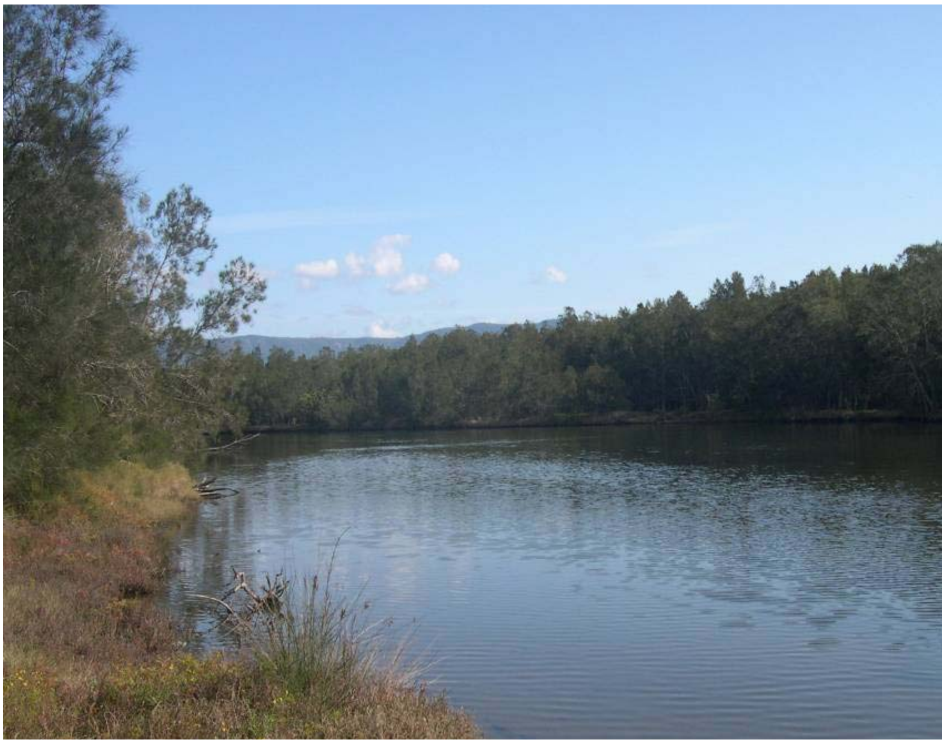
TRUenergy Tallawarra Pty Ltd

Tallawarra Lands Flood Risk Assessment



Report

16 December 2010

Bewsher

TRUenergy Tallawarra Pty Ltd

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Flood Risk Assessment

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

Page

FIGURES

TABLES

APPENDIX

1. INTRODUCTION

This report documents the results of flood modelling and the assessment of flood risks for the proposed Tallawarra Lands development.

Its structure aligns with the flood-related information requirements of the Director General for the project, namely:

Item 6. Flooding

(a) Provision of an assessment of flood risk (in accordance with the provisions of the 2005 NSW Floodplain Development Manual) including the potential effects of climate change, sea level rise and an increase in rainfall intensity. The assessment is to include a flood study of existing conditions and a flood risk management assessment;

(b) An assessment of the changes in hydrology associated with the proposed development (i.e. runoff, tidal movement, flood flows and groundwater regime) on the environmental lands within and surrounding the development.

While the principal flood issues relate to the runoff generated by the substantial Duck Creek catchment, this report also addresses the issues for other site development areas which lie within small gullies located north of the Duck Creek catchment and which drain independently to Lake Illawarra.

2. SITE DESCRIPTION

The Tallawarra site is located on the mid-western foreshore of Lake Illawarra and the ocean entrance to the Lake is located due east of the site. The overall site area is 572.1 hectares of which 535.9 ha represent the Tallawarra lands area.

It currently comprises mostly cleared grazing land, former works associated with the original coal-fired power station, areas of native vegetation and a number of wetlands.

The Tallawarra Lands project would see development occurring in three precincts made up of the Northern Precinct, which is located within several small gully catchments having their own outlets to Lake Illawarra, and the Central and Southern Precincts both of which are located within the Duck Creek catchment.

3. DATA BASE

The following information was provided to Bewsher Consulting:

- Digital copies of the aerial photography, cadastre and AAMHatch's LiDAR (aerially derived) ground surface data set;
- Hard copies of the 2007 Cardno Forbes Rigby reports titled *Duck Creek Flood Study* (CFR 2007a) and *Review of Flooding Constraints and Development Options* (CFR 2007b) and associated information;
- Tallawarra Lands digital terrain model (DTM) developed by LandTeam (LandTeam 2010);
- Trunk drainage details associated with the two Tallawarra Power Station drains (which are known as the "North Drain" and the "South Drain").

4. 'EXISTING CONDITIONS' FLOOD STUDY

4.1 REVIEW OF CARDNO APRIL 2007 FLOOD REPORT

Cardno Forbes Rigby (CFR) used a combination of WBNM (hydrologic) modelling and HEC-RAS (hydraulic) modelling to calculate the 100 year and probable maximum flood (PMF) flood levels along the Tallawarra Lands' Duck Creek floodplain. The WBNM model assesses runoff from the whole of the catchment (i.e. to its outlet to Lake Illawarra) while the HEC-RAS model extends from the South Coast railway line (located approximately 800 metres upstream of the site's western boundary) to the creek's outlet into Lake Illawarra.

Towards the end of their commission some additional hydrologic and hydraulic assessment was undertaken of the several gullies which are located in the north-eastern portion of the site and which have their own outlets to Lake Illawarra. These assessments were quite rudimentary compared with the Duck Creek catchment modelling.

Bewsher Consulting's review of the modelling found:

- the choice of WBNM software and the subsequent model setup approach was quite satisfactory;

- the HEC-RAS model setup approach also appeared to be generally satisfactory for Duck Creek itself. That is, since they had adopted a series of near parallel floodplain cross sections for flow regimes associated with the creek it stands that the model would be satisfactory for the modelling of flow regimes which have a constant (and generally west-to-east) direction. However it did not have the capacity to adequately deal with flow regimes that are flowing in other than a constant west-to-east direction (such as various Duck Creek tributaries within the Tallawarra Lands);

- the attempt at model calibration based on a single March 1978 flood level (as reported by Wollongong City Council near the Princes Highway bridge) was undertaken with the limited rainfall information that was available. Given that scenario it is considered that the calibration probably has limited validity;

- in recognition of the lack of opportunity for model calibration and/or verification, they adopted hydrologic model parameters which were based on published regional data (which had also previously been adopted for a number of WBNM models) which CFR themselves had developed for various catchments in the Illawarra region. Their adoption of the 'regional' parameters is considered appropriate;

- their adoption of steady state modelling within HEC-RAS meant that the hydraulic model was unable to explicitly account for the routing impacts of floodplain storage. However this issue was addressed by CFR through their inclusion of a series of de-facto floodplain storage basins within their WBNM model. Most of these related to the embankment nature of the three transport corridors located just upstream of the Tallawarra Lands site – that is, the South Coast railway line, the F6 freeway and the Princes Highway. The report details the sizes of the bridges/conduits, and potential storage volumes, as assessed at each 'basin' location; and

- the CFR approaches to design flood modelling – such as using three 'reference' rainfall intensity locations and choices of initial and continuing losses – were considered to be quite satisfactory.

4.2 SITE INSPECTIONS

Bewsher Consulting undertook a detailed inspection of both the Tallawarra Lands site (in the company of TRUenergy staff), and the Duck Creek channel and tributary floodplain areas between the Tallawarra Lands western boundary and Marshall Mount Road (which as shown in **Figure 1** is located upstream of the South Coast railway line).

The following tasks were completed during the visit:

- the Duck Creek floodplain was generally inspected by following a series of access tracks which criss-cross the area. The Duck Creek channel conditions were also inspected in both the tidal and non-tidal creek reaches;

- the series of small gullies in the north-eastern portion of the site were also inspected. Additionally, details of Council's visible stormwater assets in Gilba Road Reserve in the lower part of the Barrons Gully catchment downstream of the Tallawarra Lands boundary were also gathered;

- all the conduit and bridge openings under Marshall Mount Road, the South Coast railway line, the F6 freeway, the Princes Highway and within the project site were inspected, see **Figure 1**. During those inspections, basic measurements were made of conduit sizes and bridge waterway openings and that information is presented in **Table 1**. Detailed survey of the various structures was not considered necessary since the main purpose of extending the hydraulic model beyond the Tallawarra Lands western boundary was to quantify the various flow regimes approaching the upstream boundary of the Tallawarra lands site rather than to absolutely define flood levels in those same areas; hence, "exact" waterway opening dimensions were not required. At some locations, the conduit and waterway openings were found to be different to those reported by CFR and an additional South Coast rail corridor culvert was located on the Duck Creek floodplain (i.e. Structure No. 9 in **Table 1**).

TABLE 1: BRIDGE AND CONDUIT SUMMARY TABLE

Structure No. (refer Figure 1)	Location	Watercourse	Type of Structure	% Blocked in 'Blocked' Model Scenario
1	Marshall Mount Road	Duck Creek northern tributary	2.4m x1.2m single cell box culvert	0
2	South Coast Railway	Yallah Gully	3.0m x 2.17m brick arch culvert	100
3	F6 Freeway	Yallah Gully	3 off 0.9m dia. Pipes	100
4	F6 Freeway/Princes Highway	Yallah Gully	3 off 0.9m dia. pipes	100
5	South Coast Railway	Duck Creek southern tributary	4m x 0.8m box culvert	100
6	F6 Freeway	Duck Creek southern tributary	4 off 0.9m dia. Pipes	100
7	Princes Highway	Duck Creek southern tributary	4 off 0.9m dia. pipes	100
8	South Coast Railway	Duck Creek	Multi-span bridge	0
9	South Coast Railway	Duck Creek floodplain	2.7m x 2.4m single cell box culvert	0
10	F6 Freeway	Duck Creek	Twin multi-span bridges	0
11	Princes Highway	Duck Creek	Multi-span bridge	0
12	Former railway crossing	Duck Creek	19 metre single span bridge	0
13	Former railway crossing	'Central Precinct' drainage line	3 off 1.8m x 1.8m box culvert	0
14	Yallah Bay Road	'Central Precinct' drainage line	3 off 1.8m x 1.8m box culvert	0
15	Power Station	Power Station North Drain	2 off 1.7m x 1.7m box culvert with transition to 2 off 1.5m dia. Pipes	0
16	Power Station	Power Station South Drain	1.35 m dia. Pipe	0
17	Gilba Road Reserve	Barrons Gully	0.375 m dia. Pipe	0

A second inspection supplemented the original observations made in the areas adjacent to the Tallawarra Lands site with special attention paid to watershed boundaries and the associated flow regimes for various Duck Creek tributaries whose flows eventually pass through the site.

A collection of photographs taken during the inspections and showing a range of creek and overbank conditions plus various bridge/culvert crossings are presented in **Appendix A**.

4.3 HYDROLOGIC MODELLING

4.3.1 Choice of Software and Model Set-Up

Bewsher Consulting also chose the WBNM software to generate a hydrologic model to calculate the 'current conditions' 100 year flows for not only the Duck Creek catchment but also the minor site catchments which drain directly to Lake Illawarra.

Based on regional contour information, the overall catchment draining to Duck Creek was determined while AAMHatch's LiDAR aerially derived ground surface/contour information was used to determine the extents of the (small) gully catchments in the northern part of the site. The Duck Creek catchment was also subdivided into a suitable number of sub-catchments which included as-necessary separate definitions of the various Duck Creek tributaries which follow separate depressions through the South Coast railway, F6 freeway and Princes Highway embankments/corridors.

Figure B1 in **Appendix B** defines the overall catchment and associated sub-catchment boundaries and good agreement was found with the 2007 CFR catchment map.

Similar to the 2007 CFR approach, three 'reference' points were used to define design rainfall intensities for the WBNM model. These have then been used to define the local area storm pattern depths (based on rainfall intensity-frequency-duration (or IFD) data) for the lower, middle and upper portions of the Duck Creek catchment. (Since Council no longer provides its own definition of IFD data throughout its LGA, the reference IFD information was derived using the BoM web site-based approach and the resultant design data sets are reproduced in **Appendix B**.

The WBNM hydrologic parameters used by CFR were considered to be appropriate and therefore also adopted. The same loss rates as adopted by CFR bar one were also adopted. The only loss rate change was the adoption of a pervious area continuing loss of 2.0 mm/h rather than 2.5 mm/h. While this was done to be consistent with the neighbouring Mullet Creek value, it is noted that the variation in loss rate has less than a 1% impact on the peak 100 year flood flow value.

TABLE 2: WBNM HYDROLOGIC PARAMETERS

Parameter	Value
C (lag parameter)	1.29
Initial loss (pervious surface)	0 mm
Initial loss (impervious surface)	0 mm
Continuing loss	2.0 mm/h

Appendix B lists WBNM inputs for each of the sub-catchments.

4.3.2 100 Year ARI Flows

A range of storm durations from 25 minutes to 12 hours was tested in the WBNM model and the resultant peak flows are presented in **Appendix B**. The table shows that while the peak flows for the reach of Duck Creek through Tallawarra Lands are very similar for storms of 2, 3 and 6 hours duration, the 6 hour storm is the critical duration event. It is noted that a six hour critical duration is consistent with the 2007 CFR model finding.

Table 3 lists the 6 hour duration 100 year ARI peak flows at the Tallawarra Lands western and eastern boundaries.

TABLE 3: DUCK CREEK 100 YEAR FLOWS

Location	WBNM Node No.	Peak Flow (m^3/s)
Duck Creek at F6 Freeway	A8_DS	237.1
Duck Creek at Lake Illawarra outlet	Lake1	289.0

While for the small northern gully catchments the peak flows for the 1 and 2 hour duration storms are very similar, the dominant critical duration is 2 hours.

4.4 HYDRAULIC MODELLING

4.4.1 Choice Of Software

Given the potential for floodplain and overland flow paths to be quite complex in the Tallawarra lands it was recognised that the adoption of hydraulic modelling software which was more sophisticated than one-dimensional software (such as HEC-RAS) was very important.

Hence the widely used and Australian developed two-dimensional (2D) software known as TUFLOW was chosen. The technical description of the TUFLOW model and its specific application to the Tallawarra Lands project is provided in **Appendix C**.

4.5.2 TUFLOW Model Set-Up

Model Coverage

The TUFLOW model covers the following areas:

(a) the Duck Creek floodplain from upstream of the South Coast railway line to Lake Illawarra;

(b) the Duck Creek tributary catchments which drain separately under the South Coast railway line, the Princes Highway and the F6 Freeway and pass through the site before reaching the Duck Creek channel; and

(c) the small gully catchments north of Duck Creek which also lie within the site but which have their own outlets to the Lake.

Model Inputs

The model is based on the following inputs:

- a DTM utilising the following:

  (i) Within the Tallawarra Lands site, the project-specific DTM prepared by Landteam (Landteam 2010) was generally adopted but with the incorporation of AAMHatch LiDAR levels where the latter levels were more than 0.2 metres lower than the former levels in low-lying/potentially floodprone areas;

  (ii) Duck Creek tidal zone bathymetry as published in the 2007 Duck Creek Flood Study report (CFR 2007a) based on earlier Tallawarra Lands site survey and also HEC-RAS creek channel cross sections;

  (iii) Outside the Tallawarra Lands site, the adoption of the AAMHatch's LiDAR data set;

- bridge and culvert dimensions as detailed in **Section 4.2**;

- current North Drain and South Drain trunk drainage elements (provided by TRUenergy);

- importation of WBNM-derived flow hydrographs (reference **Section 4.3**) for a range of potential critical storm durations into the TUFLOW model; and

- utilisation of Lake Illawarra design flood level information to define flood regime conditions at the outlet of the various catchments to the Lake. Since the 100 year Lake level varies with the duration of Lake catchment-wide storm event being modelled, the project flood mapping is based on an envelope of the following:

  (i) utilising the Lake six hour storm duration water level of RL 1.6 mAHD (BMT WBM 2010a) coincident with the various WBNM 100 year storm outputs; and

  (ii) the Lake maximum water level of RL 2.24m AHD with no coincident catchment runoff.

4.5 100 YEAR EVENT MAPPING

4.5.1 Culvert Blockage Modelling

Since Wollongong City Council has a conduit blockage policy which is mandatory for the calculation of design event flood levels in the vicinity of structures, the implications of that policy have been considered in developing the final flood map.

The flood modelling was initially undertaken assuming ‘nil’ blockage for all bridge and conduits within the footprint of the flood model (that is, all those structures presented in **Figure 1**). These results would represent the ‘worst’ flow scenarios for all the tributaries of Duck Creek passing through the site on their way to Duck Creek since the introduction of any blockage of those culverts would in some way limit the peak flow downstream of each culvert. It follows that any reduction in those flows would also lead to a reduction in the tributary water levels.

However it also follows that the potentially ‘worst’ scenario for Duck Creek watercourse flows (as distinct from tributary flows) would be where additional flow is directed to Duck Creek due to spill occurring as a result of blockage at the tributary culverts.

The definitive worst case of such spill would be the situation whereby full (i.e. 100%) blockage (as per Council’s policy) is modelled for all of the tributary minor conduits at the South Coast railway, F6 Freeway and Princes Highway corridors, as listed in **Table 1**. Subsequent modelling of this scenario confirmed that spill/transfer would occur to the main Duck Creek floodplain, hence increasing the peak flow being conveyed along the main creek alignment. The model results showed that the (marginally) worst flood levels in Duck Creek downstream of the Princes Highway occur in the six hour storm duration ‘blocked’ run.

4.5.2 Composite Flood Map

The above results show that neither unblocked nor blocked model outputs would provide a definitive worst case scenario of flooding within Tallawarra Lands. Rather, the various model outputs need to be combined to provide a definitive overall picture of 100 year flood inundation.

Therefore the flood map presented in **Figure 2** represents the compilation of worst 100 year flood levels based on (i) the enveloping of various critical duration blocked and unblocked catchment storm events and (ii) the maximum Lake Illawarra 100 year flood level (of RL 2.24m AHD).

Figure 2 shows how the downstream areas of the Duck Creek floodplain are dominated by the Lake Illawarra maximum flood level.

4.5.3 Definition of Flooding in Bunded Areas

Figure 2 includes a definition of “flooding” within the two bunded areas that lie either side of the Duck Creek watercourse. Since the ‘micro’ drainage patterns within those areas are potentially complex and outlet conditions uncertain, their flow patterns have been modelled by (i) “dumping” the local runoff associated with the bunded area into its centre and then “allowing” the hydraulic model to define the flow patterns based on the dumped flow following local ground slopes, and (ii) assuming there was no outlet for the bunded area runoff. As noted in the figure, it follows that the modelled maximum water level within the bunded areas would increase as a function of longer duration storms and longer term rainfall patterns. While such a modelling approach is essentially diagrammatic it is considered adequate for the assessment of the local drainage since it does not have any bearing on the overall Tallawarra Lands picture. This is because the proposed development of either or both bunded areas would be accompanied by drainage provisions in accordance with Wollongong City Council’s trunk drainage requirements. Hence those design drainage conditions would more properly define drainage patterns and peak water levels in the bunded areas.

4.5.4 Hydraulic Hazard Mapping

The hydraulic hazard zones in the 100 year flood scenario have been mapped in accordance with Figure L.2 of the NSW Floodplain Development Manual (DIPNR, 2005). That is, the combinations of calculated flood depths and velocities have been assessed for each of the 'unblocked' and 'blocked' flood model runs used to generate the **Figure 2** map. Together with an assessment of flood depths associated with the maximum Lake Illawarra water level, the 'hazard' results have been enveloped and the resultant picture is presented in **Figure 3.** Since the drainage conditions in the two bunded areas are not relevant to the assessment of flood risk, it will be seen that those areas have been excluded from the hazard figure.

5 FLOOD RISK ASSESSMENT

5.1 POTENTIAL ENCROACHMENT INTO FLOOD PRONE AREAS

Both 100 year ARI maps showing extents of inundation (**Figure 2**) and hydraulic hazard zones (**Figure 3**) include the proposed Tallawarra Lands precinct cadastre footprints. By comparing the cadastre footprints with the inundation and hazard information, it is possible to assess the potential impact of the project on the 100 year floodprone areas.

Putting aside the diagrammatic picture of potential ponding inside the bunded area which forms the basis of the Southern Precinct development (reference the bunded area modelling discussion in **Section 4.5.3**), it can be seen that there are only minor areas where the development would encroach into the 100 year floodplain. They are as follows:

- <u>Northern Precinct</u>: Residential development within an area of overland flow associated with an unnamed gully in the Northern Precinct;

- <u>Central Precinct</u>: (i) Road reserve encroachment into the flow path associated with the Central Precinct Drainage Line and (ii) the Employment Area fronting Yallah Bay Road having a flowpath passing through it adjacent to its Yallah Bay Road frontage;

- <u>Southern Precinct</u>: Minor encroachments into the Yallah Gully and Wollingurry Creek flowpaths on the respective western and eastern sides of the precinct.

In actual fact some of the flow depths associated with the above list – that is, all the Northern Precinct and Central Precinct locations - are only minor and hence can be considered to represent local overland flow regimes rather than floodprone areas. It therefore follows that they can be fully addressed at a future stage as part of detailed design of trunk drainage elements as per Council's design requirements.

Of the two Southern Precinct locations, the encroachments are seen to be very minor. The encroachment into the Yallah Gully flowpath corresponds to a man-made dam location rather than a 'natural' flow path feature and therefore the encroachment represents just a minor loss of storage rather than causing any diversion impact on the flowpath. **Figure 2** shows that the (minor) encroachment on the Wollingurry Creek side of the precinct is within the area impacted by the maximum Lake water level. Hence again this is a situation whereby a minor amount of floodplain storage is lost and this would have no impact on the flood level (since it is a function of the very large body of water which is the Lake itself).

5.2 FLOOD-TIME ACCESS

The project will bring residential and worker populations to areas which are currently undeveloped. Given the project area is crossed by Duck Creek and several of its minor tributaries plus there are also minor gullies draining separately to Lake Illawarra, issues of flood-time access need to be addressed.

5.2.1 Level of Flood Immunity to be Provided on the Roads

The NSW Floodplain Development Manual (DIPNR, 2005) requires that in planning new development areas, consideration be given to the full range of floods that can possibly occur. This involves consideration of floods bigger than the 100 year ARI event, up to the probable maximum flood (PMF).

Consideration of road access during floods is an important flood risk consideration. This occurs not only for communities that are inundated during major floods, but also those that are not inundated but become isolated because access roads are cut and therefore they may be unable to obtain emergency services (e.g. fire brigade and ambulance) and often helicopter access is not available in bad weather.

This issue of flood-time access has been a major consideration in the flood risk assessments for the nearby West Dapto Release Area and also an issue of major concern to the existing communities adjacent to the release area. In these areas, whilst the development land itself is in many cases above the PMF, access is cut frequently during wet weather periods. Consequently Wollongong City Council is currently investigating a major transport upgrade to improve flood access in the area.

In our opinion, based on current best practice, all new urban areas within Tallawarra Lands would need to be serviced by one or more roads that would enable continuous access by emergency services personnel during a 100 year flood event. (As discussed below, this would include both short duration and long duration flood events). Further, it would also be desirable to have road access for emergency services vehicles into Tallawarra at a level higher than the 100 year.

5.2.2 Tallawarra Lands Flood Mechanisms

It is important to note that the Tallawarra Lands flood prone areas are potentially inundated by either of two flood producing mechanisms - being local catchment-based runoff and Lake Illawarra catchment-based inundation - and there are distinct timing differences between them. As detailed earlier in this report, the 100 year flood modelling found that the within-site catchment runoffs peaked in the two hour storm event and Duck Creek itself peaked in the six and nine hour storm events, while Lake Illawarra modelling done by others shows that it is the 36 hour Lake catchment storm event which generates the maximum ‘current conditions’ Lake Illawarra 100 year flood levels.

It therefore follows:

(a) the two flood scenarios – i.e. local catchment-based runoff and lake catchment-based flooding - will not occur concurrently; and

(b) the lake catchment-based inundation will typically result in much longer periods of elevated water levels than would occur in local catchment runoff-based inundation. Indeed due to their fast rising water levels and short durations, the latter events can be categorized as 'flash' flooding.

5.2.3 Estimates of Flood Levels in Excess of the 100 Year Regime

For the purposes of this report, a combination of the 100 year ARI model results (see **Section 4.5** of this report) and the PMF modelling undertaken by Cardno Forbes Rigby (CFR, 2007a) have been used to interpret the ranges of flood-time conditions in each of the three Tallawarra Lands precincts.

With regard to Lake Illawarra-based flooding, work done by others for the Lake Illawarra Authority shows that the current 100 year flood level is RL 2.24m AHD (Worley Parsons 2010), the 'high level' potential climate change level is 3.04m AHD (Worley Parsons 2010) and the current PMF level is RL 3.26m AHD (BMT WBM 2010a). It therefore follows that the potential impact of climate change would be a maximum of about 800mm higher than the 100 year level.

With regard to local catchment-based flooding, we consider that a reasonable estimate would be an allowance of 500mm for the impact of potential climate change on the Duck Creek flood levels defined in **Figure 2**. We note in their 2007 Duck Creek flood study, CFR calculated PMF levels which were approximately one metre higher than their 100 year ARI levels and we consider that this is also an appropriate allowance for the purposes of this report. That is, we have assumed that the PMF flood levels along Duck Creek would be approximately one metre higher than the flood levels defined in **Figure 2**. For all the minor tributaries of Duck Creek and the various Tallawarra Lands local gully catchments, the increases in flood level for both climate change and PMF conditions would be very much smaller than the above Duck Creek allowances of 500mm and 1000mm.

5.2.4 Individual Precinct Assessments

North Shore Precinct

As detailed in **Section 5.1**, all of the proposed residential areas are clear of 100 year flood inundation with the exception of one gully which passes through the precinct. The runoff associated with that gully as it enters the precinct would be accommodated through the construction of a trunk stormwater pipe and associated roadway-based surcharge flowpath (which in combination would carry all gully flows to the lake).

Based on current ground levels, the minimum ground level in the precinct is of the order of 6m AHD and therefore the whole of the precinct is some metres above the 'high level' potential climate change lake level (i.e. RL 3.04m AHD). All properties would also be well above the Lake Illawarra extreme flood level of RL 3.26m AHD.

If flood-time access was required the modelling of the flood scenario for Barrons Gully (i.e. the most northern gully which includes the Council Hector Harvey Park sports reserve fronting Gilba Road) shows that Gilba Road would be inundated by the 100 year gully catchment flood event but would not be inundated by any Lake Illawarra sourced flooding (reference **Figure 2**) while the hydraulic hazard condition would be 'low' (reference **Figure 3**). Given that the critical storm duration for the gully catchment was found to be two hours, this section of the road would typically be inundated for periods of less than an hour. While additional modelling of adjacent Koonawarra urban catchment flow regimes will be required to confirm the potential depths of water in other locations along Gilba Road, this road would most likely form the principal floodtime access route.

Lakeside Road South of North Shore Precinct

The lowest levels of this road correspond to the current roadway in front of the Tallawarra Power Station which has minimum levels of about RL 2.2m AHD. This means that the road would just be inundated at the peak of the 'current conditions' Lake Illawarra 100 year event (of RL 2.3m AHD). This road would potentially serve as a secondary flood time access route for the Northern Precinct.

Southern Precinct

This precinct will be created by infilling a majority of the currently bunded area which sits above the Duck Creek floodplain. It is proposed that the area will be filled to levels not less than the potential climate induced 100 year flood levels (i.e. say 500mm higher than the adjacent flood levels shown in **Figure 2**.

Figure 2 shows that the 100 year flood level at the crossing of the Duck Creek floodplain is approximately RL 4m AHD. Based on a freeboard allowance of 500mm and an additional flood level allowance for potential climate change-related rainfall increases of say 500mm, the minimum road level across the Duck Creek floodplain would be say RL 5m AHD. It is noted that this is very similar to the current ground level of about RL 5.1m AHD at its intersection with Yallah Bay Road. At the bridge opening it is recommended that a minimum clearance of 500mm relative to the climate change-related 100 year flood level be provided to the underside of the bridge superstructure. Based on a flood level of RL 4.5m and say a bridge superstructure depth of one metre, the resultant road level at the bridge would be approximately RL 6m. The net result of such road levels would be a flood time access route serving the Southern precinct which is at or above the (current) PMF flood level.

Figure 2 shows that in the 100 year regime, the Princes Highway would not be inundated at the bridge over Duck Creek however it would most likely be inundated by shallow flood waters south of the entry road to the business office/large retail area (i.e. at both minor Duck Creek southern tributaries one of which is Yallah Gully). It therefore follows that flood time access for the business office/large retail area of the Southern Precinct would be northwards along the highway or alternatively reaching the highway (and again heading northwards) via the Southern Precinct crossing of Duck Creek and Yallah Bay Road.

Central Precinct

As noted earlier (in **Section 5.1**) **Figure 2** shows that both the residential areas and the employment areas are essentially outside the 100 year floodplain. While there are the several minor exceptions they represent only minor local flow regimes – that is, along the Central Precinct Drainage Line and are some local drainage issues along Yallah Bay Road (in the vicinity of the Employment Areas) – and those issues can be readily resolved during future project design phases.

It is important that flood-time access be maintained to the Princes Highway and **Figure 2** shows that it is currently available during 100 year 'current conditions' flood inundation. In order to make provision for both a freeboard allowance of 500mm and the additional flood level allowance for potential climate change-related rainfall increases of 500mm, the road level would need to vary between say RL 5m AHD (at the Southern Precinct access road intersection, as detailed above) and RL 7m AHD at the intersection with the highway. Since those two road levels are currently about RL 5.1m AHD and RL 7.8m AHD it follows that the route is above the potential climate change 100 year flood levels and also at or above the (current) PMF flood level.

East of its intersection with the proposed Lakeside Precinct access road intersection, Yallah Bay Road roadway levels drop to about RL 3.3m AHD before then rising again. Conceptual design road levels of about 5m AHD will serve to set the road above all flood regime scenarios (up to and including the PMF event) while also providing vertical flexibility for the sizing of the cross drainage culverts which will be required to convey the Central Precinct Drainage Line flows to Duck Creek.

It is noted that the Central Precinct residential area also has alternative flood free access via the proposed intersection with Cormack Avenue.

5.3 IMPLICATIONS OF POTENTIAL CLIMATE CHANGE

The implications of potential climate change impacts across the whole Tallawarra Lands project have been detailed by BMT WBM (2010c). One of these is the risk of potentially hazardous flood time conditions as a consequence of increases in both Lake Illawarra water levels and/or increases in catchment runoff associated with potential increases in rainfall intensities.

5.3.1 Sea Level/Lake Level Rise

As detailed in the BMT WBM report (2010c), the 2009 NSW Sea Level Rise Policy Statement specifies sea level planning benchmarks for the NSW coastline. In summary, these benchmarks are an increase above 1990 mean sea levels of 40 centimetres by 2050 and 90 centimetres by 2100. In their 2010 Tallawarra Lands coastal processes study, Worley Parsons quote the currently defined 100 year flood levels for the Tallawarra foreshore of Lake Illawarra for existing conditions and the above sea level planning benchmarks and these are reproduced in **Table 4**.

TABLE 4: LAKE ILLAWARRA 100 YEAR FLOOD LEVELS AT TALLAWARRA

2010	2050 (+0.40m Sea Level Rise)	2100 (+0.90m Sea Level Rise)
2.24m AHD	2.49m AHD	3.04m AHD

Source: Worley Parsons (Table 4.8 of WP 2010)

It is noted that the lake levels listed in **Table 4** do not have any direct impact on the Tallawarra Land project since there is no proposed development in the low lying areas which would be subject to either current conditions or potential climate change induced 100 year lake levels. The only impact would be the potential to use the current roadway adjacent to the Tallawarra Power Station as an alternative flood time access route since its current minimum roadway level is only similar to the current 100 year lake water level. However this matter is addressed in **Section 5.2.4** where it is proposed that this roadway constitute only a secondary flood time access route for the Northern Precinct development.

5.3.2 Rainfall Increases

With regard to potential rainfall intensity increases, an allowance of 500mm freeboard relative to current Duck Creek 100 year flood levels (reference **Figure 2**) has been adopted in this report for the purposes of assessing Central and Southern Precinct minimum subdivisional fill levels and also flood time evacuation routes in and adjacent to the Duck Creek floodplain.

As detailed in **Sections 5.2.3** and **5.2.4**, the Northern Precinct development areas are located within small gully catchments and for the one location of overland flow within the precinct, the trunk drainage provisions will take full account of potential changes in local runoff.

6. IMPACT OF HYDROLOGIC CHANGES ON THE TALLAWARRA LANDS SITE

Item 6 (b) of the Director General's Requirements calls for an assessment of the impact of runoff, tidal movement, flood flows and groundwater regime changes on the environmental lands within and surrounding the development.

This section reports on those potential impacts.

6.1 CHANGES IN RUNOFF AND ASSOCIATED IMPACTS

Issues associated with site development runoff quality and quantities are detailed in the BMT WBM Drainage Assessment report (BMT WBM 2010).

Listed amongst its surface water quality objectives the report includes 'the prevention of pollution of existing surface and groundwater water systems' and the range of works by which this will achieved are subsequently detailed. It documents how best practice WSUD measures (including biofiltration basins, rain gardens, etc) will potentially be incorporated into the development in order to minimize changes to the current hydrological regime. events

With regard to runoff quantity the report identifies that since the site is located on the foreshore of Lake Illawarra Wollongong City Council does not require on-site stormwater detention works to be incorporated into the development. However the report stresses the importance of environmental flows (i.e. flows which are smaller than 1 year ARI) that cumulatively convey high loads of additional flow volume and pollutants to receiving waters and which potentially therefore impact on issues such as stream ecology and wetting/drying cycles in wetlands. The report goes on to show these flows will be mitigated through the achievement of specific retention targets as part of the WSUD measures.

In summary the report shows how the potential drainage-related environmental impacts of the proposed Tallawarra Lands development have been addressed through the provision of major biofiltration basins and associated minor source control WSUD measures which include the disconnection of impervious areas and use of permeable paving, rain gardens and biofiltration swales. As well as detailing how the major basins can be designed to serve to intercept, retain, filter and treat the stormwater from the development areas the report shows how in all cases the basins are purposely positioned between the development areas and the various receiving waters.

It is recognised that the project would result in an increase in total major storm runoff into Lake Illawarra. However given the total catchment area draining to Lake Illawarra and also the size of new major development areas (e.g. West Dapto) within that catchment, the project's increases will have a very insignificant impact on Lake water levels.

6.2 CHANGES TO TIDAL MOVEMENT AND ASSOCIATED IMPACTS

Worley Parsons detail the Lake Illawarra tidal regime characteristics in their coastal processes study (Worley Parsons 2010). They determined that the tidal high water level for the Lake was effectively 0.36m AHD and hence lake levels higher than that value correspond to freshwater flooding; that is, major storm runoff generated by the very large catchment areas which drain to the lake.

Since the proposed development will not include any filling of lands which are within the tidal zone it follows that it will have nil impact on the local tidal regime.

6.3 CHANGES TO FLOOD FLOWS AND ASSOCIATED IMPACTS

As detailed elsewhere in this report, two of the proposed development precincts – being the Southern and Central Precincts - are located within the very large Duck Creek catchment. However their associated footprints are located almost exclusively outside of the Duck Creek 100 year floodplain. While there will be an increase in major storm peak flows and flow volumes associated with the two precincts, their magnitudes will be exceedingly small when compared with the peak flows generated by the overall Duck Creek catchment. It therefore follows that the changes in the site hydrologic regime will have no impact on either the Duck Creek flood flow regime or its associated peak water levels.

As also detailed elsewhere, in the third precinct – i.e. the Northern Precinct – the catchment sizes are both very small and relatively steep. Not only are they discharging their flows directly into Lake Illawarra but the runoff is also not passing through any significant environmental areas before entering the lake. While there will be an increase in major storm peak flows and flow volumes associated with precinct runoff there will be no local environmental impacts associated with major storm flows and again the increases in volume are insignificant in terms of the change in total runoff volumes entering the lake.

6.4 CHANGES TO GROUNDWATER REGIME AND ASSOCIATED IMPACTS

Earth2water undertook the assessment of groundwater for Tallawarra Lands and their findings are presented in their July 2010 report (Earth2water 2010). Based on their analysis of a range of bore holes and groundwater wells they concluded that in the hilly portions of the site there was minimal groundwater recharge and high percentages of runoff due to the impervious clay-bedrock conditions. In those areas the water table was many metres below the surface.

Not surprisingly they found the picture was very different in the low lying parts of the site where the water table was close to the surface. Sampling of surface and groundwater in these areas showed that the water quality was associated with fresh to brackish water which corresponds to the groundwater and saltwater interface for the tidal reach of Duck Creek and Lake Illawarra.

Earth2water were able to conclude that the local groundwater quality had not been significantly impacted by past and present site activities.

Coffey Environments (Coffeys 2010a) have also looked at groundwater quality for the project. They reported that the largest area of environmental concern was the former ash ponds area (that is, the area to be occupied by a major part of the Southern Precinct) and this was due to their groundwater water quality findings. In a subsequent supplementary report (Coffeys 2010b) they determined that if the subsoil conditions in that area were to be disturbed then care would be needed to avoid creating conditions where the local groundwater might discharge into the surrounding receiving environment. It is however noted that their determination relates to general civil works rather than specifically to site runoff regime impacts (which is the focus of this particular review).

In summary it follows that the runoff regime associated with the proposed development will not have any significant impact on the current groundwater regime or its quality since:

(a) the proposed development of some of the hilly portions (with associated minor changes in ground level and formal stormwater conveyance systems) will not change the slow vertical seepage regimes associated with the substantially impervious clay-bedrock conditions;

(b) with the singular exception of part of the Southern Precinct works, development is not proposed in the low lying areas where the groundwater and saltwater interface occurs; and

(c) in the Southern Precinct area which occupies the former ash pond area, care will be taken with the associated civil works to avoid the promotion of local groundwater migration into adjoining areas.

7. REFERENCES

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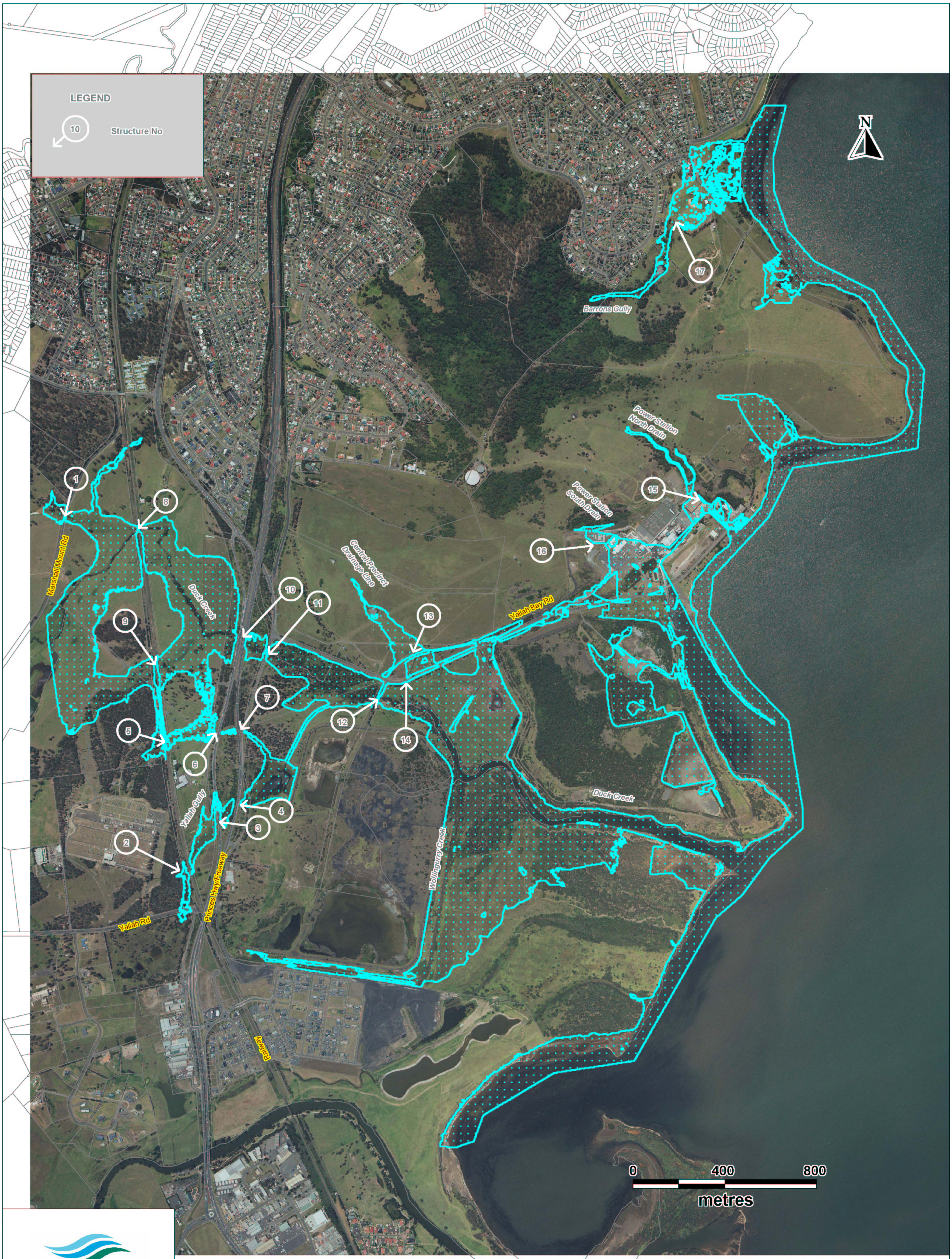

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Figure 1:
Tallawarra Lands Project
Existing Hydraulic Structures