 Post-Developed Flooding Patterns

Figures 11 and **12** show the indicative extent and depth of inundation for the 1% AEP and PMF events, respectively, while **Figures 13** to **18** show the impact that the proposed development will have on both the depth and extent of overland flow for design storm events with AEP's ranging from 20 to 0.2 per cent, as well as the PMF. Peak flood levels in the trapped low point in Lot 11 DP 1013030 and in Herbert Street under post-developed conditions are also given in **Table 1**.

The key findings of the investigation as they relate to post-developed conditions were as follows:

- Maintaining natural surface levels along the Reserve Road frontage will ensure that the overland flow will be confined to the road reserve for all storms up to the 0.2% AEP event.
- In a 1% AEP storm event, a maximum flow of about 1.5 m^3/s will surcharge the 900 mm trunk drainage line at Pit 4A, where it will flow in an easterly direction toward the trapped low point in Lot 11 DP 1013030.[4]
- If 1.5 m^3/s was able to surcharge Pit 4A, the depth of flow at the pit would be about 250 mm. This would equate to a peak flood level of RL 75.50 m AHD, which is 500 mm below the finished floor level of the basement.
- In a 1% AEP storm event, the peak flood level in the trapped low point in Lot 11 DP 1013030 will be RL 75.39 m AHD. The available freeboard to the finished floor level of the basement will therefore exceed 500 mm.
- The peak 1% AEP flood level in Herbert Street will remain unchanged at RL 75.63 m AHD.

[4] Note that this finding assumes that the rate at which stormwater surcharges the drainage system is not constrained by the dimensions of the pit or its grate. While this flow rate represents ideal flow conditions, in reality, the rate at which stormwater will surcharge the pit will be less than under ideal flow conditions.

6.4 Sensitivity to Blockage of Pipes

The mechanism and geometrical characteristics of blockages in the piped system are difficult to quantify and would no doubt be different for each storm event. Realistic scenarios would be limited to one or two pipes becoming partially blocked during a storm event. However, for the purposes of the present investigation, analyses were carried out with the cross sectional areas of all pipes and conduits reduced for storm events with varying AEP's. The following blockage scenarios were assessed:

- 20% AEP event with 100% blockage of the enclosed drainage system (**Blockage Scenario 1**); and
- 1% AEP event with 50% blockage of the enclosed drainage system (**Blockage Scenario 2**).

Table 2 provides peak flood levels for present day, post-developed and post-developed with blockage conditions at PFL1 and PFL2, while **Figures 19** and **20** show the indicative extent and depth of inundation under Blockage Scenarios 1 and 2, respectively.

TABLE 2
IMPACT OF BLOCKAGE ON PEAK FLOOD LEVELS IN VICINITY OF SITE 4B [(1)]

AEP (%)	Conditions	Peak Flood Level (m AHD)	
		PFL1	PFL2
20	Present Day	74.25	75.25
	Post-Developed	74.30	75.23
	Post-Developed (Blockage Scenario 1)	76.30	76.30
1	Present Day	75.41	75.63
	Post-Developed	75.39	75.63
	Post-Developed (Blockage Scenario 2)	76.06	76.06

1. Refer **Figures 19** to **20** for location of peak flood level identifier.

The key findings of the investigation as they relate to blockage of the enclosed drainage system under post-developed conditions were as follows:

- Overland flow will not surcharge Reserve Road onto the access driveway under both blockage scenarios.
- Backwater flooding from the trapped low point in Herbert Street would inundate the basement to a depth of 300 mm under Blockage Scenario 1.
- Backwater flooding from the trapped low point in Herbert Street would inundate the basement to a depth of 60 mm under Blockage Scenario 2.

6.5 Potential Impacts of Climate Change

Scientific evidence shows that climate change will lead to sea level rise and potentially increase flood producing rainfall intensities. The significance of these effects on flood behaviour will vary depending on geographic location and local topographic conditions. Climate change impacts on flood producing rainfall events show a trend for larger scale storms and resulting depths of rainfall to increase, while future impacts on sea levels are likely to result in a continuation of the rise which has been observed over the last 20 years[5].

OEH recommends that its guideline *Practical Considerations of Climate Change* (DECC, 2007) be used as the basis for examining climate change induced increases in rainfall intensities in projects undertaken under the State Floodplain Management Program, according to procedures set out in NSW Government's *Floodplain Development Manual* (NSWG, 2005). The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent. On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit. Under present day climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce a 0.2% AEP event.

The principal issue regarding climate change is the potential increase in peak flood levels adjacent to the proposed development and how this will impact on the available freeboard to finished floor levels.

Table 1 gives peak flood levels in the vicinity of the proposed development for the 10 and 30 per cent climate change scenarios, while **Figures 21** and **22** show the impact increases of 10 and 30 per cent in 1% AEP rainfall intensities would have on flooding behaviour, respectively. Under the 10 and 30 per cent climate change scenarios, the peak 1% AEP flood level in the trapped low point in Lot 11 DP 1013030 would increase to RL 75.63 m AHD and RL 75.87 m AHD, respectively, reducing the available freeboard to the finished floor level of the basement to 370 mm and 130 mm, respectively.

7. Compliance with Council's Flood Related Planning Controls

Under WCC's updated Technical Standard, Sites 4A and 4B have been assigned a **Major Drainage** classification due to the presence of overland flow. Hydrologic and hydraulic modelling undertaken as part of the present investigation has demonstrated that overland flow will be contained within the road reserve and therefore not discharge to Site 4A for storms with AEP's up to 0.2 per cent.

While the available freeboard to the basement level is less than the required minimum of 500 mm at the location where stormwater will surcharge the existing trunk drainage line at Pit 4A, the computed freeboard of 210 mm is based on the assumption that the flow is not constrained by the dimensions of the pit and its grate. In reality, the flow surcharging the pit at this location will be less than this value, hence the freeboard to the basement level will be closer to 300 mm. To add to this, the flow surcharging the pit will reduce following the construction by WCC of the 4000 m^3 tank in Gore Hill Oval. It is also noted that the depth of flow surcharging Pit 4A will be less than the height of the retaining wall which will be built at the eastern end of the driveway adjacent to Pit 4A, thereby forcing flow to discharge in an easterly direction toward the trapped low point in Lot 11 DP 1013030 (i.e. away from the building).

[5] The impact of sea level rise has not been assessed as part of the present investigation as L&A, 2017 found that an increase in sea levels in Middle Harbour will not affect flooding behaviour in the vicinity of the proposed development.

While the footprint of the new building will increase, its extension in a northerly direction by up to 30 m and in an easterly direction by up to 10 m will not impede the passage of overland flow. As a result, the new building will not adversely affect drainage patterns in adjacent development.

Evacuation from the basement will be possible via the ground floor entrance which is located at the level of Reserve Road.

We trust that the findings presented in this letter report will assist you in obtaining an approval for the proposed development. Should you require further advice in relation to the above assessment, please contact the undersigned.

Yours faithfully
Lyall & Associates Consulting Water Engineers

Scott Button
Principal

N

30 0 30 60 90 m

Scale: 1:3,000

LEGEND

- SHOR Project Boundary
- Site Boundary
- Catchment Boundary
- Extent of Gore Hill Park Redevelopment
- Modelled Stormwater System

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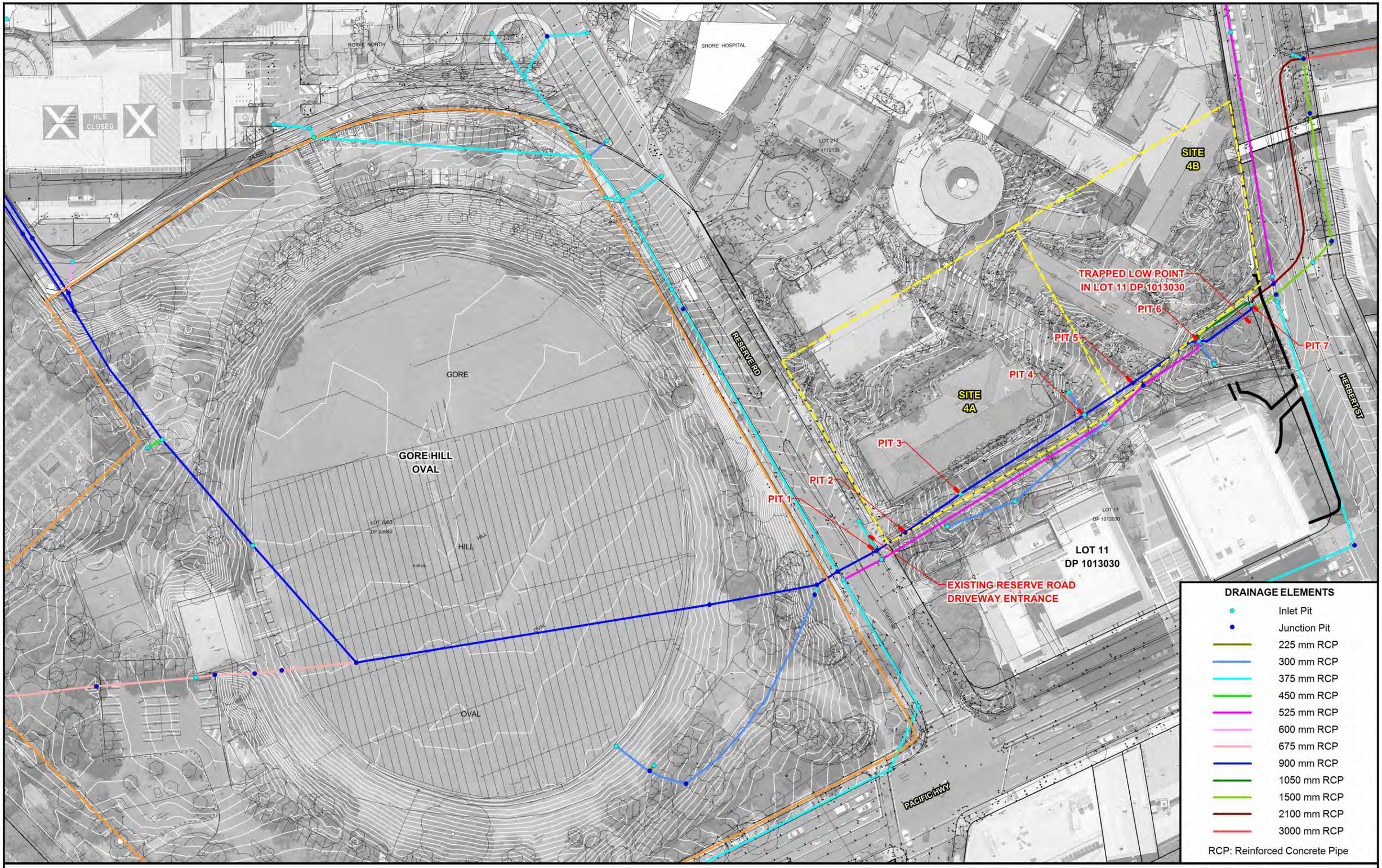
ST LEONARDS HEALTH ORGANISATION RELOCATION
FLOODING ASSESSMENT

Figure 1

LOCATION AND CATCHMENT PLAN



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Scale: 1:1,000

LEGEND

- Site Boundary
- Existing Concrete Wall / Raised Garden Beds
- Extent of Gore Hill Park Redevelopment

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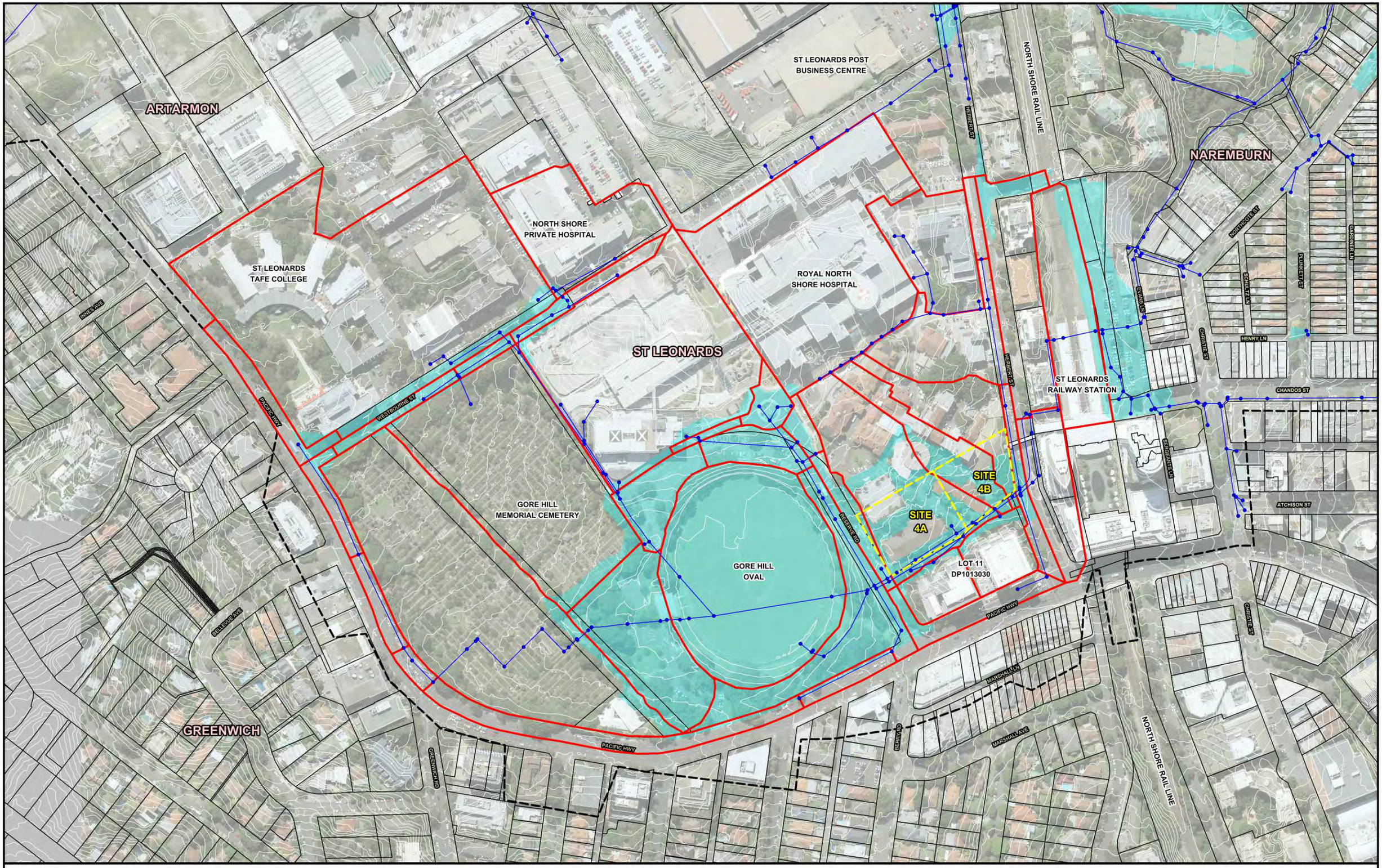
ST LEONARDS HEALTH ORGANISATION RELOCATION FLOODING ASSESSMENT

Figure 2

KEY FEATURES OF EXISTING STORMWATER DRAINAGE SYSTEM IN VICINITY OF THE SITE



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LEGEND

- Site Boundary
- Sub-catchment Boundary
- Two-dimensional Model Boundary
- Modelled Stormwater System
- Extent of Detailed Ground Survey Data

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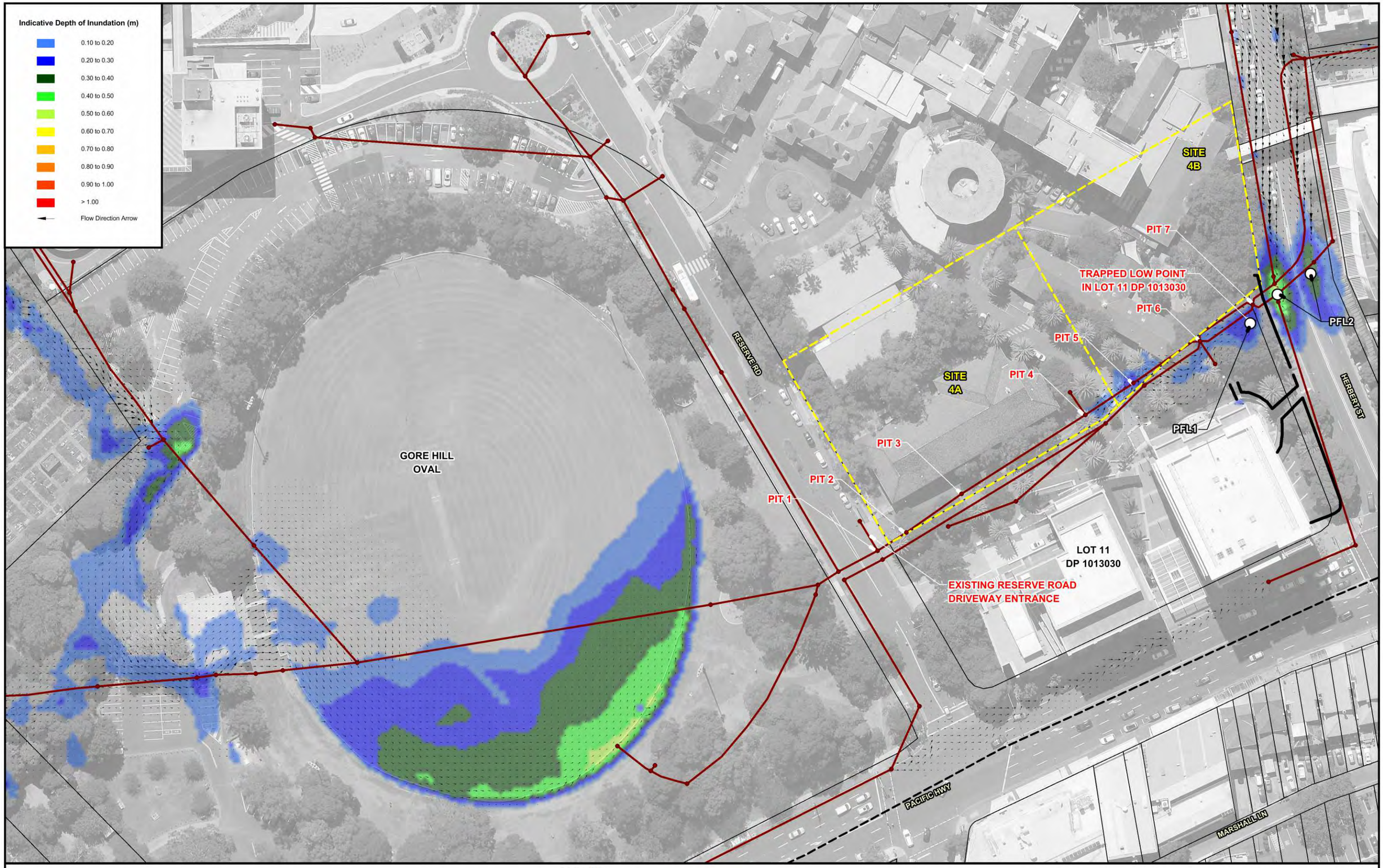
ST LEONARDS HEALTH ORGANISATION RELOCATION FLOODING ASSESSMENT

Figure 3

EXTENT OF HYDROLOGIC AND HYDRAULIC MODELS IN VICINITY OF THE SITE



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LEGEND

- Site Boundary
- Two-dimensional Model Boundary
- Modelled Stormwater System
- PFL1 Peak Flood Level Location and Identifier
- Existing Concrete Wall / Raised Garden Beds

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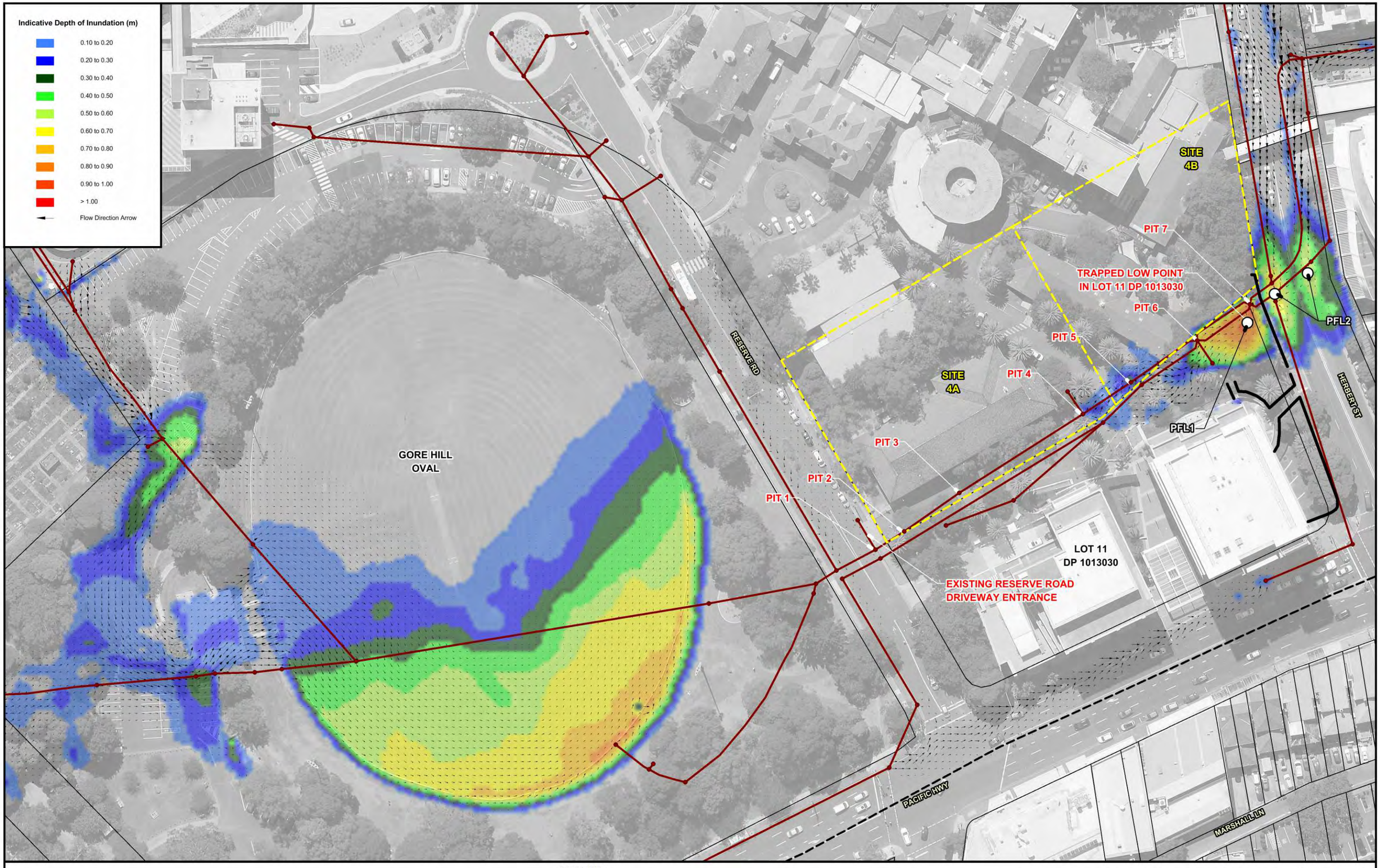
FLOODING ASSESSMENT

Figure 4

PATTERNS OF OVERLAND FLOW IN VICINITY OF DEVELOPMENT SITE
PRESENT DAY CONDITIONS - 20% AEP



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LEGEND

- Site Boundary
- Two-dimensional Model Boundary
- Modelled Stormwater System
- PFL1 Peak Flood Level Location and Identifier
- Existing Concrete Wall / Raised Garden Beds

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Figure 5

PATTERNS OF OVERLAND FLOW IN VICINITY OF DEVELOPMENT SITE
PRESENT DAY CONDITIONS - 5% AEP