PENTIUM WATER

DISTRICT WATER MANAGEMENT STRATEGY

North-east Baldivis District Structure Plan

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Executive Summary

This District Water Management Strategy (DWMS) has been prepared to support the North-east Baldivis District Structure Plan (DSP) which comprises of 760 ha of the North-east Baldivis region, approximately 38 km south of Perth CBD. The objective of this DWMS is to demonstrate that the land has the capacity to support the proposed land use change with best practice water management outcomes in terms of water supply, stormwater, surface water and groundwater management. This report provides an extensive view of management strategies for future development.

The proposed development will include total water cycle management principles and objectives guided by the Better Urban Water Management Framework (WAPC 2008). This has been accomplished by assessing current hydrological elements of the site and completing technical assessment and concept design for the major water related constraint for the site (flooding). A summary of the key DWMS elements detailed in this report is provided below.

Planning background and current land use

The site is currently zoned 'Rural' under the Metropolitan Region Scheme and a mixture of 'Public Purpose', 'Rural' and 'Special Rural' under the City of Rockingham's Town Planning Scheme (TPS) No. 2. To accommodate future residential development, the subject site will require rezoning to Urban through an amendment MRS scheme and rezoning to Development under the TPS No. 2.

Lots 1 and 2 comprise the "Wellard Farms" livestock holding facility, with all other lots being either rural residential or pastoral and/or cropping agriculture. A recreational ski lake facility and an aquaculture and accommodation business also occupy portions of the site.

Existing environment

The topography of the site comprises relatively flat and low-lying land with an elevation between approximately 5 and 9 mAHD. The subject site is located between the Peel Main drain to the adjacent west and the Birrega Main drain approximately 500 m to the east.

The surface geology is comprised of alluvial sand and clay with shallow marine estuarine lenses and local conglomerate being part of the Guildford clay formation. The Northern part of the site is part of the Bassendean Sands formation, with basal conglomerate overlain by dune quartz sand with heavy mineral concentrations.

The superficial formation is underlain by the Pinjar, Wanneroo and Mariginiup subareas as part of the Leederville formation, formed in the Mesozoic era. These subareas are characterised by sandstone, siltstone and shale.

Groundwater

The AAMGL ranges from approximately 3.8 mAHD to 8.0 mAHD with a generally west-southwesterly groundwater flow direction in winter south-westerly direction during summer.

Hydrology and wetlands

The subject site is located within the Peel-Harvey Coastal Plain catchment and drains via the Peel Main Drain to the Peel Inlet located approximately 30 km to the south. Surface water at the site drains to the Peel Main Drain through a network of small agricultural drains (and natural drainage lines in the eastern / upstream portion of the site), as well as two Water Corporation drains that run through the site from east to west.

Regional mapping shows that majority of the site is mapped as Multiple Use Wetland (WUW) with a few smaller Resource Enhancement wetlands (REW) located in the northwest and northeast corners of the larger site boundary.

The site is subject to winter inundation from shallow groundwater, limited drainage potential (low landscape positioning and flat topography) and flooding associated with Birrega and Peel main drains (DoW 2015). Recent flood modelling undertaken by DWER identifies a significant floodplain function / storage volume associated with the site, which will need to be maintained following development.

Water source planning

The site is located on the Stakehill groundwater system. The aquifers underlying the site include the Superficial (unconfined), Leederville (confined) and Yarragadee (Confined). The site is on the

Stakehill groundwater management area which covers two management subareas including the Maramanup (Superficial aquifer) and Stakehill confined (Leederville and Yarragadee aquifers).

Two irrigation scenarios have been prepared based on the current base case (3 primary schools) and then a conservative planning scenario where 4 primary schools and one high school might be required.

- Base case scenario: For two co-located school ovals, traditional POS areas and three primary schools the estimated irrigation requirement for is 185,322 kL/yr.
- Conservative scenario: The total irrigation demand of 206,323 kL/yr with four primary schools including two co-located school ovals, one High school, District Open Space and traditional POS areas.

There are four existing groundwater licences within the site, with a total allocation of 187,180 kL/yr from the Maramanup subarea of the superficial aquifer.

A groundwater licence request was submitted in November 2022 for an allocation of 50,000 kL. Obtaining this additional allocation would secure the water licenses to support the conservative scenario and some additional irrigated areas. The DWER officer has confirmed the substantial progression of the licence application and is awaiting information from the project team relating landscape masterplanning before formally issuing the licence.

Stormwater management

Small rainfall event (up to 15 mm) runoff from road reserves plus any lots with stormwater connections will be treated and infiltrated as close to the source as possible, within bioretention areas in the road reserve, POS or flood corridors.

Road reserve drainage via pit-and-pipe drainage systems will collect and convey stormwater (up to the critical duration 20% AEP event) generated by the road pavement towards downstream treatment or detention areas, to maintain serviceability of road and pedestrian areas. Stormwater management for major (i.e., up to 1% AEP) rainfall events will provide safe conveyance of flows to protect people and property as well as providing adequate flood detention, whilst having no impact to downstream hydrology.

The site is required to maintain the existing conditions floodplain storage volume (inclusive of potential breakout volumes associated with a Birrega Main Drain spoil bank failure), which is a very significant volume. Both DWER and Pentium Water have undertaken detailed flood modelling to understand the dynamics of the existing and post-development conditions flood regime. A concept flood mitigation design is presented which controls flood storage volumes, heights and discharge rates and volumes.

Groundwater management

Shallow groundwater will be managed by the installation of a subsoil drainage system and importation of fill to provide clearance to roads and building pads. The level at which subsoil drains are installed (CGL) will be set according to Water resource considerations when controlling groundwater levels in urban development (DoW 2013). At the LWMS stage of development appropriate controlled groundwater levels will be defined in accordance with the IPWEA (2016) *Specification Separation Distances for Groundwater Controlled Urban Development* as well as DoW (2013b).

Future monitoring requirements

Pre-development groundwater and surface water monitoring over two winter peaks will be required for LWMS stage. Whilst this has technically been completed already, further supplementary monitoring is proposed. Post-development monitoring requirements are to be refined at the LWMS and UWMP stage.

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1. Introduction

1.1. Background

This District Water Management Strategy (DWMS) has been prepared to support the North-east Baldivis District Structure Plan (DSP) which comprises of 760 ha of the North-east Baldivis region, approximately 40 km south of Perth CBD. It is bounded by the Telephone Lane, Freight Railway line 13 and Duckpond Road to the North; Duckpond Road to the east; Mundijong Road to the south and Kwinana Freeway to the west. The DSP area consists of the following lots, herein referred to as "the site".

- Lot 4, 50 Pug Road
- Lot 2, 54 Pug Road
- Lot 1, 56 Pug Road
- Lot 3, 58 Pug Road
- Lots 1, 455, 456, 457 and 458 Pug Road.
- Lots 465, 466, 467, 468 and 1261 Mundijong Road.
- Lot 469, 271 Mundijong Road
- Lot 470, 355 Mundijong Road
- Lot 3, 5 St Albans Road
- Lot 24, St Albans Road
- Lot 23, 75 St Albans Road
- Lot 101, 136 St Albans Road
- Lots 22 and 466 St Albans Road.
- Lot 21, 108 Telephone Lane
- Lots 1, 2, 3, 100, 452 and 454 Telephone Lane
- Lot 451, 156 Telephone Lane
- Lot 100, 222 Telephone Lane
- Lots 1 and 2 on Plan P077728
- Lot 201 on Plan P036173.

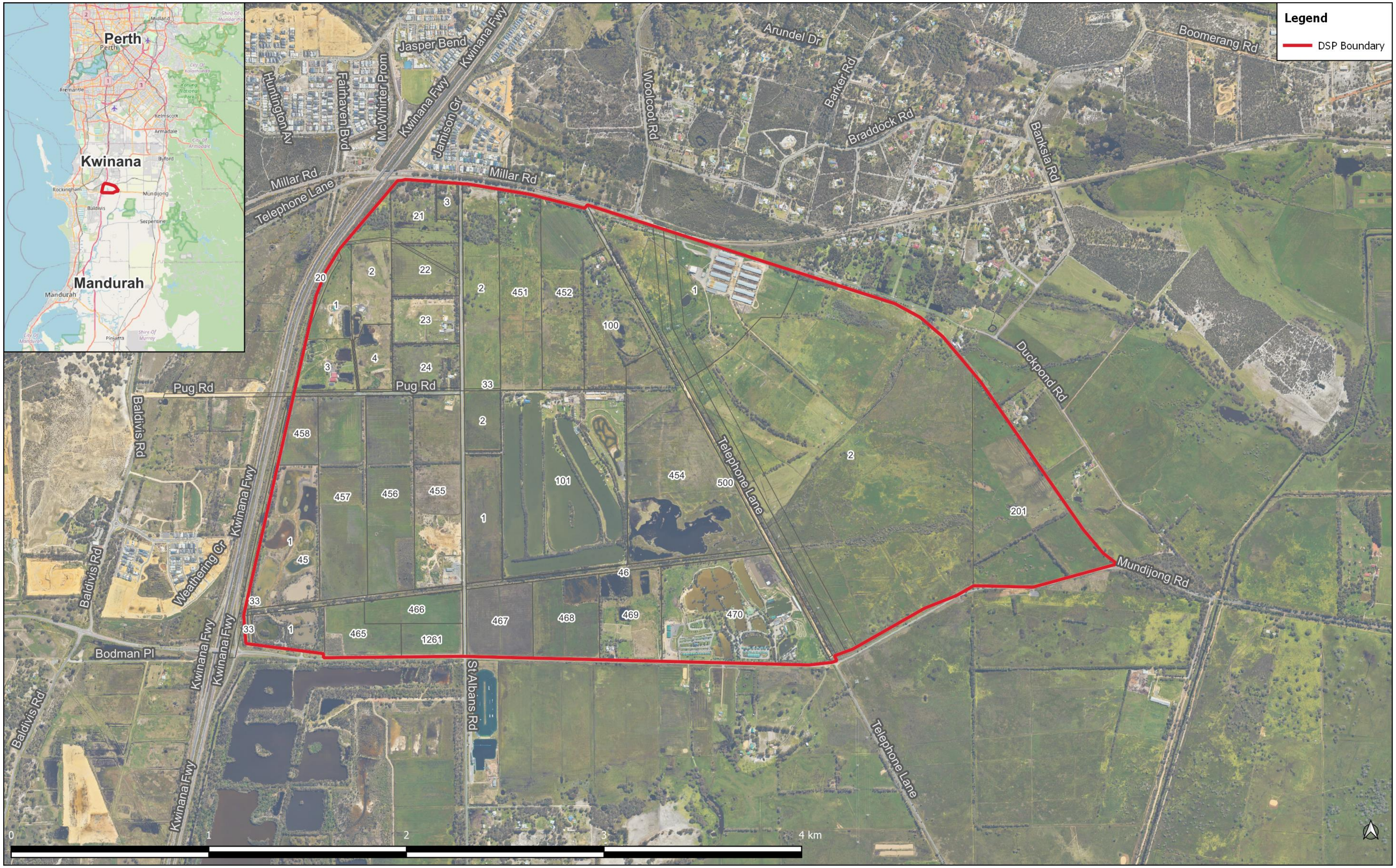


Figure 1: Site location

1.2. Planning context

The site is currently zoned 'Rural' under the Metropolitan Region Scheme (MRS) and a mixture of 'Public Purpose', 'Rural' and 'Special Rural' under the City of Rockingham's Town Planning Scheme (TPS) No. 2.

As outlined in the Perth and Peel @3.5 million Planning Investigation Areas update (September 2022, WAPC), the development area is identified as 'Urban Expansion'. 'Urban Expansion' is defined as "land suitable for urban development as previously identified in planning studies, or which represents the logical expansion of an existing urban area". In accordance with the *South Metropolitan Peel Sub-regional Planning Framework* (March 2018) ('the Framework'), the Department of Planning, Lands and Heritage (DPLH) has advised that a District Structure Plan (DSP) is required to provide strategic-level coordination of future planning processes. In addition to standard structure planning requirements, the PIA Updates list 6 key considerations for this Urban Expansion area. Of the 6 key considerations, the following are relevant to this DWMS:

- Servicing infrastructure coordination and staging.
- Protection of significant environmental values.
- Land to be set aside for flooding and drainage.
- Sand fill require to provide separation to groundwater and flood level.

The DSP will guide and inform subsequent planning processes that will need to be undertaken prior to urban development. These processes include rezoning the land to 'Urban' through an amendment to the MRS, rezoning to 'Development' under the TPS No. 2 and preparation of local structure plans (and local water management strategies). These processes will proceed the submission of the DSP and this accompanying DWMS.

1.3. Key documents and previous studies

A number of investigations have been completed and relied upon to prepare this DWMS including:

- North-east Baldivis flood modelling and drainage study (DoW, 2015a)
- Birrega and Oaklands flood modelling and drainage study (DoW, 2015b)
- Perth and Peel @3.5 million (WAPC, 2018)
- East of Kwinana flood modelling and drainage study (DWER, 2021a).
- East of Kwinana and Pinjarra and Ravenswood planning investigation areas. Flood risk management land capability assessment (DWER, 2021b)

2. Water management principles and objectives

The following principles and objectives have been adapted from the *Better Urban Water Management (*WAPC 2008) and Decision process for stormwater management in Western Australia (DWER 2017).

Table 1: DWMS principles and objectives

Key element	Principles	Objectives
Water conservation	▪ No potable water should be used outside of homes and buildings with the use of water to be as efficient as possible.	▪ Meet the *State Water Plan* (Government of WA 2007) water consumption target of 100 kL/person/yr, including not more than 40-60 kL/person/yr scheme water. ▪ Irrigation of public spaces to be by groundwater or an alternate water supply scheme.
Water quantity	▪ Maintain the pre-development hydrologic regime and meet the ecological requirements of the receiving environment. ▪ Protection of property and infrastructure by the safe conveyance of excessive run-off from extreme events. Protection of property and infrastructure within the DSP Area as well as downstream so there is a need to consider the impact of peak discharge from the study area.	▪ Maintain ecological flows into important wetlands and water dependent ecosytems ▪ Design stormwater management systems to provide serviceability, amenity and road safety during minor rainfall events. ▪ Maintain the 1% annual exceedance probability (AEP) pre-development flood regime (flood level, peak flow rates and storage volumes). ▪ Safely convey run-off from extreme events up to the 1% AEP event and ensure that the flood channel capacity of the receiving waterway is not exceeded by retaining or detaining the run-off from storm events where appropriate. ▪ Protect people and property from flooding by constructing building habitable floor levels with appropriate minimum clearances above the 1% AEP flood level.
Water quality	▪ Maintain surface water quality at pre-development levels and, if possible, improve the quality of the water leaving the development area to maintain and restore ecological systems in the sub-catchment in which the development is located.	▪ Manage – retain and/or detain and treat (if required) – stormwater run-off from constructed impervious surfaces generated by the first 15 mm of rainfall at source as much as practical.
Groundwater management	▪ Protect buildings and other infrastructure by providing adequate separation from maximum groundwater levels. ▪ Maintain groundwater quality at pre-development levels and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub-	▪ Set the Controlled Groundwater Level (CGL) according to Department of Water and Environmental Regulation (DWER) guidelines and at a level to protect groundwater dependant ecosystems and infrastructure. The preliminary design should be provided at local structure plan scale to protect specific environmental values and after the results of more detailed

Key element	Principles	Objectives
	catchment in which the development is located.	groundwater monitoring information is available. ▪ Subsoil drainage to be laid at or above the CGL. ▪ Nutrient export from the site will not be increased.

3. Existing environment

3.1. Existing and historical use

Table 2 is a summary of the main current land uses and structures associated with the site.

Table 2: Site land uses

Lot/site number	Industry/Land use	Structures and/or sensitive receptors
1 and 2	Wellard Farms	▪ Sheep Feedlots (Lot 1) ▪ Containment infrastructure for contaminated stormwater/wastewater ▪ Workshops ▪ Office and Breakout Areas ▪ Residence ▪ Power line corridor
3, 100, 451, 452, 454, 456, 457, 458, 465, 466 and 1261	Rural Residential and/or Agricultural (Pastoral and/or Cropping)	

3.2. Climate and rainfall

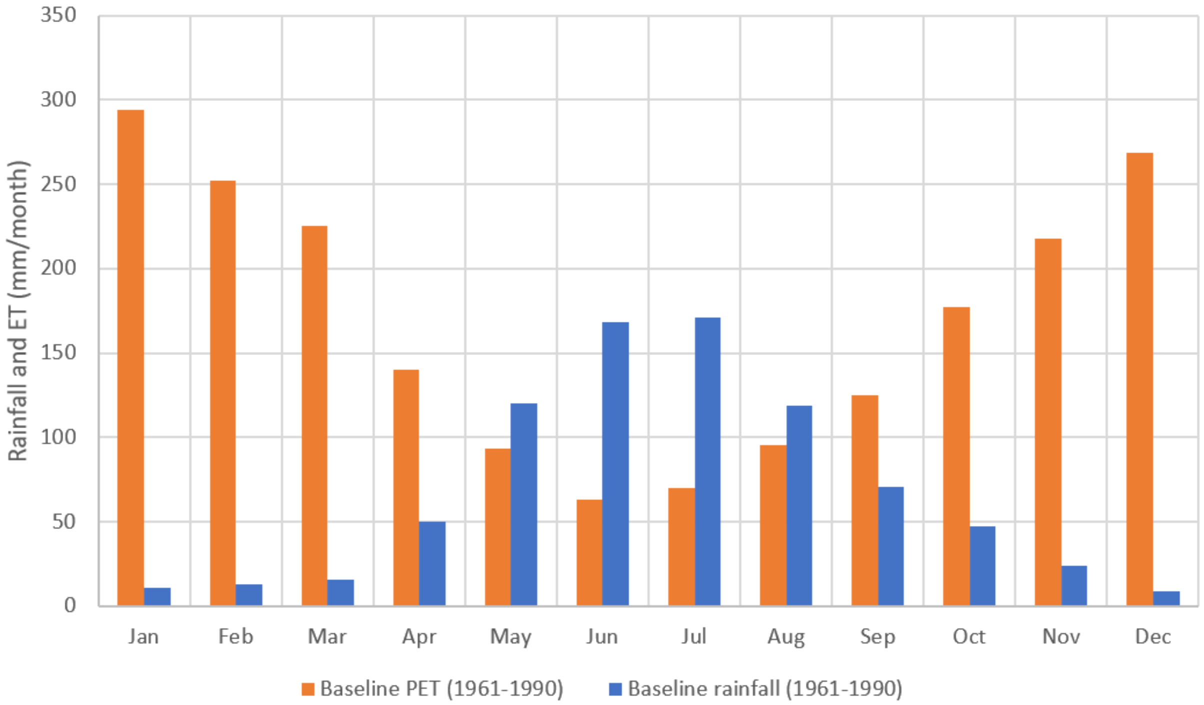
3.2.1. Baseline

The site is typical of the Swan Coastal Plain, being warm and dry during summer and cooler and wetter during winter. Baseline rainfall (1961 to 1990) as defined by DWER (then DoW, 2015) at the site is 819 mm, determined using SILO data drill output, which interpolates rainfall between nearby stations (State of Queensland, 1995 - 2018). Rainfall over the last decade (2012-2022) is 13% lower than the baseline at 712 mm.

The potential evapotranspiration (PET) calculated using the Penman-Monteith formula by SILO (State of Queensland, 1995-2018) is 2,022 mm, and 2% higher over the last decade (2,065 mm). A climate summary is provided in Table 3 and Graph 1.

Table 3: Monthly rainfall and potential evapotranspiration

Statistic (mm/mth)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline rainfall	11	13	16	50	120	168	171	119	71	47	24	9	819
Rainfall (2012-2022)	21	18	23	32	93	112	147	119	74	35	24	15	712
Baseline PET	294	252	226	140	93	63	70	95	125	177	218	268	2,022
PET (2012-2022)	304	256	223	149	97	66	68	94	129	181	232	267	2,065



Graph 1: Baseline rainfall and potential evapotranspiration

3.3. Topography

The site is quite flat with a gentle slope from east to west, with natural surface levels ranging from approximately 9 to 5 m AHD at the eastern and western boundaries, respectively. The subject site is located between the Peel Main drain to the adjacent west and Birrega Main drain approximately 3km to the east. Surface water drainage is from the east to west, toward the Peel Main drain. Figure 2 illustrates the topography of the subject site and surrounds, with 2m contours. More detailed aerial survey has been collected for the subject site and was used to create a high-resolution Digital Elevation Model (DEM) to support hydraulic modelling, the details of which are provided in Section 6.

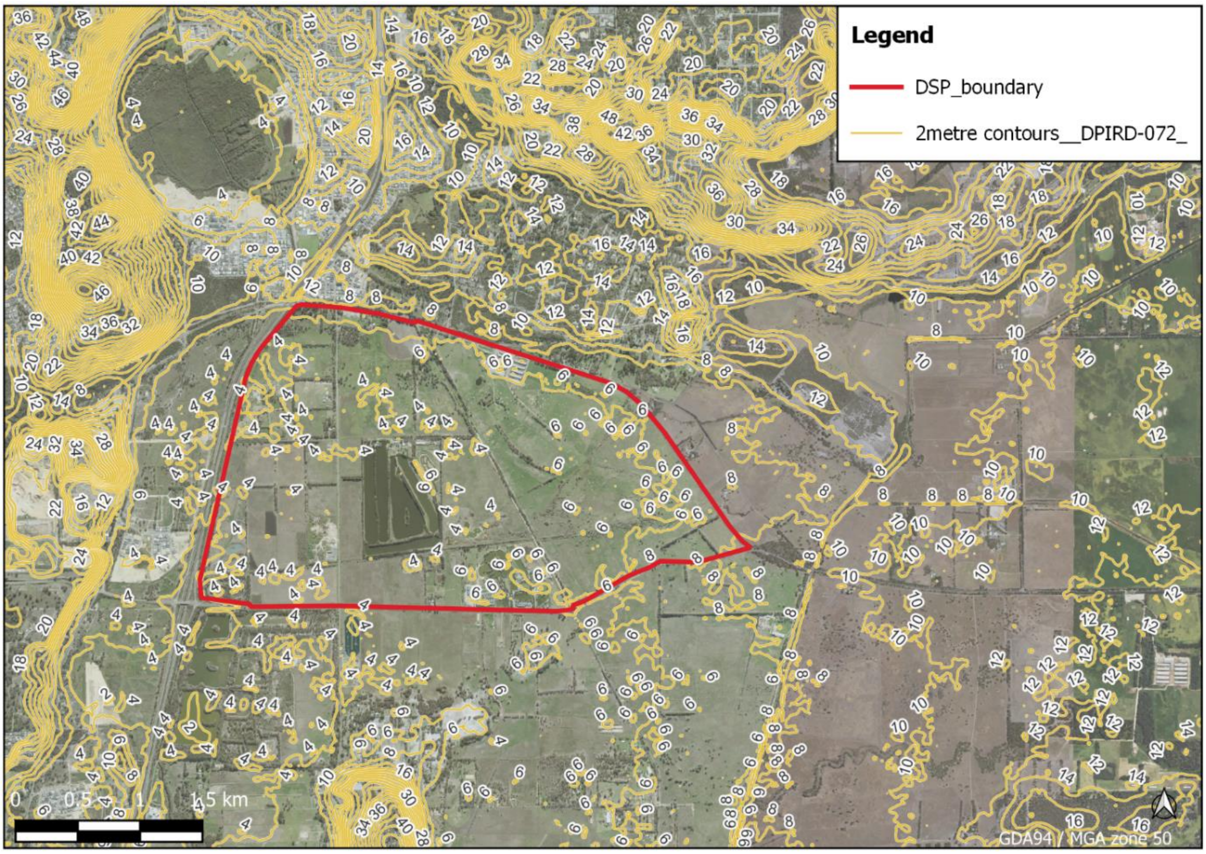


Figure 2: Existing topography

3.4. Geology

3.4.1. Regional Mapping

The site is located on the low-lying Swan Coastal Plain and regional mapping indicates that the surficial geology across the majority of the site consists of the Guildford formation which is described as alluvial sand and clay with shallow-marine estuarine lenses and local conglomerate (Davidson 1995). The Northern part of the site is mapped as part of the Bassendean Sands formation, described as basal conglomerate overlain by dune quartz sand with heavy mineral concentrations (Davidson 1995). Regional surficial geology mapping is shown in Figure 3.

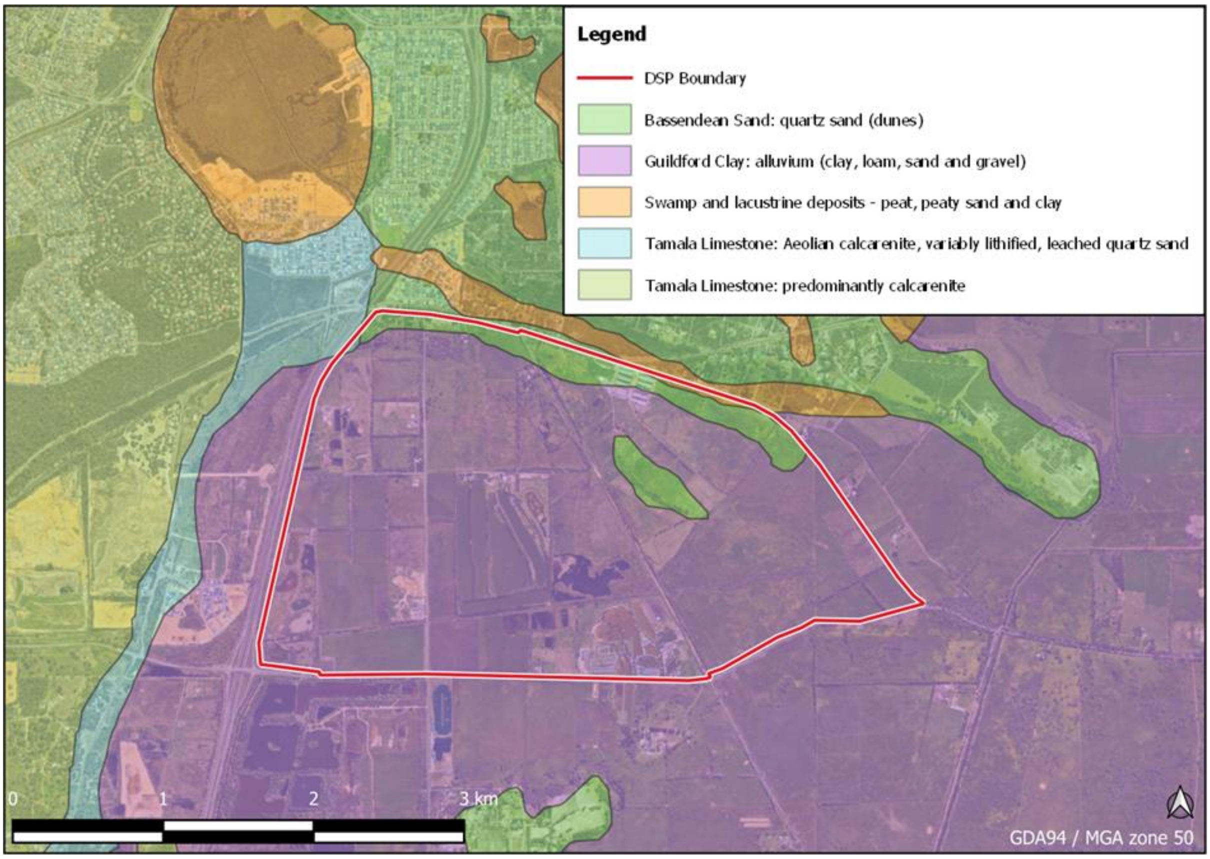


Figure 3: Soil systems

3.4.2. Site Investigations

Stockland commissioned Cardno (WA) Pty Ltd (Cardno) to undertake ongoing surface water and groundwater monitoring at Lots 1 – 3, 100, 201, 451 and 454 Telephone Lane, Baldivis from April 2018 to December 2020. The assessment included the installation and monitoring of 12 nested groundwater monitoring bores and installation and monitoring of four surface water sites. The key findings included:

- Surface water flows increased from the upstream surface water monitoring sites (located to the east) to the downstream sites (to the west)
- Runoff coefficient across the catchment ranged from 1.0% to 2.1% indicating the soils at site absorbed a large portion of rainfall
- Clay layers were encountered at majority of the groundwater bore locations
- Shallow groundwater bore winter elevations ranged from 2.2 mAHD to 7.88 mAHD with an inferred groundwater flow to the west/southwest.
- Deep groundwater bore winter elevations ranged from 4.39 mAHD to 7.86 mAHD with an inferred groundwater flow to the west/southwest

Golder Associates were commissioned to undertake a geotechnical investigation of Lots 456 to 458 Pug Road and Lots 465, 466 and 1261 Mundijong Road, Baldivis in 2010. The investigation included a broad assessment of subsurface soil and groundwater conditions on site as well as a number of other geotechnical assessments. The key findings include:

- Subsurface soil conditions included sand overlain by clay overlain by silty clay topsoil.
- The clayey organic topsoil was encountered to be up to 0.4 m thick and underlain by a typically firm to stiff soft organic plasticity clay.
- Groundwater was encountered at approximately 1.0 and 2.2 m below ground level at the north and south ends of the site respectively and is considered likely to be close to ground surface during wet periods.

3.5. Acid sulfate soils

The site is mapped by DWER as having a moderate to low risk of ASS occurring within the top 3 m of the natural soil surface but high to moderate risk of ASS beyond this depth.

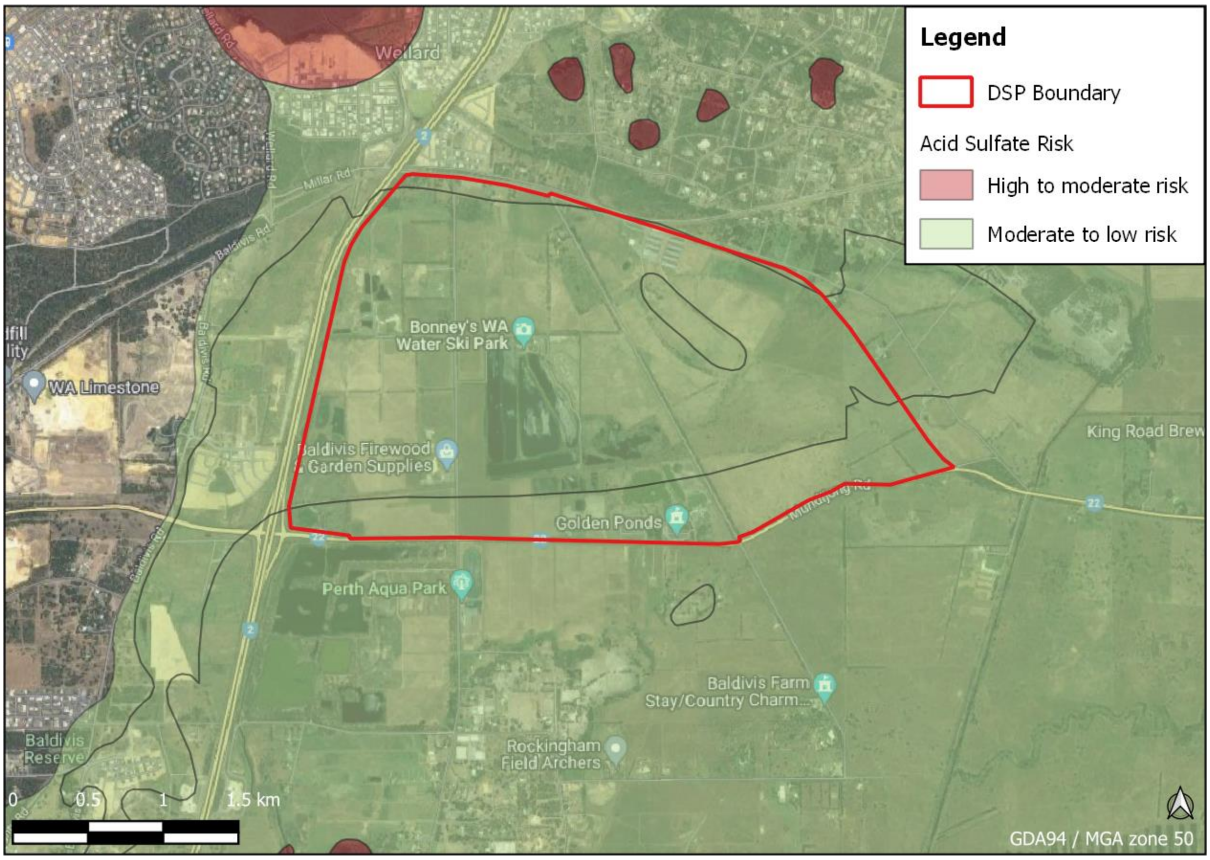


Figure 4: Acid Sulfate Soils

3.6. Contaminated Sites

A review of the DWER Contaminated Sites Register did not identify any known contaminated site under Section 11 of the Act within the Site or in the immediate surrounds.

3.7. Aboriginal Heritage

A search of the Department of Planning Land and Heritage, Aboriginal Heritage (DPLH) Inquiry system identified one listed heritage site potentially within the site boundaries. Registered site Wally's Camp (ID 3568) was identified extending across the Kwinana Freeway and into the north-west corner of the site (Figure 5). Further consultation will be required to assess cultural heritage values across the area as the development progresses.

A search of the EPBC Protected Matters Search Tool identified no Commonwealth listed heritage sites within 1 km of the site.

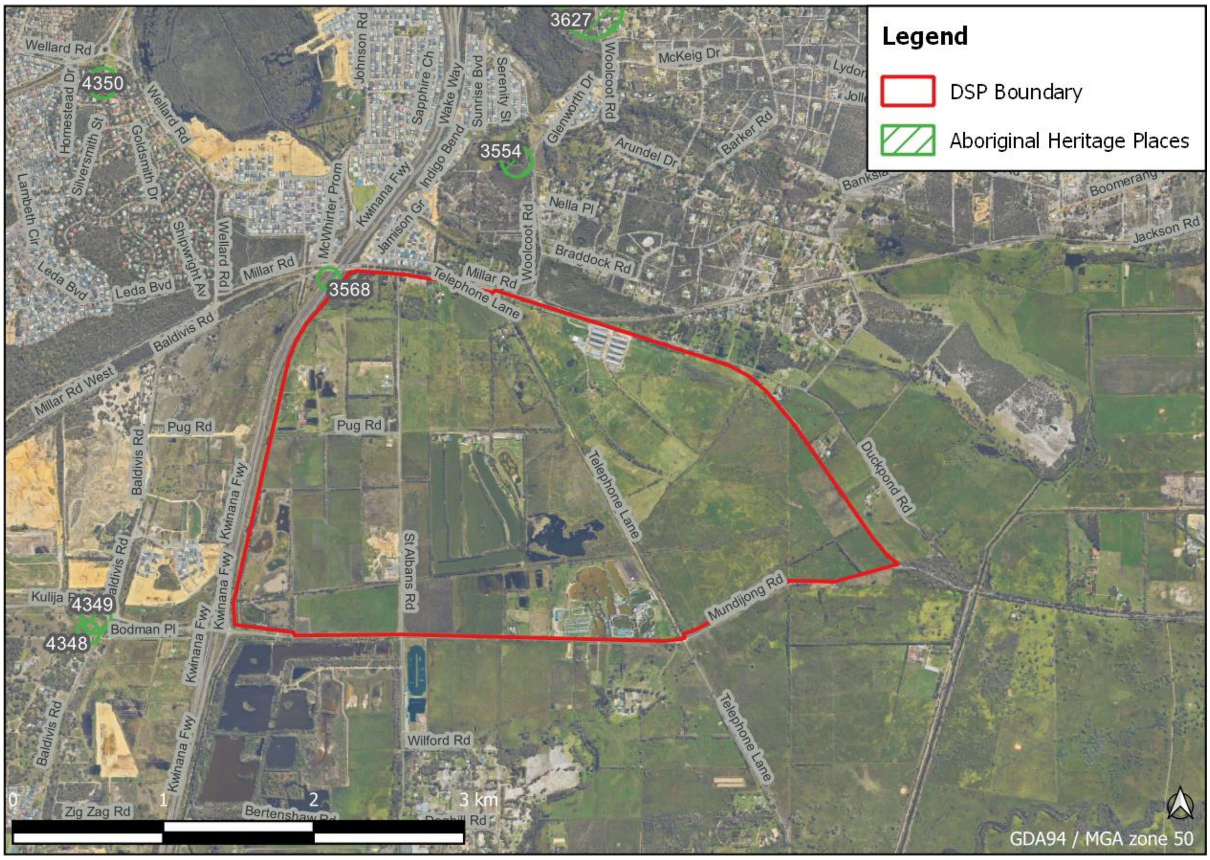


Figure 5: Aboriginal Heritage Sites

3.8. Bush Forever Sites

A search of the Department of Plannings Lands and Heritage Bush Forever mapping did not identify any Bush Forever sites within the site (DPLH 2019). The nearest Bush Forever sites are site no. 360 and 349, which are located directly to the east of the site and to the northwest on the opposite side of Kwinana Freeway, respectively (refer Figure 6).

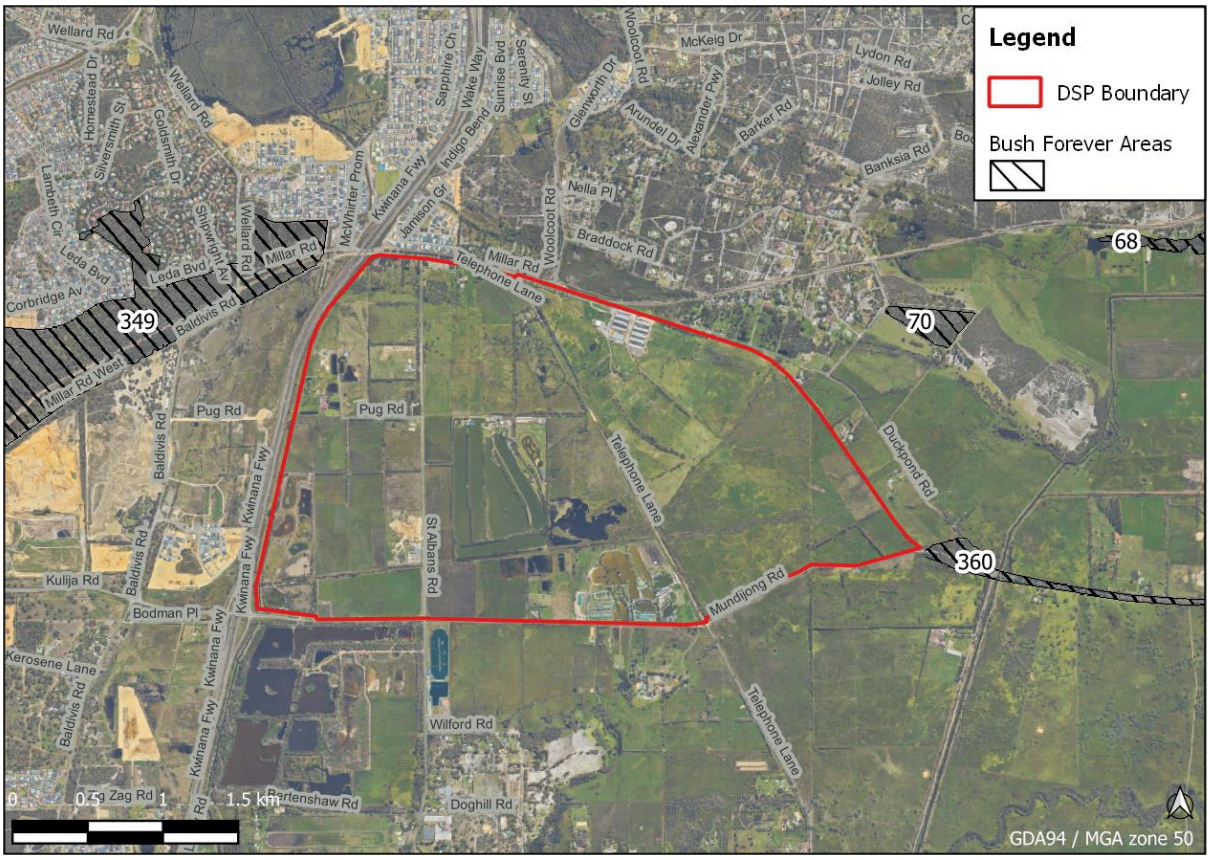


Figure 6: Bush Forever Sites

3.9. Wetlands

The Department of Biodiversity, Conservation and Attractions' (DBCA) mapping of Geomorphic Wetlands of the Swan Coastal Plain indicates that most of the site consists of palusplain Multiple Use wetlands (MUW (UFI162021) (refer Figure 7). MUW are typically wetlands with few remaining important ecological attributes and functions and do not generally pose a constraint to developments.

The site contains a number of Resource Enhancement wetlands (REW): UFI 14646, 14647, 14665, 14666 and 14736. REW are typically wetlands that have been partly modified but will support ecological attributes and values. The EPA advises that reasonable measures are taken to minimise potential impacts on REW and their appropriate buffers (WRC 2001; EPA 2008).

One Conservation Category wetland (CCW) is located just outside of the site boundary to the southeast (UFI 14780). The land use planning buffer (50 m) is located just inside of the site boundary, with DWER (2019) mapping indicating this area is also classified as an Environmentally Sensitive Area (ESA). ESA's are discussed further in Section 3.11.

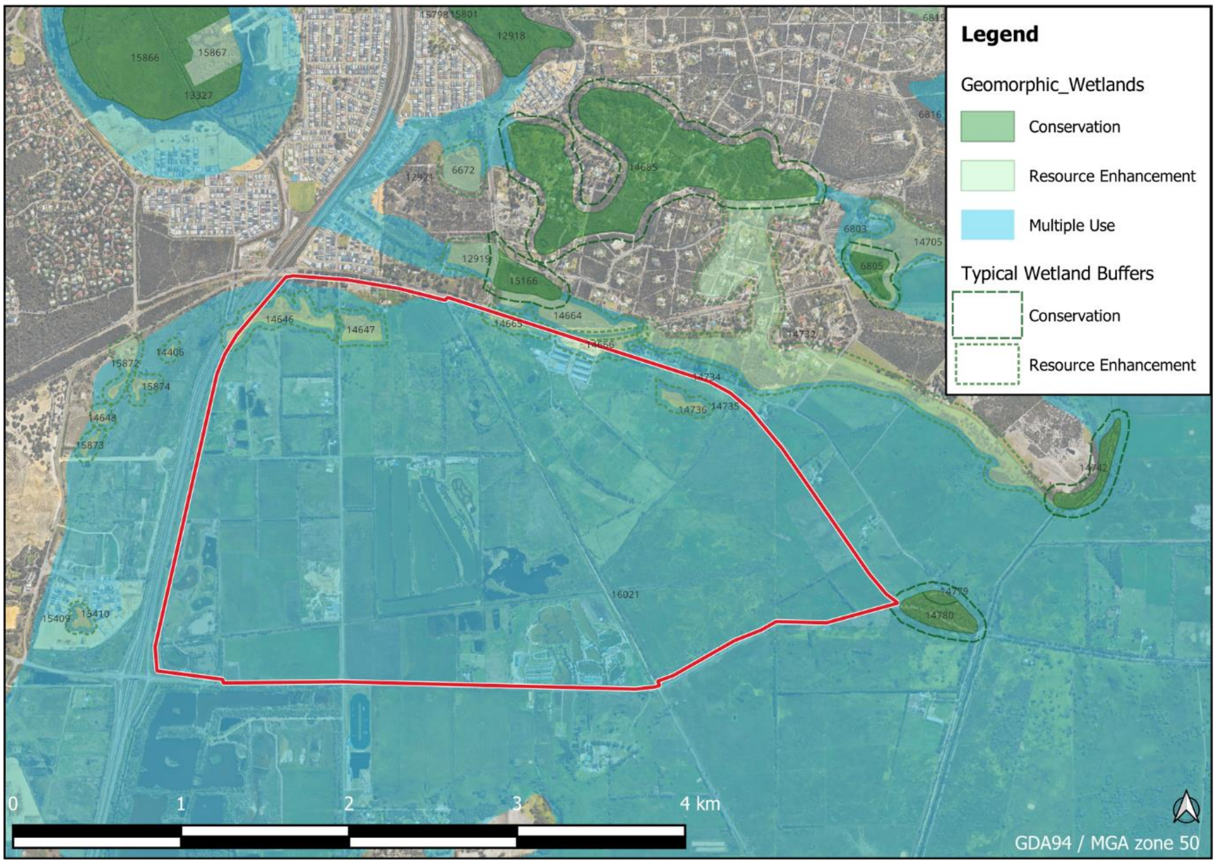


Figure 7: Geomorphic Wetlands

3.10. Public Drinking Water Source Areas

There are no Public Drinking Water Source Areas (PDWSAs) or wellhead protection zones within the site boundaries. The nearest PDWSA is a Priority 1 area within the Jandakot Underground Water Pollution Control Area, approximately 3.6 km north of the site, as shown in Figure 8.

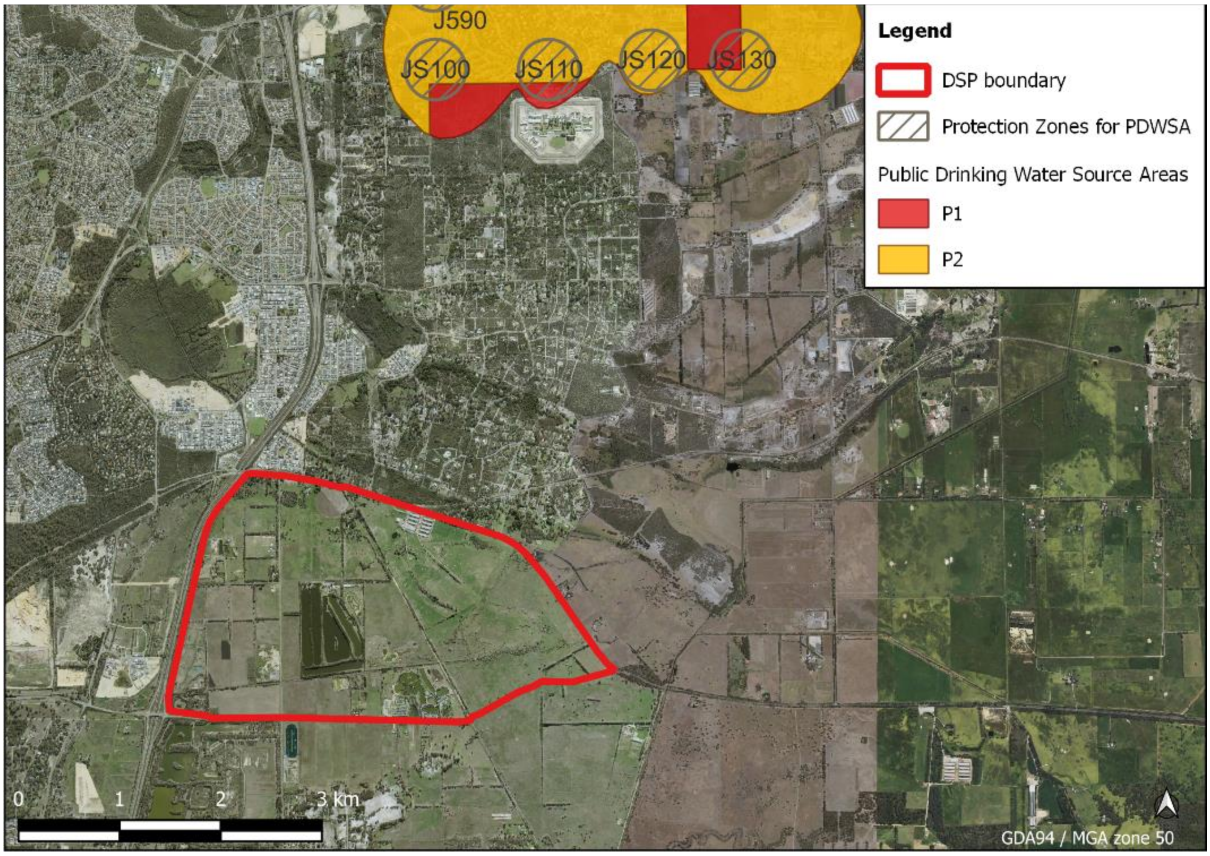


Figure 8: Public Drinking Water Source Areas and Wellhead Protection Zones

3.11. Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESAs) are classes or areas of native vegetation where the exemptions for clearing vegetation under the Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (Clearing Regulations) do not apply. ESAs ensure that clearing within these areas are assessed under the clearing permit process.

The site is mapped as an ESA according to the DWER Environmentally Sensitive Areas Map Viewer (DWER 2019). This ESA is associated with the CCW and associated 50 m buffer, as well as a Threatened Ecological Community (TEC) identified within the same area.

3.12. Groundwater

3.12.1. Groundwater areas, subareas and aquifers

The site lies in the Stakehill groundwater area within the Maramanup groundwater subarea and the Stakehill Confined groundwater subarea (refer Figure 9). The site is underlain by the following hydrogeological units (aquifers):

- Unconfined Perth – Superficial Swan aquifer
- Confined Perth - Leederville aquifer
- Confined Perth - Yarragadee North aquifer

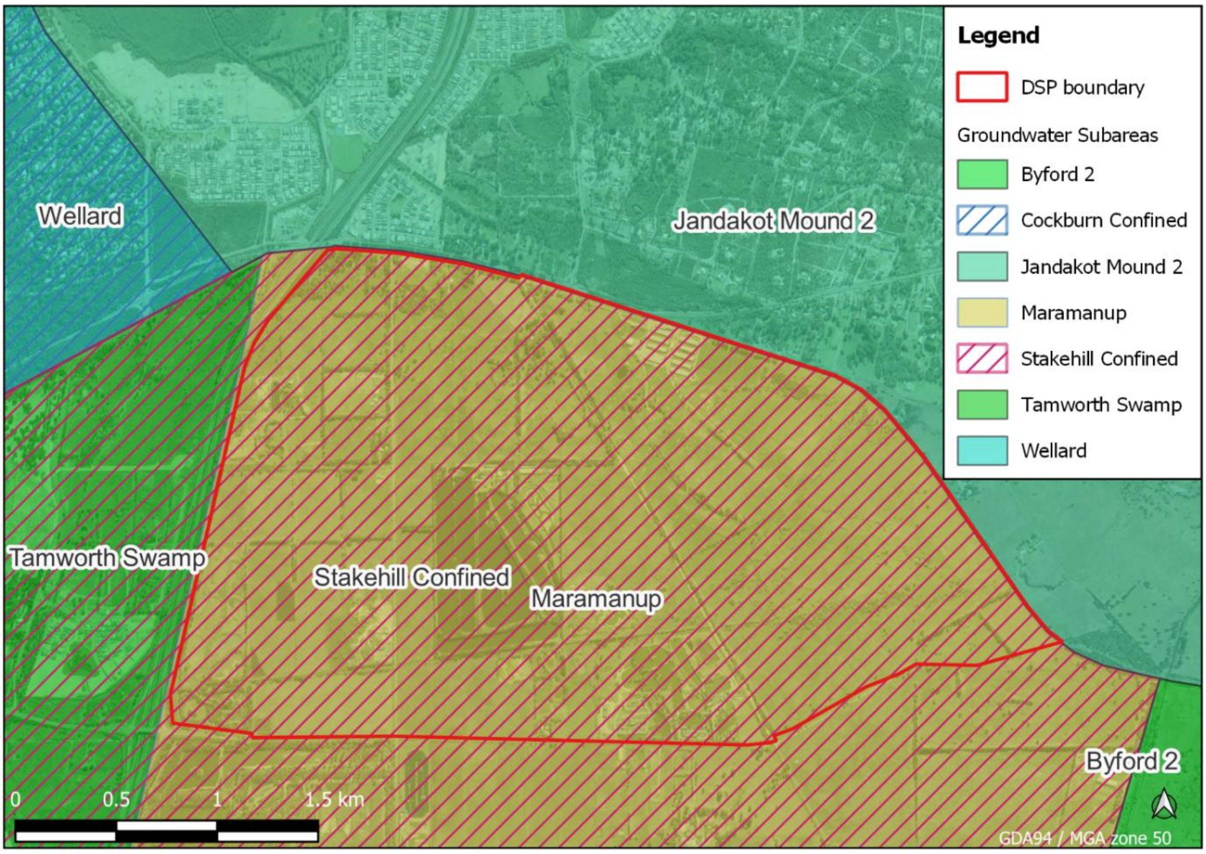


Figure 9: Groundwater subareas

3.12.2. Local Hydrogeology and Drainage

The surficial geology across the majority of the site consists of interfingering alluvial and lacustrine sands and clays of the Guildford Formation, with sands of the Bassendean Formation occurring in shallow dunes to the north. Although the vertical distribution of sands and clays is variable across the site, drilling and test pit logs across the site indicate there is typically a shallower sand or clayey sand layer above a lower permeability more clay rich layer, grading back into a sandier unit at depth. To the north where the Bassendean sands occur the clay layer is generally not present, however a lower permeability layer of coffee rock often occurs around the water table level. The site is relatively flat and poorly draining, therefore several artificial drainage channels have been constructed to manage groundwater and surface water across the site.

3.12.3. Groundwater levels

Twenty-eight bores, located across the site (listed in Table 4), were monitored monthly by Cardno from June 2018 to December 2020 (Appendices B and C respectively), including three annual peaks (Cardno 2021). Several of the bores were nested “shallow” and “deep” bores (e.g., MW01S and MW01D, respectively), installed above and below the low permeability layers. Monitoring results indicate there is a perched system sitting on top of the clays across most of the site. The water level in the perched aquifer is shallow and intersects ground surface in some areas in winter. Water levels show the regional flow direction is towards the west and southwest, likely controlled by the invert of the Peel Main Drain.

The pre-development Average Annual Maximum Groundwater Level (AAMGL) and Maximum Groundwater Level (MGL) were calculated for the DSP area and surrounds using a combination of groundwater data, drain AAMGL elevations, and topography. The objective of calculating the AAMGL is to provide an understanding of the pre-development groundwater elevation at the site.

The long-term AAMGL and MGL for each site bore were calculated by correcting the measured annual peaks in each bore against the calculated AAMGL and MGL of nearby longer-term monitoring records in DWER registered bores. Six DWER bores within the vicinity of the site (listed in Table 4) provided a longer-term record for the corrections. Bore 61410130 was monitored from 2000 onwards, bore 61410094 was monitored between 2000 and 2010 (except for 2007 and 2008) and from 2015 onwards (although the winter peak was not captured in 2017), and the remaining DWER bores to the north-east of the site were monitored from 2011 onwards. Although bore 61410130 had the longest record, the amplitude of water level fluctuation and seasonal water level response in this bore differed to the observations from the site bores. Furthermore, this bore was screened from 3 to 13 mgbl (metres below ground level) in sand below a clay layer, so was potentially giving the response the deeper groundwater system rather than the perched groundwater system. Bore 61410130 was therefore not used to correct the site bores.

Bore 61410094 was also screened from 3 mbgl (metres below ground level) in sand below a clay layer, however the water level hydrograph from this bore showed a similar trend to the hydrographs from the shallow and deep site bores installed in sandy clays and clayey sands across the site. Despite the shorter record, this bore provided the only suitable record for correction of the site bores screened in sandy clays and clayey sands. The four bores monitored from 2011 were installed in sand and were used to correct the water levels from the northern site bores that were installed predominantly in Bassendean sand.

The AAMGL estimated along the alignment of the Peel Main Drain (PMD) was included for the interpolation of the AAMGL surface to control the AAMGL on the western side of the site. The AAMGL surface across the site was corrected for topography using a 2m DEM of the site.

Groundwater monitoring data is included in Appendices A and B, with DWER and site hydrographs included in Appendix C. The peak water level, year of peak level, maximum measured water level, corrected AAMGL and corrected MGL for each bore have been summarised in Table 4. The AAMGLs estimated for the nested shallow bores generally exceeded the AAMGL for the deeper bores, except for MW09D and MW11D in which the deeper bore AAMGL was 0.11 m and 0.08 m higher than the adjacent shallow bore, respectively.

AAMGL contours and depth to AAMGL across the DSP area, are shown in Figure 10 and Figure 11, respectively. The contour surfaces were interpolated from the estimated AAMGLs for the shallow bores across the site and the PMD. The shallow AAMGL ranges from approximately 3.5 mAHD to 8.0 mAHD and AAMGL contours generally indicate a west/southwest groundwater flow direction.

It is noted that during the winter groundwater is inferred to flow in a west/southwest direction, whilst inferred to flow in a more south westerly direction during the summer.

Table 4: Pre-development groundwater levels

Bore ID	Easting	Northing	Annual peaks	Year of peak	Max level (mAHD)	AAMGL (mAHD)	MGL (mAHD)
MW01S	393976	6428037	3	2018	8.14	7.85	8.17
MW01D	393973	6428034	3	2018	8.13	7.83	8.15
MW03S	394169	6426760	3	2020	8.33	7.98	8.69
MW03D	394169	6426759	3	2018	8.29	7.97	8.67
MW04S	393511	6426411	3	2020	7.28	6.93	7.63
MW04D	393511	6426411	3	2020	7.02	6.67	7.38
MW05S	393493	6427428	3	2018	6.71	6.39	7.09
MW05D	393485	6427425	3	2018	6.49	6.17	6.88
MW06	393407	6428257	3	2018	8.10	7.81	8.13
MW07S	392461	6427219	3	2020	5.62	5.27	5.98
MW07D	392461	6427219	3	2019	5.16	4.86	5.57

Bore ID	Easting	Northing	Annual peaks	Year of peak	Max level (mAHD)	AAMGL (mAHD)	MGL (mAHD)
MW08S	392498	6427784	3	2019	5.49	5.19	5.89
MW08D	392500	6427785	3	2019	5.41	5.11	5.82
MW09S	392544	6428404	3	2020	6.62	6.27	6.98
MW09M	392541	6428406	3	2020	6.52	6.17	6.87
MW09D	392543	6428405	3	2018	6.70	6.38	7.08
MW10S	391822	6427758	3	2020	5.52	5.17	5.88
MW10D	391823	6427758	3	2019	5.21	4.91	5.61
MW11S	392012	6428655	3	2018	7.33	7.04	7.35
MW11D	392014	6428658	3	2018	7.41	7.12	7.44
MW12S	391355	6428799	3	2018	6.31	6.02	6.34
MW12D	391358	6428798	3	2018	5.99	5.69	6.01
MW13S	391067	6427717	3	2020	4.98	4.63	5.34
MW13D	391067	6427716	3	2020	5.00	4.65	5.35
B1 (deep)	391337	6427712	3	2020	4.92	4.57	5.28
B2 (deep)	390701	6427371	3	2020	5.23	4.88	5.59
B3 (deep)	391119	6427154	3	2019	4.63	4.33	5.03
B5 (shallow)	390824	6426426	3	2019	3.45	3.15	3.85
61410094	392259	6426307	15	2021	5.79	5.09	5.79
61410130	396548	6426516	22	2018	10.85	10.11	10.85
61410491	394757	6428761	11	2011	10.79	10.59	10.91
61410492	395381	6428464	11	2018	10.50	10.20	10.52
61410493	394930	6428588	11	2018	10.53	10.23	10.55
61410497	395565	6428910	11	2018	12.56	12.26	12.58

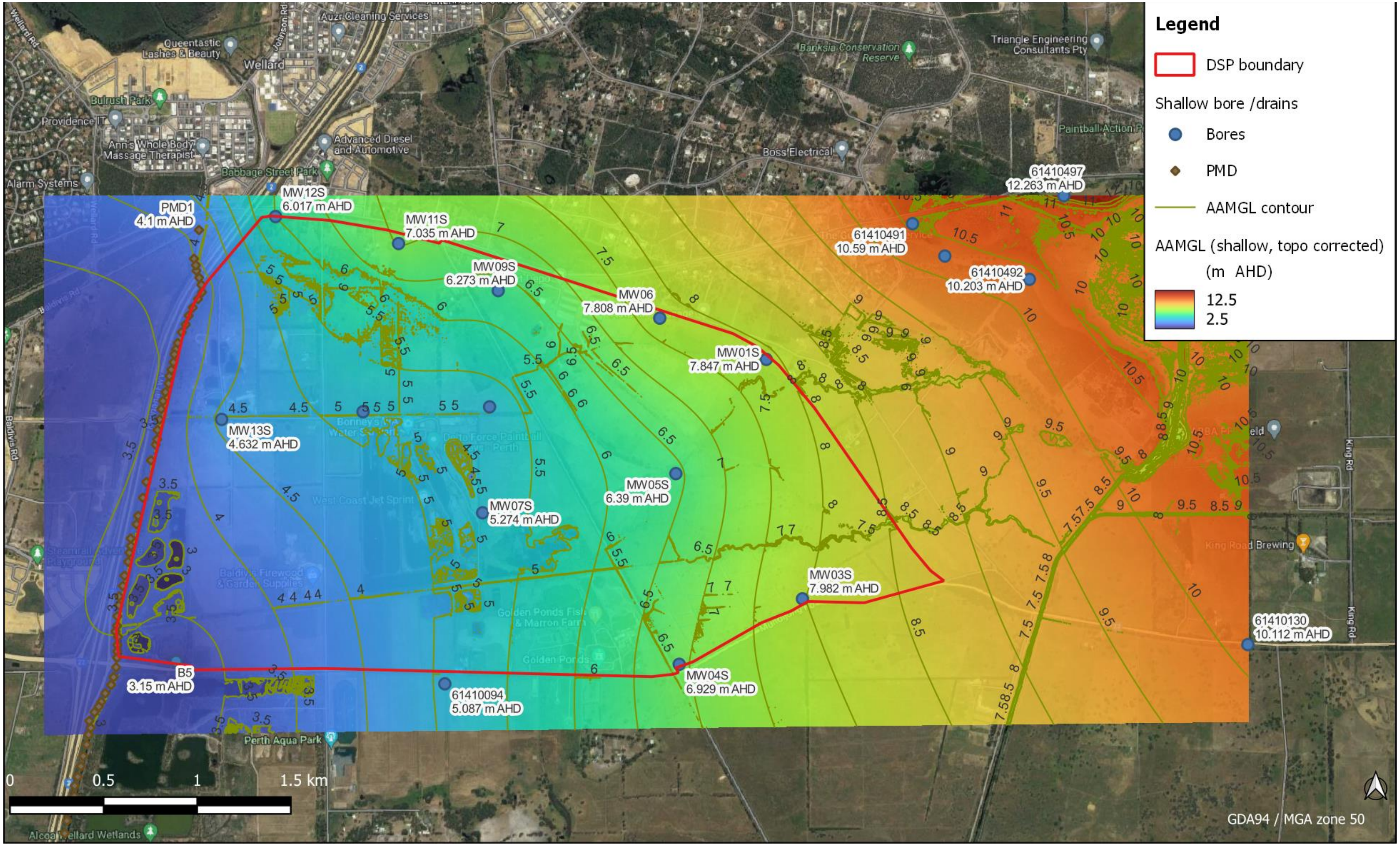


Figure 10: Shallow bore AAMGL

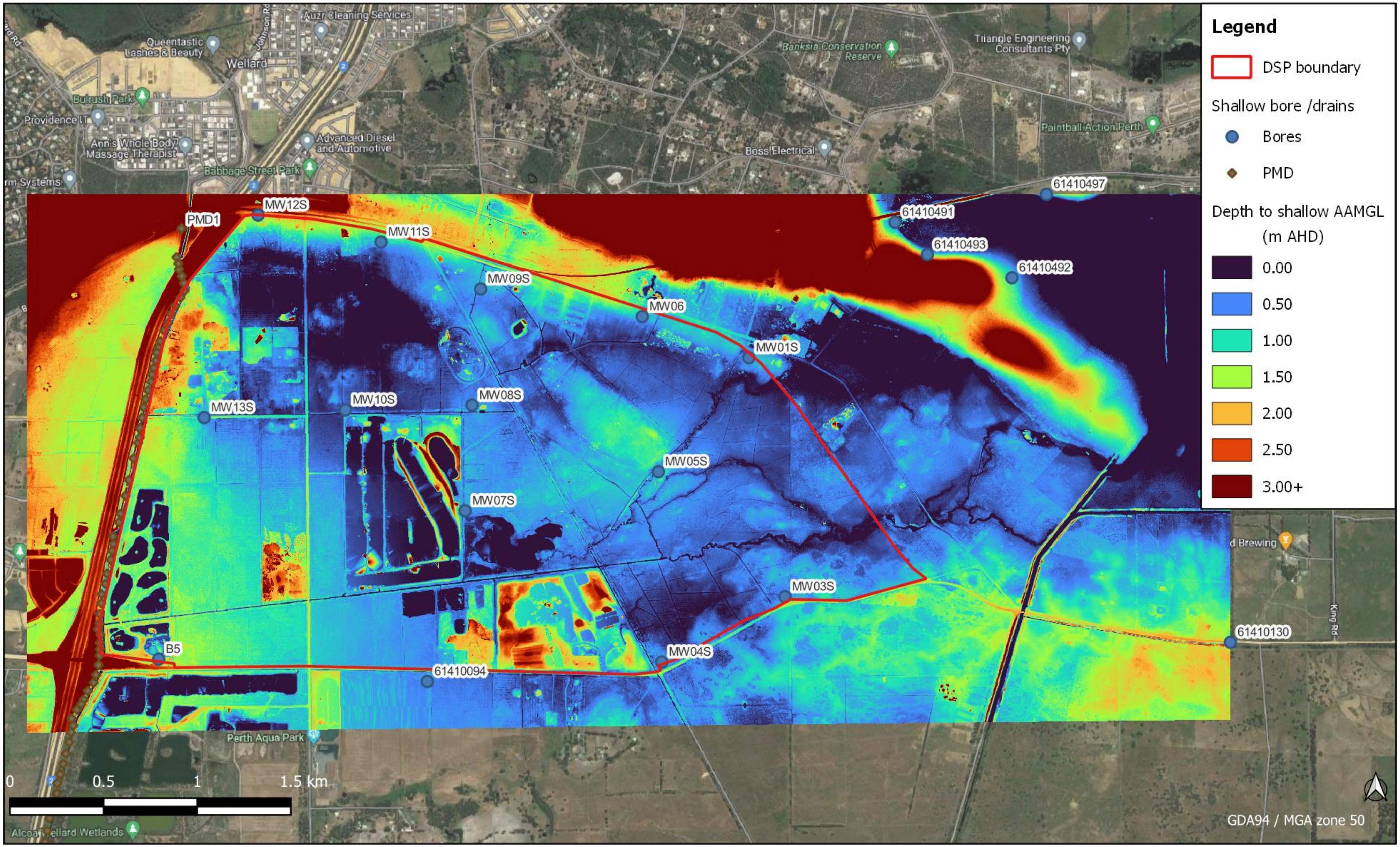


Figure 11: Depth to shallow bore AAMGL

3.12.4. Groundwater quality

Cardno has undertaken a groundwater and surface water monitoring program at the North-east Baldivis site. Tabulated groundwater analytical results are available in Appendix D. The monitoring results recorded to date have been summarised below, with the following conclusions made. The assessment guidelines referred to in this report are outlined Appendix D.

- Concentrations of pH recorded over the monitoring period recorded near neutral conditions with a median pH of 6.38 across the shallow and deep bores, with concentrations of 6.5 and 6.2 respectively.
- TDS concentrations varied across the network with a minimum concentration of 202 mg/L and a maximum concentration of 22,637 mg/L, however, the median concentration for the shallow bores was 1,041 mg/L and 1,598 mg/L for deeper bores indicating marginal groundwater conditions across the study area, with a number of locations above the groundwater is considered fresh to marginal with a majority of locations above NPUG criteria.
- Concentrations of ammonia, nitrate, TN and TP were recorded above their adopted assessment criteria across the network, both shallow and deep bores, with the highest concentrations of ammonia and nitrate recorded in MW11D, whilst the highest concentrations of TN and TP recorded in MW05S and MW01S respectively. However, it is noted that all groundwater monitoring bores recorded at least one concentration above the above the adopted assessment criteria for TP (0.05 mg/L) during the monitoring period. It is considered that the TN concentrations are predominantly due to high TKN concentrations commonly associated with farming and agricultural land uses as in the DSP area.
- Concentrations of arsenic, chromium, copper, lead, nickel and zinc were recorded above the laboratory LOR. All groundwater monitoring bores recorded at least one concentration of zinc above the adopted ANZECC (2018) Freshwater 95% assessment criteria (0.008 mg/L) during the monitoring period with the exception of MW01S and MW12S. However, all concentrations were reported below the adopted human health assessment criteria. It is considered that the heavy metals concentrations recorded are respective of natural groundwater conditions.
- The results of the major ion analysis indicate that samples from the shallow and deep bores are representative of groundwater of the same domain and supports a conclusion that the groundwater sampled from the bores are from the same source with no definitive differences. The anion and cation concentrations from the monitoring events indicate a predominantly sodium chloride chemistry. However, it is noted that there are varying degrees of hydraulic separation of the shallow and deep bores due to the presence of a clay layers. Elevated levels of E-Coli and Enterococci are likely the result of current farming activities on the site; and
- Higher concentrations of nutrients, metals and microbiological materials were found in the shallow bores than in the deeper aquifer, considered due to special-rural land use activities and likely to naturally attenuate through the clay layers into the deeper portion of the superficial aquifer. This creates somewhat of a natural barrier when considering water source protection of the lower aquifers.

3.13. Surface Hydrology

The subject site is located within the Peel-Harvey Coastal Plain catchment and drains via the Peel Main Drain to the Peel Inlet which is located approximately 30 km downstream of the site to the south-southwest.

The site itself comprises relatively flat and low-lying land located between the Peel Main Drain (adjacent to the west) and the Birrega Main Drain (approximately 500 m to the east). These main drains were constructed to control groundwater and drain surface water from rural land, and they have a very low grade, eventually discharging to the Peel Inlet. Surface water at the site drains to the Peel Main Drain through a network of small agricultural drains that dissect the site, as well as two Water Corporation drains that run through the site from east to west. The main drainage channels through and in the vicinity of the site are shown in Figure 12.

The upstream catchment area to the site is quite small, comprising the land extending several hundred metres from the eastern site boundary of the site as far as Birrega Main Drain to the east and a dunal ridge to the north-east. The construction of Birrega Main Drain (BMD) effectively altered the drainage catchments in the region such that runoff from land upstream (east) of the BMD, which would previously have drained through the site, is now intercepted by the BMD and conveyed south. However, major flood events may result in discharge of floodwater from the upstream catchment into the subject site, via either overflow or breach/failure of the BMD spoilbank. This is discussed further in Section 3.13.2.

Located centrally within the site is the Bonney's Ski Park which comprises a series of large lakes totalling approximately 55 ha in area. The ski lakes are bounded on the north and south by the two Water Corporation drains. It is understood that surface water can be diverted from the southern Water Corporation drain (under licence) during periods of high-flow, and similarly can be discharged to the southern Water Corporation drain during high lake water conditions, though there is no record of discharge from the lake occurring.

A number of structures (ie. culverts and small bridges) have been installed along the drains within the site. A feature survey of these structures was undertaken which included measurement of dimensions and elevations of 36 culverts and 4 bridges across the study area. Many of these culverts were found to be partially blocked and/or buried. The survey data for existing culverts is provided as Appendix E.

Figure 12 illustrates that surface water drainage features within and surrounding the site.

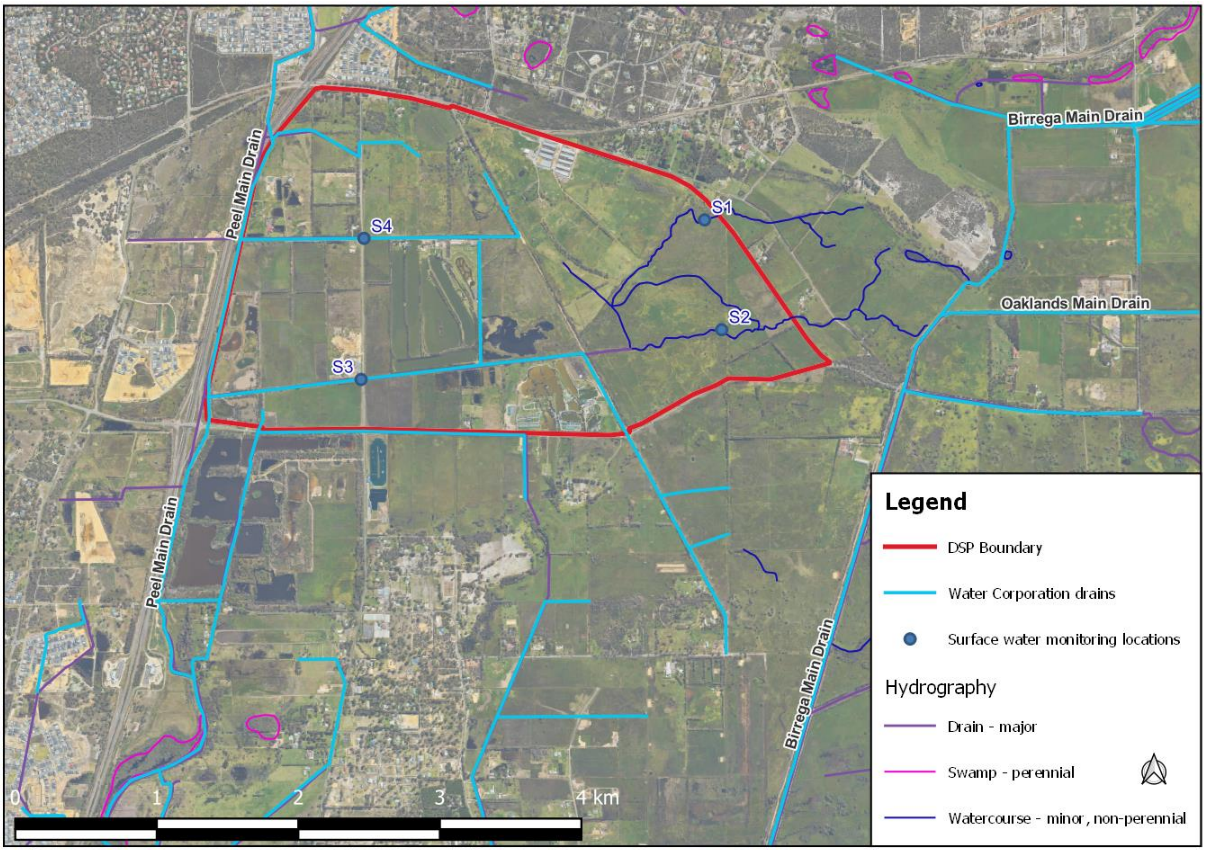


Figure 12: Watercourses

3.13.1. Peel Harvey Catchment

The DSP is located within the Peel-Harvey Coastal Plain catchment and therefore within the subject area of the Environmental Protection (Peel Inlet – Harvey Estuary) Policy 1992 (EPP) and the State Planning Policy No. 2.1 – Peel-Harvey coastal plain catchment (SPP 2.1), which will be superseded by State Planning Policy 2.9 – Planning for Water once gazetted.

The EPP provides environmental quality objectives to be achieved and maintained for the total phosphorus loads within the EPP catchment area. The purpose of SPP 2.1 is to improve the social, economic, ecological, aesthetic and recreational potential of the catchment whilst balancing land use changes and economic growth of the catchment. The development criteria specifies that all residential lots must be connected to reticulated sewage, unless alternative wastewater treatment and effluent disposal systems are approved by the Western Australian Planning Commission. The policy also specifies that remnant vegetation should be protected, and replanting should be encouraged to help reduce nutrient flow into the Peel Harvey estuary.

3.13.2. Flooding

A number of flood studies relating to the site have been commissioned or undertaken by the Department of Water and Environmental Regulation, the most relevant of which are summarised below.

In 2012, the Western Australian Planning Commission identified the north-east Baldivis area as a potential site for developing a non-heavy industrial estate in the economic and Employment Land Strategy (EELS; WAPC 2012). This prompted the *North-east Baldivis flood modelling and drainage study* (DoW 2015a), which assessed the proposed industrial site and its surrounding (which included the subject site) to identify constraints associated with flooding, and to provide technical information to support site development plans. The study discovered that regular winter inundation from shallow groundwater, limited drainage potential (associated with low landscape positioning and flat topography), and location between the Birrega and Peel main drains contribute to the flood risk across the area (DoW 2015a). The report concluded that the study area (including the subject site) may be flooded via groundwater inundation, direct rainfall and/or backwater from the Peel main drain, and spoil bank overtopping or failure on the Birrega main drain (DoW 2015a).

In 2021, DWER produced two (unpublished) reports comprising updated flood modelling and a land capability assessment, respectively, for the East-of-Kwinana and Pinjarra-Ravenswood planning investigation areas (PIAs). The updated modelling and land capability assessment was undertaken specifically to inform the Department of Planning, Land and Heritage's analysis of the PIAs.

The 2021 DWER modelling included combining and updating two previous DWER flood studies over the PIAs and overall catchment area; the Birrega and Oaklands flood modelling and drainage study (Hall 2015) and the North-east Baldivis flood modelling and drainage studies (Marillier 2015). The two previous models were effectively merged into a single "East of Kwinana" model and then updated to follow more recent best practice approaches and parameters (i.e. Australian Rainfall and Runoff 2019) and increase model resolution in areas.

The purpose of the flood modelling and drainage study (DWER 2021a) was to understand the flood behaviour under existing catchment landuse and potential development scenarios through floodplain mapping, and some of the key findings (as relate to the DSP area) are summarised as follows:

- DWER suggest that "the design, construction and maintenance of the Birrega Main Drain spoil bank system indicate that an uncontrolled failure of the banks in a large flood event is likely which will cause a rapid change in flooding behaviour following the natural east-west flow of the land"
- A range of spoil bank failure scenarios were tested involving the length of spoil bank adjacent to the DSP assumed to be damaged / removed. It was found that the discharge into the site was relatively insensitive to these scenarios, ranging from 63.1 to 73.7 m^3/s (partial length failure to full length failure), with the full length failure being adopted as the base-case assumption.
- The BMD spoil bank failure adjacent to the DSP was also tested in combination with potential spoil bank failures at other locations along the Birrega and Oaklands Main Drains. These produced discharge rates into the DSP ranging between 69.8 and 78.2 m^3/s, again demonstrating a relatively low sensitivity to the potential coincident failure conditions.
- A local scale model was developed for the DSP area and surrounds, referred to in DWER (2021a) as "*North East Baldivis north of Mundijong Road*". Floodplain mapping and assessment of land capability for the area was undertaken using this local model, with the design inflow to the local model taken from the results of the East of Kwinana regional model's full length spoil bank failure scenario (ie. 73.7 m^3/s).

The purpose of the land capability assessment (DWER 2021b) was to inform the DPLH's comparative analysis of East of Kwinana and Pinjarra-Ravenswood PIAs in 2021, the outcome of which was the Perth and Peel @ 3.5 million Planning Investigation Areas Update issued by DPLH in September 2022, which endorsed a framework land use classification of Urban Expansion for the DSP area. The key conclusions of DWER's land capability assessment (as relate to the DSP area) are summarised as follows:

- DWER determined that the "spoil bank adjacent to the Birrega Main Drain in this location will fail in a 1 in 100 year flood event, flooding the North East Baldivis north of Mundijong Road precinct. This is the base case to which any future development proposal is compared".
- DWER considered that installing a levee as a means to increase developable area within the DSP would cause increased flooding on land for 5kms upstream and downstream in a 1% AEP event.
- In addition, DWER considered that flood levees are not fail-safe and can pose a risk to human safety and infrastructure and would not be considered best practice flood mitigation for a greenfield site.
- DWER determined that 55% of the precinct (which includes the DSP area plus the land extending east to the Birrega Main Drain) can be developed with flood protection in the 1% AEP flood event, with the remaining 45% without flood protection and therefore with limitations on use.

It is noted that one of the key differences between the 2015 and 2021 DWER flood studies is the higher 1% AEP flow rate identified as discharging from BMD into the DSP area (55 m3/s in the earlier study and 73 m^3/s in the latter). This is understood to be due to a different storm duration being used in the two studies. The 2015 flood modelling was based on the 24-hour duration event whereas the 2021 study identified the 18-hour event as being the critical duration in the DSP location, with a higher peak discharge from BMD. This is also evident in Figure 6-2 of DWER (2021a) which shows that the 24-hour event peak discharge from BMD into the DSP area is approximately 58 m^3/s (ie. very similar to the 2015 results).

The modelled flood extent and depth from DWER (2021a) is shown below in Figure 13.

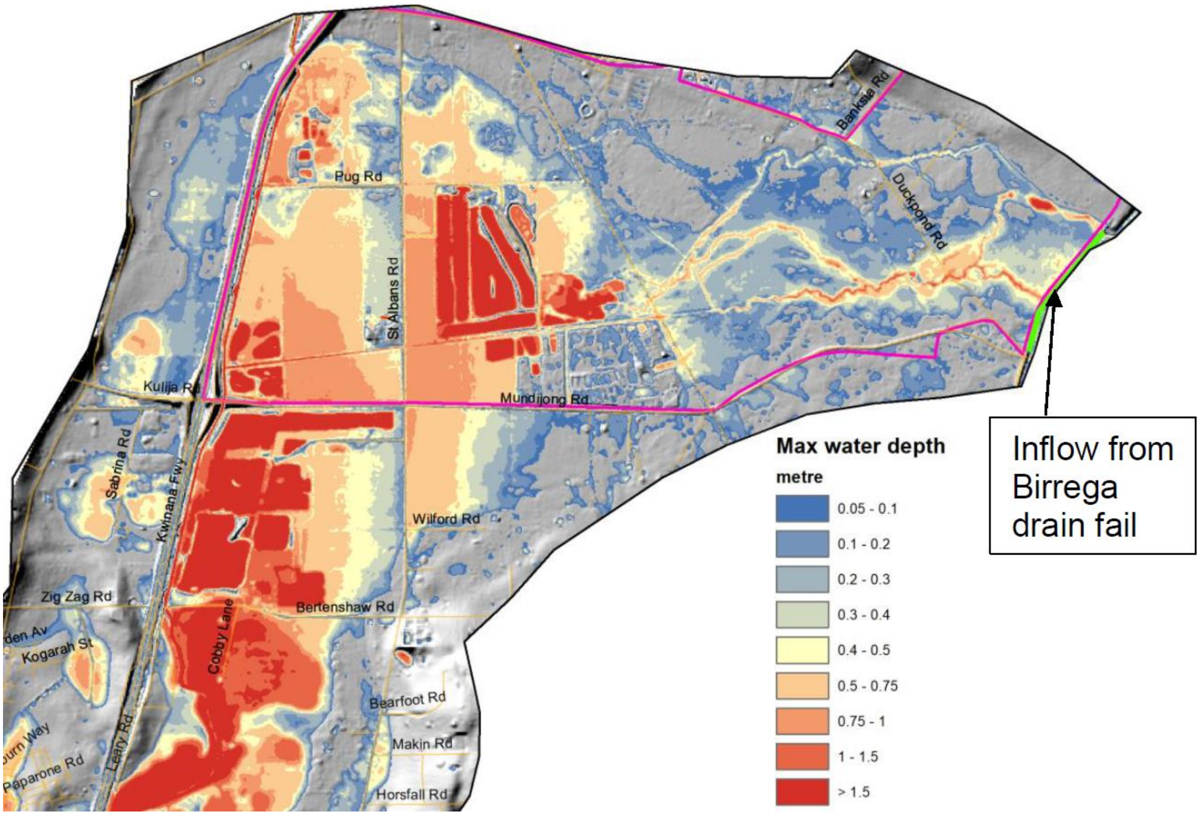


Figure 13: DWER flood modelling over DSP (source: Figure 6-16 of DWER, 2021a)

3.13.3. Spoil bank failure assumption

As described above, the more recent (2021a and 2021b) DWER reports indicate that spoil bank failure is more likely than not in a 1% AEP flood event and should be considered the base-case assumption (for the DSP area) against which development proposals are compared. This advice appears to differ slightly from that in the earlier (2015) flood studies in which spoil bank failure was highlighted as a possibility but with less discussion around the likelihood of such an event.

Failure of the spoil bank during a 1% AEP event cannot be considered a certainty. Therefore, the “base case” or “worst-case” scenario in terms of flooding is considered to differ between locations (ie. some locations would experience more severe flooding in the event that the spoil bank did not fail). In relation to the DSP area, the spoil bank failure scenario results in the most significant flooding and volume of flood storage through the site and is therefore the appropriate base-case assumption, ie. it is necessary to plan and design within the DSP area for the possibility of significant flooding from the Birrega Main Drain following a spoil bank failure situation.

3.13.4. Surface water quality and flow monitoring

A surface water monitoring program was undertaken by Cardno from April 2018 to December 2020 and included the monitoring of water levels and water quality at four locations (S1, S2, S3 and S4) along the major creeks and drains through the site (Cardno 2021). S1 and S2 are located near the eastern boundary of the DSP site while S3 and S4 are located down-stream, in the western portion of the site slightly downstream of where the two Water Corporation drains run past the ski lakes. The monitoring locations, along with the mapped watercourses throughout the DSP are shown in Figure 12.

Water level data is recorded at 5-minute intervals using loggers installed at the monitoring locations. Discharge measurements were obtained by establishing a relationship between water level and flow (rating curve) for each site. A summary of the water level and discharge measurements are presented in Table 5.

Table 5: Surface water quality

Site	Catchment area (ha)	Max Daily Flow (m^3/d)	Total Flow (m^3/d)	Run-off Coefficient (%)[1]
S1	45.3	425.8	16,144.3	2.1
S2	129.3	1,017.5	17,198.3	0.8
S3	411.2	4,186.0	86,362.8	1.2
S4	180.2	3,713	32,393.7	1.0

Note: Based on 1,732.4 mm of rainfall for the monitoring period.

It is noted from the monitoring results that:

- Flows increased from the upstream monitoring sites (S1 and S2) to the downstream site (S3).
- Runoff coefficient across the catchment ranged from 1.0% to 2.1% indicating the soils at site absorbed a large portion of the rainfall.

3.13.5. Surface water quality monitoring

Cardno has undertaken a groundwater and surface water monitoring program at the North-east Baldivis site. A summary of the monitoring results recorded to date and conclusions are discussed below. The surface water analytical results, as well as relevant assessment guidelines, are outlined in Table 6.

Table 6: Summary of surface water monitoring

Site	Date	Temp	pH	EC (µS/cm)	Ammonia as N (µg/L)	Nitrogen (µg/L)	Zinc (mg/L)	Phosphorus (mg/L)	Copper (mg/L)
LOR		-	-	-	10	100	0.005	0.01	0.001
ANZECC 2000 FWG		-	6 – 8.5	-	900	-	0.008	-	0.0014
ANZECC 2000 ILTTVs		-	-	-	-	5000	2	0.05	0.2
DoH 2014		-	-	-	-	-	3	-	20
S1	17/10/2018	26.2	7.35	913	<50	7500	<0.005	2.33	0.002
	19/08/2020	15.4	7.38	853	40	3200	0.008	1	0.002
	29/09/2020	16.7	6.38	891	190	55,700	<0.005	12.9	<0.001
S2	17/10/2018	32.6	7.46	5660	20	2,000	<0.005	<0.01	<0.001
	19/08/2020	14.1	7.47	1125	20	1,800	<0.005	0.3	0.001
	29/09/2020	14.3	6.06	1373	20	2,600	0.005	0.22	<0.001
S3	17/10/2018	30.6	7.72	2740	<10	4,900	<0.005	1.7	0.001
	19/08/2020	17.9	7.49	7947	<10	2,000	0.006	0.34	0.002
	29/09/2020	19.1	7.23	8635	<10	1,600	0.012	0.19	<0.001
S4	17/10/2018	31.4	8.26	1540	<10	7,000	<0.005	9.91	<0.001
	19/08/2020	18.5	7.8	1301	<10	8,200	0.033	3.15	0.002
	29/09/2020	19.4	7.18	1262	70	5,000	0.012	5.59	0.001

- Concentrations of pH recorded over the monitoring period recorded near neutral conditions with a median pH of 7.49.
- TDS concentrations varied across the monitoring period network with a minimum concentration of 532 mg/L and a maximum concentration of 532 mg/L, however, the median concentration of 968 mg/L indicates freshwater conditions.
- Concentrations of ammonia, TKN, nitrite, nitrate, TN, TP and RP were recorded above the laboratory LOR.
- A maximum TN concentration of 55.7 mg/L was recorded in S1 during the September 2020 event, this concentration is significantly higher than the next concentration above the adopted assessment criteria which was 8.2 mg/L recorded in S4 during the August 2020 event. Only S1 and S4 recorded concentrations above the adopted assessment criteria (5.0 mg/L).
- A maximum TP concentration of 12.9 µg/L was recorded at S1 during the September 2020 event. All samples recorded concentrations above the above the adopted assessment criteria (0.05 mg/L) during the monitoring period with the exception of a sample from S2 during the October 2018 event.
- Concentrations of arsenic, chromium, copper, nickel and zinc were recorded above the laboratory LOR; Copper was reported above the ANZG (2018) Freshwater (95%) toxicant DGVs criteria (0.0014 mg/L) a total of three times at isolated surface water sampling locations and events. A maximum concentration of 0.002 mg/L was recorded. Zinc was reported above the ANZG (2018) Freshwater (95%) toxicant DGVs criteria (0.008 mg/L) a total of five times at isolated surface water sampling locations and events A maximum zinc concentration of 0.033 mg/L was recorded in S4 during the August 2020 event.
- The results of the major ion analysis indicate samples are representative of surface water of the same domain and supports a conclusion that the surface water sampled is from the same source with no definitive differences. The anion and cation concentrations from the monitoring events indicate a predominantly sodium chloride chemistry, however, it is noted S1 and S4 are more of mixed chemistry as compared to S2 and S3.
- Elevated levels of E-Coli and Enterococci are likely the result of current farming activities on the Site.
- It is considered that the nutrient, heavy metal and pathogen concentrations recorded are representative of natural conditions or a result of the current land use, consisting predominantly of agricultural land use.

4. Water source planning

4.1. Potable water supply

Potable water will be accessed via a connection to Water Corporations Integrated Water Supply Scheme.

Based on the available information, it is likely that a DN250 water main extension would be required to extend from the intersections of Bertenshaw Rd and St Albans Rd. This will replace the existing DN150 water main which extends north along Bertenshaw Rd to Wilford Rd and extend a total distance of 1.3km to service the site.

It is noted that more extensive upgrades may be required depending on the timing of development and capacity of Water Corporation infrastructure in the surrounding areas at that time. The Water Corporation may require more extensive upgrades based on their strategic planning to upgrade and reinforce their infrastructure to meet the demands of the wider area.

4.2. Non-potable water supply

4.2.1. Irrigation Water Requirements

As per the water conservation principle of "No potable water should be used outside of homes and buildings with the use of water to be as efficient as possible" in *Better Urban Water Management* (WAPC 2008), a non-potable water supply will need to be sourced to service the irrigation requirements of POS within the site.

4.2.1.1. Irrigation Demand

Table 7 below outlines the irrigation water demand for the proposed development. The table estimates the irrigation demand based on the known area of POS, school sites, and DOS areas required to be provisioned through the planning process based on the net developable area and dwellings being planned across the urban expansion area. The estimated irrigation demands are presented in Table 7 below. A landscape concept is provided in Appendix F which illustrates the various landscape treatments being considered across the open space areas.

Table 7: Irrigation water demand

Area	Irrigated area (ha)	Irrigation rate (kL/ha/yr)	Total water demand (kL/yr)
Primary School 1	0.80	7,500	6,000
Primary School 2	0.702	7,500	5,267.6
Primary School 3	0.701	7,500	5,257.5
Primary School 4	0.80	7,500	6,000
Co-located school oval 2	1.26	10,000	12,635
Co-located school oval 3	1.48	10,000	14,753
High School	2.00	7,500	15,000
District Open Space	4.51	10,000	45,063
POS areas	12.85	7,500	96,347
Total irrigation demand	25.10		206,323

4.2.1.2. Groundwater licence application to support DSP

A groundwater licence request was submitted in November 2022 for an allocation of 50,000 kL. Obtaining this additional allocation would secure the water licences to support the irrigation requirement and some additional irrigated areas. DWER are currently assessing this request under DWER reference number DWERVT11036. The DWER officer has confirmed the substantial progression of the licence application and is awaiting information from the project team relating landscape masterplanning before formally issuing the licence.

4.2.2. Existing groundwater availability and licences

4.2.2.1. Groundwater allocation availability

The DSP site is located within the Swan groundwater area. The following aquifers are present in the area:

- Perth – Superficial Swan (Unconfined, Maramanup subarea).
- Perth – Leederville (Confined, Stakehill Confined subarea).
- Perth – Yarragadee (Confined, Stakehill confined subarea).

An aquifer allocation request (12th September 2022) indicated that 50,000 kL is unallocated in the superficial aquifer.

4.2.2.2. Existing Groundwater Licences

The DSP area overlies several landholdings that contain groundwater licences, but it is not anticipated that all of them will be available for use as an irrigation water supply to support the future urban expansion area as not all these landholdings will be subject to land use change. The existing licences are illustrated in Figure 14 and documented in Table 8 below. The licences are as follows:

- GWL157696, GWL157699, and GWL206614: Ausvision Rural Services (Wellard Farms) has a current allocation of 127,180 kL across three licences. These are currently used for irrigation of agricultural areas that will make way for urban expansion. It has been assumed that this allocation volume will be made available for irrigation of future POS, DOS, school sites and playing field.
- GWL96597 and GWL206554: the operator of the recreational lake has a combined licence allocation of 210,000 kL. These licences are used to supply water to the lake and its operations. These facilities are not planned to be replaced through urban expansion and hence the groundwater licences will still be required.
- GWL62906: Golden Ponds has a licence allocation 210,000 kL. This facility is unlikely to be altered based on the proposed urban expansion. Therefore, the licence allocation will remain dedicated to this use.
- GWL 204209: Everlast International Investment has a licence across multiple properties (within and outside the DSP area for 60,000 kL. We believe some of this licence may be transferred to support irrigation of the residential development.

As is outlined above, it is our understanding that Golden Ponds and the Lake Operator require their allocations to maintain their own facilities. It is likely that a portion of the Everlast International licence volume, perhaps half (30,000 kL), will be made available for irrigation of the future community. The allocation held by Ausvision will be available for use for irrigation of the future community. Therefore, it is estimated that the groundwater licence contribution from the existing groundwater licences within the proposed DSP area (urban expansion) is approximately 157,180 kL/yr. Provided these allocations are available for use, there is still a further minimum of 49,143 kL/yr required to fulfill the estimated irrigation demand for the development as outlined in Table 7 in Section 4.2.1.1 above. As discussed above, a groundwater licence application has been submitted to DWER and is currently under assessment. This additional groundwater licence application, if approved, would secure an irrigation water source for the entire DSP area.

Table 8: Existing groundwater licences within DSP boundary

Groundwater licences	Owner and address	Allocation (kL/yr)	Subareas	Expiry date
62906	**Golden Ponds (WA) Pty Ltd:** 4 Salpietro Street Bibra Lake WA 6163	200,000	Maramanup	03/2024
96597	**Mark Brian and Sally Elizabeth Siviour:** 136 St Albans Rd Baldivis WA 6171	200,000	Maramanup	10/2024
157696	**Ausvision Rural Services Pty Ltd:** 2/1050 Hay Street West Perth WA 6005	67,650	Maramanup	06/2029
157699	**Ausvision Rural Services Pty Ltd:** 2/1050 Hay Street West Perth WA 6005	3,350	Maramanup	07/2029
204209	**Everlast International Investment Pty Ltd:** 6 Majestic Close Applecross WA 6153	60,000	Maramanup	04/2030
206554	**Mark Brian and Sally Elizabeth Siviour:** 136 St Albans Rd Baldivis WA 6171	10,000	Stakehill Confined	10/2031
206614	**Ausvision Rural Services Pty Ltd:** 2/1050 Hay Street West Perth WA 6005	56,180	Maramanup	11/2031

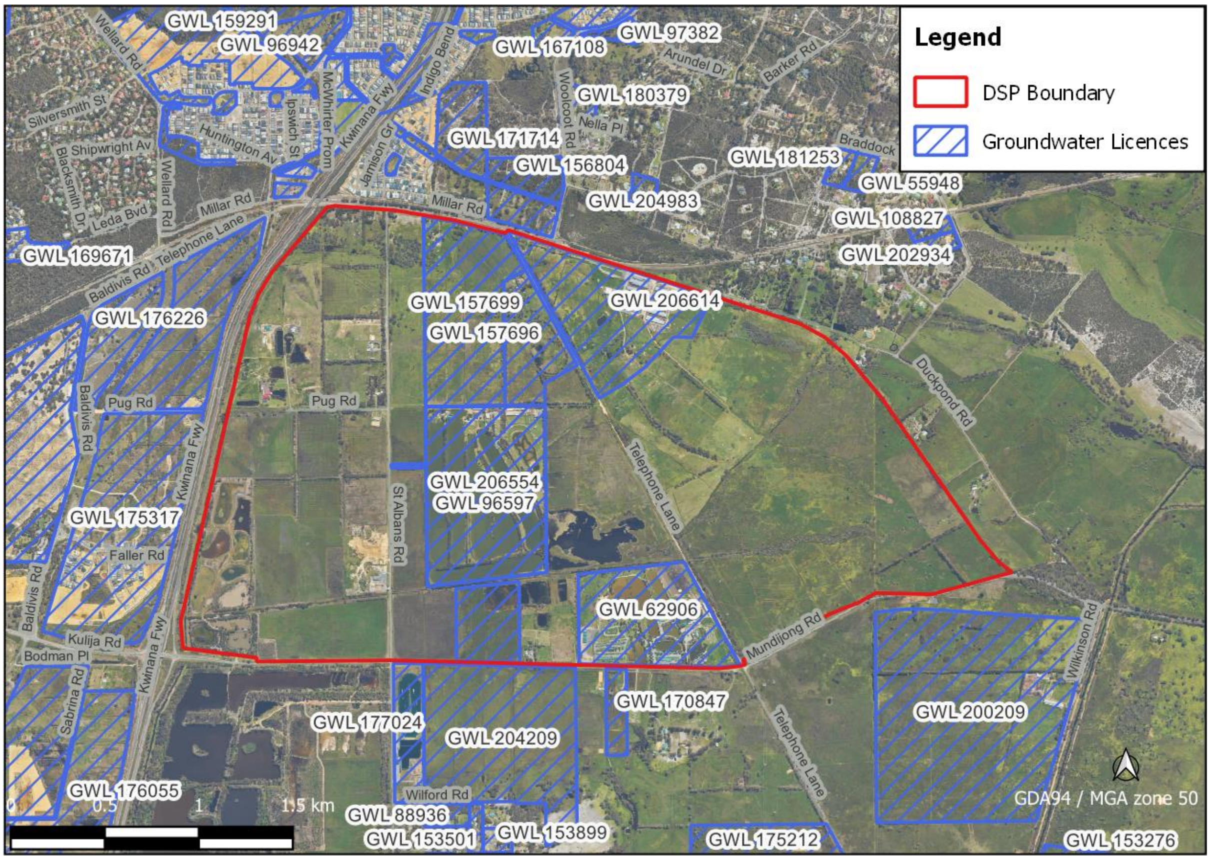


Figure 14: Existing groundwater licences in proximity to the site

4.3. Wastewater servicing

The subject land is located within the Water Corporation licensed area for operating sewerage services. No wastewater planning has currently been undertaken for the DSP area as the area was only recently identified for potential urban development and is still zoned as ‘Rural’.

Within the DSP area, the typical approach to wastewater planning for a sewer catchment will likely be adopted, which utilises reticulated gravity sewer to direct flows to a wastewater pumping station(s) across the DSP. Further investigation will be required as planning progresses to confirm the ultimate outfall for flows generated from the site. It is assumed flows from the site will be discharged to the west and ultimately to the East Rockingham Wastewater Treatment Plant (Cossill and Webley 2022).

5. Water conservation strategies

Water efficiency, reuse and recycling are integral components of total water cycle management (Government of Western Australia 2006). The State Water Plan (Government of Western Australia 2007) is a strategic policy and planning framework to meet the state's water demands to the year 2030. One of the key targets is to reduce scheme water consumption to 40-60 kL per person per year. The Water Corporation's (2011) Water Forever Whatever the Weather has a target of 125 kL per person per year and supersedes the target in the State Water Plan.

To meet this target, several water saving initiatives to reduce potable water use will be investigated and implemented within the development. The development will comply with the following objectives:

- No potable water should be used outside the homes and buildings where alternative water sources are available. Efficient use of scheme water should be achieved.
- Developments should aim to achieve a target of less than 125 kL per person per year.
- Waterwise landscaping techniques should be employed in POS to reduce the irrigation requirement.
- Methods that will be utilised to achieve these criteria include:
  - Water efficient fixtures and fittings to be installed in households
  - Irrigation of POS with groundwater or another alternative water supply such as subsoil drainage harvesting
  - Landscaping design will incorporate waterwise native plants, hydro-zoning and xeriscaping to reduce irrigation demand and turf will be limited to areas of active recreation.

5.1. Household water conservation

The Building Code of Australia sets minimum standards of efficiency for water-using fixtures and fittings in homes. These include:

- All tap fittings, except bath outlets, garden taps and toilets must be a minimum 4-star WELS rated.
- All showerheads must be a minimum of 3-star WELS rated.
- An outdoor private swimming pool or spa associated with a Class 1 building must be supplied with a cover or blanket.
- All internal hot water outlets (such as taps, showers and washing machine water supply fittings) must be connected to a hot water system or a recirculating hot water system with pipes installed and insulated in accordance with AS/NS 3500.
- Lot owners will be encouraged to install grey water systems for the irrigation of individual household landscaping.
- Lot owners will be encouraged to install rainwater tanks. Rainwater tanks can be connected to water using fixtures such as toilets, washing machines and external taps to reduce potable water demand as well as assisting in reducing stormwater run-off.

5.2. Waterwise landscaping

While detailed landscaping plans have not been prepared at this stage of the development, broad landscaping principles will be set to ensure waterwise features will be implemented in future designs. This will include but is not limited to:

- Minimising areas of turf to "kick about" recreation areas and active recreational areas
- Amended soil will be applied in POS areas
- Biofiltration areas will be planted with species selected from Vegetation Guidelines for Stormwater biofilters in the south-west of Western Australia (Monash University 2014)
- Garden beds will be mulched
- Hydrozoning and xeriscaping principles will be implemented where required

- Planting will consist of predominantly endemic native species following consultation with the local government
- Remnant vegetation will be retained as much as possible
- Vegetated swales or living streams will be incorporated where possible as a Water Sensitive Urban Design structure for stormwater conveyance as well as providing ecological linkages
- Efficient use of fertilisers and pesticides.

Water-use efficiency for irrigation of POS will be enhanced through:

- Prioritising irrigation areas
- Best practice turf maintenance
- Optimal irrigation design and management including adjusting irrigation rates in accordance with weather and site-specific requirements.

6. Stormwater management

6.1. Drainage principles and criteria

Integrated urban water management recognises that the urban water cycle should be managed as a single system and water supply, stormwater, wastewater, flooding, water quality and wetlands is interconnected (WAPC 2006). The aim of the stormwater management strategy, as per Water Sensitive Urban Design (WSUD) principles, is to:

- Protect natural systems.
- Integrate stormwater treatment into the landscape to maximise the visual and recreational amenity of the development.
- Protect water quality.
- Maintain peak flows to pre-development rates if discharging off site.
- Add value to the development.

The site will effectively manage stormwater quantity and quality generated from small, minor and major events, incorporating best practice WSUD principles. Table 9 summarises the drainage criteria for several objectives based on Stormwater management manual for Western Australia (DWER 2004-2007) and Decision process for stormwater management in Western Australia (DWER 2017).

Table 9: Stormwater management design criteria

Event	Objective	Criteria
Small (eg. 1 EY)	▪ Manage water quality	▪ Manage – retain and/or detain, and treat (if required) – stormwater run-off from constructed impervious surfaces generated by the first 15 mm of rainfall at-source as much as practical
	▪ Maintain form and hydrology of sensitive receiving environments	▪ Maintain pre-development peak flow rates and total volume runoff from the outlets of the development area for the critical 1 exceedance per year (EY) event
Minor (20% or 10% AEP)	▪ Maintain serviceability of road networks including pedestrian areas, public open space and drainage networks	▪ Provide piped drainage system capacity for the critical 20% AEP event in residential areas and 10% AEP in commercial areas, or maintain appropriate maximum gutter flow widths where overland flow is proposed in place of piped conveyance
Major (1% AEP)	▪ Manage catchment flooding	▪ Maintain the pre-development 1% AEP flood regime by maintaining the floodplain storage volume, flood level and flow rates downstream of the site
	▪ Prevent building and critical infrastructure flooding	▪ Habitable floor levels to be at least 0.3 m above the 1% AEP flood level of the urban drainage system and road reserve
		▪ Habitable floor levels at least 0.5 m above the 1% AEP flood level of the regional flood regime (ie. the flood corridors through the site)

6.2. Stormwater management strategy

6.2.1. Small and minor event drainage

Managing small rainfall events close to the source is particularly important for the management of water quality. Runoff generated from the first 15 mm of rainfall can mobilise substances such as soluble materials, fine dusts and silts, oils, grease and other non-volatile hydrocarbons from constructed impervious surfaces.

Managing this runoff 'at-source' will reduce the transport of pollutants downstream. It will also reduce the volume of stormwater requiring treatment downstream, which reduces the size of the stormwater quality management system required.

Run off generated from rainfall events up to 15 mm will be managed as close to source, and as high in the catchment, as possible with the aim to manage water quality and maintain the form and hydrology of sensitive receiving environments.

6.2.1.1. Lot drainage

It is anticipated that the earthwork strategy for the site may include re-use of some site-won material (ie. excavated clay material) at depth to reduce overall fill importation requirements. This may lead to the creation of some lots with Class S geotechnical classification and others with Class A. It is therefore possible that some lots will have insufficient depth of permeable material to facilitate the use of on-site stormwater disposal structures (ie. soakwells), whilst others will have suitable ground conditions for on-site disposal.

Where conditions allow, lots will be required to contain stormwater on-site via the use of soakwells or other appropriate measures (eg. rain gardens, rainwater tanks plumbed into appliances for water re-use etc). Where conditions do not allow for on-site disposal, lots will need to be provided with stormwater connections into the council-maintained piped drainage system through the road reserves. Lot stormwater connections will also be required for small lots on which soakwells are difficult to accommodate (likely to apply to lots below 300 m^2 in size, with this criterion to be confirmed in future LWMS and UWMP documents).

Where lot connections are provided, sufficient stormwater treatment and detention capacity will need to be provided downstream at end-of-pipe locations within road reserve, POS or the flood detention corridors. The design criteria in this regard will be to retain, treat and infiltrate runoff generated from constructed impervious surfaces during the first 15 mm of rainfall. This will likely be in the form of bioretention basins which are sized to accommodate flows from both the connected lots and the road pavement catchment areas.

The use of direct stormwater connections for lots can sometimes be problematic in terms of balancing stormwater management requirements with POS useability and amenity objectives (ie. requiring larger stormwater treatment basins within POS areas). In this case, where the DSP is required to provide very significant flood detention areas, the overall allocation, design and useability of POS is not likely to be impacted by the use of lot stormwater connections, as there will be ample space available within the flood corridors to accommodate the treatment and detention requirements.

Future LWMS reports will further assess and detail the preferred lot-scale stormwater management approaches specific to each LSP area and the ultimate earthworks and drainage design thereof. The following approaches are recommended for further consideration at LWMS stage:

- Soakwells designed with overflow connections to the road drainage system (eg. grated overflow pits at front of lots, or piped connections from soakwells).
- Mandated rainwater tanks via planning instruments (e.g. Detailed Area Plans) with the approach to be confirmed with the City of Rockingham.

6.2.1.2. Road reserve

Road reserve drainage will primarily comprise pit-and-pipe drainage systems to collect and convey stormwater generated by the road pavement towards treatment areas located in POS or flood corridors. The piped drainage system will be designed to convey the critical duration 20% AEP event whilst maintaining trafficability in vehicle and pedestrian areas.

Road runoff from constructed impervious surfaces of road reserve generated by the first 15 mm of rainfall will be managed (retain and/or detain, and treat if required) within appropriately sized bioretention areas. These bioretention areas may be in the form of roadside or median swales / raingardens, tree pits or swales and basins within either POS areas or flood corridors. Bioretention areas will include littoral planting and amended soils to provide stormwater quality treatment. Plant species to be used within stormwater management areas will be selected from the Vegetation Guidelines for Stormwater Biofilters in the South-west of Western Australia (Monash University 2014) and in liaison with CoR and will be identified within future LWMS and UWMP documents and landscape documentation.

6.2.2. Major drainage system

Stormwater management for the major (ie. up to 1% AEP) rainfall events is typically focused on providing safe conveyance of flows to protect people and property as well as providing adequate flood detention storage so as not to impact flow rates, flow volumes and flood levels downstream of the development.

The DSP area is located within the Water Corporation's Mundijong Drainage District which drains to the Peel-Harvey Estuary. Historically, developments within this catchment contributing flows to the Peel Main Drain have been required to restrict discharge rates to 4.5 litres per second per hectare for the 1% AEP event.

As discussed in the next section, the site is located within a significant floodplain area which has the potential to receive major breakout flows from the Birrega Main Drain (BMD) further upstream (ie. in the event of failure of the existing spoil bank alongside the BMD). The potential 1% AEP flow through the site in a spoil bank failure event has been estimated as 73 m^3/s by the Department of Water and Environmental Regulation, and the resulting volume of floodplain storage within the DSP is 3,380 ML as modelled by Pentium Water (refer Section 6.6).

The DSP will be required to provide the same amount of floodplain storage as occurs under existing conditions. This volume of flood storage is far greater than that which would be required for a typical site that only needs to meet the typical Peel Main Drain discharge criterion described above, thus rendering that criterion irrelevant for this DSP area. In other words, the DSP layout (or more specifically, the amount and design of flood storage areas within the DSP) is strongly dictated by the response to regional flooding rather than local stormwater management considerations.

Emergency access for flood events needs to be considered and demonstrated in the designs presented in future LWMS reports. It is anticipated that Mundijong Road will be upgraded to facilitate future traffic volumes and these upgrades will also provide the road with flood immunity (whereas it is currently expected to experience submergence along a section of the road in a 1% AEP event). Mundijong Road will serve as the main vehicle access route to the DSP area, and once it has been upgraded, will provide flood emergency access given internal roads within the DSP (including road connections over the flood corridors) are proposed to be constructed above the 1% AEP flood level).

6.3. Stormwater management concept design

A conceptual stormwater management plan is provided in Figure 15, which illustrates the general arrangement of stormwater conveyance, treatment, and detention within the DSP. The concept plan is based on the preliminary earthworks concept for the DSP area, which was developed by the project engineers Cossil & Webley to provide an understanding of likely design levels and grading across the developed DSP area. The earthworks concept is provided in Appendix G.

The earthworks design, finished levels, and stormwater catchments are all subject to refinement through subsequent LSP and subdivision stages of development. However, this will not impact the approach to stormwater treatment and detention within the DSP. As discussed in Section 6.6.4, the DSP layout provides substantially more space than is required to manage the site's stormwater requirements, due to the need to accommodate massive flood detention volumes associated with a potential BMD spoil bank failure scenario. Therefore, any potential future changes to the earthworks strategy and stormwater catchments will not present any challenges given the proximity of all areas within the DSP to one of the large flood corridors which provide space to implement stormwater management requirements.

The general approach to stormwater management, as illustrated below in Figure 15, is as follows:

- Small rainfall event (ie. first 15 mm) runoff from road reserves plus any lots with stormwater connections to be treated and infiltrated as close-to-source as possible, within the road reserve, POS or flood corridor.
- Larger rainfall events to overflow (via vegetated overland flow paths wherever possible) or be piped to downstream detention areas within flood corridors.
- Peak 1% AEP discharge from the site to be controlled via hydraulic controls (ie. culverts) located within the flood corridors, to match existing conditions storage volume, peak discharge rate and hydrograph shape as discussed in Section 6.6.3.
- It should be noted that the stormwater management concept plan provided in Figure 15 focuses on general flow directions and treatment locations of locally generated stormwater only. It does not depict the flood mitigation design (ie. bunds and culverts to provide detention of major events) as these are presented in Figure 20 (Section 6.6).
- It should also be noted that the proposed bioretention basin locations are indicative only at this stage and the final locations will be subject to more detailed analysis (at LSP stage) of earthworks catchments and proposed landscaping and uses for POS areas (ie. some POS areas may be kept entirely free of stormwater drainage infrastructure given there is opportunity to locate it within the flood corridor).

The conceptual stormwater management approach and requirements to be considered and demonstrated in future LWMS reports are further summarised in Table 10 and illustrated in Figures 15-17.

Table 10: Summary of stormwater management requirements

Aspect	Objective	Conceptual design and LWMS considerations
Earthworks / fill strategy and groundwater control*	▪ Site earthworks to achieve freeboard to flood levels and groundwater separation	▪ Cut-to fill earthworks (ie. re-use of site-won material) where possible and fill importation to provide lots with 0.5m separation to design flood levels through corridors ▪ Subsoil drainage system to provide a controlled groundwater level* ▪ Earthworks and fill strategy to consider intended lot geotechnical classification and lot-scale stormwater management approach
Lot-scale drainage	▪ Retain stormwater on-lot where ground conditions allow ▪ Manage lot runoff in downstream drainage areas where on-lot infiltration is not possible	▪ Use of soakwells to contain stormwater on lots where lot geotechnical conditions allow ▪ Where the design post-compaction permeability or separation to clay / groundwater is lower, stormwater overflow or connection to road drainage system to be used ▪ Preferred stormwater connection from lots to be confirmed in consultation with City of Rockingham
Road reserve / estate-scale drainage	▪ Manage road runoff (and lot runoff where relevant) as close to source as practical. ▪ Treat first 15 mm of runoff from constructed impervious surfaces. ▪ Maintain trafficability of road networks and pedestrian areas	▪ At-source treatment approaches (eg. road reserve-scale systems such as tree pits and rain gardens) to be considered where feasible ▪ Overland flow to / through vegetated areas to be encouraged (ie. where possible via flush kerbing or kerb openings etc) ▪ Piped drainage where required to maintain road trafficability in the 20% AEP event. ▪ End-of-pipe treatment areas / basins where required to capture and treat the first 15 mm of runoff from constructed impervious surfaces
Major event / flood management	▪ Peak 1% AEP event discharge from DSP to be controlled in-line with existing conditions	▪ Hydraulic structures (bunds and culverts) within the flood corridors to provide the same total flood storage volume and discharge characteristics as modelled for the existing (spoil bank fail) conditions. ▪ Further modelling and design at LWMS stage to demonstrate flood management criteria are met.

* Note; groundwater management is covered in greater detail in Section 7 of this DWMS.

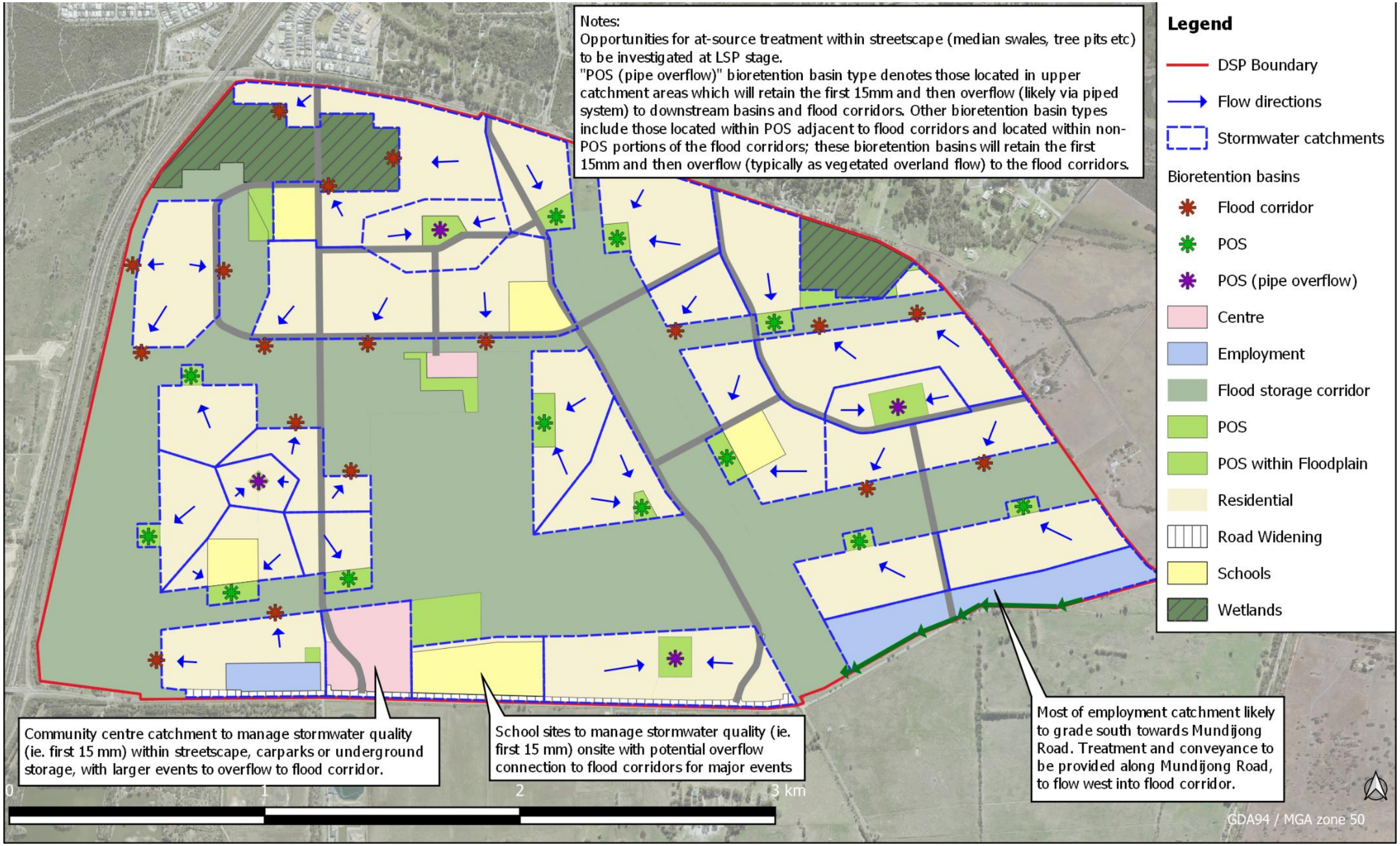


Figure 15: Stormwater management concept plan

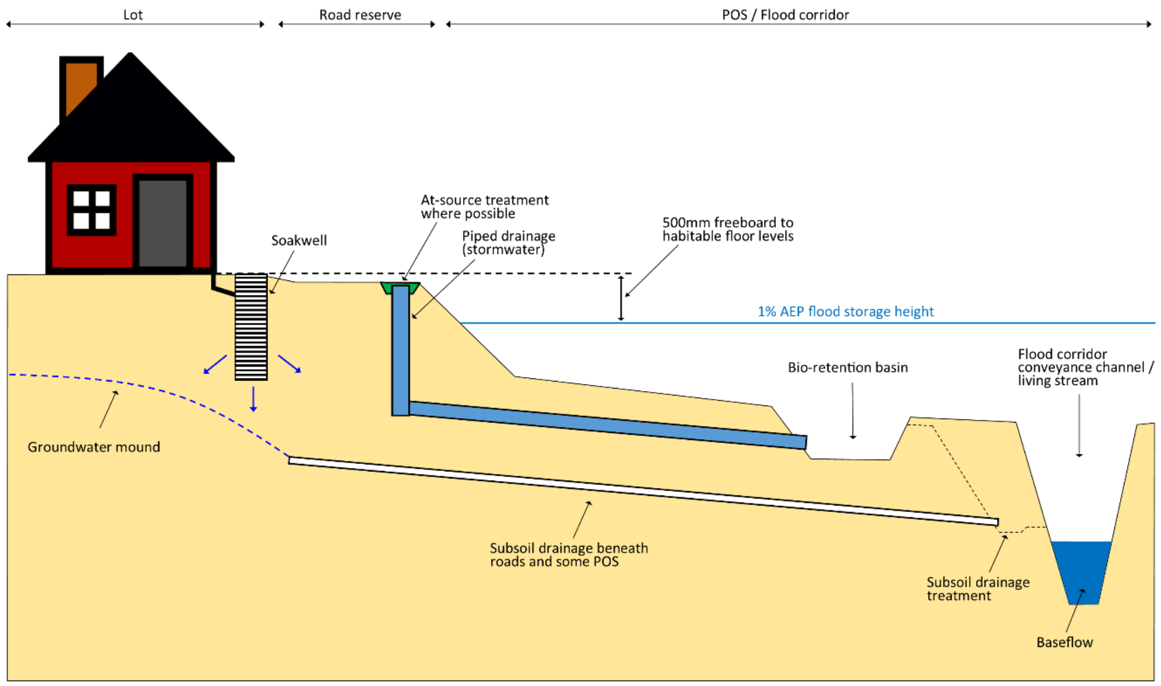


Figure 16: Stormwater management concept for sandy / Class A lots

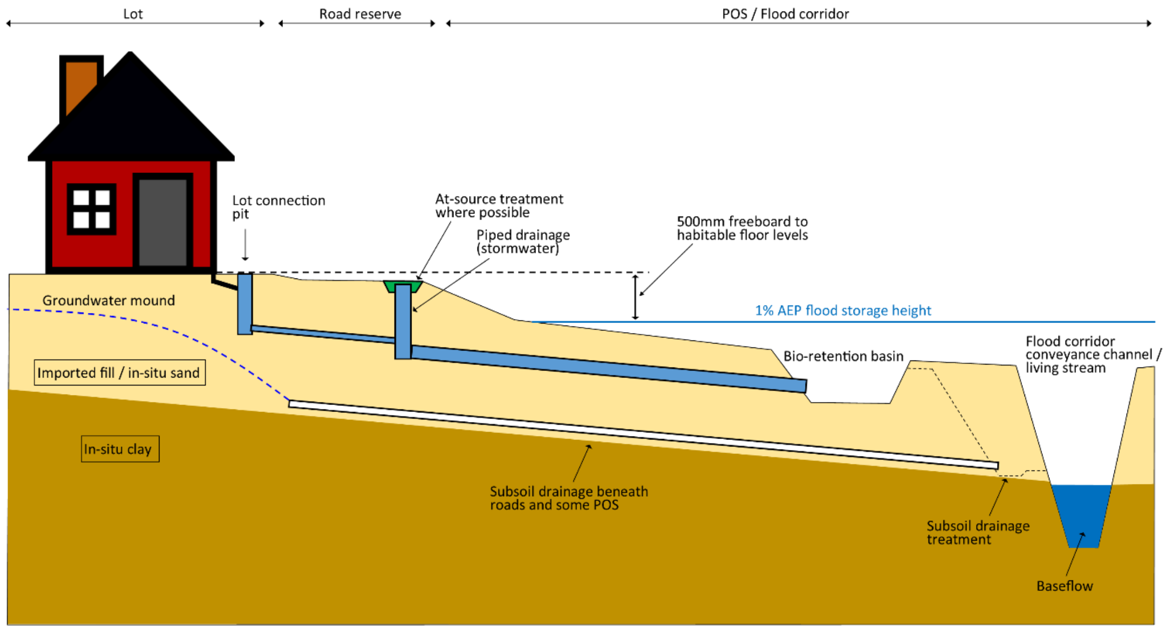


Figure 17: Stormwater management concept for clayey / Class S lots

6.4. Vegetation

Vegetation will be included in all suitable stormwater management areas to help prevent erosion, maintain soil infiltration, restrict water flows and remove particulate and soluble pollutants, particularly nitrogen. The plants will mainly be associated with bio-retention areas and will be appropriately selected based on their intended function, using native vegetation as much as possible. The plant species to be used within stormwater management areas will be identified within future UWMPs.

6.5. Non-structural controls

Non-structural controls will be used to provide additional stormwater quality management and will include establishing operation and maintenance activities and controlling land use and management. The following non-structural controls will be implemented (via management plans to be prepared as part of subsequent approval stages) to improve stormwater quality and reduce contamination.

6.5.1. Nutrient control and landscaping

Design guidelines and a landscaping policy will be implemented to control POS landscaping designs and practices. It is expected that these measures will provide improvement of stormwater quality through ensuring:

- Appropriate native plant species are continually used
- Bioretention areas to contain an amended soil with a minimum PRI of 10
- POS and bioretention areas to be maintained
- Recommended fertiliser, pesticide and irrigation regimes are followed.

6.5.2. Waste and construction management

Waste management plans will include provisions for stormwater protection through:

- “At source” management of litter, sediment and organic material such as regular street sweeping
- Prompt removal of litter when discovered
- Discouraging waste dumping in drains and drainage swale through restricted access (i.e. bollards around POS) and signage
- Providing sufficient public facilities for rubbish disposal

All development construction projects, including road and infrastructure construction, will be subject to sediment and erosion control measures.

6.6. Flood management

As discussed in Section 3.13.2, major flooding associated with the regional catchment is a key consideration for development of the site. Regional flood modelling undertaken by DWER (2015 and 2021a) has identified the potential for major breakout flows from the Birrega Main Drain (BMD) located to the east of the site, due to failure of the associated spoil bank. The flood management considerations and design responses for the site are driven primarily by this regional flood regime and the base-case assumption that has been adopted by DWER regarding the failure of the BMD spoil bank. The following sections summarise the flood modelling that has been undertaken to inform the DSP, which is provided in detail in Appendix H (flood modelling report).

6.6.1. Modelling approach

The modelling undertaken to inform this LSP has taken key input parameters (ie. inflows to the site) directly from the DWER (2021a) modelling outcomes, given the extensive nature of the DWER study which included detailed assessment of the flood management requirements and land capability relating to the DSP area. The modelling herein does not seek to test or validate the DWER modelling, but rather to test and refine various DSP layout and flood mitigation concepts to ensure that the DSP is consistent with the assumptions and requirements of the extensive DWER investigations to support the PIA outcomes.

The DWER (2021a) modelling estimated a peak discharge from the BMD into the DSP area of 73 m^3/s based on the “median” result from several spoil bank failure scenarios (locations and extents of spoil bank failure). DWER (2021a) also notes that whilst several scenarios were tested, exhaustive testing of possible spoil bank failure scenarios and combinations thereof (ie. a probabilistic analysis of potential spoil bank breakout flow rates) was not undertaken due to the impracticality of doing so. Therefore, there remains some uncertainty regarding the exact likelihood and nature of spoil bank failure and associated flow volumes and rates into the DSP area. However, the following is noted with respect to this uncertainty:

- The floodplain storage volume within the DSP area is relatively insensitive to the magnitude of breakout flow, due to the controlling influence of the topographic surface and existing structures / roads.
- Therefore, a large increase in the volume and rate of BMD breakout flow into the site would not result in a proportional increase in floodplain storage volume, ie. floodplain storage volume would increase only slightly whilst peak discharge through / from the site would increase significantly
- The implication of this is that the adopted design criteria (to replicate the existing conditions floodplain volume) and design response (ie. the DSP layout and flood storage area design) are likewise not particularly sensitive to the design breakout flow from the BMD.
- The main implications of a potentially larger peak discharge from the BMD into the site is the safe conveyance of that flow and the separation from flood levels to house pads and critical infrastructure levels. These factors have been tested though the hydraulic modelling (refer to the flood modelling report provided as Appendix H) which demonstrates that the typical 0.5 m freeboard requirement for major floodplain areas is adequate to cater for this uncertainty.
- The other consideration in terms of discharges from the BMD in a spoil bank failure scenario is the potential for a sudden / instantaneous failure of a section of spoil bank and the associated high flow rates and velocities that could occur immediately downstream of the failure location. However, this risk factor is not considered relevant to the DSP area given it is located approximately 1 km downstream of the BMD spoil bank.

Pentium have undertaken detailed hydraulic modelling of the DSP area for both existing conditions and post-development conditions. The modelling adopted the DWER-modelled BMD spoil bank failure breakout flow hydrograph as the upstream boundary condition (i.e. specified inflow). Whilst the DWER (2021) modelling has already defined existing conditions flooding over the DSP area, Pentium have also undertaken existing conditions modelling (i.e. replicating the work of DWER in a sense) to provide a basis for direct comparison for the Pentium post-development simulations (i.e. to allow like-to-like comparisons of extracted model results).

6.6.2. Model setup

A combined 1D-2D hydraulic model was developed in XP-SWMM. The entire subject site as well as some of the upstream and downstream floodplain areas were modelled in 2D using a highly detailed Digital Terrain Model (DTM), whilst the 1D component of the model was used to simulate flow through culverts. As previously discussed, the model adopts as its upstream boundary condition the DWER modelled breakout flow from BMD in a 1% AEP spoil bank failure event (the median spoil bank failure scenario as adopted by DWER for their base-case). Similarly, the DWER modelled inflow to the site via Peel Main Drain is used as a boundary condition. Locally generated rainfall runoff is simulated via rain-on-grid, using the same 18-hour (temporal pattern no. 1) design storm as adopted by DWER for their base case. A flood modelling report is provided as Appendix H which provides full details of the modelling methodology.

The existing conditions model was used to simulate flow through the site and the subsequent water depths / levels, storage volumes and discharge hydrograph from the site as well as further downstream. These outputs were then used to test various post-development layouts for the purpose of:

- Confirming the spatial requirements of flood corridors to maintain the existing conditions flood storage volume
- Undertake concept level design for the flood corridors, including the design of hydraulic controls (ie. bunds and culverts) to control flow and water depths through the site
- Check that the flood mitigation design effectively maintains the existing conditions site discharge characteristics (ie. peak flow rates, discharge volume, timing of discharge) as well as up- and down-stream flood levels.

The post-development model was set up the same as the existing conditions model (ie. a 1D-2D XPSWMM model) with the exception that a portion of the model domain south of Mundijong Road was omitted from the post-development model in order to speed up run times which made testing multiple design scenarios more practical. The omitted part of the catchment contributes only minor flows to the subject area and these flows were included in the post-development as boundary conditions; thus negating any potential impact from the model domain modification. The other changes in the post-development model included land use definitions (ie. roughness and infiltration loss parameters) to reflect the post-development land uses, and the DTM which was developed as follows:

- Create a DTM from the concept earthworks design
- Overlay the earthworks DTM on the existing conditions DTM to create a merged DTM which represents the post-development design levels throughout the DSP area and existing ground levels elsewhere
- Minor manual modifications to the DTM to rectify minor inconsistencies in the earthworks concept (i.e. where flood corridor batters don't align properly with the DSP layout)
- Manual modification to the DTM to remove the concept earthworks over the Golden Ponds site, as this is assumed for the purpose of the flood modelling to remain in its current state and provide no flood storage.
- Manual modification to the DTM to raise the level of POS located within flood corridors by approximately 0.5m to account for the reduced storage that may occur over these areas should they be raised to accommodate subsoil drainage etc.

The post-development model was then used to design and refine the flood corridor (and therefore DSP) layout. This was an iterative process in consultation with the project planners and engineers, based primarily on the following guiding principles:

- Provide a total flood corridor area equating to approximately 45% of the DSP area, in line with the recommendations of DWER (2021b).
- Align flood corridors to be sympathetic to the existing conditions major flow paths and storage areas.
- Attempt to distribute the flood corridor area equitably across landholdings so that the development potential of any given landowner is not disproportionately impacted.
- Provide a "low-flow" channel through the flood corridors nominally 0.9 metres in depth which is intended to provide conveyance for baseflow / subsoil drainage (ie. to assist in providing a controlled groundwater level for the development) and to facilitate a small amount of groundwater separation to the design ground level through the general flood corridor area (ie. to avoid the creation of large groundwater inundated / unusable areas).
- Flood corridors are assumed to be uniformly graded longitudinally at minimum 1:1500 (steeper in some areas) for the purpose of the conceptual earthworks and flood corridor design. The design levels and grading through the corridors will be refined at subsequent planning and design stages and may include maintaining portions of the corridors at existing ground levels where appropriate (ie. for groundwater clearance) and efficient (ie. from a storage volume perspective).
- Maximum 1% AEP flood depths outside of the "low-flow" channels is up to 1.5m (typically 1.0 to 1.4 m). Note; maximum depths in the "low-flow" channels is greater, up to >2m, which is discussed further in the next section.

6.6.3. Modelling results and flood mitigation design

6.6.3.1. Existing conditions model

The existing conditions modelling produced very similar results to the DWER (2021) existing conditions modelling, which is to be expected given the modelling adopted inflow boundary conditions from the DWER model. The DWER modelled 1% AEP spoil bank failure event storage volume was 3,408 ML for the area described by DWER as "Cells 2 to 7" which roughly corresponds to the DSP area (plus a small additional area between the DSP boundary and Duckpond Road). By comparison, the Pentium modelled storage volume for the DSP area was 3,380 ML. Figure 18 illustrates the areas that were used in the floodplain volume calculation by DWER and Pentium, respectively.

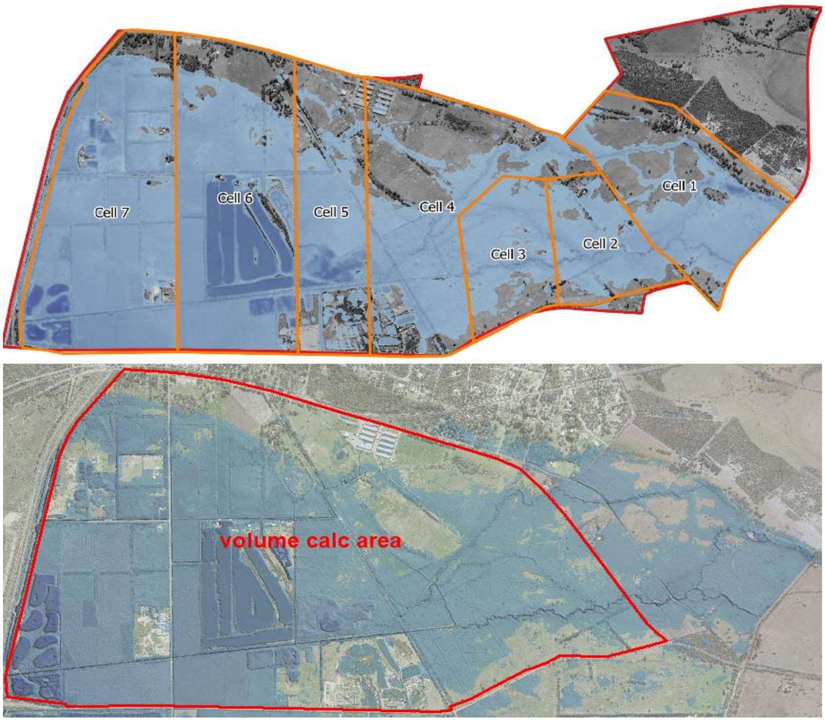
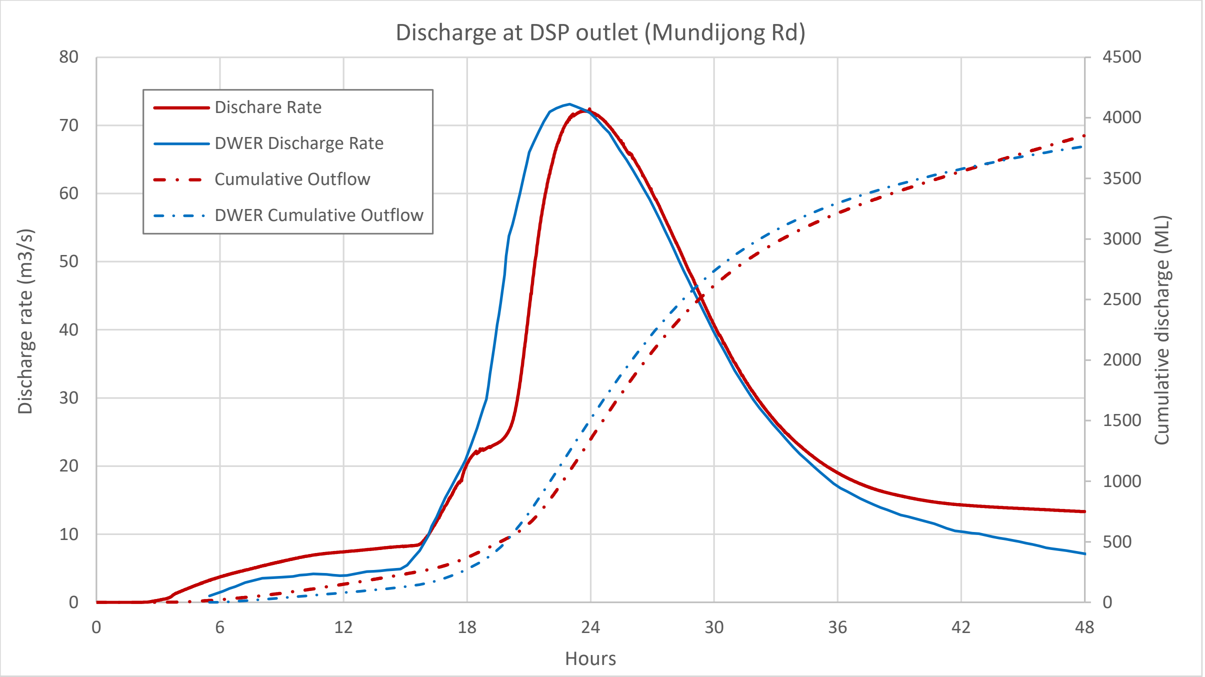


Figure 18: Flood plain volume calculation areas (DWER at top, Pentium at bottom)

Similarly, the modelled flow rate and volume for discharge from the site was very similar between the DWER and Pentium models. These are provided below in Graph 2 (it should be noted that the DWER discharge hydrograph shown below was produced via digitisation of graphical outputs in the DWER report rather than from the raw data but is expected to be accurate within approximately 1 or 2 %). The modelled peak discharge from the site at Mundijong Road (combined flow through the Peel Main Drain and over Mundijong Road) by DWER and Pentium was 73.3 m^3/s and 72.4 m^3/s, respectively. The cumulative discharge volume at Mundijong Road (arbitrarily measured at 48 hours from commencement of the simulation) from DWER and Pentium was 3,765 ML and 3,849 ML, respectively. It is noted that the shape of the combined discharge hydrograph (Peel Main Drain and flow over Mundijong Road combined) differs slightly between the DWER and Pentium models; this is expected to be due to the way in which the Peel Main Drain was simulated between the two models. It is understood that the DWER model did not explicitly include the existing Peel Main Drain culverts at Mundijong Road (instead creating an open section of equivalent width in the Mundijong Road embankment) whereas the Pentium model did.



Graph 2: Existing conditions discharge from site at Mundijong Road

Figure 19 below provides the Pentium modelled 1% AEP flood extent, depth, and levels for the existing conditions spoil bank failure scenario.

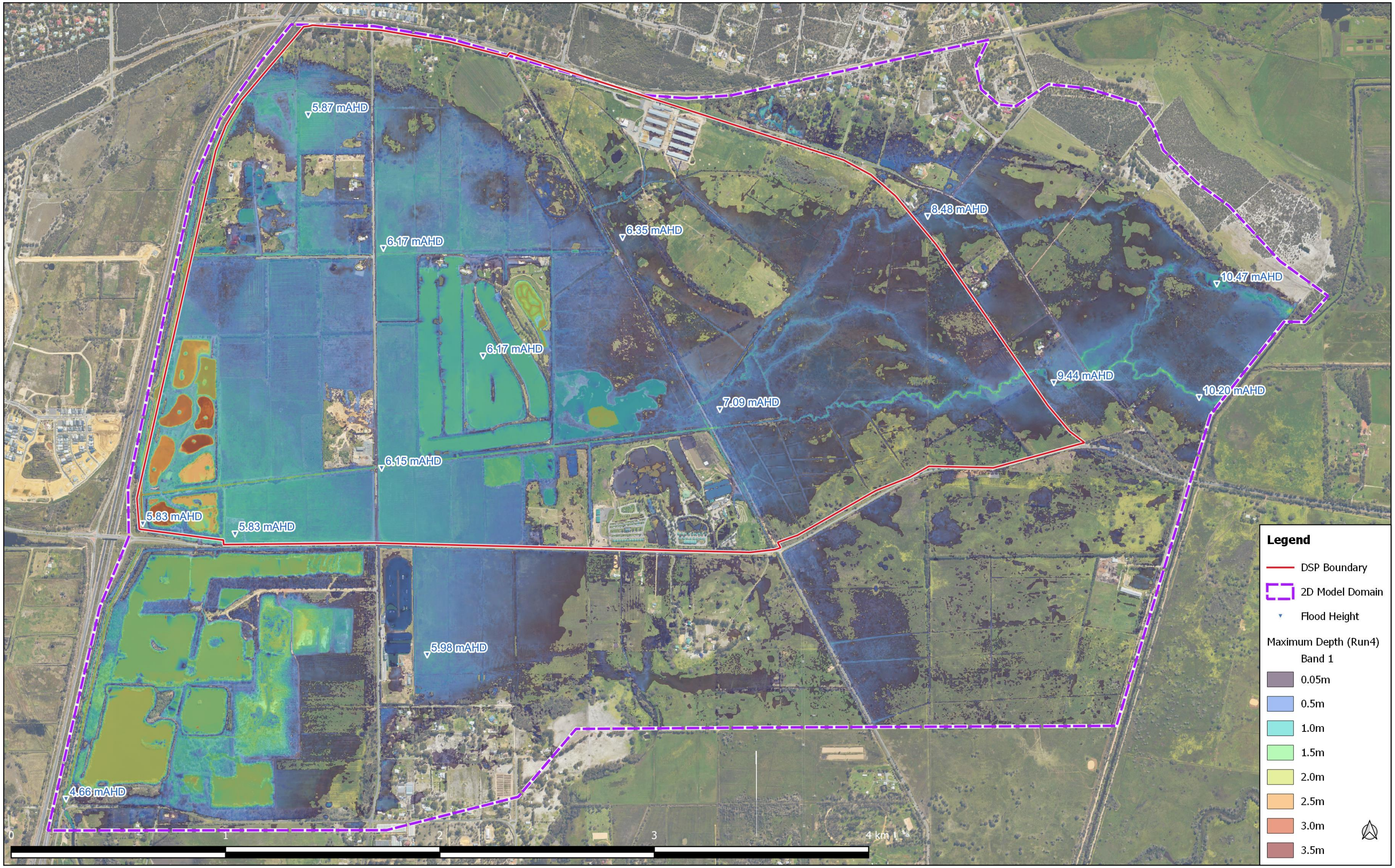


Figure 19: Existing conditions 1% AEP (spoil bank failure scenario) flood map

6.6.3.2. Post-development model

The post-development model was used to assess and refine and the DSP and flood corridor layout and preliminary design of the flood mitigation infrastructure (hydraulic controls) until a satisfactory design was achieved, based on the following key parameters:

- Total storage volume within the flood corridors
- Peak discharge rate and cumulative discharge volume at Mundijong Road
- Peak discharge rate and cumulative discharge volume at the downstream model boundary
- Maximum water depths within the flood corridors consistent with those described in Section 6.6.2

One of the key findings of the flood modelling was the sensitivity of the site discharge hydrograph shape to the type of hydraulic controls used throughout the site, and subsequently, the sensitivity of peak flow rate at the downstream model boundary to the site discharge hydrograph shape. Essentially, it was found that simply matching the overall flood storage volume and peak discharge rate at Mundijong Road did not adequately maintain flow conditions further downstream from the site.

It was found that if the shape of the discharge hydrograph was broader (ie. a larger volume of discharge over a given time period) then this had the effect of causing higher flow rates in downstream parts of the floodplain. It was determined that hydraulic controls which are designed to replicate the existing floodplain dynamics involving trapped storage behind long road embankments (and subsequent slow release of water) are necessary to maintain the site discharge hydrograph shape and downstream floodplain dynamics.

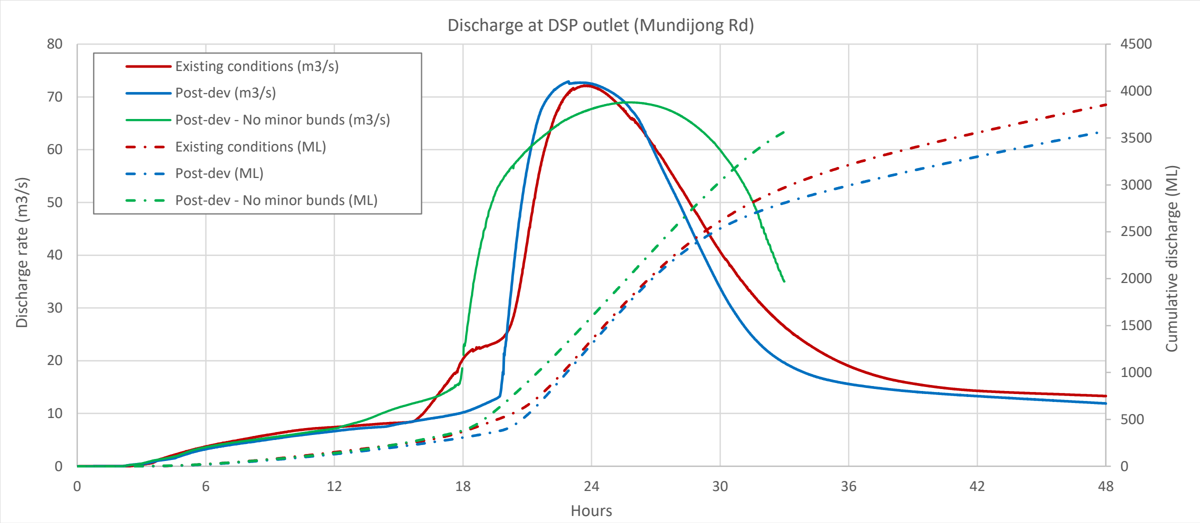
To this end, the flood corridor and flood mitigation design has incorporated the following major features:

- Road crossings comprising embankments raised above the 1% AEP TWL and with very large culverts designed to convey the full 1% AEP flow rate with no flow over the road (to maintain emergency access during flood events).
- Minor bunds comprising embankments across the entire flood corridor but with a crest height below the 1% AEP TWL such that the peak flood flow can overtop the bund but then a large volume of water is held behind the bund. Water temporarily stored behind these bunds is slowly released via a much smaller culvert than what is required to convey the peak flow, ie. these minor bunds replicate the influence that existing topographic features (ie. roads) have on the floodplain dynamics.
- Bund along Peel Main Drain to facilitate the proposed flood storage height in the western portion of the DSP, which is approximately 0.4m higher than under existing conditions, whilst preventing impacts to flood levels outside of the DSP area.
- Figure 20 below illustrates the locations and details of these hydraulic controls within the flood corridors as was modelled. This provides the concept flood mitigation design which demonstrates how flow through the proposed DSP can be managed to achieve the storage volume and discharge criteria.

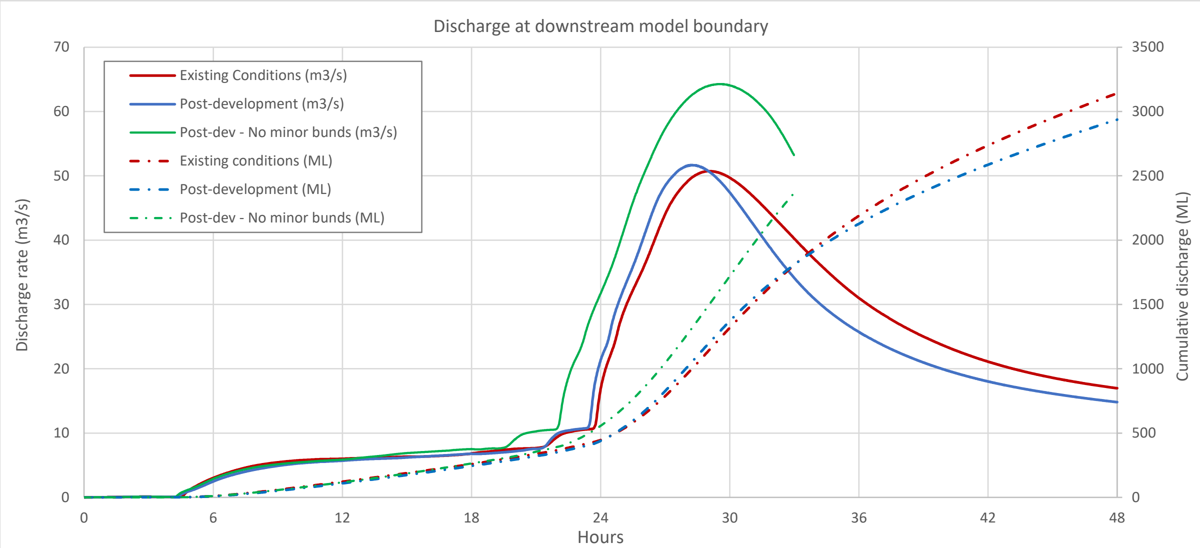
With the conceptual design hydraulic controls illustrated in Figure 20 the post-development flow regime through the site and discharge hydrograph at the downstream boundary of the DSP area are consistent with the existing conditions. This is demonstrated below in Graphs 3 and 4 which show the existing conditions versus post-development discharge hydrograph at both the DSP boundary (Mundijong Road) as well as further downstream near the model boundary (at Bertenshaw Road). It shows that, at both locations, both the peak discharge rate and hydrograph shape are very similar between existing and post-development conditions.

This is contrasted with the "Post-development - No minor bunds" scenario shown on the same graphs, which refers to a scenario in which the hydraulic controls were designed to meet both the storage volume and peak discharge rate criteria, but with no regard to the shape of the discharge hydrograph. In this scenario (without the proposed minor / overtopping bunds), the shape of the discharge hydrograph at Mundijong Road broadens significantly which has a significant adverse impact on the downstream discharge rate. This demonstrates the benefit of the proposed minor bunds in the concept design.

Figure 21 further below provides the 1% AEP post-development flood map.



Graph 3: Modelled discharge at DSP boundary (Mundijong Road)



Graph 4: Modelled discharge downstream of site

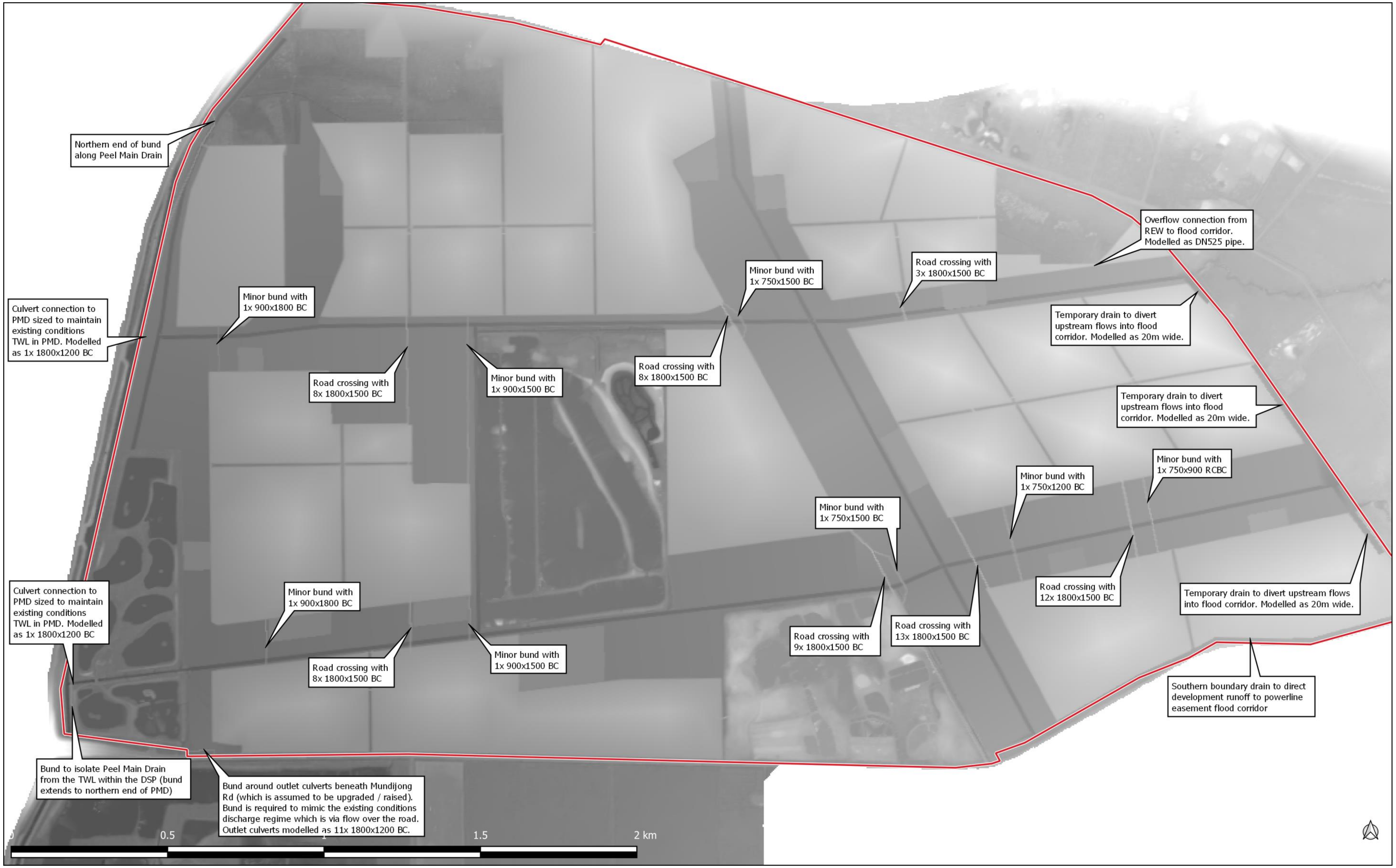


Figure 20: Concept design for flood corridor hydraulic controls

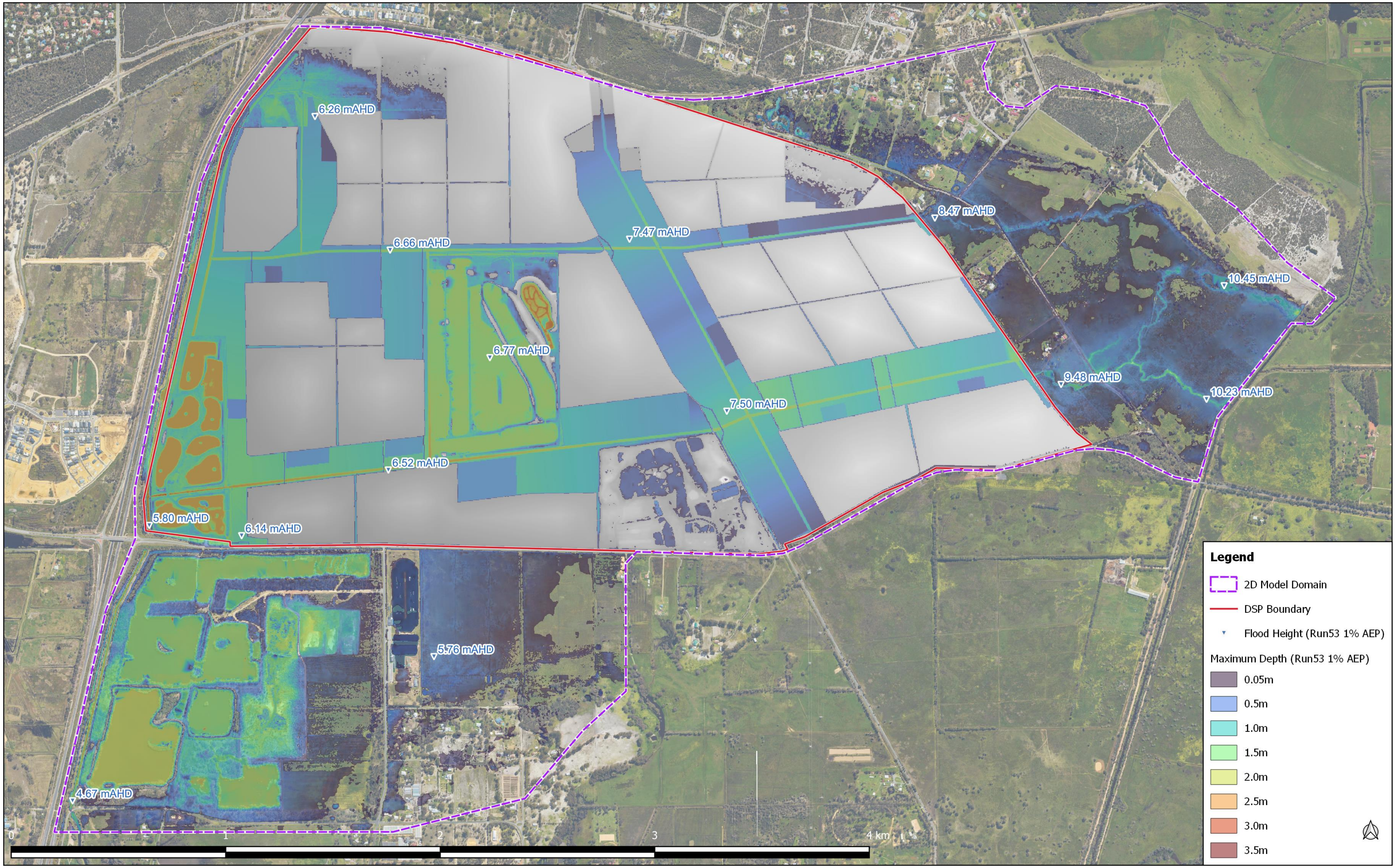


Figure 21: Post-development 1% AEP (spoil bank failure scenario) flood map

6.6.3.3. Key model results

Figures 19 and 21 above show that the existing and developed conditions modelled flood levels are consistent outside of the DSP area. Table 11 summarises some of the other key model outputs used to confirm that the conceptual flood mitigation design effectively controls the movement and discharge of floodwater through the site to prevent impacts to upstream and downstream properties.

Table 11: Modelled storage volumes and discharge rates

AEP	Scenario	DSP Storage	Discharge from DSP	Discharge at model boundary
1% AEP (spoil bank fail)	Existing	3.38 GL	72.4 m^3/s	50.7 m^3/s
	Developed	3.35 GL	72.9 m^3/s	51.7 m^3/s
5% AEP (spoil bank fail)	Existing	1.90 GL	10.9 m^3/s	6.9 m^3/s
	Developed	1.83 GL	8.9 m^3/s	6.3 m^3/s
5% AEP (spoil bank intact)	Existing	0.63 GL	7.3 m^3/s	6.4 m^3/s
	Developed	0.68 GL	6.5 m^3/s	6.1 m^3/s
20% AEP (spoil bank intact)	Existing	0.42 GL	5.7 m^3/s	5.2 m^3/s
	Developed	0.46 GL	5.2 m^3/s	4.9 m^3/s

A detailed flood modelling report is provided as Appendix H which provides further detail on the modelling approach and methodology as well as additional model outputs, including:

- Further discussion on the purpose and function of proposed hydraulic controls (minor and major bunds, Peel Main Drain bund, Mundijong Rd outlet etc)
- Large format flood maps for the AEP events listed in Table 11
- Further discussion on modelled inundation depths, velocities and hazard assessment
- Sensitivity analysis and assessment of model / design robustness

6.6.4. Staged implementation of flood storage

A key principle of the flood management strategy is the provision of an equivalent volume of flood detention storage compared to existing conditions. As the site is developed and raised (with imported fill) to provide freeboard from the urban landscape to the 1% AEP flood levels, the natural storage volume provided by the floodplain in its current state will decrease. To offset this loss of floodplain area and volume, the post-development flood mitigation design will incorporate structures (ie. bunds and culverts) to increase the depth of flood storage within designated flood corridors, thus maintaining the overall storage volume.

The overall DSP layout and engineering concept have been designed to maintain the existing conditions flood storage volumes, and this has been confirmed through the hydraulic modelling (Appendix H). However, as the site will be developed by multiple landholders over a period of at least several years, the implementation of the flood mitigation design (ie. earth working of flood corridors to their design levels, construction of bunds and culverts etc), will not be delivered in its entirety by a single proponent.

Therefore, it will be necessary for the progressive and cumulative impacts of development of the site to be assessed and mitigated through appropriate flood management infrastructure (ie. including temporary structures where required). This will need to be determined as development progresses, to respond to the spatial and temporal implementation of development.

Whilst it is not possible to provide a meaningful development schedule (in terms of the spatial staging of works) at this step in the planning process, a broad assessment of the anticipated staging of development and flood mitigation works has been undertaken. The purpose of this is to illustrate the type of temporary flood mitigation measures that may be required during the course of development of the DSP area, focusing on the first two indicative LSP stage areas. The staging concept (based only on current expectations and subject to change) is shown in Figure 22.

Further below are listed the key considerations to be addressed at later stages of planning and development in relation to interim or temporary drainage requirements. These aim to provide a framework (ie. guiding design objectives and criteria) to inform future assessment and design of temporary flood mitigation infrastructure, which will need to be presented in future LSP and LWMS documents.

Under the staging concept shown in Figure 22, the first area to be developed would be the south-west corner of the DSP, with development then progressing through the central and eastern portions of the site (ie. from downstream to upstream), with the north-west corner of the DSP expected to be developed later. High-level considerations for the indicative LSP stages are as follows.

LSP1 – South-west

- The timing of construction of the proposed bund along Peel Main Drain to facilitate increased flood storage height in this area:
  - Subject to modelling, the bund may not be immediately required if sufficient flood storage exists across the balance of the DSP, in which case development of the first LSP (or first stages thereof) may be able to proceed in advance of the bund construction.
  - When it becomes necessary to construct the Peel Main Drain bund to facilitate the overall flood storage volume, it will be necessary to assess the increased flood heights / risk to other landholdings, particularly those in third-party ownership and containing dwellings (ie. those in the north-west corner of the DSP) and establish temporary protection measures / bunds as required.
- The timing of upgrade works to Mundijong Road:
  - As part of upgrade works to Mundijong Road, the ultimate flood outlet from the site will need to be designed and constructed which is anticipated (based on the concept design herein) to involve a large bank of culverts through the raised Mundijong Road embankment. This is consistent with the spoil bank-failure flood regime under existing conditions, whereby the majority of the floodwater flows over Mundijong Road.
  - Prior to upgrading of Mundijong Road, the flood storage design for the site will likely be constrained by maintaining the existing conditions flood height so as not to increase flows over Mundijong Road; the assessment and design of temporary flood storage areas will need to take this into consideration.
  - Following upgrade works to Mundijong Road including the anticipated lifting of the road to give it flood immunity, the increased flood storage level that is ultimately proposed for the DSP (facilitated by the proposed bund along Peel Main Drain) will be able to be implemented.
- Earthworking and construction of major structures (bunds / culverts) within the flood corridors may not initially be required given relatively minor impact of the development footprint on overall floodplain storage volume; to be confirmed through modelling which should identify when the extent of development causes a significant change in floodplain behaviour thus requiring construction of flood corridor features. It is noted that DWER (2021b) refers to 0.03 m being the acceptable tolerance for external flood level increases on the Peel Main Drain floodplain (0.01 m where the impact is to existing homes and structures). It is suggested that this be used as the threshold for acceptable interim impact in the absence of other criteria agreed in consultation with DWER (to be confirmed in future LWMS documents).
- Obstruction to natural flow paths caused by the development footprint has potential to redistribute flows and affect adjacent landholdings; modelling required to confirm 1% AEP (spoil bank failure) flow paths and depths and design temporary bunding or diversion drains where required.

LSP2 – Central

- Removal of floodplain storage due to filling of the development footprint is likely to reach critical point (where impact to flood storage volumes / heights become unacceptable) in this stage if it didn't already during the first stage. Therefore, earthworking of flood corridors (within the developed portions of the site) and construction of hydraulic controls (bunds / culverts) is likely to be required.

- As for the first stage LSP, the proposed increased flood storage height adjacent to Peel Mian Drain (facilitated to the proposed bund along the Peel Main Drain) has the potential to impact landholdings and dwellings within the north-western portion of the DSP area. Temporary bunding may be required to isolate those properties from increased flood storage heights within the constructed flood corridors.
- Obstruction of natural flow paths at the upstream development boundary to be considered and temporary bunding and diversion structures to be used where required to control flows and protect adjacent landholdings that are not under the same ownership (refer to acceptable flood level increase criteria described further above).

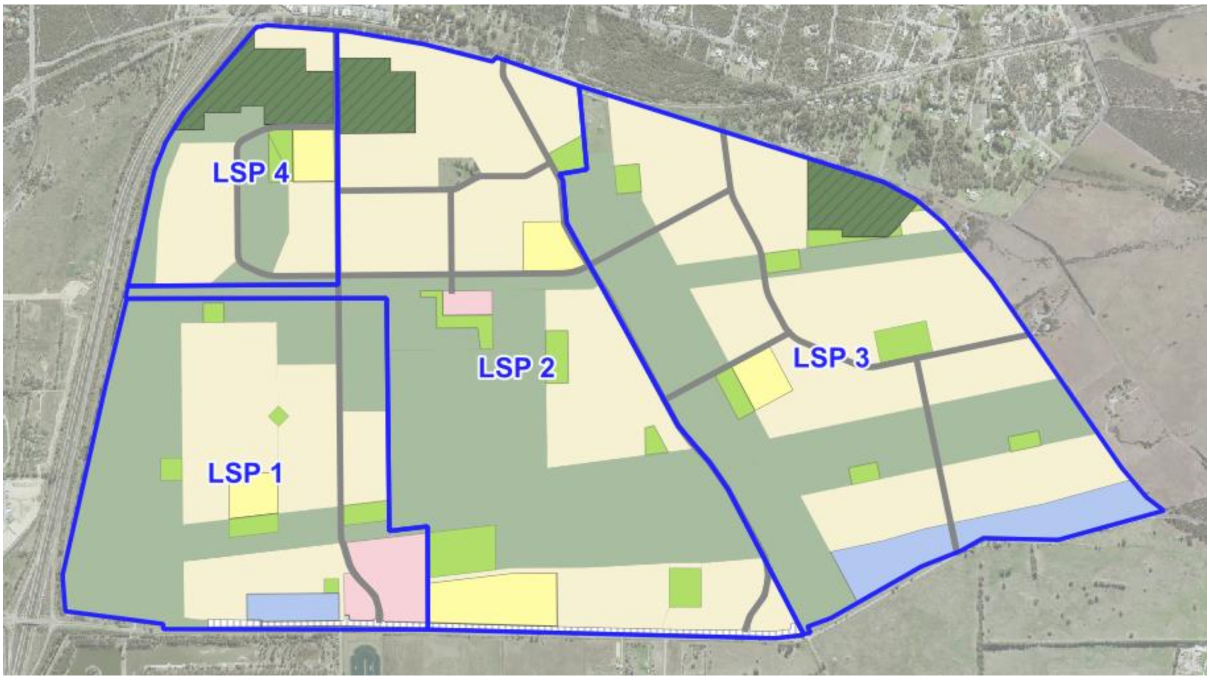


Figure 22: Indicative development staging

The breakdown of flood storage area versus development area for each of the indicative LSP areas shown in Figure 22 above is provided in Table 12. However, it should be noted that these proportional areas are considered nominal at this stage and subject to change through refinement of the LSP boundaries and flood corridor boundaries.

Table 12: Indicative flood storage area per LSP

LSP	Area (ha)	Flood Storage Area (ha)*
1	164	79
2	266	103
3	266	100
4	68	32
Total	764	314

* Note: for the purpose of these indicative areas, flood storage area has been taken to include the flood storage corridors, ski lakes, powerline easements and retained wetland areas and POS / DOS located within the flood corridor.

The above provides and indicative list of key flood mitigation considerations to be addressed during the staged implementation of this DWMS. However, the exact timing and nature of implementation of the DWMS requirements is unknown at this stage of the planning process. Table 13 summarises the key principles and requirements to be considered at local structure planning stage and addressed in future LWMS'.

Table 13: Considerations for staged implementation of flood management

Flood management principle	Considerations and actions
Floodplain storage volume	How does the interim development footprint affect the overall floodplain storage volume?
	Volumetric analysis and hydraulic modelling to confirm storage volumes and heights for the 1% AEP (spoil bank failure) event.
	Implement earthworking and construction of hydraulic controls within the flood corridors as required to maintain storage volume requirement.
Flood discharges from site	What is the peak discharge rate (and hydrograph shape) from the site? Does it match that of pre-development conditions?
	Hydraulic modelling to determine if the interim development footprint and flood corridors maintain the pre-development floodplain dynamics.
	Implement hydraulic structures such as bunds and culverts (either ultimate or temporary) to manage the flow of water through the site and maintain the pre-development discharge characteristics.
Flood heights and risk to properties	Where hydraulic controls (either ultimate or temporary) are required to increase flood storage depth, what are the impacts to adjacent (third party-owned) properties in terms of increased flood heights or risk? DWER (2021a) stated acceptable flood level increase is 0.03 m on the Peel Main Drain floodplain (0.01 m where the impact is to an existing house or structure). However, it is noted that this applies to permanent impacts and considers a total acceptable flood level increase from catchment-wide development of 0.15m. Therefore, alternative (ie. less restrictive) criteria may be appropriate for temporary flood level increase however this would need to be agreed in consultation with DWER and supported by appropriate assessment / modelling.
	Hydraulic modelling to define post-development flood heights relative to pre-development conditions.
	Where required to protect existing property and infrastructure from design (post-development) flood heights, implement temporary measures such as bunds.
Flow paths and safe conveyance of floods	What are the flow paths around and through the interim development footprint?
	Hydraulic modelling to define flow paths and how the flood regime interacts with the development footprint.
	Assessment of: ▪ risk relating to increased flow into adjacent properties. ▪ upgrades required for existing infrastructure (eg. culverts) ▪ risk to the environment through scour / changes to hydrologic regime etc
	Design and implement temporary diversion structures / bunding to control flow of water through the site.

6.7. Drainage asset management

6.7.1. Multiple use (flood) corridors

6.7.1.1. Potential land uses

The ultimate use of the flood corridors will need to be further considered and defined at LSP / LWMS stage in relation to defining land use, long-term maintenance requirements and responsible parties or governance arrangements, as well as how any temporary flood management requirements will be coordinated around these factors. The DSP report provides further detail on the potential uses and long-term governance of the flood corridors, which is summarised in this section. Appendix F also provides a high-level landscape concept which illustrates the open space areas and an indication of the proposed treatments for various areas.

The flood corridors described in this DWMS are accommodated within the DSP as multiple use corridors. These are not able to be developed as urban area given their hydrological function is to remain at a lower elevation without flood immunity. Whilst these areas cannot accommodate buildings, a unique opportunity exists for the land to be used for recreation, movement and enhance the natural amenity of the site in a way that will not compromise its primary drainage function.

The hydrological form and function of the multiple use (flood) corridors is described in Section 6.6.2 and in greater detail in the flood modelling report (Appendix H). In terms of the potential uses and inundation frequency of various zones of the flood corridors, the following summary is provided:

- A small proportion of the overall multiple use corridor area will be comprised of "low flow" channels which can be expected to carry baseflow almost year-round and therefore be unusable other than for hydrological, water treatment, ecological functions.
- The majority of the multiple use corridor areas will be elevated approximately 0.9m or more above the low-flow channel and therefore will not experience frequent inundation. Much of this broader multiple use corridor area will only experience inundation in large events, ie. 5% AEP to 1% AEP, whilst smaller portions of the multiple use corridors will be inundated in minor events, eg. 20% AEP. These inundation zones are illustrated in the flood modelling report (Appendix H).
- The broader multiple use corridor areas (outside of the low flow channels) will generally be free of groundwater inundation, making them suitable for passive recreation. Specific areas of active recreation with even greater groundwater separation can also be accommodated via localised filling within the corridor. The filling of such areas will reduce their flood storage capacity; therefore all proposed District and Local Open Space areas within the corridors have been accounted for (and modelled as raised with fill) in the flood modelling. These areas will experience even less frequent (and less depth of) inundation.

The multiple use and landscaping of these areas is a fundamental component of the DSP and presents an opportunity to create a master planned community that achieves a nature-positive outcome. Some of the proposed or potential land uses being considered for the multiple use corridors include:

- District and Local Open Space (noting that the likely filling of these areas to facilitate the required amenity / groundwater separation etc has been factored into the modelling described herein)
- Large-scale planting or revegetation for:
    - Restoration of native vegetation
    - Ecosystem and habitat creation
    - Carbon capture
    - Nature positive landscape outcomes
- A continuous path network for pedestrian movement and recreational walking
- Mountain bike paths or other active community infrastructure
- Collaboration opportunities with Traditional Owners

The DSP provides further information on the proposed development and land use outcomes for the site. These have been selected as the most practical and achievable outcomes at this stage of the planning process but are not intended to be exclusive and other opportunities for the development and use of the multiple use corridors may be proposed and endorsed as part of future local structure planning.

6.7.1.2. Management of multiple use corridors

The DSP acknowledges that the development of the multiple use areas will be the responsibility of the proponent or other third parties with an interest in developing the corridors. Development of these areas is not the responsibility of Government (either Local or State).

Whilst management of these areas post-development may involve Local and/or State Government where appropriate (ie. for District and Local Open Spaces, and for stormwater management assets such as living streams), the construction, planting and embellishment of these areas is a development responsibility.

A range of management options exist for the multiple use (flood) corridors. Ultimately, it is expected that management will occur under a range of mechanisms, given the size and scale of the areas. The management options that have been identified as the most practical and feasible are summarised below. Whilst the DSP identifies the management options that are anticipated as most likely to occur, other options may be explored and presented as part of future local structure plans.

Private management under a carbon offset scheme

It is proposed that nature positive planting delivered through a carbon offset scheme will occupy the majority of the multiple use corridors. The scale of these areas presents an opportunity for a carbon planting project. Referred to as a 'Carbon Offset Scheme', the proposal would involve the planting, growing, and maintaining of a permanent forest of native trees on land where historical clearing occurred. Under this scenario, the proposed revegetation of the DSP flood corridors would be registered as a carbon credit program with the Emissions Reduction Fund (ERF) in accordance with the Commonwealth's Carbon Credits (Carbon Farming Initiative) Act 2011. The ERF is a voluntary Australian Government scheme that provides opportunities for land managers and owners to generate carbon credits (Australian Carbon Credit Units) by removing greenhouse gases from the atmosphere (sequestration), principally by storing it in vegetation and soil.

ACCUs generated in accordance with one of the approved 'methodologies' can be registered with the ERF as an 'eligible offsets project'. Planting initiatives store carbon in trees as they grow, earning carbon credits over a 25-year crediting period. ACCUs can then be sold to the Government, sold to others through the secondary or voluntary markets or used by the proponent to offset its own emissions.

A registered carbon credit scheme would creates a revenue stream that could cover the cost of planting the area as well as on-going management of the area for a 25-year period. The revenue stream could also allow for the creation of a sinking fund for the ongoing management of the land beyond 25-years when the revenue stream from the ACCUs ends. Under this scenario, the land could be retained in private ownership or alternatively, could be owned by the Local or State Government, with the ongoing management and maintenance undertaken by a third party under the terms of the carbon planting project.

Other private land use / management opportunities

Opportunities exist for private recreation activities to be operated as commercial enterprises. Under this scenario, the land would remain in private ownership with commercial leases to third parties, enabling maximum beneficial use from these areas. Construction of permanent buildings or structures would not be permitted in accordance with the land's primary drainage function; however, this does not encumber the use of the land, with examples of potential private recreation land uses including min golf, outdoor laser tag, mountain bike track, obstacle course, archery range etc.

Local government

Innovative and alternative management options are favoured over the Local Government being responsible for managing significant areas over and above the standard 10% public open space requirement. Whilst these options will be pursued and implemented where possible, it is likely that the Local Government will need to maintain some additional areas to the benefit of the local community. For example, areas where community infrastructure is developed, such as bike tracks and nature trails will likely need to be managed by the Local Government once developed and maintained for the developer for the prescribed period. Similarly, District and Local Open Space areas that may be developed within the multiple use flood corridors would be developed and function in the same manner as any other area of POS and form part of the mandatory minimum 10% POS contribution; accordingly, it is expected that such areas would be ultimately managed by the Local Government.

Third party management groups

Planting as a response to climate change and biodiversity loss and the need to increase tree canopy within an urban context are important objectives that are becoming increasingly accepted. As such, there exists not-for-profit private entities whose mandate is to restore the natural environment and create healthy landscapes where people and nature coexist to mutual benefit. An example of one such organisation is 'Greening Australia' with others expected to emerge in the future, as the impetus to increase green spaces and biodiversity magnifies.

Opportunities to collaborate with third party groups should be explored with a view to sharing management responsibilities to the broader benefit of all.

6.7.2. Ski lakes

The stormwater management concept does not propose any integration of the development's stormwater systems with the existing ski lakes. Stormwater runoff from the development will not be directed into the lakes and will, therefore, not present any impact to the existing lake operational conditions or water quality. Flow into the lakes will only occur during large events when flood depths within the corridors are sufficiently high to overtop the existing banks of the lake such that the temporarily detained floodwater inundates the lakes.

Water quality of the ski lakes is understood to be an important consideration with respect to recreational uses and human health. Therefore, the stormwater management strategy for the development does not propose to change the current operational conditions of the lakes.

6.7.3. Water Corporation drains

A number of the existing open drains through the DSP area are currently managed by Water Corporation. It is anticipated that as part of the development and urbanisation of the area, many of these drains will be modified to integrate them with open space areas, improve their aesthetics and enhance their hydrological function and ecological outcomes; for example by being modified into living streams. Opportunities to achieve these outcomes should be identified and defined at LSP stage.

Given that the area served by these assets (with the exception of the Peel Main Drain) is generally limited to the DSP area itself, it is expected that these drains may be transferred into the management responsibility of the City of Rockingham where appropriate. Any modification to these assets, and their long-term management, will be resolved at LSP stage.

7. Groundwater management

7.1. Overview

As discussed in Section 3.12.3, much of the site is underlain by shallow groundwater. Groundwater levels are expected to rise due to increased infiltration associated with urban development, unless otherwise controlled. This groundwater level rise is proposed to be managed by the installation of a subsoil drainage system to be placed beneath road reserves and POS areas. Fill will be imported to provide clearance from the controlled groundwater level to roads and building pads where required.

7.2. Groundwater management objectives

The proposed DSP will utilise the unconfined aquifer as a means of stormwater disposal. Groundwater will be controlled with a system of subsoil drains located within road reserves and beneath POS areas. The level at which subsoil drains are installed, the Controlled Groundwater Level (CGL), will be set according to *Water resource considerations when controlling groundwater levels in urban development* (DoW 2013b). As specified in DoW (2013b), the CGL will be set with consideration of:

- A free-flowing drainage outlet
- Infrastructure protection
- Groundwater quality and treatment of subsoil drainage discharge
- Protection of water dependent ecosystems (WDEs)
- Catchment and nearby land use constraints.

At the LWMS stage of development appropriate controlled groundwater levels will be defined in accordance with the IPWEA (2016) Specification Separation Distances for Groundwater Controlled Urban Development as well as DoW (2013b).

Regarding groundwater quality management, the first 15 mm of rainfall run-off on impervious areas will be treated prior to infiltration in line with best practice.

7.3. Free-flowing drainage outlet

DoW (2013) specifies that subsoil drainage discharge to stormwater systems should be at least 0.1 m above the stormwater pipe or the winter/wet season level for back-flooded stormwater systems (clearance not specified for discharge to natural drainage features other than ensuring WDE protection and a free-flowing outlet). The subsoil drainage system for the DSP will therefore discharge into either existing drainage channels throughout the site or modified / new drainage channels which will be created as part of the flood detention system within the large flood corridors. Ultimately the subsoil discharge will be to the Peel Main Drain along the western boundary of the site. Subsoil drainage outlet locations and levels will be determined as part of more detailed investigations at the LWMS stage and will involve consideration to likely winter baseflow through these drainage systems, including the Peel Main Drain.

The subsoil drains will grade back from the discharge locations at a typical grade of 1 in 500, which is considered appropriate in terms of installation feasibility. The subsoil outlets may be inundated for a short period during large storm events which is typical for design of subsoil drainage systems in the Perth region. However, this temporary inundation of the subsoil outlets is considered acceptable as the unsaturated zone soil (i.e., fill) across the development will have sufficient storage to compensate for this short term rise in the hydraulic grade line.

7.4. Infrastructure protection

At the LWMS stage of development, preliminary lot levels and design subsoil drainage levels will be determined and supporting modelling or analysis provided to demonstrate adequate separation from the phreatic crest (ie. including groundwater mounding between subsoil drainage alignments) to finished lot levels. IPWEA (2016) provides minimum separation criteria for private spaces which include a separation from the 50% AEP phreatic surface of 0.15 m for residential lots <400 m2 in size and 0.3 m for residential lots 400 to 800 m2 in size. The 50% AEP phreatic surface is defined in IPWEA (2016) as the phreatic surface that will be exceeded in 50% of years (50% chance each year).

7.5. Groundwater quality management

Many of the stormwater management measures will improve the quality of infiltrated water through reducing flow velocities, biological uptake, adsorption to soil and increasing infiltration/treatment areas.

The stormwater management strategy is expected to provide a significant level of treatment of infiltrating stormwater. To further ensure groundwater quality protection the following additional measures will be adopted:

- Minimise and control the number of fertilisers and pesticides applied to the site through appropriate plant selection and appropriate operation and maintenance protocols.
- Maintain healthy and well-established plants, particularly in vegetated drainage systems.
- Monitor groundwater quality entering and leaving the site to verify that pre-development values are being maintained or improved. The monitoring requirements are detailed in Section 8.

The subsoil drainage water quality is expected to improve significantly compared to pre-development quality according to the results of monitoring of two urban developments, one of which is the Rivergum development in a similar setting in Baldivis and the other is the Whiteman Edge development in Brabham. The monitoring has been undertaken as part of CRC research (Davies, Oldham and Vogwill 2018).

It is also highly likely that local subsoil networks will grade to the low flow channel within the flood corridors. The subsoil drainage and local groundwater will be treated inline through these vegetation flow channels.

7.6. Protection of water dependent ecosystems (WDEs)

The key water dependent ecosystems at the North-east Baldivis DSP area are the conservative category and resource enhancement wetlands to be retained across the district. There are currently wetlands proposed to be retained, and their associated implementation requirements are summarised in Section 8. Management strategies for wetlands will need to be informed by wetland assessments and having consideration of landform integration, management of stormwater and drainage interfaces and landscape including bushfire risk. The appropriate protection of WDEs relate to both water quality and water quantity.

Actions to manage water quality risk to wetlands have been identified in Section 6.1 to 6.6 through the implementation of water sensitive urban design approaches throughout the development and in Section 7.5 through groundwater quality management. The establishment of appropriate controlled groundwater levels through the subsoil drainage system design (i.e. appropriate subsoil drain elevations) is a critical design component that will be determined at the precinct planning stage so as not to alter the hydrological regime of any WDEs.

The site has largely been cleared of native vegetation and contains very few areas that would be considered a WDE. Some small mapped REW areas associated with remnant vegetation exist near the north-western and north-eastern corners of the DSP, which are proposed to be retained. There is also a CCW mapped adjacent to (outside of) the south-eastern corner of the DSP and some REW and CCW areas to the north of the DSP.

The groundwater management strategy for the DSP will need to be cognisant of the existing hydrological regime and groundwater levels at these retained wetland areas. It is anticipated that groundwater modelling will be undertaken to support the Local Structure Planning process and associated Local Water Management Strategies, to confirm that earthworks and drainage (stormwater and subsoil) levels are appropriately designed to protect these areas. Wetland assessments should be undertaken as part of local structure planning to inform proposed open space areas and local structure plan design.

8. Implementation framework

The district water management strategy will be implemented through incorporation of its requirements into local structure planning through the preparation of local water management strategies (LWMS').

8.1. Local Water Management Strategy preparation

The information and recommendations presented in this DWMS should guide development of LWMS' for individual precincts in the North-east Baldivis DSP area. The requirements for LWMS' are outlined in DWER's Interim: Developing a local water management strategy (2008a). The LWMS is prepared by the developer and should demonstrate to the satisfaction of the WAPC on the advice of DWER in accordance with this DWMS:

- How the key principles and strategies of this strategy have been addressed
- How the urban structure will address water use and management
- Existing and required water management infrastructure
- Detailed land requirement for water management including the flood corridor and flood storage requirements.

The LWMS must demonstrate proof of concept including how the water management design addresses the issues identified in the DMWS. A LWMS is required to be prepared to accompany a local structure plan for each precinct.

Detailed surface water modelling will be required to support future local structure plans and presented in LWMS'. Some of the key surface water modelling and flood management considerations and objectives which are to be addressed in future LWMS' for this DSP area are:

- Does the interim development footprint, constructed extent of flood corridors and undeveloped floodplain area maintain the overall storage volume requirement? Volumetric assessment and hydraulic modelling will be required to demonstrate interim floodplain behaviour, flood storage heights, discharge rates etc.
- What is the peak discharge rate (and hydrograph shape) from the site, ie. does the constructed extent of flood corridors and undeveloped floodplain area provide adequate storage and reasonably match the pre-development floodplain dynamics? If not, then hydraulic structures such as bunds and culverts (either ultimate or temporary) will be required to manage the flow of water through the site and maintain the pre-development discharge characteristics.
- Where hydraulic controls (either ultimate or temporary) are required to increase flood storage depth, what are the impacts to adjacent (third party-owned) properties in terms of increased flood heights or risk? Where these impacts are unacceptable, temporary measures such as bunds will be required to protect adjacent properties.
- What are the flow paths through / around the interim development footprint?
  - Assessment of risks relating to increased flow / flood height through adjacent properties.
  - Assessment of risk to infrastructure (e.g. existing roads, culverts etc) and requirements for upgraded or temporary infrastructure.
  - Assessment of risk to the environment through scour, modified hydrological regime etc.
  - Design of temporary diversion structures / bunding to control flow of water through the site

The surface water modelling report outlines the modelling outcomes and flood storage volumes required across the entire district. The volume of flood storage across the DSP will be provided to LSP proponents. The LWMS' prepared for each LSP area will be required to demonstrate the LSP design can accommodate the appropriate proportion of flood storage volume.

Other technical investigations that will be necessary to support the LWMS' include, but are not limited to:

- Geotechnical testing to determine infiltration rates
- Assessment of pre-development hydrogeology, including monitoring of groundwater levels and quality, to determine implications of groundwater recharge and the proposed stormwater management system
- Wetland assessments (if required)

The LWMS and any subsequent urban water management plan (UWMP) will be referred to DWER for consultation in recognition that it is a sensitive site in regards to flood management.

8.2. Water monitoring program

In addition to the implementation of LWMS', it will be critical to undertake a more extensive pre- and post-development monitoring program through the DSP with the following objectives:

Pre-development

- Provide baseline water quality and level information for the precinct scale design purposes
- Establish more accurate level information of the existing surface water features including Peel Main Drain, existing lake, wetlands, surface water drains and groundwater to inform future designs.

During and Post-development

- Provide ongoing assessments of surface and groundwater system health.
- Provide early warning for arising issues enabling adaptive management of surface and groundwater management systems.
- Review the performance of water quality and quantity management systems and propose design adjustments where necessary.

8.2.1. Pre-development monitoring

LWMS' supporting LSPs will be required to report on pre-development monitoring data relevant to their site recorded over a period not less than 18 months and two winter peaks. Additional site-specific monitoring may be required and should be confirmed with DWER prior to commencement.

Water samples should be collected and sent to a NATA-accredited laboratory for analysis of nutrients, dissolved metals and TSS as a minimum. It is recommended that physico-chemical parameters are measured in the field for a more representative result.

Pre-development monitoring allows for baseline conditions to be established and site-specific trigger values to be set. This monitoring would also be used to identify potential areas that are affected by elevated nutrients. Trigger values will be finalised at UWMP stage as per ANZECC and ARMCANZ (2000) guidelines and relevant targets.

8.2.2. Post-development monitoring

The duration of post-development monitoring will be determined at LWMS and UWMP stage to assess any potential impacts from the development. It is recommended that a similar monitoring network and Sampling and Analysis Plan (SAP) is followed to allow for comparison with the pre-development conditions.

8.3. Future Water Management Reports

Water Management Reports (or urban water management plans) are required to be prepared to demonstrate that designs achieve objectives, strategies and design criteria outlined in this DWMS and any future LWMS'. They are required to be prepared in support of applications for subdivision. Where an endorsed LWMS exits, the final water management report (or UWMP) is able to be prepared as a condition of subdivision (or development). Any water management report should be prepared in consultation with the City of Rockingham and DWER and submitted to these agencies for approval.

Water Management Reports are based on local site investigations appropriate to the proposal and level of risk to water resources. The WMR should be consistent with the requirements of DWER's Urban water management plans: Guidelines for preparing plans and for complying with subdivision conditions (DoW 2008b).

Specifically, the WMR should include detailed engineering designs (drainage and wastewater) and any landscape designs relating to water quality improvement or water efficiency improvement. The WMR will also include a framework for implementing the water management strategies and plans through the construction and post-development phases of the project.

8.4. Roles and responsibilities

This DWMS has been completed to address the objectives of BUWM (WAPC 2008) and demonstrate that the site can support future development in terms of water supply planning, flood mitigation, drainage management, groundwater management and water quality protection.

As part of the implementation of this DWMS, further investigations will be required at local planning and subdivision stages to inform Local Water Management Strategies (LWMS') and Urban Water Management Plans (UWMPs) which will need to be prepared as part of the water management and land planning process.

The roles and responsibilities for the implementation of this DWMS are outlined in Table 14.

Table 14: Summary of roles and responsibilities

Implementation item	Responsibility	Planning stage
Development of local flood, stormwater drainage and groundwater management concepts: ▪ Refine stormwater management concept including catchment boundaries and treatment and detention locations ▪ Flood mitigation concept design including flood corridors and hydraulic controls, typical cross sections etc ▪ Confirm discharge points and peak flow rates	Landowner / developer	Local structure plan (local water management strategy)
Development of conceptual Landscaping plan incorporating wetland protection and WSUD	Landowner / developer	Local structure plan (local water management strategy)
Development of refined water balance and confirmation of fit-for-purpose water sources	Landowner / developer	Local structure plan (local water management strategy)
Identification of water source for irrigation of public open space	Landowner / developer	Local structure plan (local water management strategy)
Acid sulfate soils investigations/ potential acid sulfate soils management plan	Landowner / developer	Local structure plan (local water management strategy)
Geotechnical investigations	Landowner / developer	Local structure plan (local water management strategy)

Implementation item	Responsibility	Planning stage
Flora and fauna investigations	Landowner / developer	Local structure plan (local water management strategy)
Potable water supply planning and connection to main distribution network	Water Corporation	Local structure plan (local water management strategy)
Wastewater planning and connection to main distribution network	Water Corporation	Local structure plan (local water management strategy)
Confirmation of a water supply for POS irrigation	Landowner / developer	Local structure plan (local water management strategy)
Implementation of pre-development monitoring program	Landowner / developer	Local structure plan (local water management strategy)
Confirmation of post-development monitoring program	Landowner / developer	Local structure plan (local water management strategy)
Referral to the EPA of specific mechanisms and provisions to adequately secure, protect and manage the environmental values within the DSP area	Landowner / developer	As part of MRS amendment
Design of water distribution networks	Landowner / developer	Subdivision (urban water management plan)
Design of wastewater reticulation networks	Landowner / developer	Subdivision (urban water management plan)
Design of drainage networks	Landowner / developer	Subdivision (urban water management plan)
Aboriginal consultation	Landowner / developer	Subdivision (urban water management plan)
Stormwater and contamination management plan	Landowner / developer	Subdivision (urban water management plan)
Management of local stormwater infrastructure	City of Rockingham, except if these fall within alternative management arrangements per Section 6.6.5.2	Post-development
Management of regional drainage assets	Refer Section 6.7	Post-development
Management of public open space including flood corridor	Refer Section 6.7	Post-development
Management of lakes	Private owner / operator	Post-development
Construction of drainage infrastructure and modification to existing assets	Landowner / developer	Subdivision / construction phase

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Appendix A: Groundwater levels 2018–2019

Bore ID	MW1D	MW1S	MW3D	MW3S	MW4D	MW4S	MW5D	MW5S	MW6	MW7D	MW7S	MW8D	MW8S
June 2018	7.59	7.63	7.54	7.60	6.57	6.59	6.17	6.48	7.38	4.82	4.95	5.10	5.10
July 2018													
August 2018	8.13	8.14	8.29	8.31	6.99	7.03	6.49	6.71	8.10	4.85	5.31	5.33	5.43
September 2018	7.97	8.07	7.54	7.61	6.64	6.64	6.27	6.46	7.93	4.78	5.01	5.16	5.25
October 2018	7.99	8.02	7.70	7.70	6.48	6.47	6.15	6.24	7.98	4.85	4.86	5.13	5.22
November 2018	7.63	7.77	7.08	7.08	5.86	5.18	5.79	5.99	7.71	4.49	4.37	4.71	4.84
December 2018	7.22	7.55	6.45	6.45	5.23	5.24	5.42	5.66	7.51	4.12	3.88	4.28	4.40
January 2019	7.01	7.38	6.10	6.09	4.72	4.88	4.97	5.35	7.31	3.95	3.46	3.93	3.94
February 2019													
March 2019	6.59	7.04	5.54	5.53	4.35	4.35	4.69	4.89	6.89	3.61	3.07	3.46	3.29
April 2019	6.55	6.98	5.33	5.31	4.18	4.22		4.67	6.74	3.65	3.32	3.43	3.25
May 2019	6.48		5.21	5.19	3.81	4.52	4.45	4.59	6.69	3.72	3.55	3.46	3.26
June 2019	6.92	7.20	5.33	5.31		4.96	4.85	4.95	6.95				
July 2019	6.48		5.21	5.19	3.81	4.52	4.45	4.59	6.69	3.72	3.55	3.46	3.26

Note: Groundwater levels are in metres above height datum (mAHD)

Bore ID	MW9D	MW9M	MW9S	MW10D	MW10S	MW11D	MW11S	MW12D	MW12S	MW13D	MW13S	B1	B2	B3
June 2018	6.02	6.41	6.55	4.81	4.26	6.79	6.72	5.37	5.59	4.50	4.28			
July 2018														
August 2018	6.70	6.47	6.18	4.80	5.14	7.41	7.33	5.99	6.31	3.43				
September 2018	6.61	6.36	6.35	4.75	4.71	7.23	7.14	5.90	6.16	3.62	3.94			
October 2018	6.61	6.43	6.39	4.79	4.66	7.20	7.09	5.82	6.10	4.46	4.16			
November 2018	5.66	6.27	6.20	4.43	4.35	7.01	6.92	5.69	5.98	4.27	4.03			
December 2018	5.38	6.01	6.04	4.28	4.15	6.82	6.73	5.49	5.81	4.02	3.71	3.97	4.64	3.80
January 2019	5.32	5.78	5.85	3.91	3.61	6.64	6.55	4.96	5.64	3.86	3.37			
February 2019														
March 2019	5.52	5.23		3.58	3.29	6.23	6.11	4.89	5.31	3.49	2.96	3.50	4.15	3.30
April 2019	5.46	4.96		3.64	3.48	6.11	5.99	4.85		3.56	3.09	3.55	4.17	3.31
May 2019	5.28	4.88		4.00		6.11	5.99	4.84		3.59	3.21	3.61	4.22	3.35
June 2019	5.65	5.85	5.95	4.06	3.84	6.40	6.29	5.49	5.26	3.87	3.42	3.93	4.47	3.63

Bore ID	MW9D	MW9M	MW9S	MW10D	MW10S	MW11D	MW11S	MW12D	MW12S	MW13D	MW13S	B1	B2	B3
July 2019	5.28	4.88		3.70	3.57	6.11	5.99	4.84		3.59	3.21	3.61	4.22	3.35

Note: Groundwater levels are in metres above height datum (mAHD)

Appendix B: Groundwater levels 2019–2020

Bore ID	MW1D	MW1S	MW3D	MW3S	MW4D	MW4S	MW5D	MW5S	MW6	MW7D	MW7S	MW8D	MW8S
August 2019	7.90	7.86	8.04	8.17	6.89	7.00	6.43	6.62	7.69	5.16	5.59	5.41	5.49
September 2019	7.75	7.82	7.75	7.81	6.56	6.61	6.22	6.39	7.57	4.98	5.20	5.15	5.20
October 2019	7.49	7.67	7.11	7.11	5.51	6.13	5.74	5.97	7.41	4.24	3.45	4.69	4.82
November 2019	7.33	7.40	6.70	6.50	4.85	5.62	5.38	5.64	7.20	4.12	3.60	4.19	4.21
December 2019	7.07	7.29	6.06	5.93	4.41	4.98	5.03	5.33	6.98	3.95	3.51	3.90	3.65
January 2020	6.71	7.15	5.69	5.65	4.17	4.71	4.80	5.12	6.84	3.75	3.45	3.66	3.47
February 2020	6.50	7.02	5.47	5.46	4.29	4.32	4.84	5.07	6.72	3.51	3.20	3.38	3.21
March 2020	6.30	6.48	5.34	5.33	4.22	4.25	4.60	4.84	6.63	3.34	3.09	3.22	3.06
April 2020	6.34	6.46	5.14	5.11	4.00	4.12	4.39	4.70	6.54	3.68	3.12	3.26	3.03
May 2020	5.92	6.26	4.94	4.90	4.17	4.13	4.14	4.46	6.26	3.57	3.18	3.23	3.09
June 2020	6.86	7.20	5.58	5.63	5.22	5.17	5.13	5.23	6.81	4.15	3.79	4.22	4.03
July 2020	7.59	7.56	7.86	7.88	6.86	7.14	6.13	6.39	7.24	4.84	5.62	5.03	5.03
August 2020	7.82	7.76	8.27	8.33	7.02	7.28	6.41	6.54	7.41	5.11	5.62	5.39	5.37
September 2020	7.76	7.77	7.96	7.98	6.77	6.92	6.26	6.45	7.42	4.94	5.45	5.16	5.21
October 2020	7.51	7.63	7.33	7.41	6.15	6.23	6.02	6.15	7.28	4.63	4.65		4.93
November 2020	7.34	7.59	7.14	7.14	5.91	6.01	5.90	6.21	7.26	4.52	4.59	4.85	4.91
December 2020	7.12	7.42	6.51	6.48	5.28	5.28	5.56	5.97	7.10	4.15	4.17	4.51	4.37

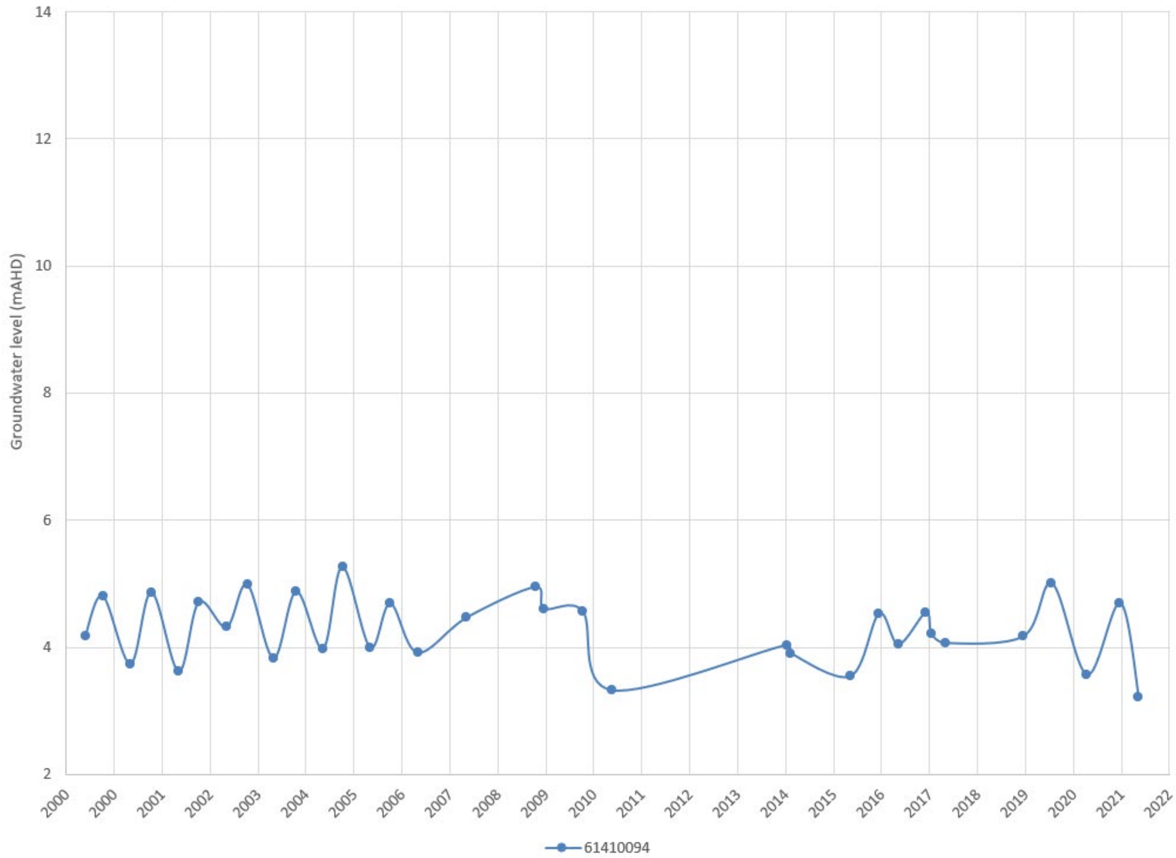
Note: Groundwater levels are in metres above height datum (mAHD)

Bore ID	MW9D	MW9M	MW9S	MW10D	MW10S	MW11D	MW11S	MW12D	MW12S	MW13D	MW13S	B1	B2	B3	B5
August 2019	6.53	6.50	6.60	5.21	5.40	7.06	7.01	5.83	5.65	4.77	4.84	4.88	5.09	4.63	2.77
September 2019	6.28	6.32	6.32	4.78	4.92	6.90	6.83	5.58	5.62	4.42	4.42	4.76	4.71	4.48	2.98
October 2019	5.98	6.18	6.16	4.38	4.35	6.76	6.72	5.36	5.60	4.30	4.08	4.35	4.91	4.09	3.45
November 2019	5.80	5.86	5.91	4.12	3.98	6.55	6.55	5.28	5.38	4.09	3.79	4.11	4.68	3.83	2.75
December 2019	5.54	5.51	5.85	3.85	3.53	6.43	6.32	4.95	5.22	3.94	3.50	3.94	4.54	3.69	2.05
January 2020	5.45	5.29	5.82	3.61	3.27	6.28	6.17	4.76	5.18	3.67	3.02	3.68	4.33	3.49	1.70
February 2020	5.12	5.01	5.83	3.48	3.08	6.14	6.03	4.80	5.17	3.49	2.87	3.47	4.15	3.29	1.64
March 2020	4.64	4.63	5.81	3.32	2.99	6.06	5.95	4.72	5.16	3.39	2.79	3.34	4.03	3.18	1.52
April 2020	4.96	4.78	5.80	3.50	3.22	6.03	5.94	4.66	5.12	3.48	2.95	3.45	4.08	3.18	1.38
May 2020	5.02	4.74	5.80	3.42	2.90	6.08	5.97	4.41	5.12	3.57	2.95	3.14	3.68	3.31	1.33

Bore ID	MW9D	MW9M	MW9S	MW10D	MW10S	MW11D	MW11S	MW12D	MW12S	MW13D	MW13S	B1	B2	B3	B5
June 2020	5.73	5.88	6.03	4.14	3.85	6.39	6.29	5.15	5.12	4.08	3.49	3.99	4.48	3.67	1.86
July 2020	6.24	6.38	6.37	4.91	4.30	6.76	6.65	5.21	5.44	4.52	4.51	4.67	5.03	4.39	2.20
August 2020	6.54	6.52	6.62	5.18	5.52	6.87	6.78	5.36	5.49	5.00	4.98	4.92	5.23	4.62	2.45
September 2020	6.51	6.35	6.33	5.01	4.96	6.85	6.76	5.39	5.58	4.57	4.43	4.71	5.13	4.47	2.95
October 2020	6.08	6.23	6.20	4.66	4.65	6.76	6.92	5.22	5.45	4.22		4.46		4.22	2.46
November 2020	5.80	6.24	6.22	4.49	4.39	6.68	6.58	5.22	5.42			4.35		4.12	2.39
December 2020	5.14	6.05	6.06	4.11	4.00	6.50	6.39	5.05	5.30			3.98		3.82	1.97

Note: Groundwater levels are in metres above height datum (mAHD)

Appendix C: DWER and site hydrographs



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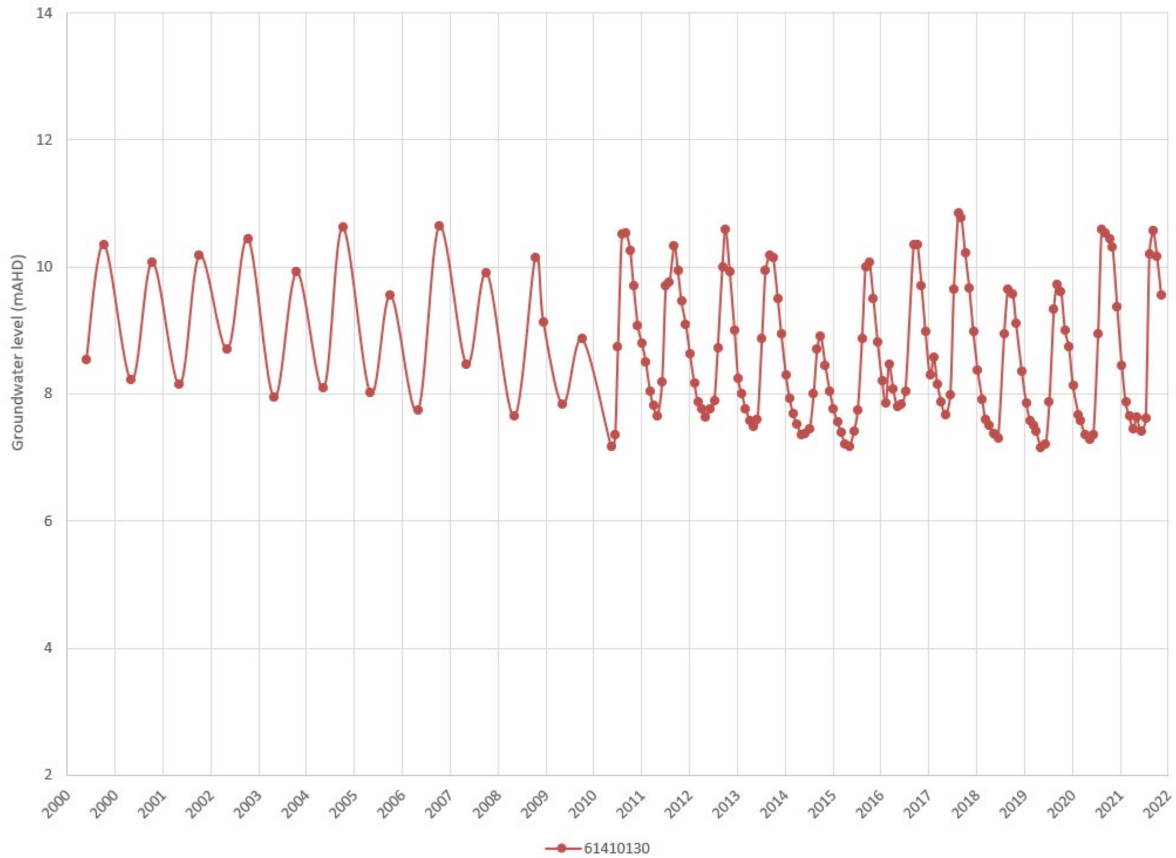

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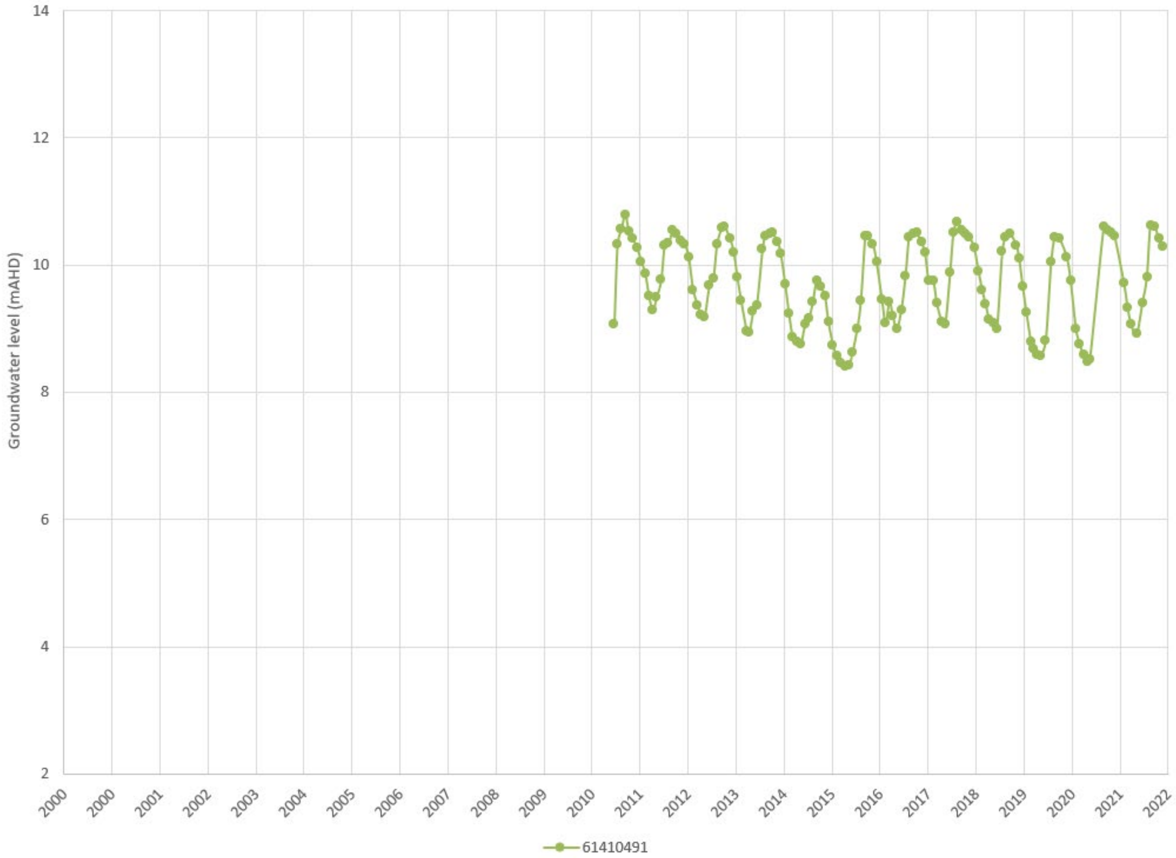

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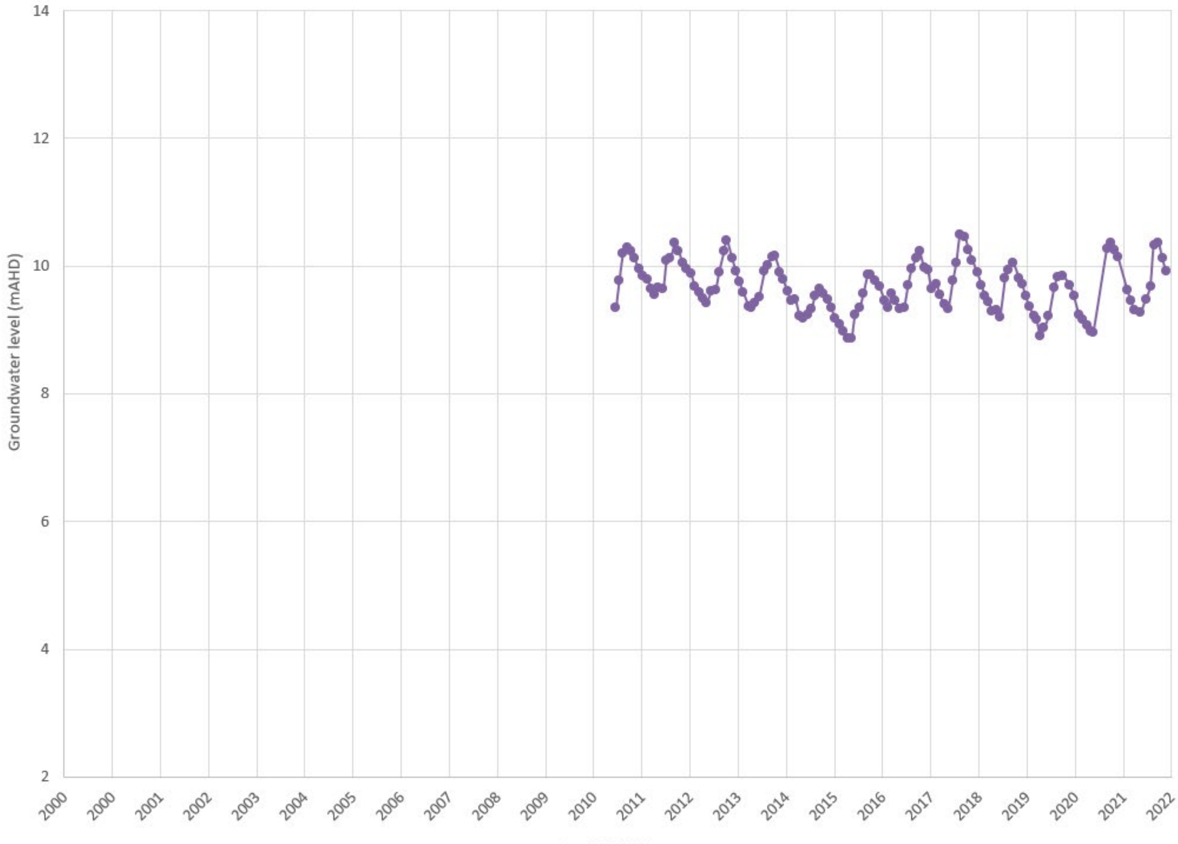

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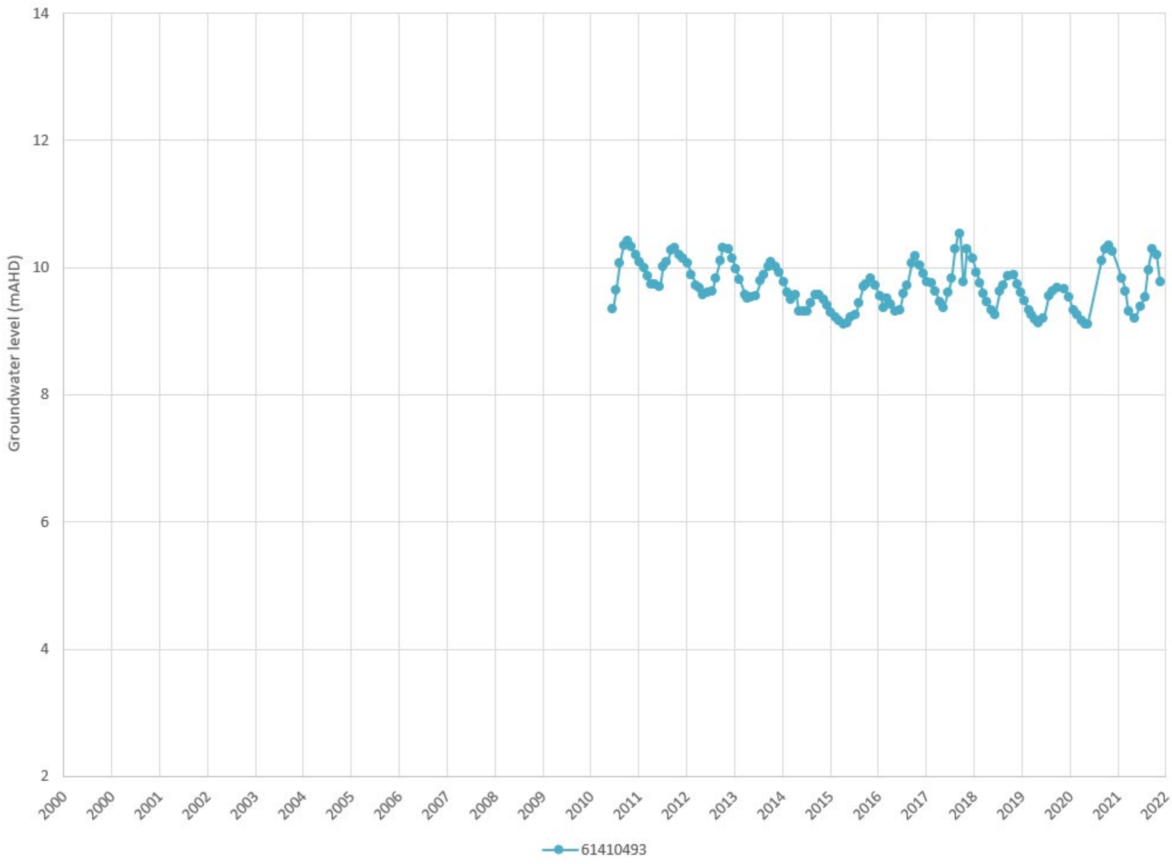

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Groundwater level (mAHD)
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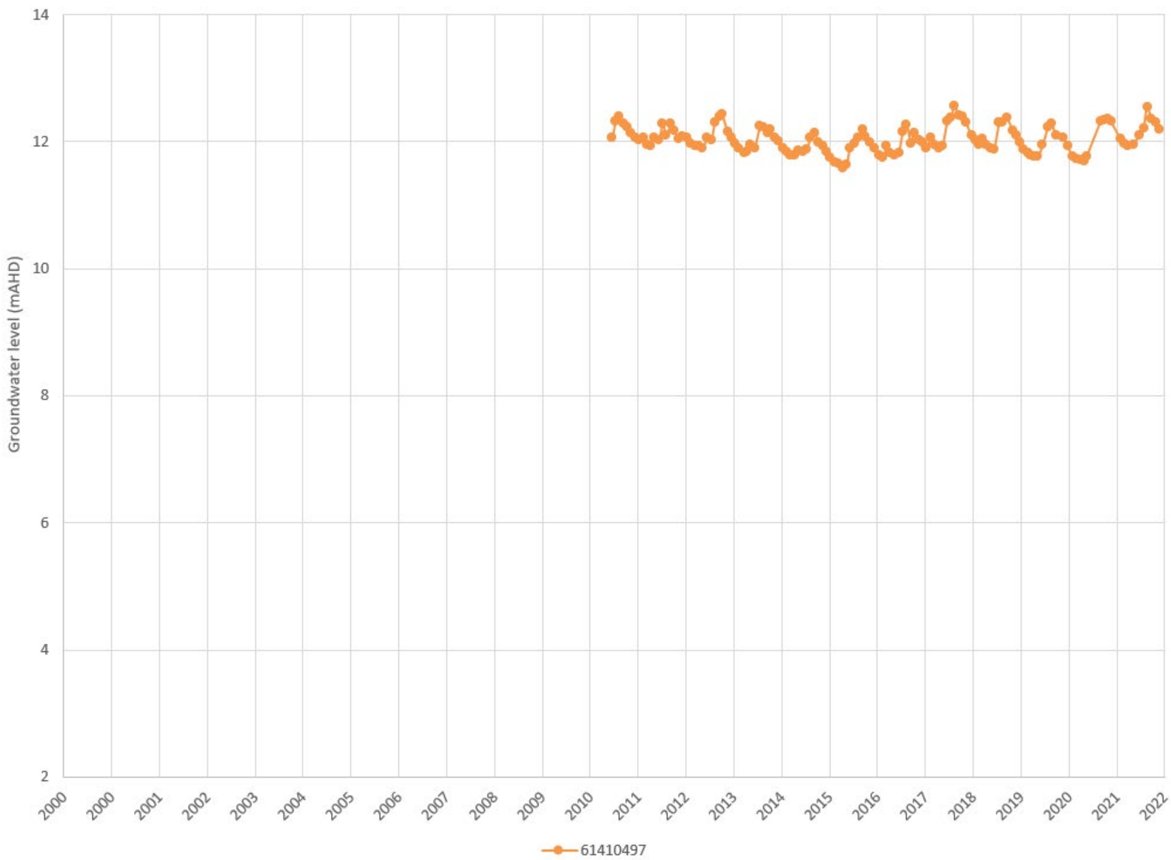

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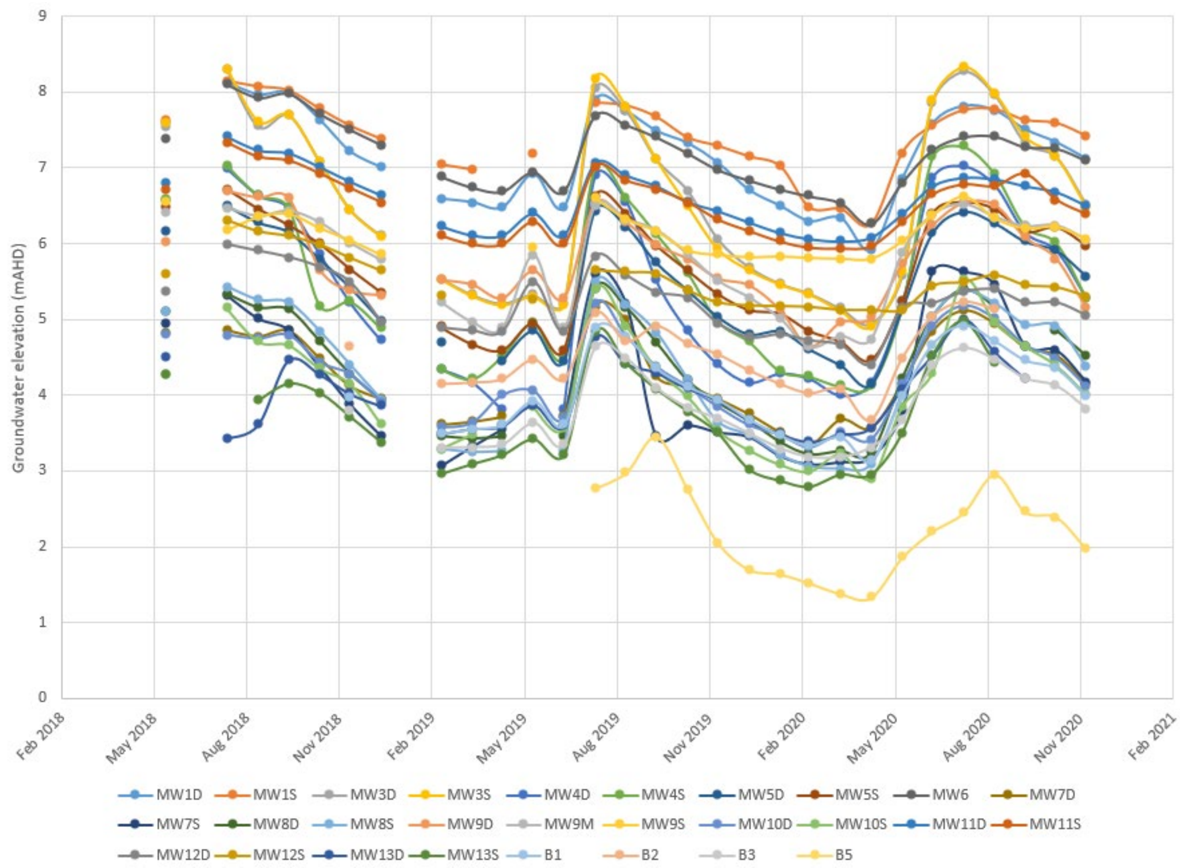
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Groundwater elevation (mAHD)
Feb 2018
May 2018
Aug 2018
Nov 2018
Feb 2019
May 2019
Aug 2019
Nov 2019
Feb 2020
May 2020
Aug 2020
Nov 2020
Feb 2021
MW1D
MW1S
MW3D
MW3S
MW4D
MW4S
MW5D
MW5S
MW6
MW7D
MW7S
MW8D
MW8S
MW9D
MW9M
MW9S
MW10D
MW10S
MW11D
MW11S
MW12D
MW12S
MW13D
MW13S
B1
B2
B3
B5

Appendix D: Groundwater quality results, Cardno

			Field						Inorganics																																Microbiological	
			Dissolved Oxygen (Filtered)	EC (field)	pH (Field)	Redox Potential	Temp (Field)	TDS (Field)	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (Carbonate as CaCO3)	Nitrite + Nitrate as N	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Anions Total	Cations Total	Calcium (Filtered)	Chloride	Electrical conductivity *(lab)	Fluoride	Ionic Balance	Kjeldahl Nitrogen Total	Magnesium (Filtered)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Potassium (Filtered)	Phosphorus	Reactive Phosphorus as P	Sodium (Filtered)	Sulfate as SO4 - Turbidimetric (Filtered)	Hardness as CaCO3 (Filtered)	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Lead (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Zinc (Filtered)	E. Coli	Enterococci
			mg/L	uS/cm	pH_Units	mV	oC	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	meq/L	meq/L	mg/L	mg/L	uS/cm	mg/L	%	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cfu/100 mL	cfu/100mL
LOR									1	1	0.01	1000	1	10	0.01	0.01	1	1	1	0.1	0.01	0.1	1	0.01	0.01	100	1	0.01	0.01	1	1	1	0.001	0.0001	0.001	0.001	0.001	0.0001	0.001	0.005	1	1
ANZG 2018 Fresh Water (95%)														900										7.2										0.0002		0.0014	0.0034	0.0006	0.011	0.008		
ANZECC 2000 Irrigation Long Term Trigger Values					6-8.5															1						5000		0.05					0.1	0.01	0.1	0.2	2	0.002	0.2	2		
DOH 2014																		250		15														0.02		20	0.1	0.01	0.2	3		
Location Code	Well Code	Sampled Date																																								
B1	B1	24/04/2019	1.07	3920	6.18	-102.4	21.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B1	23/07/2019	-	-	-	-	-	-	340	<1	0.03	<1000	340	100	51.3	53.2	138	1510	5450	0.2	1.81	0.6	183	0.03	<0.01	600	4	3.21	0.03	715	90	1100	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.024	250	340
	B1	31/10/2019	3.02	3770	7.41	1.9	18.7	2744	253	<1	0.02	<1000	253	<10	36.9	35.8	74	1090	3650	0.2	1.52	1.2	122	0.02	<0.01	1200	3	10.1	0.08	505	52	687	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.023	20	30
	B1	30/01/2020	1.35	3556	7.13	-101.2	21.2	2107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B1	24/04/2020	0.72	3499	6.97	-44.7	19.8	2522	225	<1	0.08	<1000	225	110	35.2	36.6	76	1050	3760	0.2	1.85	0.3	113	0.08	<0.01	400	3	0.28	0.02	538	54	655	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.014	<1	<1
	B1	23/07/2020	1.1	3247	6.83	-42.9	18.7	2029	252	<1	<0.01	<1000	252	100	35.2	34.9	79	1030	3770	0.2	0.38	0.3	111	<0.01	<0.01	300	3	2.14	0.07	500	52	654	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<1	2
	B1	28/10/2020	0.93	3316	7.07	-136.9	20.4	1997	163	<1	<0.01	<1000	163	110	33.9	35.3	85	1040	3710	0.2	2.08	0.3	118	<0.01	<0.01	300	3	0.32	0.02	489	61	698	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.026	<1	<1
B2	B2	24/04/2019	-	4031	6.51	-107.3	19.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B2	23/07/2019	-	-	-	-	-	-	323	<1	0.89	<1000	323	220	37.8	40.1	143	1100	4030	<0.1	2.94	1.2	86	0.89	<0.01	2100	10	0.19	0.01	590	17	711	<0.001	<0.0001	0.001	0.002	<0.001	<0.0001	<0.001	0.029	45	69
	B2	31/10/2019	2.35	4088	7.15	-84.9	17.8	3029	393	<1	0.03	<1000	393	1160	40.3	39.6	128	1140	4030	<0.1	0.94	2.4	88	0.03	<0.01	2400	9	2.41	<0.01	591	15	682	0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	0.026	<10	280
	B2	30/01/2020	1.7	4044	7	-114	20.9	2414	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B2	24/04/2020	1.05	3859	6.84	-63.7	18.7	2847	343	<1	<0.01	<1000	343	1540	40.1	42	159	1160	4460	<0.1	2.28	2.1	92	<0.01	<0.01	2100	10	0.16	<0.01	603	26	776	0.001	<0.0001	0.001	<0.001	<0.001	<0.0001	<0.001	0.013	<1	<1
	B2	23/07/2020	1.4	3368	6.62	-83.6	17.3	2173	377	<1	0.73	<1000	377	400	37.8	37.2	135	1060	4070	<0.1	0.87	1	79	0.71	0.02	1700	10	0.22	<0.01	544	18	662	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.007	<1	20
B3	B1	24/04/2019	2.48	8596	6.23	-102.2	21.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B2	23/07/2019	-	-	-	-	-	-	200	<1	0.15	<1000	200	<10	130	124	306	4220	12100	0.2	2.43	0.2	493	0.15	<0.01	400	7	0.2	<0.01	1570	359	2790	0.003	<0.0001	<0.001	0.003	<0.001	<0.0001	0.002	0.027	38	73
	B3	31/10/2019	0.1	11,090	6.97	-20.4	18.4	8242	204	<1	0.02	<1000	204	160	133	122	275	4370	12,100	0.2	4.19	0.2	506	0.02	<0.01	200	7	0.34	<0.01	1540	283	2770	0.009	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	0.02	<1	17
	B3	30/01/2020	3.69	10,830	6.82	-43.8	21.2	6419	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B3	24/04/2020	0.66	10,300	6.58	6.9	19.1	7540	176	<1	<0.01	<1000	176	170	116	114	281	3820	12,600	0.2	0.78	0.3	438	<0.01	<0.01	300	7	0.11	<0.01	1470	227	2500	0.04	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.016	<1	24
	B3	23/07/2020	3.85	15,000	6.47	-114.1	18.2	9488	215	<1	0.76	<1000	215	110	211	190	520	6150	18,300	0.2	5.15	0.8	912	0.76	<0.01	1600	9	2.37	0.02	2050	1600	5050	0.006	<0.0001	<0.001	0.002	<0.001	<0.0001	0.003	0.006	4	5
	B3	28/10/2020	3.92	12,460	6.49	-193.2	19.7	7612	142	<1	<0.01	<1000	142	210	152	152	458	4730	14,300	<0.1	0.13	0.3	656	<0.01	<0.01	300	9	0.12	0.02	1720	732	3840	0.028	<0.0001	<0.001	<0.001	0.002	<0.0001	0.002	0.024	<1	<1
B5	B5	31/10/2019	2.44	11,570	6.66	4.9	18.4	8612	340	<1	0.02	<1000	340	200	147	138	310	4340	13,300	0.2	3.06	0.6	487	0.02	<0.01	600	18	0.06	<0.01	1890	851	2780	0.01	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.021	76	72
	B5	24/04/2020	2.32	11,430	6.78	40.2	19.7	8288	347	<1	0.03	<1000	347	200	132	130	302	3840	14,000	0.2	0.77	0.4	425	0.03	<0.01	400	17	0.02	<0.01	1820	788	2500	0.011	<0.0001	<0.001	0.001	<0.001	<0.0001	0.002	0.076	<1	11
	B5	23/07/2020	1.4	9974	6.49	-76.8	19.5	6132	371	<1	0.09	<1000	371	100	125	117	292	3600	11,900	0.2	3.28	0.2	380	0.08	0.01	300	16	0.04	0.02	1620	753	2290	0.01	<0.0001	<0.001	0.001	<0.001	<0.0001	0.001	0.008	<1	4
	B5	28/10/2020	0.39	11,050	6.62	-130.9	20.8	6600	241	<1	0.07	<1000	241	80	126	128	337	3690	12,500	0.1	0.78	0.1	426	0.07	<0.01	200	18	0.02	<0.01	1730	802	2600	0.011	<0.0001	<0.001	<0.001	0.029	<0.0001	0.001	0.028	<1	<1
MW01D	MW01D	27/06/2018	-	2387	6.34	-233.4	21.5	1408	125	<1	0.35	<1000	125	560	27.5	23.1	31	884	2510	<0.1	8.66	14.2	68	0.25	0.1	14,600	6	0.84	0.45	364	4	357	0.009	<0.0001	0.018	<0.001	0.002	<0.0001	0.004	0.006	2000	<10
	MW01D	16/10/2018	0.6	2690	6.01	-189.6	23.2	-	141	<1	0.44	<1000	141	180	27.9	26.7	28	888	2710	<0.1	2.16	9.7	69	0.4	0.04	10,100	3	0.34	0.33	450	2	354	0.013	<0.0001	0.027	<0.001	0.006	<0.0001	0.006	0.094	40	20
	MW01D	18/01/2019	-	1843	5.91	-144.4	20.5	1094	166	<1	1.01	<1000	166	240	27.2	25.4	32	837	2520	<0.1	3.39	7.6	68	1	0.01	8600	3	0.27	0.25	418	15	360	0.003	<0.0001	0.008	<0.001	<0.001	<0.0001	0.003	<0.005	<10	<10
	MW01D	23/04/2019	0.78	2552	5.87	-161.4	21.5	-	194	<1	0.37	<1000	194	310	28.9	27.8	31	804	2650	<0.1	1.86	10.6	73	0.37	<0.05	11,000	2	0.13	0.24	465	112	378	0.003	<0.0001	0.007	<0.001	<0.001	<0.0001	0.002	0.012	<1	<1
	MW01D	23/07/2019	-	-	-	-	-	-	145	<1	0.47	<1000	145	440	26	27.2	39	801	2570	<0.1	2.24	10.1	72	0.44	0.03	10,600	6	0.34	0.34	440	23	394	0.004	<0.0001	0.016	<0.001	<0.001	<0.0001	0.005	0.04	120	130
	MW01D	31/10/2019	0.92	2300	6.27	-173.9	19.9	1807	169	<1	<0.1	<1000	169	250	22.1	23.7	33	664	2120	0.1	3.48	7.5	62	<0.1	0.04	7500	8	2.66	2.17	385	<10	338	0.002	<0.0001	0.006	<0.001	<0.001	<0.0001	0.003	0.011	8	43
	MW01D	30/01/2020	0.78	1843	5.91	-144.4	20.5	1094.5	207	<1	0.03	<1000	207	90	8.3	8.63	65	127	812	0.2	1.95	4.6	18	0.03	<0.01	4600	49	5.86	5.87	61	28	236	0.001	<0.0001	0.001	<0.001	<0.001	<0.0001	0.002	0.005	<1	<1
	MW01D	24/04/2020	0.57	2596	5.88	-153.4	21.7	1801	180	<1	0.42	<1000	180	390	26.5	27.7	36	811	2690	<0.1	2.19	12.5	70	0.37	0.05	12,900	2	0.22	0.22	461	<20	378	0.002	<0.0001	0.007	<0.001	<0.001	<0.0001	0.003	0.009	<1	<1
	MW01D	23/07/2020	0.95	1718	6.13	-36	19.6	1056	179	<1	0.27	<1000	179	310	26.2	25.2	39	794	2590	<0.1	1.88	8.9	64	0.27	<0.05	9200	10	0.63	0.44	408	10	361	0.003	<0.0001	0.006	<0.001	0.002	<0.0001	0.003	0.008	5	100
	MW01D	28/10/2020	1.16	2398	6.1	-317.2	20.8	1436	152	<1	0.37	<1000	152	300	28.1	26.3	38	771	2560	<0.1	3.22	7.3	68	0.3	0.07	7,700	4	0.2	0.25	431	159	375	0.002	<0.0001	0.007	<0.001	<0.001	<0.0001	0.003	0.005	<1	<1
MW01M	MW01M	24/04/2020	3.11	1321	6.12	-81.4	23.4	884	229	<1	0.08	<1000	229	900	12.7	14.2	84	208	1300	0.2	5.68	9.8	30	0.08	<0.01	9900	111	9.81	9.81	108	107	333	0.001	<0.0001	0.002	0.004	<0.001	<0.0001	0.002	0.005	1	2
	MW01M	23/07/2020	0.73	961	6.34	6.1	18.5	605	265	<1	0.02	<1000	265	90	12.1	12.9	94	155	1090	0.2	3.28	8.2	21	0.02	<0.01	8200	80	18.5	18.8	102	116	321	0.002	<0.0001	<0.001	0.006	<0.001	<0.0001	0.004	0.006	140	5
	MW01M	28/10/2020	0.29	980	6.61	-27.4	20.5	594	278	<1	0.02	<1000	278	110	10.5	11.7	98	124	1020	0.1	5.54	6.2	23	0.02	<0.01	6,200	73	12	12.7	70	68	339	0.001	<0.0001	<0.001	<0.001	0.003	<0.0001	0.003	<0.005	<1	5
MW01S	MW01S	27/06/2018	-	532	6.81	-112.9	18	335.5	82	<1	0.24	<1000	82	60	5.19	6.28	37	64	603	0.1	9.44	3.6	19	0.24	<0.01	3800	44	5.71	5.64	40	84	171	0.002	<0.0001	<0.001	0.002	<0.001	<0.0001	0.002	0.031	2300	<10
	MW01S	16/10/2018	0.47	877	6.22	-165.8	28.6	-	109	<1	2.5	<1000	109	330	5.84	6.01	34	70	603	0.1	1.44	6.2	17	2.34	0.16	8700	51	4.58	4.46	37	81	155	<0.001	<0.0001	<0.001	0.004	<0.001	<0.0001	0.004	0.1	60	<10
	MW01S	18/01/2019	-	626	6.46	-160.7	24.5	346.5	307	<1	<0.01	<1000	307	80	12.5	12.2	98	116	1160	0.2	1.2	4.7	34	<0.01	<0.01	4700	90	10	9.74	52	151	385	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	<0.005	<10	<10
	MW01S	23/07/2019	-	-	-	-	-	-	196	<1	0.03	<1000	196	<10	13	13.8	111	129	1230	0.1	2.91	10.7	35	0.03	<0.01	10,700	85	7.35	6.9	74	263	421	0.003	<0.0001	<0.001	0.005	<0.001	<0.0001	0.003	0.085	10	25
	MW01S	31/10/2019	0.57	915	6.35	-195.1	19.9	656.5	288	<1	<0.02	<1000	288	70	8.58	9.34	75	100	864	0.2	4.27	10.6	20	<0.02	<0.01	10,600	78	10.5	9.45	45	<10	270	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.004	<0.005	50	70
	MW01S	30/01/2020	0.5	626	6.46	-160.7	24.5	346.5	449	<1	0.01	<1000	449	1100	13.8	14.8	111	172	1360	0.2	3.32	13	27	0.01	<0.01	13,000	150	8.15	8.04	73	<20	388	0.003	<0.0001	<0.001	0.001	<0.001	<0.0001	0.002	<0.005	<10	<10
	MW01S	23/07/2020	2.27	1226	6.29	16.6	17.6	781	314	<1	<0.05	<1000	314	<10	13.9	13	90	163	1220	0.2	3.13	8.1	24	<0.05	<0.01	8100	129	14.8	14.4	75	144	324	0.002	<0.0001	<0.001	0.004	<0.001	<0.0001	0.004	<0.005	22	10
	MW01S	28/10/2020	0.16	917	6.44	-79.3	19.9	596.05	270	<1	0.05	<1000	270	10	9.71	11.5	81	153	1040	0.3	8.33	5.9	24	0.05	<0.01	6,000	91	11.7	11.2	72	<20	301	0.003	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	<0.005	<1	<1
MW03D	MW03D	26/06/2018	-	-	-	-	-	-	4	<1	0.02	<1000	4	30	23.3	20.4	5	727	2470	<0.1	6.56	0.1	44	0.02	<0.01	100	1	0.04	0.02	380	130	194	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	<0.005	43	<1
	MW03D	26/06/2018	-	2328	5.54	-96.1	21.4	1375	5	<1	0.03	<1000	5	40	24	20.3	5	748	2430	<0.1	8.32	0.3	44	0.03	<0.01	300	2	0.04	0.02	377	135	194	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	<0.005	47	<1
	MW03D	17/10/2018	1.08	2155	5.68	-132.7	22.6	-	77	<1	0.03	<1000	77	100	22.2	21.2	18	614	2210	0.1	2.4	0.3	33	0.03	<0.01	300	<1	0.02	<0.01	404	162	181	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	0.008	<1	480
	MW03D	18/01/2019	-	1783	5.24	-85.3	20.2	1123	12	<1	0.04	<1000	12	40	22.4	21.1	6	664	2390	<0.1	2.84	0.1	38	0.04	<0.01	100	<1	0.03	0.01	407	163	171	0.003	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	<0.005	4	1
	MW03D	23/04/2019	1.54	43	4.8	-76.3	22.9	-	9	<1	<0.01	<1000	9	20	23.2	21.6	6	701	2380	<0.1	3.48	<0.1	39	<0.01	<0.01	<100	<1	0.02	0.02	416	154	176	0.003	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.006	<1	19
	MW03D	31/10/2019	2.16	1481	6.17	120.7	19.2	1105	82	<1	0.06	<1000	82	<10	16	14.3	15	419	1560	0.1	5.74	0.4	23	0.06	<0.01	500	<1	0.06	0.02	268	124	132	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.002	0.891	8	13
	MW03D	30/01/2020	0.16	1783	5.24	-85.3	20.2	1123	50	<1	<0.01	<1000	50	<10	11.8	10.9	11	284	1250	0.1	3.75	0.3	13	<0.01	<0.01	300	<1	0.03	<0.01	214	133	81	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	0.458	<1	<1
	MW03D	24/04/2020	0.88	2171	5.02	131.7	21.9	1502	8	<1	<0.01	<1000	8	40	21.2	21.5	5	651	2270	<0.1	2.43	0.3	40	<0.01	<0.01	300	<1	0.04	0.01	413	129	177	0.004	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.048	<1	1
	MW03D	23/07/2020	0.88	1004	5.82	-28.1	19.4	616	44	<1	0.02	<1000	44	400	10.8	10.7	7	247	1110	0.1	0.48	0.6	10	0.02	<0.01	600	<1	0.13	0.01	220	144	59	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.031	<1	170
	MW03D	28/10/2020	0.33	2238	5.3	22.7	21.3	1326	<1	<1	0.18	<1000	<1	20	22.4	21.1	6	683	2410	<0.1	2.97	<0.1	41	0.18	<0.01	200	<1	<0.01	0.02	401	151	184	0.003	<0.0001	<0.001	<0.001	0.002	<0.0001	0.001	0.056	<1	3
MW03S	MW03S	26/06/2018	-	585	6.11	-84.5	19.4	375.5	1	<1	21.6	<1000	1	20	5.77	5.07	3	124	643	<0.1	6.45	2.3	10	21.6	<0.01	23,900	2	0.02	0.02	93	34	49	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.007	1	<1
	MW03S	17/10/2018	2.71	1063	4.63	-101.6	24.2	-	2	<1	17.6	<1000	2	80	7.92	8.79	6	252	971	<0.1	5.2	3.6	19	17.6	<0.01	21,200	2	0.07	<0.01	158	37	93	<0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	0.002	0.025	<10	<10
	MW03S	18/01/2019	-	1122	4.53	-62.9	21	665	<1	<1	12.2	<1000	<1	60	11.8	13.4	6	365	1220	<0.1	6.3	4.5	21	12.2	<0.01	16,700	1	0.04	<0.01	262	33	101	<0.001	<0.0001	<0.001	0.003	<0.001	<0.0001	0.003	0.013	1	<1
	MW03S	23/04/2019	8.1	37.7	4.91	-87.1	18.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW03S	31/10/2019	4.44	801	4.63	191.2	18	598	<1	<1	11.6	<1000	<1	10	7.26	7.48	5	231	835	<0.1	1.49	2.4	17	11.6	<0.01	14,000	2	0.23	0.01	133	36	82	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.003	0.095	10	30
	MW03S	30/01/2020	0.9	1122	4.53	-62.9	21	665	2	<1	11.7	<1000	2	20	5.9	6.8	3	185	784	<0.1	7.08	9	11	11.7	<0.01	20,700	2	0.48	<0.01	131	31	53	<0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	0.003	0.027	1	<10
	MW03S	23/07/2020	5.8	440.6	5.13	-56.1	18.2	278.9	3	<1	6.2	<1000	3	20	4.12	4.2	3	105	490	<0.1	0.96	1	7	6.2	<0.01	7200	<1	0.08	<0.01	80	53	36	<0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.001	0.016	1	4600
	MW03S	28/10/2020	5.22	592	4.65	51.1	19.8	363	<1	<1	8.74	<1000	<1	<10	5.51	5.97	3	163	646	<0.1	4	1.7	12	8.74	<0.01	10,400	2	<0.05	0.01	110	44	57	<0.001	<0.0001	<0.001	<0.001	0.013	<0.0001	0.001	0.111	<1	<1
MW04D	MW04D	26/06/2018	-	4600	6.48	-97.1	20.1	2756	34	<1	0.02	<1000	34	70	48	41.2	27	1370	5010	0.2	7.61	0.7	78	0.02	<0.01	700	4	0.34	<0.01	767	418	389	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.006	0.028	290	15
	MW04D	17/10/2018	1.25	4554	6.01	-174	22.1	-	54	<1	0.08	<1000	54	1720	45.1	44.8	32	1290	4860	0.3	0.38	1.8	72	0.08	<0.01	1900	2	0.11	<0.01	855	367	376	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.005	0.006	530	21
	MW04D	18/01/2019	-	5444	5.67	-94.5	20.5	3272	37	<1	0.03	<1000	37	390	66.2	62.3	44	2100	6970	0.2	3.1	0.5	137	0.03	<0.01	500	3	0.12	<0.01	1120	301	674	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.005	0.006	<1	<1
	MW04D	23/04/2019	0.02	6429	4.87	-75.7	23.2	-	20	<1	0.02	<1000	20	70	67.5	62.8	38	2150	6930	0.2	3.66	0.4	136	0.02	<0.01	400	3	0.16	<0.01	1140	311	655	0.002	<0.0001	0.008	<0.001	<0.001	<0.0001	0.003	0.029	<1	<1
	MW04D	31/10/2019	1.62	1089	5.66	164.6	18.4	707.85	7	<1	15.4	<1000	7	10	8.61	9.05	4	219	1020	<0.1	2.5	4.8	5	15.4	<0.01	20,200	<1	0.4	0.01	194	110	30	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.001	0.667	<10	20
	MW04D	30/01/2020	0.49	5444	5.67	-94.5	20.5	3272	12	<1	0.11	<1000	12	80	70.3	63.4	44	2270	6680	0.1	5.2	0.4	140	0.11	<0.01	500	3	0.02	<0.01	1140	291	686	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	0.013	<1	<1
	MW04D	24/04/2020	6	6633	5.44	74.9	22.8	4498	17	<1	<0.01	<1000	17	60	69.5	65.1	40	2220	6930	0.1	3.29	0.2	142	<0.01	<0.01	200	3	0.04	<0.01	1180	315	685	0.002	<0.0001	0.041	0.002	<0.001	<0.0001	0.002	0.032	4	<1
	MW04D	23/07/2020	2.4	3798	5.26	-70	19	2359	2	<1	13.3	<1000	2	430	38.6	38.5	22	1180	4480	<0.1	0.17	2.4	72	13.3	<0.01	15,700	2	0.06	<0.01	722	254	351	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	0.125	1	4
	MW04D	28/10/2020	3.34	5675	5.58	5	21.2	3371	11	<1	0.02	<1000	11	100	58.3	55.3	38	1810	6110	0.1	2.58	0.2	120	0.02	<0.01	200	3	<0.01	<0.01	1000	336	589	0.002	<0.0001	<0.001	<0.001	0.002	<0.0001	0.002	0.03	<1	<1
MW04S	MW04S	26/06/2018	-	1590	5.96	-78.4	21.1	946	10	<1	6.82	<1000	10	90	17	14.2	6	307	1730	0.1	8.89	1.8	10	6.77	0.05	8600	<1	0.11	<0.01	302	393	56	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.005	0.013	2100	<10
	MW04S	17/10/2018	2.59	1537	5.85	-150.1	21.3	-	6	<1	16.6	<1000	6	480	12	13.2	2	258	1400	<0.1	4.8	4.1	6	16.5	0.13	20,700	<1	0.29	0.03	290	221	30	<0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	0.002	0.036	1100	1400
	MW04S	18/01/2019	-	1269	4.45	-73.7	21.9	742.5	<1	<1	24.4	<1000	<1	80	10.8	11.6	2	249	1300	<0.1	3.5	5.5	6	24.4	0.02	29,900	<1	0.06	0.02	253	182	30	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.022	<10	30
	MW04S	23/04/2019	0.03	1336	5.13	-92.7	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW04S	31/10/2019	2.42	6690	4.38	200.9	18.9	4953	<1	<1	0.15	<1000	<1	120	64.8	63	35	2080	6570	0.1	1.44	0.3	141	0.15	<0.01	400	3	0.04	<0.01	1140	297	668	<0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	0.003	0.047	21	14
	MW04S	30/01/2020	3.54	1269	4.45	-73.7	21.9	742.5	4	<1	14.4	<1000	4	120	9.07	8.91	2	225	1060	<0.1	0.89	15.5	4	14.4	<0.01	29,900	<1	1.22	<0.01	195	127	21	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.001	0.14	<10	<10
	MW04S	24/04/2020	4.03	1067	5.41	94.6	22.6	728	10	<1	7.95	<1000	10	160	9.36	9.39	4	223	1050	0.1	0.16	12.1	6	7.92	0.03	20,000	<1	1.34	<0.01	200	138	35	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.002	0.291	13,000	1000
	MW04S	23/07/2020	2.44	475.9	5.99	-109.8	17.2	305.8	50	<1	9.84	<1000	50	30	4.36	4.69	12	78	524	<0.1	3.62	1.6	8	9.84	<0.01	11,400	<1	0.12	<0.01	79	56	63	<0.001	<0.0001	<0.001	0.005	<0.001	<0.0001	0.002	0.68	<1	2200
	MW04S	28/10/2020	5.68	824	5.64	1.5	21.8	484	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW05D	MW05D	27/06/2018	-	13740	7.04	-60.7	20.8	8245	62	<1	0.02	<1000	62	290	164	139	164	5460	14700	0.2	8.16	1.3	448	0.02	<0.01	1300	14	1	<0.01	2150	401	2250	0.004	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.005	0.315	1100	480
	MW05D	16/10/2018	1.74	15170	6.13	-159.9	21.4	-	50	<1	0.07	<1000	50	280	198	170	199	6610	17300	0.2	7.4	1.6	537	0.07	<0.01	1700	4	1.08	<0.01	2670	487	2710	0.003	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.008	0.646	<10	<10
	MW05D	18/01/2019	-	17330	5.95	-71.7	19.8	10590	45	<1	0.09	<1000	45	380	207	193	234	6890	19500	0.1	3.41	0.7	626	0.06	0.03	800	4	0.08	<0.01	2990	564	3160	0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	0.01	0.056	55	<1
	MW05D	23/04/2019	1.28	17550	4.88	-79.5	22.5	-	53	<1	0.08	<1000	53	270	207	194	210	6870	19300	0.1	3.07	1.1	637	0.08	<0.01	1200	3	0.41	<0.01	3020	567	3150	<0.002	<0.0002	<0.002	<0.002	<0.002	<0.0001	0.01	0.185	<1	<1
	MW05D	23/07/2019	-	-	-	-	-	-	34	<1	1.86	<1000	34	20	218	203	252	7240	20300	0.1	3.66	0.6	660	1.86	<0.01	2500	4	0.01	<0.01	3120	633	3350	<0.001	0.0001	<0.001	0.004	<0.001	<0.0001	0.013	0.071	25	89

			Field						Inorganics																																Microbiological	
			Dissolved Oxygen (Filtered)	EC (field)	pH (Field)	Redox Potential	Temp (Field)	TDS (Field)	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (Carbonate as CaCO3)	Nitrite + Nitrate as N	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Anions Total	Cations Total	Calcium (Filtered)	Chloride	Electrical conductivity *(lab)	Fluoride	Ionic Balance	Kjeldahl Nitrogen Total	Magnesium (Filtered)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Potassium (Filtered)	Phosphorus	Reactive Phosphorus as P	Sodium (Filtered)	Sulfate as SO4 - Turbidimetric (Filtered)	Hardness as CaCO3 (Filtered)	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Lead (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Zinc (Filtered)	E. Coli	Enterococci
			mg/L	uS/cm	pH_Units	mV	oC	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	meq/L	meq/L	mg/L	mg/L	uS/cm	mg/L	%	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cfu/100 mL	cfu/100mL
LOR									1	1	0.01	1000	1	10	0.01	0.01	1	1	1	0.1	0.01	0.1	1	0.01	0.01	100	1	0.01	0.01	1	1	1	0.001	0.0001	0.001	0.001	0.001	0.0001	0.001	0.005	1	1
ANZG 2018 Fresh Water (95%)														900										7.2										0.0002		0.0014	0.0034	0.0006	0.011	0.008		
ANZECC 2000 Irrigation Long Term Trigger Values					6-8.5															1						5000		0.05					0.1	0.01	0.1	0.2	2	0.002	0.2	2		
DOH 2014																		250		15														0.02		20	0.1	0.01	0.2	3		
Location Code	Well Code	Sampled Date																																								
MW05D	MW05D	31/10/2019	1.16	18,770	6.05	32.4	17.9	12,201	42	<1	0.37	<1000	42	250	238	202	228	7920	20,500	0.1	8.19	0.6	674	0.35	0.02	1000	<5	0.07	<0.01	3100	644	3340	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.0001	0.014	0.042	36	41
	MW05D	30/01/2020	1.8	17329	5.95	-71.7	19.8	10587	39	<1	0.54	<1000	39	180	222	212	274	7380	20,800	<0.1	2.24	0.6	694	0.53	0.01	1100	4	0.01	<0.01	3240	603	3540	<0.001	0.0002	<0.001	0.002	<0.001	<0.0001	0.012	0.021	1	<1
	MW05D	24/04/2020	4.12	21,210	5.77	83.6	26.3	3442	38	<1	0.02	<1000	38	240	218	206	254	7260	20,300	<0.1	2.77	1.5	676	0.01	0.01	1500	4	0.18	<0.1	3160	578	3420	<0.001	0.0001	<0.001	0.003	<0.001	<0.0001	0.011	0.122	2	30
	MW05D	23/07/2020	2.05	7306	6.31	-15.2	18.4	4604	216	<1	2.33	<1000	216	60	114	113	140	3520	11,300	0.2	0.72	2.6	321	2.29	0.04	4900	6	0.14	0.03	1830	502	1670	0.001	0.0002	<0.001	0.008	<0.001	<0.0001	0.021	0.011	59	680
	MW05D	28/10/2020	4.74	18,810	5.93	-50.8	21.8	1045	41	<1	0.02	<1000	41	120	202	206	282	6650	20,100	<0.1	0.94	0.6	690	0.02	<0.01	600	4	0.03	<0.01	3100	652	3540	0.002	0.0001	<0.001	<0.001	<0.001	<0.0001	0.011	0.12	<1	3
MW05S	MW05S	27/06/2018	-	16,400	7.42	-57.3	19.5	10660	277	<1	57.2	<1000	277	1730	194	182	84	5850	17,800	1.6	3.24	11.6	416	57.1	0.11	68,800	7	0.43	0.01	3290	1120	1920	0.002	<0.0001	<0.001	0.001	<0.001	<0.0001	0.002	<0.005	15000	2400
	MW05S	16/10/2018	2.86	14,240	6.65	-146	20.4	-	174	<1	133	<1000	174	830	214	189	96	6610	19,500	0.9	6.13	14.7	395	132	0.85	148,000	2	0.14	<0.01	3490	1150	1870	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.005	0.133	70	30
	MW05S	18/01/2019	-	14,140	6.72	-68.6	21	8431	281	<1	183	<1000	281	840	136	142	64	3720	13,600	1.7	1.94	32.2	238	182	0.75	215,000	1	0.05	<0.01	2740	1250	1140	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.003	0.005	1	22
	MW05S	23/04/2019	3.6	12,940	5.8	-70.2	24.2	-	379	<1	11.3	<1000	379	80	131	137	49	3470	13,700	2.2	2.26	30.9	207	10.8	0.53	42,200	<1	0.04	<0.01	2700	1220	975	0.001	<0.0001	<0.001	0.004	<0.001	<0.0001	0.003	0.007	<1	30
	MW05S	23/07/2019	-	-	-	-	-	-	344	<1	139	<1000	344	100	168	170	88	4760	16,600	1.4	0.48	3.7	324	139	0.29	143,000	1	0.07	<0.01	3190	1300	1550	0.001	<0.0001	<0.001	0.004	<0.001	<0.0001	0.005	0.04	130	140
	MW05S	31/10/2019	1.96	14,690	6.6	-0.8	18	1031	336	<1	102	<1000	336	30	217	219	107	6580	19,600	1.2	0.5	28	512	101	0.78	130,000	<5	0.52	<0.01	3950	1190	2380	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.0001	<0.005	<0.025	40	30
	MW05S	30/01/2020	3.86	14136	6.72	-68.6	21	8431	301	<1	190	<1000	301	10	151	148	72	4260	14,000	2.1	0.87	36	245	190	0.4	226,000	<1	0.27	0.02	2860	1180	1190	0.001	<0.0001	<0.001	0.005	<0.001	<0.0001	0.004	0.007	1	<10
	MW05S	23/04/2020	1.79	17,560	6.39	40.7	23.3	1785	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW05S	23/07/2020	1.4	10,070	6.13	-57.6	17.2	6507	390	<1	148	<1000	390	560	134	120	57	3770	14,000	1.5	5.3	24.6	204	148	0.04	173,000	1	0.03	0.02	2320	957	982	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.004	0.007	1	170
	MW05S	28/10/2020	4.64	13,320	6.81	-53.7	20	8101	255	<1	129	<1000	255	450	162	138	76	4930	17,100	1	7.94	16.2	260	129	0.16	145,000	<1	0.06	<0.01	2600	863	1260	0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	0.003	0.006	<10	<10
MW06D	MW06D	26/06/2018	-	696	5.85	-129.3	20.9	412.5	54	<1	0.01	<1000	54	210	7.28	6.67	10	220	759	<0.1	4.42	1.8	14	0.01	<0.01	1800	4	0.23	0.05	113	<10	83	<0.001	<0.0001	0.017	<0.001	<0.001	<0.0001	<0.001	<0.005	190	30
	MW06D	16/10/2018	1.27	814	5.81	-186.5	21.3	-	58	<1	0.02	<1000	58	250	8.59	8.07	11	256	816	<0.1	3.11	1.8	17	0.02	<0.01	1800	3	0.08	0.04	139	10	97	0.001	<0.0001	0.017	<0.001	<0.001	<0.0001	<0.001	0.051	<1	<1
	MW06D	18/01/2019	-	875	5.5	-119.3	19.8	533.5	65	<1	0.02	<1000	65	290	9.41	8.68	13	284	942	<0.1	4.06	2	20	0.02	<0.01	2000	3	0.07	0.04	145	5	115	0.001	<0.0001	0.016	<0.001	<0.001	<0.0001	<0.001	<0.005	<1	<1
	MW06D	23/04/2019	1.39	807	5.62	-100.4	18.5	-	68	<1	0.02	<1000	68	370	9.06	8.81	12	264	877	<0.1	1.36	2	18	0.02	<0.01	2000	3	0.08	0.04	153	12	104	0.001	<0.0001	0.015	<0.001	<0.001	<0.0001	<0.001	0.024	<1	<1
	MW06D	23/07/2019	-	-	-	-	-	-	59	<1	0.02	<1000	59	220	8.78	8.49	13	265	897	<0.1	1.66	1.9	19	0.02	<0.01	1900	4	0.07	0.06	142	6	111	0.001	<0.0001	0.019	<0.001	<0.001	<0.0001	0.001	0.019	6	32
	MW06D	31/10/2019	1.08	1448	5.88	-103.2	18	1086	67	<1	0.03	<1000	67	340	9	8.37	11	268	894	<0.1	3.66	2.2	19	0.03	<0.01	2200	3	0.14	0.05	142	5	106	0.001	<0.0001	0.014	<0.001	<0.001	<0.0001	<0.001	0.01	15	56
	MW06D	30/01/2020	0.27	875	5.5	-119.3	19.8	533.5	56	<1	0.02	<1000	56	330	10	9.11	15	315	957	<0.1	4.69	2	20	0.02	<0.01	2000	4	0.05	0.05	152	<1	120	0.002	<0.0001	0.017	<0.001	<0.001	<0.0001	<0.001	0.01	<1	<1
	MW06D	24/04/2020	0.67	876	5.34	-60.7	20.5	624	53	<1	0.02	<1000	53	360	9	8.98	13	275	909	<0.1	0.11	2	20	0.02	<0.01	2000	3	0.07	0.04	152	9	115	0.001	<0.0001	0.016	<0.001	<0.001	<0.0001	<0.001	0.02	<1	<1
	MW06D	23/07/2020	1.2	855	5.61	-9.6	20	516	63	<1	0.02	<1000	63	270	9.13	8.25	13	279	915	<0.1	5.04	1.7	18	0.02	<0.01	1700	3	0.08	0.04	139	<1	106	0.001	<0.0001	0.013	<0.001	<0.001	<0.0001	<0.001	0.008	410	180
	MW06D	28/10/2020	0.4	802	5.74	4.7	20.1	489.5	49	<1	0.02	<1000	49	310	8.09	8.3	14	250	847	<0.1	1.28	1.5	18	0.02	<0.01	1,500	3	0.05	0.05	139	9	109	0.001	<0.0001	0.018	<0.001	<0.001	<0.0001	<0.001	0.023	<1	<1
MW07D	MW07D	28/06/2018	-	5849	7.86	-147.7	20.1	3548	176	<1	<0.01	<1000	176	440	56.7	52.4	175	1770	6330	0.2	3.95	<0.5	202	<0.01	<0.01	<500	8	0.48	<0.01	617	157	1270	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.008	1600	480
	MW07D	17/10/2018	0.99	14890	6.77	-170	22.3	-	177	<1	0.21	<1000	177	340	173	170	517	5340	15500	0.3	0.82	0.8	802	0.21	<0.01	1000	5	0.21	<0.01	1790	886	4590	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.006	<1	10
	MW07D	18/01/2019	-	9057	6.91	-78.4	19.6	5544	189	<1	0.01	<1000	189	410	102	95	323	3230	10200	0.2	3.37	0.9	418	0.01	<0.01	900	5	0.72	<0.01	1020	324	2530	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	<0.005	1	<1
	MW07D	23/04/2019	3.28	8324	5.89	-93.4	21	-	209	<1	<0.01	<1000	209	300	89.8	84.5	237	2830	8810	0.2	3.02	0.3	348	<0.01	<0.01	300	4	0.1	<0.01	1010	277	2020	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.011	1	57
	MW07D	23/07/2019	-	-	-	-	-	-	162	<1	<0.01	<1000	162	200	214	207	551	5950	18400	0.4	1.65	0.4	1020	<0.01	<0.01	400	5	0.05	<0.01	2190	2050	5580	<0.001	<0.0001	<0.001	0.003	<0.001	<0.0001	0.004	0.022	200	140
	MW07D	31/10/2019	2.17	8716	6.77	7.9	17.4	6578	230	<1	<0.01	<1000	230	310	236	228	487	6920	18,900	0.4	1.68	1.3	1220	<0.01	<0.01	1300	<5	0.6	<0.01	2380	1740	6240	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.0001	<0.005	<0.025	80	90
	MW07D	30/01/2020	0.48	9057	6.91	-78.4	19.6	5544	190	<1	0.03	<1000	190	330	106	112	348	3360	10,500	0.2	2.61	0.9	476	0.03	<0.01	900	5	0.24	<0.01	1270	367	2830	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.014	<1	<1
	MW07D	24/04/2020	0.8	8434	6.74	-27.8	19.9	6078	190	<1	<0.01	<1000	190	360	97.4	95.5	291	3100	8960	0.2	1.03	0.5	390	<0.01	<0.01	500	5	0.09	<0.01	1120	298	2330	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.014	3	66
	MW07D	23/07/2020	1.05	12,190	6.47	2.5	19.5	7486	200	<1	0.11	<1000	200	20	157	146	395	4400	14,200	0.4	3.64	0.7	672	0.11	<0.01	800	4	0.1	0.01	1630	1390	3750	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	0.002	0.027	1	13
	MW07D	28/10/2020	2.59	10564	6.82	-28.1	19.7	6462	148	<1	<0.01	<1000	148	290	119	130	394	3590	12,100	0.2	4.26	0.4	596	<0.01	<0.01	400	5	0.01	<0.01	1400	716	3440	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.021	<1	<1
MW07S	MW07S	28/06/2018	-	811	7.41	-75.9	19	20450	168	<1	1.3	<1000	168	570	504	479	976	14100	36,900	0.7	2.53	1.2	3070	1.26	0.04	2500	9	0.09	<0.01	4080	4940	15100	<0.005	<0.0005	<0.005	0.009	<0.005	<0.0001	0.023	0.032	130	160
	MW07S	17/10/2018	1.83	34410	6.55	-156.8	22.3	22366.5	202	<1	0.59	<1000	202	550	479	497	1110	12300	35,700	0.7	1.84	1.4	2860	0.57	0.02	2000	2	0.03	0.03	4740	6150	14500	0.002	<0.0001	<0.001	0.008	<0.001	<0.0001	0.008	0.031	2	<1
	MW07S	18/01/2019	-	15950	6.67	-68.3	20.5	9608	236	<1	0.02	<1000	236	500	451	424	974	12700	36,400	0.5	3.12	0.5	2570	0.02	<0.01	500	4	0.07	<0.01	3760	4230	13000	<0.005	<0.0005	<0.005	0.005	<0.005	<0.0001	0.022	0.033	1	27
	MW07S	23/04/2019	0.02	20650	5.42	-97.7	21.8	-	186	<1	0.01	<1000	186	230	269	246	511	8210	22,800	0.5	4.44	0.3	1340	0.01	<0.01	300	3	0.06	0.01	2540	1630	6790	0.006	<0.0002	<0.002	<0.002	<0.002	<0.0001	0.018	0.033	9700	680
	MW07S	23/07/2019	-	-	-	-	-	-	408	<1	<0.01	<1000	408	130	21.4	21.9	116	332	1920	0.5	1.1	5.4	84	<0.01	<0.01	5400	2	0.7	0.49	210	187	636	0.01	<0.0001	0.002	0.002	<0.001	<0.0001	0.009	2.52	130	150
	MW07S	31/10/2019	1.6	7223	6.56	0.2	17.6	5473	419	<1	0.02	<1000	419	240	91.4	87.1	228	2110	7920	0.5	2.44	10.4	404	<0.01	0.02	10,400	1	1.48	0.28	975	1130	2230	0.007	<0.0001	<0.001	0.001	<0.001	<0.0001	0.01	0.238	290	80
	MW07S	30/01/2020	0.95	15945	6.67	-68.3	20.5	9608	246	<1	<0.01	<1000	246	330	193	185	479	5810	17,000	0.5	1.99	3	968	<0.01	<0.01	3000	3	0.25	0.06	1880	1160	5180	0.006	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.011	0.16	1	<1
	MW07S	24/04/2020	1.47	16,030	6.68	14.9	20.4	1434	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW07S	23/07/2020	0.9	877	6.29	27.3	18.1	555.5	338	<1	<0.01	<1000	338	50	11.6	11.1	95	134	995	0.4	1.95	3.1	36	<0.01	<0.01	3100	4	1.5	0.9	76	49	385	0.008	<0.0001	0.001	0.002	<0.001	<0.0001	0.004	1.66	1	28
	MW07S	28/10/2020	1.49	4475	6.77	-22	17.8	2849	275	<1	0.15	<1000	275	70	53.1	53.3	149	1240	5240	0.4	0.23	2.4	222	0.15	<0.01	2,600	2	0.64	0.49	634	606	1290	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.006	0.082	<1	13
MW08D	MW08D	27/06/2018	-	4847	7.36	-159.1	20.8	2899	115	<1	<0.01	<1000	115	380	48.7	45.4	72	1460	5240	0.2	3.53	0.8	137	<0.01	<0.01	800	6	0.03	0.02	698	251	744	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	29	14
	MW08D	17/10/2018	1.09	5016	6.81	-175.5	23.7	-	122	<1	0.28	<1000	122	240	53	46.6	74	1560	5710	0.3	6.38	1.1	128	0.28	<0.01	1400	4	0.15	0.03	742	313	712	0.007	<0.0001	0.001	0.002	<0.001	<0.0001	0.001	0.021	<10	30
	MW08D	18/01/2019	-	4183	6.75	-119.2	19.8	2541	110	<1	<0.01	<1000	110	280	41.6	44.8	65	1220	4660	0.1	3.73	0.7	125	<0.01	<0.01	700	2	0.03	0.02	718	239	677	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	1	<1
	MW08D	23/04/2019	1.22	4312	5.93	-115.4	20.8	-	162	<1	<0.01	<1000	162	340	44.8	44.4	61	1290	4720	0.1	0.46	0.8	121	<0.01	<0.01	800	2	0.1	0.03	721	250	650	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<1	<1
	MW08D	23/07/2019	-	-	-	-	-	-	94	<1	0.19	<1000	94	<10	27.9	27.6	36	808	2940	0.1	0.56	0.8	67	0.19	<0.01	1000	2	0.04	0.02	465	155	366	<0.001	<0.0001	0.001	0.002	<0.001	<0.0001	0.001	0.021	27	4
	MW08D	31/10/2019	1.34	3800	7.06	-124.1	18	2840	121	<1	<0.01	<1000	121	330	38.9	38.3	51	1140	3960	0.1	0.83	0.9	106	<0.01	<0.01	900	2	0.05	0.03	620	209	564	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.005	16	29
	MW08D	30/01/2020	1.2	4183	6.75	-119.2	19.8	2541	97	<1	<0.01	<1000	97	210	27.1	27.1	37	790	2900	0.1	0.02	1	64	<0.01	<0.01	1000	2	0.04	0.03	458	138	356	<0.001	<0.0001	0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<1	<1
	MW08D	24/04/2020	0.75	4445	6.6	-88	20.7	3153	114	<1	<0.01	<1000	114	330	43.3	46.3	70	1290	4770	0.1	3.4	0.9	128	<0.01	<0.01	900	2	0.04	0.03	741	221	702	<0.001	<0.0001	0.001	<0.001	<0.001	<0.0001	<0.001	0.008	1	<1
	MW08D	23/07/2020	3.8	2739	6.73	1.4	20	1661	103	<1	0.24	<1000	103	40	29.9	28.2	39	857	3140	0.1	2.92	0.7	71	0.24	<0.01	900	2	0.07	0.05	469	178	390	<0.001	<0.0001	0.001	0.001	<0.001	<0.0001	0.001	0.01	1	7
	MW08D	28/10/2020	0.66	4555	6.99	-16.2	20.4	2745	95	<1	<0.01	<1000	95	340	47.7	46.8	79	1420	5100	<0.1	1	0.7	133	<0.01	<0.01	700	2	0.04	0.02	732	277	745	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.009	<1	<1
MW08S	MW08S	27/06/2018	-	6637	7.33	-95.1	20.2	4026	112	<1	<0.01	<1000	112	220	77.6	72.4	78	2170	7440	0.5	3.46	1.2	255	<0.01	<0.01	1200	5	0.07	<0.01	1090	680	1240	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	16000	90
	MW08S	17/10/2018	1.99	3130	6.7	-168.2	21.6	-	104	<1	0.16	<1000	104	330	32.9	32.4	21	929	3450	0.8	0.77	11.1	67	0.16	<0.01	11,300	<1	1.29	<0.01	595	224	328	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	80	90
	MW08S	18/01/2019	-	3672	6.86	-76.6	24.8	2024	116	<1	0.01	<1000	116	110	32.9	33.1	22	925	3580	0.8	0.25	1	69	0.01	<0.01	1000	<1	0.09	<0.01	605	217	339	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	1	<10
	MW08S	23/04/2019	0.02	3800	6.31	-94.3	23.5	-	137	<1	0.34	<1000	137	240	54.2	54.9	51	1460	5690	0.5	0.71	0.8	169	0.34	<0.01	1100	3	0.09	0.02	883	492	823	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.007	<1	<1
	MW08S	23/07/2019	-	-	-	-	-	-	136	<1	0.04	<1000	136	170	74.8	70.4	81	2090	7330	0.4	3	0.7	230	0.04	<0.01	700	2	0.02	<0.01	1090	630	1150	<0.001	<0.0001	<0.001	0.004	<0.001	<0.0001	0.001	0.037	190	140
	MW08S	31/10/2019	1.2	5388	7.2	-79.1	17.6	4069	126	<1	0.02	<1000	126	140	49.1	47.7	39	1350	4890	0.4	1.44	2.2	136	0.02	<0.01	2200	1	0.06	<0.01	794	408	657	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.012	530	230
	MW08S	30/01/2020	1.6	3672	6.86	-76.6	24.8	2024	185	<1	0.01	<1000	185	180	61.9	59.3	65	1710	5850	0.4	2.14	2.1	178	0.01	<0.01	2100	2	0.21	<0.01	950	477	895	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	1	<10
	MW08S	24/04/2020	2.8	6852	6.78	-10.5	21.3	4797	141	<1	0.02	<1000	141	230	80.1	72.2	79	2290	7980	0.4	5.14	2.5	232	0.02	<0.01	2500	2	0.2	<0.01	1130	608	1150	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.012	10	10
	MW08S	23/07/2020	0.93	3998	6.8	-1.4	20	2598.7	150	<1	0.01	<1000	150	200	71.4	71.8	85	1990	7550	0.3	0.26	0.6	228	0.01	<0.01	600	2	0.03	<0.01	1120	589	1150	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	<0.001	0.011	<1	13
	MW08S	28/10/2020	3.57	5253	7.2	-19.3	19.8	3201	96	<1	0.05	<1000	96	80	59	58	66	1650	5940	0.3	0.84	2.1	177	0.05	<0.01	2,200	1	0.27	<0.01	922	505	894	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<10	<10
MW09D	MW09D	27/06/2018	-	2273	6.24	-180.1	20.5	1365	82	<1	<0.01	<1000	82	610	23.8	20.5	41	784	2480	<0.1	7.43	2.6	52	<0.01	<0.01	2600	7	0.1	0.02	321	<50	316	0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	<0.005	260	12
	MW09D	16/10/2018	0.5	2031	6.06	-175	21.4	-	152	<1	<0.01	<1000	152	690	21	19.2	37	637	1970	<0.1	4.46	2.2	47	<0.01	<0.01	2200	4	0.18	0.05	308	<20	286	0.002	<0.0001	0.005	<0.001	<0.001	<0.0001	<0.001	0.041	<10	<10
	MW09D	18/01/2019	-	2373	5.92	-138.9	19.9	1447	79	<1	0.01	<1000	79	570	23	23.5	46	758	2580	<0.1	1.21	2.4	54	0.01	<0.01	2400	4	0.06	0.02	384	1	337	0.004	<0.0001	0.003	<0.001	<0.001	<0.0001	<0.001	<0.005	<10	<10
	MW09D	23/04/2019	0.04	2331	5.3	-117.5	20.3	-	99	<1	0.01	<1000	99	710	24.5	24.3	44	798	2550	<0.1	0.45	2.3	55	0.01	<0.01	2300	4	0.07	0.04	401	<20	336	0.003	<0.0001	0.005	<0.001	<0.001	<0.0001	<0.001	0.006	<1	<1
	MW09D	23/07/2019	-	-	-	-	-	-	76	<1	0.19	<1000	76	<10	23.5	23.6	43	760	2500	<0.1	0.28	1.3	55	0.19	<0.01	1500	4	0.03	0.01	388	27	334	0.003	<0.0001	0.005	0.002	<0.001	<0.0001	0.002	0.034	240	190
	MW09D	31/10/2019	2.2	2537	6.23	-109.3	19.3	1892	116	<1	0.01	<1000	116	720	25.3	23.7	51	816	2490	<0.1	3.24	2.1	55	0.01	<0.01	2100	4	0.1	0.05	381	<25	354	0.002	<0.0001	0.005	<0.001	<0.001	<0.0001	<0.001	0.013	43	60
	MW09D	30/01/2020	0.4	2373	5.92	-138.9	19.9	1446.5	73	<1	0.02	<1000	73	530	22.5	22	37	746	2380	<0.1	1.14	2.2	48	0.02	<0.01	2200	4	0.02	0.02	370	<1	290	0.002	<0.0001	0.004	<0.001	<0.001	<0.0001	<0.001	0.006	<1	<1
	MW09D	24/04/2020	0.52	2390	5.58	-91.1	20.1	1716	82	<1	0.01	<1000	82	660	23.5	24.2	48	774	2660	<0.1	1.47	2.1	53	0.01	<0.01	2100	4	0.06	0.02	398	<30	338	0.002	<0.0001	0.003	<0.001	<0.001	<0.0001	<0.001	0.014	<1	<1
	MW09D	23/07/2020	1.42	2088	5.93	22.9	19.8	1276	68	<1	0.14	<1000	68	30	22.3	21	33	732	2370	<0.1	3.08	1.4	48	0.14	<0.01	1500	4	0.06	0.03	351	14	280	0.002	<0.0001	0.003	0.004	<0.001	<0.0001	<0.001	0.022	1	210
	MW09D	28/10/2020	0.58	2431	5.93	-11.4	20.6	1458	127	<1	<0.01	<1000	127	660	24.8	24.3	51	791	2680	<0.1	1.05	2	56	<0.01	<0.01	2,000	5	0.04	0.03	392	<10	358	0.002	<0.0001	0.003	<0.001	<0.001	<0.0001	<0.001	0.016	<1	<1
MW09M	MW09M	27/06/2018	-	6396	6.91	-108.4	20	3889	227	<1	<0.01	<1000	227	340	66.7	64.8	47	1910	7080	0.3	1.46	1.3	180	<0.01	<0.01	1300	10	0.05	0.02	1090	400	858	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	220	36
	MW09M	16/10/2018	2.79	6186	6.42	-168	20.5	-	264	<1	<0.01	<1000	264	790	68.7	65.3	48	1950	7790	0.3	2.53	1.7	175	<0.01	<0.01	1700	8	0.04	0.02	1110	403	840	0.003	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.005	<1	<1
	MW09M	18/01/2019	-	6630	6.72	-116.5	22.3	3850	250	<1	<0.01	<1000	250	480	65	71.8	47	1820	7100	0.3	4.98	1.6	176	<0.01	<0.01	1600	5	0.05	<0.01	1260	414	842	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	1	<1
	MW09M	23/04/2019	3.42	6875	5.59	-99.4	23.1	-	294	<1	<0.01	<1000	294	490	70.1	67.1	41	1970	6900	0.3	2.19	2	160	<0.01	<0.01	2000	4	0.11	<0.01	1190	415	761	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.008	<1	<1
	MW09M	23/07/2019	-	-	-	-	-	-	288	<1	0.11	<1000	288	10	63.3	60	36	1720	6190	0.3	2.71	1.4	135	0.11	<0.01	1500	4	0.03	0.01	1080	435	646	0.002	<0.0001	0.001	<0.001	<0.001	<0.0001	0.003	0.022	36	22
	MW09M	31/10/2019	2.09	6111	6.52	-64	18.1	4570	304	<1	0.01	<1000	304	230	68.6	67.6	41	1920	6650	0.2	0.67	1.4	167	0.01	<0.01	1400	4	0.12	<0.01	1190	400	790	0.003	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	0.01	62	87
	MW09M	30/01/2020	1.2	6630	6.72	-116.2	22.3	3850	297	<1	0.02	<1000	297	180	66.5	61.6	38	1850	6250	0.3	3.81	1.9	132	0.02	<0.01	1900	5	0.14	<0.01	1120	402	638	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	0.009	<10	<10
	MW09M	24/04/2020	3.95	6284	6.44	-27.5	22.5	4290	272	<1	<0.01	<1000	272	320	68.8	65.4	43	1950	7040	0.3	2.54	1.6	154	<0.01	<0.01	1600	4	0.05	<0.01	1160	401	742	0.002	<0.0001	<0.001	0.002	<0.001	<0.0001	0.002	0.03	<1	24
	MW09M	23/07/2020	0.82	5410	6.22	22.5	19.9	3300	335	<1	<0.01	<1000	335	860	57.5	56.7	38	1480	6060	0.3	0.69	3.1	126	<0.01	<0.01	3100	4	0.17	0.05	1020	436	614	0.003	<0.0001	0.003	<0.001	<0.001	<0.0001	0.003	0.009	9	3200
	MW09M	28/10/2020	0.44	5446	6.53	-2.1	19.3	3366	223	<1	0.06	<1000	223	240	61.1	60.1	44	1680	6260	0.2	0.82	1.9	142	0.04	0.02	2,000	4	0.09	0.06	1060	444	695	0.005	<0.0001	0.001	<0.001	<0.001	<0.0001	0.002	0.027	<1	100
	MW09S	27/06/2018	-	341.4	6.54	-62.2	15.7	228.3	31	<1	7.12	<1000	31	20	2.82	4.39	20	60	404	0.4	21.8	5.1	10	7.12	<0.01	12,200	7	1.25	1	55	<100	91	0.001	<0.0001	0.003	0.008	<0.001	<0.0001	0.003	0.009	4200	1600

			Field						Inorganics																																Microbiological	
			Dissolved Oxygen (Filtered)	EC (field)	pH (Field)	Redox Potential	Temp (Field)	TDS (Field)	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (Carbonate as CaCO3)	Nitrite + Nitrate as N	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Anions Total	Cations Total	Calcium (Filtered)	Chloride	Electrical conductivity *(lab)	Fluoride	Ionic Balance	Kjeldahl Nitrogen Total	Magnesium (Filtered)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Potassium (Filtered)	Phosphorus	Reactive Phosphorus as P	Sodium (Filtered)	Sulfate as SO4 - Turbidimetric (Filtered)	Hardness as CaCO3 (Filtered)	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Lead (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Zinc (Filtered)	E. Coli	Enterococci
			mg/L	uS/cm	pH_Units	mV	oC	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	meq/L	meq/L	mg/L	mg/L	uS/cm	mg/L	%	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cfu/100 mL	cfu/100mL
LOR									1	1	0.01	1000	1	10	0.01	0.01	1	1	1	0.1	0.01	0.1	1	0.01	0.01	100	1	0.01	0.01	1	1	1	0.001	0.0001	0.001	0.001	0.001	0.0001	0.001	0.005	1	1
ANZG 2018 Fresh Water (95%)														900										7.2										0.0002		0.0014	0.0034	0.0006	0.011	0.008		
ANZECC 2000 Irrigation Long Term Trigger Values					6-8.5															1						5000		0.05					0.1	0.01	0.1	0.2	2	0.002	0.2	2		
DOH 2014																		250		15														0.02		20	0.1	0.01	0.2	3		
Location Code	Well Code	Sampled Date																																								
	MW09S	16/10/2018	2.07	529	6.18	-143	27.8	-	85	<1	<0.01	<1000	85	40	3.36	4.54	8	59	406	0.2	14.9	2.8	11	<0.01	<0.01	2800	4	1.12	1.06	72	<20	65	0.001	<0.0001	0.004	<0.001	<0.001	<0.0001	0.002	0.19	8	5
MW09S	MW09S	23/07/2019	-	-	-	-	-	-	45	<1	0.04	<1000	45	<10	3.35	4.06	7	78	415	0.3	9.54	4.3	9	0.04	<0.01	4300	2	0.62	0.5	67	12	54	0.001	<0.0001	0.002	0.009	<0.001	<0.0001	0.003	0.118	90	110
MW09S	MW09S	31/10/2019	1.57	696	6.94	-76.4	17.9	593.5	172	<1	0.02	<1000	172	110	6.79	7.14	6	91	645	0.2	2.47	5.7	18	0.02	<0.01	5700	2	1.86	0.04	122	38	89	0.001	<0.0001	0.006	<0.001	0.002	<0.0001	0.002	<0.005	60	32
	MW09S	23/07/2020	4.37	377.4	5.71	44.9	16.6	247	33	<1	5.1	<1000	33	60	3.13	3.7	15	67	359	0.2	8.34	8	9	5.09	0.01	13,100	10	0.59	0.44	45	28	74	<0.001	<0.0001	0.002	0.015	<0.001	<0.0001	0.005	0.006	12	<1
	MW09S	28/10/2020	1.35	463.2	6.63	-6.5	20.3	280	126	<1	0.01	<1000	126	140	5.31	5.83	10	93	548	0.2	4.7	4	18	0.01	<0.01	4,000	6	0.78	0.35	85	8	99	0.001	<0.0001	0.004	0.001	0.002	<0.0001	0.002	<0.005	1	<1
MW10D	MW10D	25/06/2018	-	2728	7.83	-119.6	22.8	1557	219	<1	<0.01	<1000	219	310	27.1	25.5	103	777	2680	0.2	2.89	1	80	<0.01	<0.01	1000	8	2.52	0.03	313	37	587	<0.001	<0.0001	<0.001	0.008	<0.001	<0.0001	0.002	<0.005	23	10
	MW10D	16/10/2018	1.23	3089	7.49	-180.5	20.2	-	202	<1	0.05	<1000	202	260	33.8	33.1	109	1000	3280	0.2	1.13	0.6	108	0.05	<0.01	600	4	1.52	0.02	429	77	717	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	10	<10
	MW10D	18/01/2019	-	3456	7.21	-72.4	21.7	2058	216	<1	0.05	<1000	216	210	34.1	35.9	126	996	3690	0.1	2.61	0.9	112	0.03	0.02	1000	5	2.82	<0.01	467	82	776	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	<0.005	1	<1
	MW10D	24/04/2019	0.33	2931	6.83	-91	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW10D	23/07/2019	-	-	-	-	-	-	258	<1	0.19	<1000	258	<10	29.7	29.4	99	845	3030	0.1	0.4	0.3	93	0.19	<0.01	500	4	0.06	0.03	385	33	630	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.016	23	17
	MW10D	31/10/2019	2.9	2782	7.63	35.6	18.5	2067	245	<1	0.07	<1000	245	10	29.5	28.2	91	850	2840	0.1	2.38	0.3	90	0.07	<0.01	400	3	0.17	0.03	371	32	598	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.022	25	79
	MW10D	30/01/2020	1.1	3456	7.21	-72.4	21.7	2057.5	224	<1	<0.01	<1000	224	160	28.7	28.4	107	835	2900	0.1	0.56	0.5	86	<0.01	<0.01	500	4	0.15	0.02	364	31	621	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.006	<10	30
	MW10D	24/04/2020	1.3	2626	7.07	-26.7	21.3	1840	223	<1	0.02	<1000	223	290	26.7	26.8	93	771	2790	0.1	0.16	3.2	85	0.02	<0.01	3200	4	11.1	0.02	347	26	582	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	30	<1
	MW10D	23/07/2020	2.89	2490	6.79	-65.4	19.2	1535	235	<1	0.24	<1000	235	20	27.7	27.4	95	793	2900	0.1	0.49	0.4	83	0.24	<0.01	600	4	0.11	0.03	362	30	579	<0.001	<0.0001	<0.001	0.002	<0.001	<0.0001	<0.001	0.007	1	3
	MW10D	28/10/2020	5.84	2575	7.47	-8	21.7	1513	199	<1	0.07	<1000	199	210	25.9	26.4	99	754	2760	<0.1	1.08	1.4	85	0.07	<0.01	1,500	4	6.3	0.04	331	30	597	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<10	<10
MW10S	MW10S	25/06/2018	-	2579	7.8	-142.1	21.4	1518	222	<1	0.01	<1000	222	240	27	25.8	82	779	2720	0.2	2.37	0.8	87	0.01	<0.01	800	6	3.02	0.04	331	31	563	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	1600	170
	MW10S	16/10/2018	2.36	20650	6.95	-160.2	20.9	-	296	<1	0.06	<1000	296	150	274	243	412	8230	22700	0.4	5.89	1.2	802	0.06	<0.01	1300	3	0.48	0.01	3600	1710	4330	0.008	<0.0002	<0.002	<0.002	<0.002	<0.0001	<0.002	0.061	1	2
	MW10S	18/01/2019	-	4570	7.28	-65.1	24.5	2546	253	<1	0.01	<1000	253	120	40.6	45	71	1120	4440	0.3	5.2	0.6	100	0.01	<0.01	600	2	0.55	0.08	764	190	589	0.002	<0.0001	0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	1	2
	MW10S	24/04/2019	2.21	2521	6.78	-96.5	19.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW10S	23/07/2019	-	-	-	-	-	-	228	<1	0.02	<1000	228	140	26.2	25.8	60	742	2670	0.2	0.74	0.8	77	0.02	<0.01	800	3	0.58	0.08	377	34	467	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.038	<1	<1
	MW10S	31/10/2019	2.4	2775	7.57	-34.3	18.2	2080	301	<1	0.02	<1000	301	40	30.2	29.5	67	797	2900	0.2	1.2	0.8	89	0.02	<0.01	800	2	0.67	0.07	431	81	534	0.004	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.024	11	42
	MW10S	30/01/2020	0.8	4570	7.28	-65.1	24.5	2546																																		
	MW10S	24/04/2020	1.27	2482	7.1	-39.6	20.6	1762	279	<1	0.02	<1000	279	250	27.1	25.8	66	745	2620	0.1	2.42	0.9	85	0.02	<0.01	900	3	0.48	0.07	356	26	515	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.028	2	<1
	MW10S	23/07/2020	1.4	2346	6.68	-54.4	19	1458	226	<1	0.02	<1000	226	200	26.1	25.5	66	744	2710	0.1	1.15	0.8	79	0.02	<0.01	800	3	1.47	0.04	360	30	490	<0.001	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.001	<0.005	1	14
	MW10S	28/10/2020	1.32	1810	7.18	-21.5	17.9	1155	192	<1	0.12	<1000	192	40	19.4	20.3	64	530	2080	0.1	2.41	0.5	64	0.12	<0.01	600	3	0.38	0.08	271	28	423	0.002	<0.0001	<0.001	<0.001	0.001	<0.0001	<0.001	0.03	<1	1
MW11D	MW11D	25/06/2018	-	929	5.87	-208.7	20.6	555.5	74	<1	0.03	<1000	74	860	11.3	8.81	17	319	1010	<0.1	12.4	3.2	23	0.03	<0.01	3200	6	0.12	0.08	136	40	137	<0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	<0.005	34	19
	MW11D	16/10/2018	0.74	940	5.75	-205.6	19.8	-	86	<1	0.04	<1000	86	790	10.5	9.78	15	307	988	<0.1	3.64	2.7	24	0.04	<0.01	2700	4	0.07	0.07	160	7	136	0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	0.014	<1	<1
	MW11D	18/01/2019	-	926	5.8	-136.3	19.8	566.5	88	<1	0.04	<1000	88	660	10.1	9.72	16	292	989	<0.1	1.99	3	25	0.04	<0.01	3000	5	0.05	0.05	155	6	143	<0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	<0.005	1500	450
	MW11D	23/04/2019	1.19	949	5.32	-203.9	20.7	-	90	<1	0.04	<1000	90	1030	10.3	9.37	12	293	1000	<0.1	4.56	11.4	24	0.04	<0.01	11,400	4	0.06	0.06	154	10	129	<0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	<0.005	<1	<1
	MW11D	23/07/2019	-	-	-	-	-	-	62	<1	0.05	<1000	62	920	10	10.1	16	306	1030	<0.1	0.18	3.6	25	0.05	<0.01	3600	5	0.06	0.06	163	8	143	0.001	<0.0001	0.003	<0.001	<0.001	<0.0001	<0.001	0.013	<1	<1
	MW11D	31/10/2019	0.98	1049	6.28	-147	19.6	1050	89	<1	0.05	<1000	89	1470	10.5	10.2	15	304	1040	<0.1	1.46	5.5	26	0.05	<0.01	5600	5	0.18	0.09	166	9	144	<0.001	<0.0001	0.001	<0.001	<0.001	<0.0001	<0.001	0.011	2	640
	MW11D	30/01/2020	0.9	926	5.8	-136.3	19.8	566.5	78	<1	0.04	<1000	78	1210	11.2	10.5	19	327	1080	<0.1	3.38	4	25	0.04	<0.01	4000	6	0.07	0.07	168	20	150	0.001	<0.0001	0.003	<0.001	<0.001	<0.0001	<0.001	0.005	<1	<1
	MW11D	24/04/2020	0.65	977	5.47	-81.9	20.4	695.5	74	<1	0.04	<1000	74	1780	10.4	9.84	15	311	1020	<0.1	3.04	4	23	0.04	<0.01	4000	6	0.06	0.05	162	10	132	<0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	0.008	12	<1
	MW11D	23/07/2020	1.03	906	5.62	-46.8	19.3	561	57	<1	0.03	<1000	57	1460	10.2	9.07	14	301	995	<0.1	5.7	4.3	20	0.03	<0.01	4300	8	0.06	0.05	150	26	117	<0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	<0.005	<1	1
	MW11D	28/10/2020	0.76	899	5.81	-12.6	19.8	550	52	<1	0.03	<1000	52	1380	9.28	9.26	16	279	962	<0.1	0.15	3.6	21	0.03	<0.01	3,600	8	0.08	0.07	150	18	126	<0.001	<0.0001	0.002	<0.001	0.008	<0.0001	<0.001	0.013	<1	4
MW11S	MW11S	25/06/2018	-	817	6.12	-173.8	18.9	1518	130	<1	0.36	<1000	130	1010	8.44	8.62	31	207	897	0.1	1.09	2.8	27	0.34	0.02	3200	18	0.66	0.66	101	<20	188	0.002	<0.0001	0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	17	<1
	MW11S	16/10/2018	0.98	888	5.10	-197.2	18.4	-	111	<1	2.09	<1000	111	780	9.58	9.63	35	255	941	<0.1	0.28	2.8	24	2.05	0.04	4900	10	0.59	0.6	130	8	186	0.002	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	0.015	<1	<1
	MW11S	18/01/2019	-	872	5.92	-130.2	21.7	511.5	174	<1	0.02	<1000	174	770	10	8.76	24	230	890	<0.1	6.74	2.7	24	0.02	<0.01	2700	11	0.29	0.26	122	3	159	0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	<0.005	22	3
	MW11S	23/04/2019	0.01	918	5.58	-148.9	22.3	-	102	<1	0.02	<1000	102	920	9.38	8.92	12	253	916	<0.1	2.53	2.8	26	0.02	<0.01	2800	7	0.1	0.16	138	10	137	<0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	<0.005	<1	<1
	MW11S	23/07/2019	-	-	-	-	-	-	114	<1	0.02	<1000	114	820	9.21	9.17	34	220	930	0.1	0.24	3.4	23	0.02	<0.01	3400	14	0.77	0.7	120	35	180	0.002	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	0.02	12	31
	MW11S	31/10/2019	1.63	1101	6.73	79.2	19	806	118	<1	5.68	<1000	118	550	12.1	10.8	27	294	1180	<0.1	5.62	6.3	24	5.67	0.01	12,000	40	2.02	1.7	148	68	166	0.004	<0.0001	0.001	<0.001	0.004	<0.0001	<0.001	0.044	22	86
	MW11S	30/01/2020	0.63	904	5.92	-132.6	21.9	528	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW11S	24/04/2020	2.48	948	5.82	-66.3	21.8	656.5	118	<1	0.02	<1000	118	1130	10	9.97	21	248	978	<0.1	0.25	3	36	0.02	<0.01	3000	17	0.62	0.62	127	32	201	<0.001	<0.0001	0.001	<0.001	<0.001	<0.0001	<0.001	0.009	6	1
	MW11S	23/07/2020	0.95	871	5.77	-71	17.7	555.5	116	<1	0.97	<1000	116	650	10.9	9.79	39	261	1020	<0.1	5.52	3.8	21	0.87	0.1	4,800	23	1.77	1.75	127	60	184	0.002	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	21	8
	MW11S	28/10/2020	1.56	1670	6.06	10.8	18.4	1051	105	<1	35.8	<1000	105	40	14.9	17.4	60	342	1900	<0.1	7.8	10.3	44	35.6	0.2	46,100	190	6.96	7.16	137	152	331	0.008	<0.0001	0.001	0.007	0.004	<0.0001	0.005	0.024	<1	5
MW12D	MW12D	25/06/2018	-	577	7.01	-72.2	23.5	324.5	154	<1	<0.01	<1000	154	260	4.93	5.83	57	57	578	0.3	8.33	1.2	15	<0.01	<0.01	1,200	9	0.02	<0.01	35	12	204	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	17	<1
	MW12D	16/10/2018	0.63	472.7	6.39	-178.2	22.3	-	117	<1	<0.01	<1000	117	280	4.4	5.12	51	42	467	0.4	7.56	1.3	11	<0.01	<0.01	1,300	9	0.02	<0.01	33	42	173	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.011	<1	<1
	MW12D	18/01/2019	-	615	6.31	-114.4	24.2	341	159	<1	<0.01	<1000	159	290	6.16	6.33	63	57	598	0.3	1.37	1.6	15	<0.01	<0.01	1,600	10	0.03	<0.01	39	66	219	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	3	2
	MW12D	24/04/2019	-	435.7	5.74	-113.2	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW12D	23/07/2019	-	-	-	-	-	-	131	<1	<0.01	<1000	131	300	5.52	5.37	51	43	534	0.3	1.35	1.8	12	<0.01	<0.01	1,800	14	0.02	<0.01	34	81	177	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.014	700	3400
	MW12D	31/10/2019	1.36	484.9	6.53	-69.1	20.1	347.8	157	<1	<0.01	<1000	157	440	5.25	4.96	50	38	469	0.3	2.83	2.1	11	<0.01	<0.01	2,100	10	0.08	0.07	30	50	170	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.013	160	520
	MW12D	30/01/2020	0.81	535	6.26	-154.7	25.4	291.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW12D	24/04/2020	0.57	551	5.74	-51	24.8	357.5	164	<1	<0.01	<1000	164	290	5.28	5.74	57	43	514	0.3	4.2	1.3	13	<0.01	<0.01	1,300	12	0.02	<0.01	35	38	196	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.013	<1	1
	MW12D	23/07/2020	1	455.5	6.08	-72.8	22.5	262.9	147	<1	<0.01	<1000	147	300	5.18	5.04	51	41	462	0.2	1.34	1.4	12	<0.01	<0.01	1,400	13	0.04	0.01	27	52	177	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	2	300
	MW12D	28/10/2020	0.62	346.2	6.38	-99.9	21.9	202.4	99	<1	<0.01	<1000	99	150	3.49	4.01	38	38	352	0.2	6.96	0.8	10	<0.01	<0.01	800	13	<0.01	<0.01	22	21	136	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.014	<1	<1
MW12S	MW12S	25/06/2018	-	771	7.36	-18	22	451	93	<1	0.31	<1000	93	30	7.43	7.49	76	78	722	<0.1	0.41	4.3	14	0.31	<0.01	4,600	1	0.41	<0.01	58	162	247	<0.001	<0.0001	<0.001	0.002	0.001	<0.0001	<0.001	0.006	120	<10
	MW12S	16/10/2018	2.9	418.3	6.37	-159.5	21.5	-	127	<1	1.17	<1000	127	30	4.28	4.39	59	28	410	0.2	1.24	0.8	8	1.15	0.02	2,000	2	0.03	<0.01	17	46	180	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.033	<1	<1
	MW12S	18/01/2019	-	952	6.5	-95.4	27.7	500.5	255	<1	<0.01	<1000	255	100	9.54	9.34	103	69	856	0.1	1.04	2.7	23	<0.01	<0.01	2,700	7	0.16	<0.01	49	120	352	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	10	<10
	MW12S	23/07/2019	-	-	-	-	-	-	195	<1	<0.01	<1000	195	20	7.07	7.68	97	44	611	0.1	4.08	6.2	13	<0.01	<0.01	6,200	1	0.52	<0.01	40	93	296	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	0.045	20	46
	MW12S	31/10/2019	1.66	617	6.36	-18.4	19.7	448.5	128	<1	0.02	<1000	128	30	5.72	4.69	50	37	506	0.1	9.93	11.1	12	0.02	<0.01	11,100	3	1.18	<0.01	26	102	174	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	260	700
	MW12S	30/01/2020	0.67	952	6.5	-65.4	27.7	500.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW13D	MW13D	26/06/2018	-	8137	7.71	-82.9	20.4	4895	187	<1	<0.01	<1000	187	480	86.8	87.7	211	2800	8840	0.1	0.5	0.7	286	<0.01	<0.01	700	21	0.15	<0.01	1220	196	1700	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	4	7
	MW13D	17/10/2018	0.8	8859	6.1	-188.8	20.3	-	211	<1	0.04	<1000	211	1120	98.6	98.1	359	3180	9810	<0.1	0.23	1.2	252	0.04	<0.01	1,200	12	0.13	<0.01	1360	223	1930	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.027	<1	51
	MW13D	18/01/2019	-	8162	6.93	-93.9	20.2	4939	196	<1	<0.01	<1000	196	620	87.6	83.6	228	2820	9020	<0.1	2.35	1	239	<0.01	<0.01	1,000	12	0.1	<0.01	1200	197	1550	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	1600	2400
	MW13D	24/04/2019	-	8006	6.49	-104.1	20.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW13D	23/07/2019	-	-	-	-	-	-	309	<1	6.27	<1000	309	20	21.1	22.8	149	372	2100	<0.1	4.01	2	73	6.27	<0.01	8,300	12	0.05	0.02	209	212	673	0.003	<0.0001	<0.001	0.004	<0.001	<0.0001	0.003	0.016	180	170
	MW13D	31/10/2019	1.11	8235	7.22	-72.5	19.3	6000	233	<1	0.23	<1000	233	480	86.9	83	180	2780	8490	<0.1	2.28	0.7	257	0.22	0.01	900	11	0.26	<0.01	1210	185	1510	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.033	61	760
	MW13D	30/01/2020	1.48	8183	6.93	-95.3	21.8	4791	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW13D	24/04/2020	0.71	8019	6.82	-32	20.5	5694	197	<1	<0.01	<1000	197	450	89.2	84.8	190	2890	8800	<0.1	2.54	0.5	251	<0.01	<0.01	500	12	0.12	<0.01	1250	182	1510	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.012	<1	<1
	MW13D	23/07/2020	1.42	2531	6.79	-16	20.3	1529	356	<1	5.55	<1000	356	450	52.8	55.5	191	1410	5660	<0.1	2.48	2	177	5.51	0.04	7,600	19	0.11	<0.01	710	283	1200	0.001	<0.0001	<0.001	0.003	<0.001	<0.0001	0.003	<0.005	<1	5
	MW13D	28/10/2020	0.2	7729	6.84	1.6	20.7	4626	144	<1	<0.01	<1000	144	430	84	84.6	216	2710	8580	<0.1	0.34	0.5	253	<0.01	<0.01	500	13	0.1	<0.01	1210	224	1580	<0.001	<0.0001	<0.001	<0.001	0.002	<0.0001	<0.001	0.033	290	4
MW13S	MW13S	25/06/2018	-	13790	7.36	-122.3	22.1	8019	675	<1	2.71	<1000	675	220	170	165	472	4990	15200	0.2	1.49	2.2	511	2.7	0.01	4,900	30	0.23	0.02	2260	740	3280	0.019	<0.0001	<0.001	0.02	<0.001	<0.0001	<0.001	0.008	9	<1
	MW13S	17/10/2018	3.54	9099	7.15	-142.3	19.5	-	704	<1	7.66	<1000	704	130	109	107	305	2860	10300	0.2	0.79	3.1	283	7.55	0.11	10,800	12	0.25	0.02	1570	676	1930	0.021	<0.0001	<0.001	0.002	<0.001	<0.0001	<0.001	0.183	<10	30
	MW13S	18/01/2019	-	10580	6.7	-90.7	24.8	5538	313	<1	1.56	<1000	313	930	98.3	95.4	336	3070	10000	0.1	1.51	1.8	237	1.48	0.08	3,400	15	0.14	<0.01	1350	262	1810	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	<0.005	10000	8000
	MW13S	24/04/2019	-	10600	6.25	-102.4	21.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW13S	23/07/2019	-	-	-	-	-	-	569	<1	8.28	<1000	569	40	95.9	89.1	262	2590	9830	0.2	3.68	2.9	249	8.27	0.01	11,200	12	0.08	0.02	1270	552	1680	0.016	<0.0001	<0.001	0.004	<0.001	<0.0001	0.002	0.031	31	89
	MW13S	31/10/2019	0.99	890	6.92	78	18.6	656.5	576	<1	2.42	<1000	576	350	95.4	88.7	262	2590	8950	0.1	3.6	11.5	229	2.31	0.11	13,900	11	2.65	0.03	1300	519	1600	0.002	<0.0001	<0.001	0.001	<0.001	<0.0001	0.001	0.008	430	430
	MW13S	30/01/2020	1.03	10580	6.7	-90.7	24.8	5538	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW13S	23/07/2020	2.65	4825	6.61	-20.6	19.6	2959	536	<1	9.21	<1000	536	40	67.7	72.6	247	1680	6940	0.2	3.49	2.3	190	9.18	0.03	11,500	11	0.1	0.01	1020	462	1400	0.004	<0.0001	<0.001	0.002	<0.001	<0.0001	0.001	0.006	1	7

Appendix E: Culvert survey data

Rev.	Description	Drawn	Date	Checked
A	Initial Issue	JCR	31/07/2018	TAV

NOT TO SCALE

The contents of this plan are current and correct as of the date stated within the revision panel. All consultants and persons wishing to utilise this data should satisfy themselves of this plans currency by contacting the McMullen Nolan Group.

Surveyor:- MTJ
Survey Date:- 18/07/2018
Precal/Cad:- WALIS

ISO 9001 Quality Management — AS/NZS 4801:2001 Occupational Health and Safety Management
FS 565311 OSH 591267

N

The boundaries shown on this plan were not re-established as part of this survey, therefore this plan does not guarantee their accuracy. Existing easements, encumbrance or interest are not depicted and a title search is recommended to obtain this information. Re-establishment of the cadastral boundaries is recommended for any proposed works on or near existing boundaries.

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Offices in: Broome, Bunbury, Kununurra, Newman, Port Hedland, Melbourne

MUNDIJONG
SURVEY LOCATIONS - (Sheet 1 of 5)
Culverts and Bridge Surveys

CLIENT:
STOCKLAND DEVELOPMENT PTY LTD

Project Mngr.	Trevor Veen	Datum	PCG94 / AHD

101097 - DE - 007 - A
(Job Number - Type - Plan Number - Revision)

Rev.	Description	Drawn	Date	Checked
A	Initial Issue	JCR	31/07/2018	TAV

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Surveyor:- MTJ
Survey Date:- 18/07/2018
Precal/Cad:- WALIS

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FS 565311 OSH 591267

N

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www.mngsurvey.com.au
ABN 90 009 363 311

MUNDIJONG
SURVEY LOCATIONS - (Sheet 2 of 5)
Culverts and Bridge Surveys

CLIENT:
STOCKLAND DEVELOPMENT PTY LTD

Project Mngr.	Trevor Veen	Datum	PCG94 / AHD

101097 - DE - 007 - A
Job Number / Type / Plan Number / Revision

Rev.	Description	Drawn	Date	Checked
A	Initial Issue	JCR	31/07/2018	TAV

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CLIENT:
STOCKLAND DEVELOPMENT PTY LTD

Project Mngr.	Trevor Veen	Datum	PCG94 / AHD

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SURVEY LOCATIONS - (Sheet 4 of 5)
Culverts and Bridge Surveys

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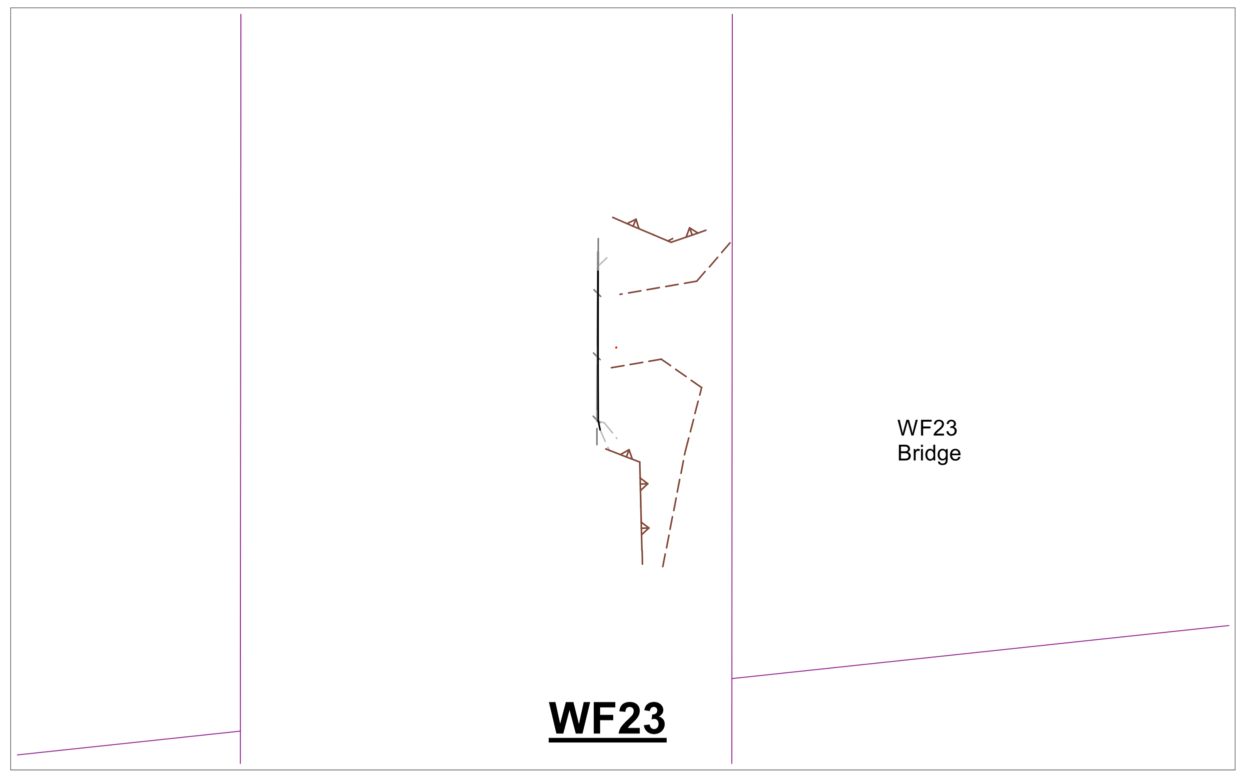
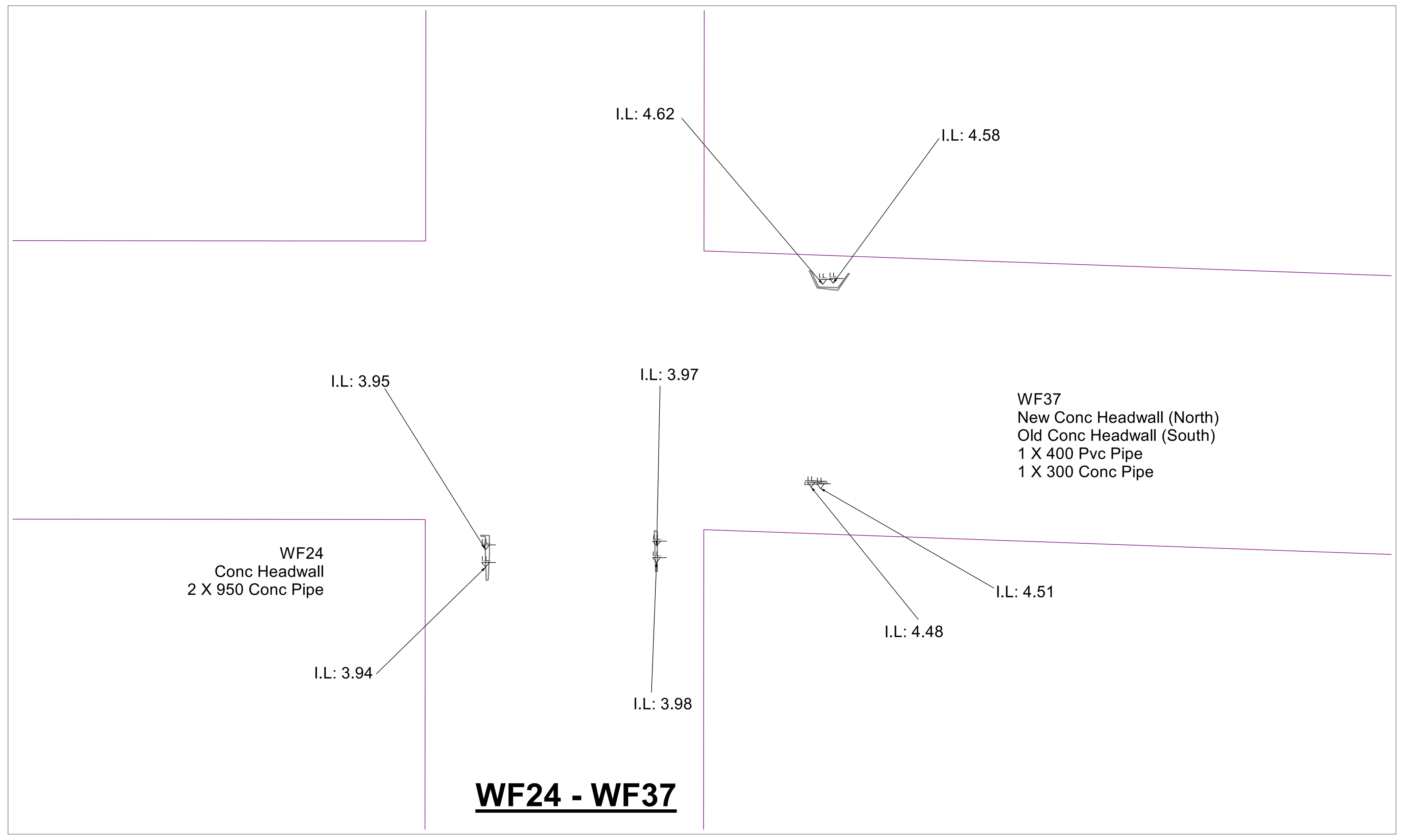
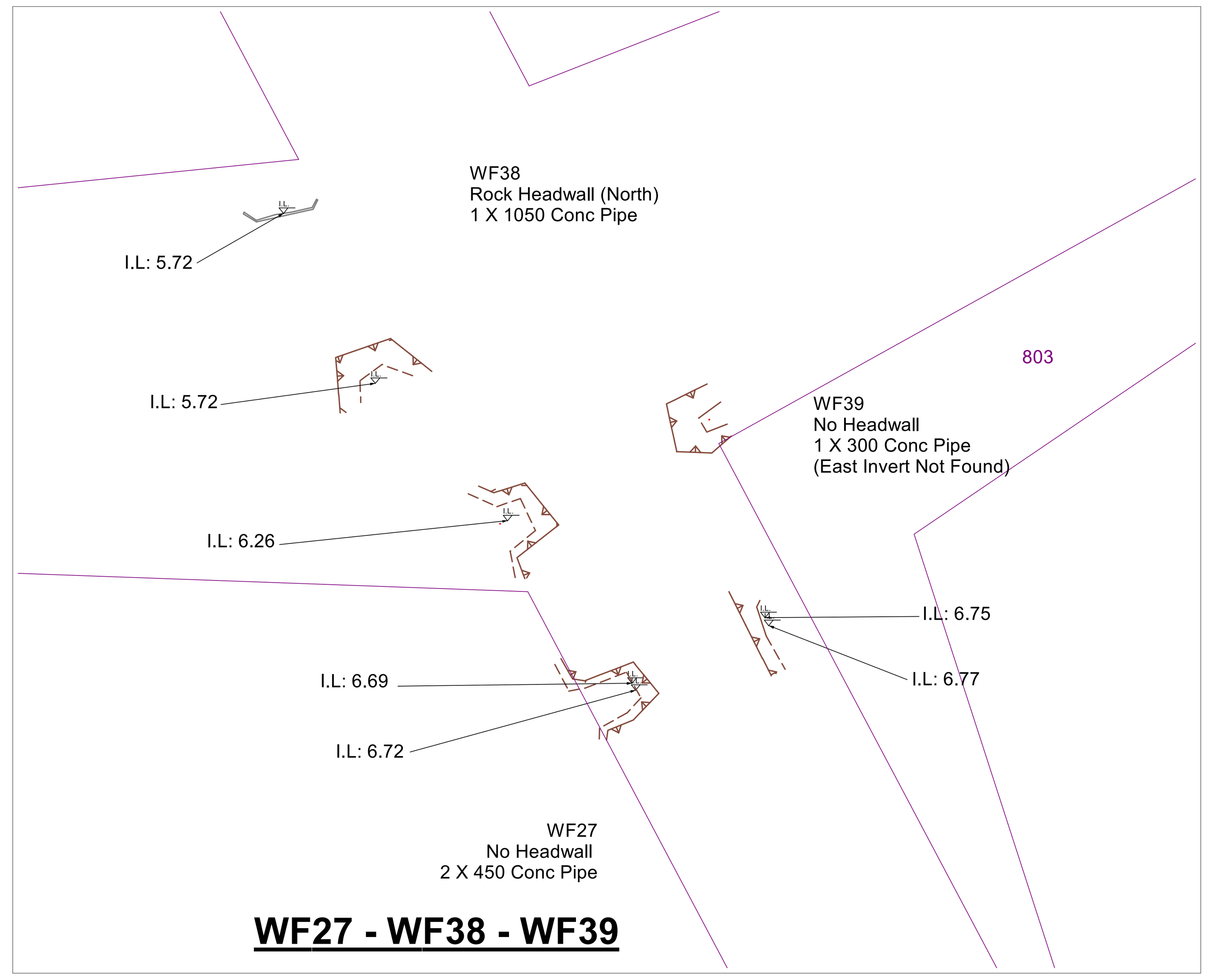
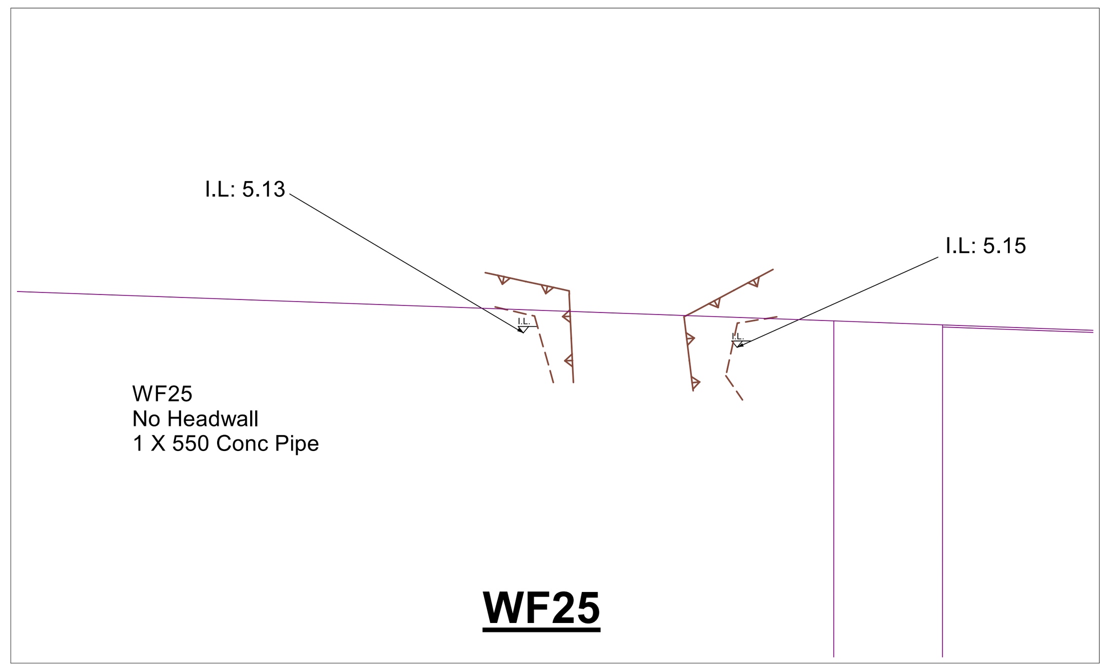
Project Mngr.	Trevor Veen	Datum	PCG94 / AHD

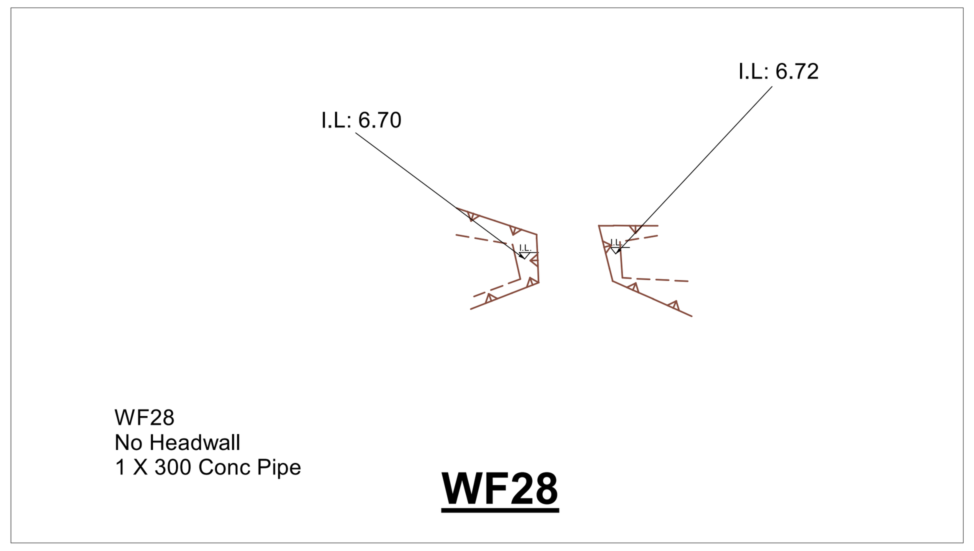
101097 - DE - 007 - A
Job Number / Type / Plan Number / Revision

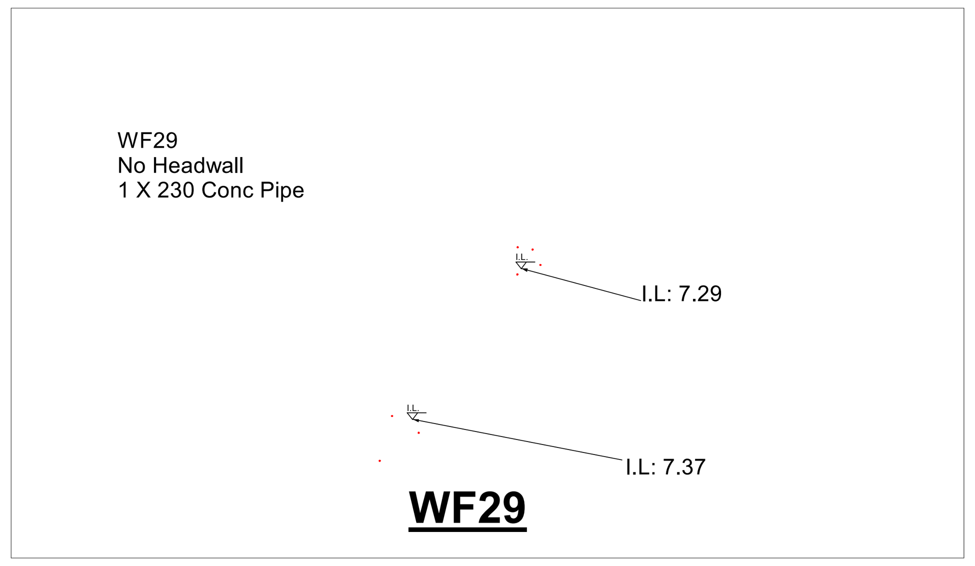


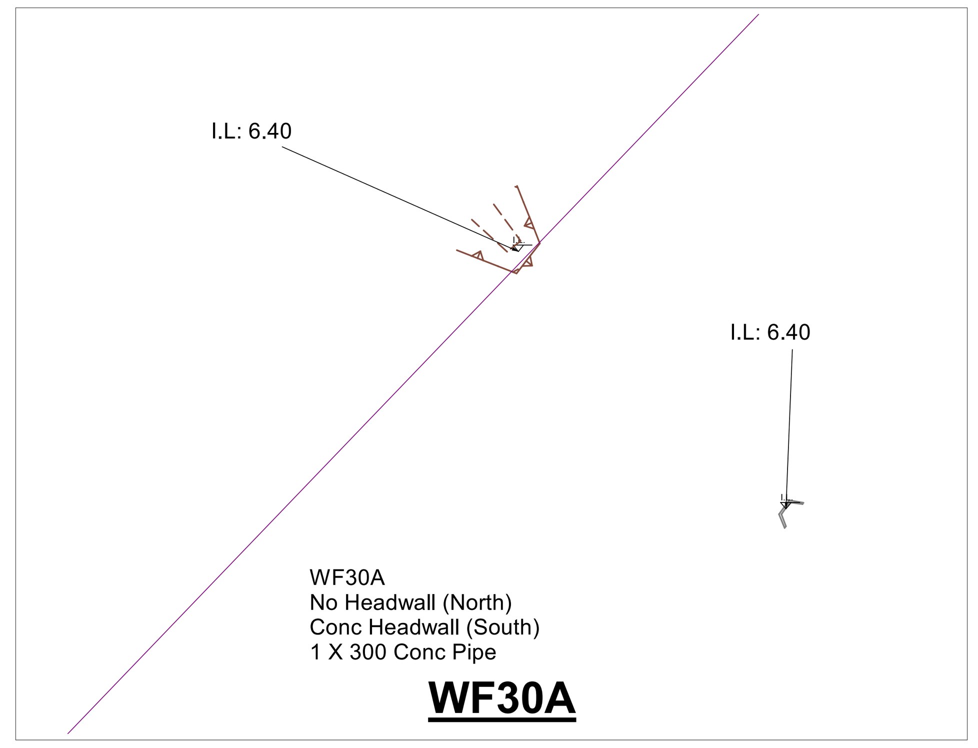


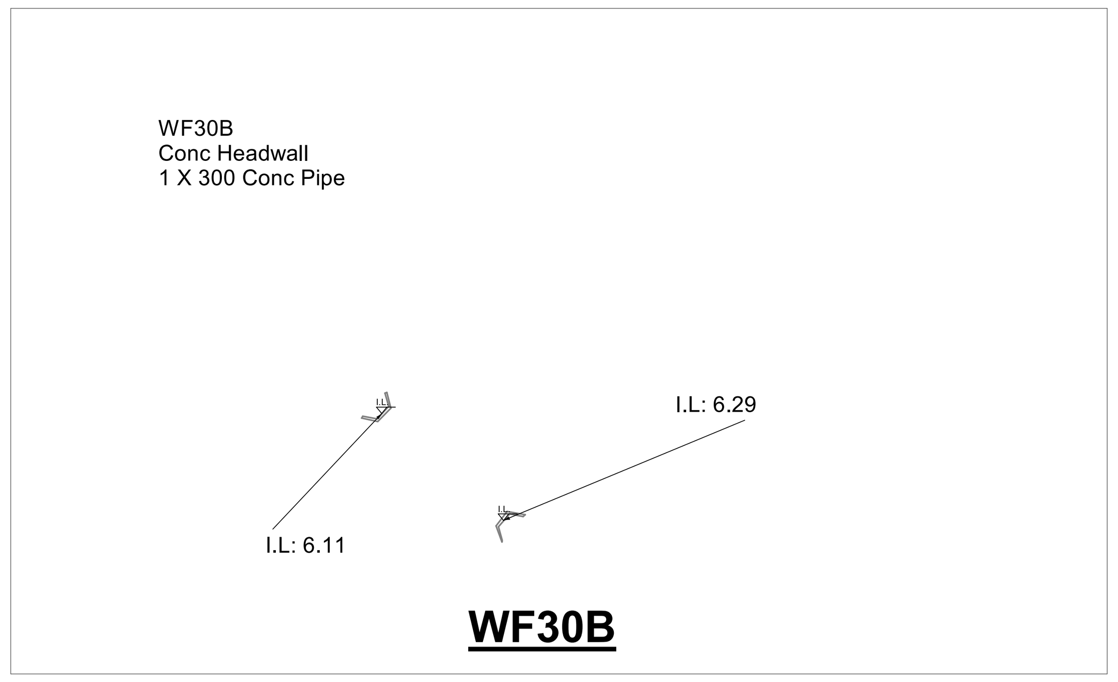


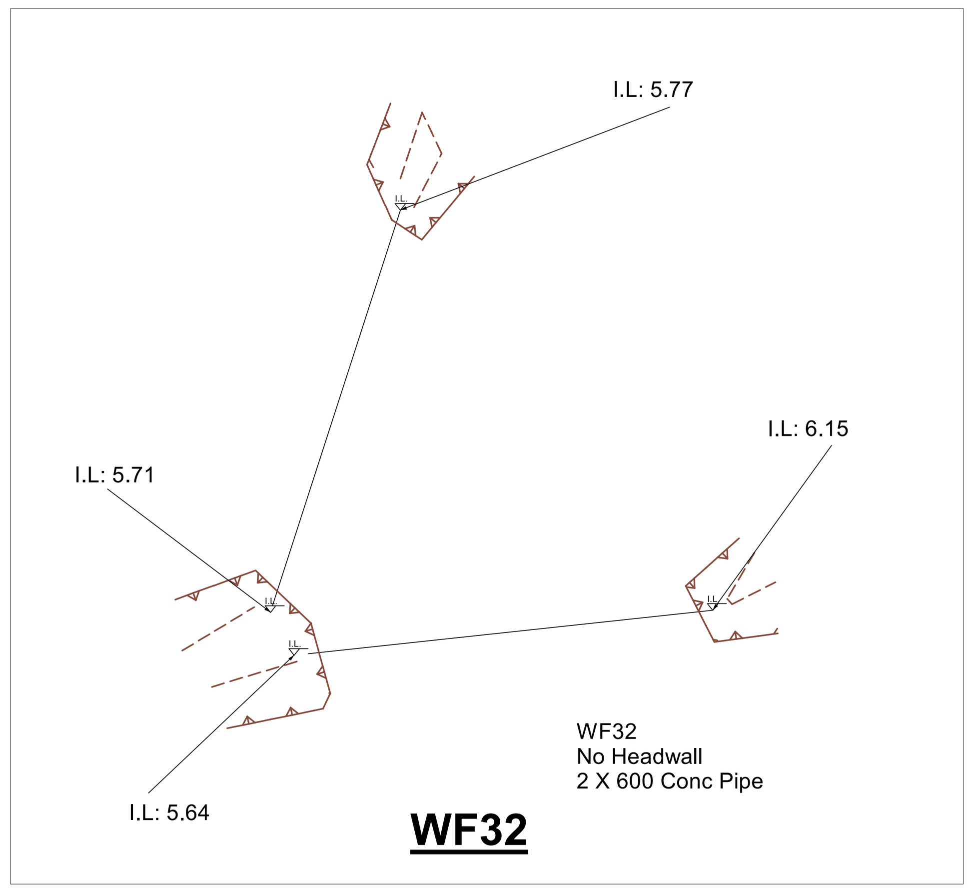


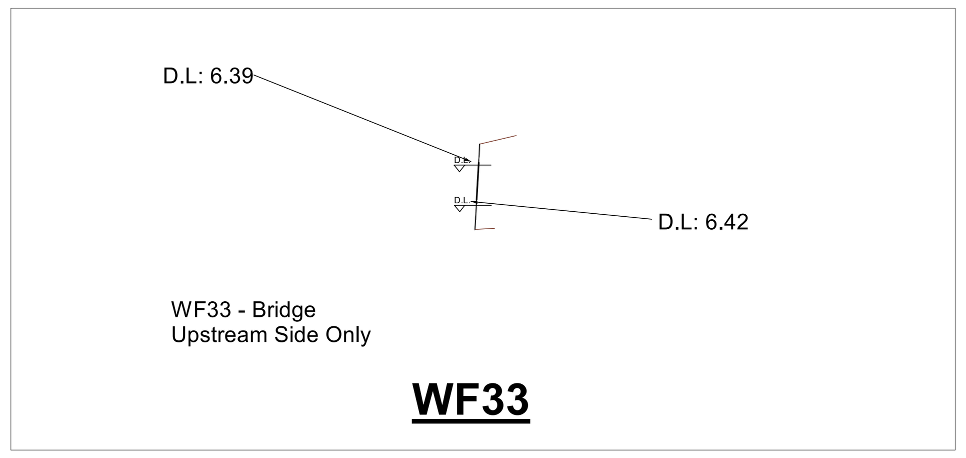


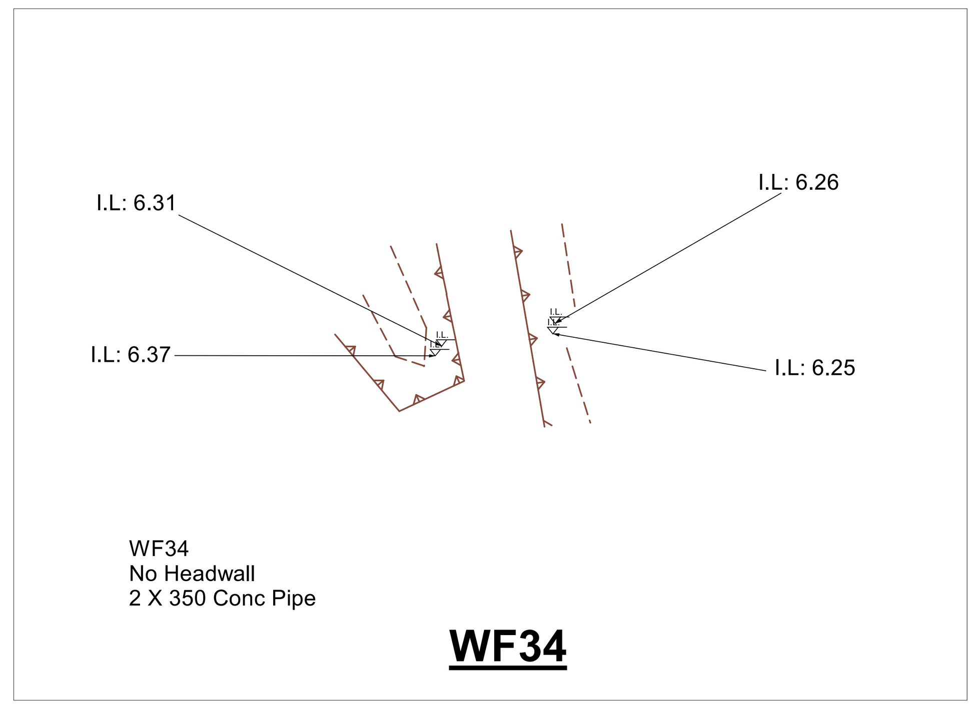


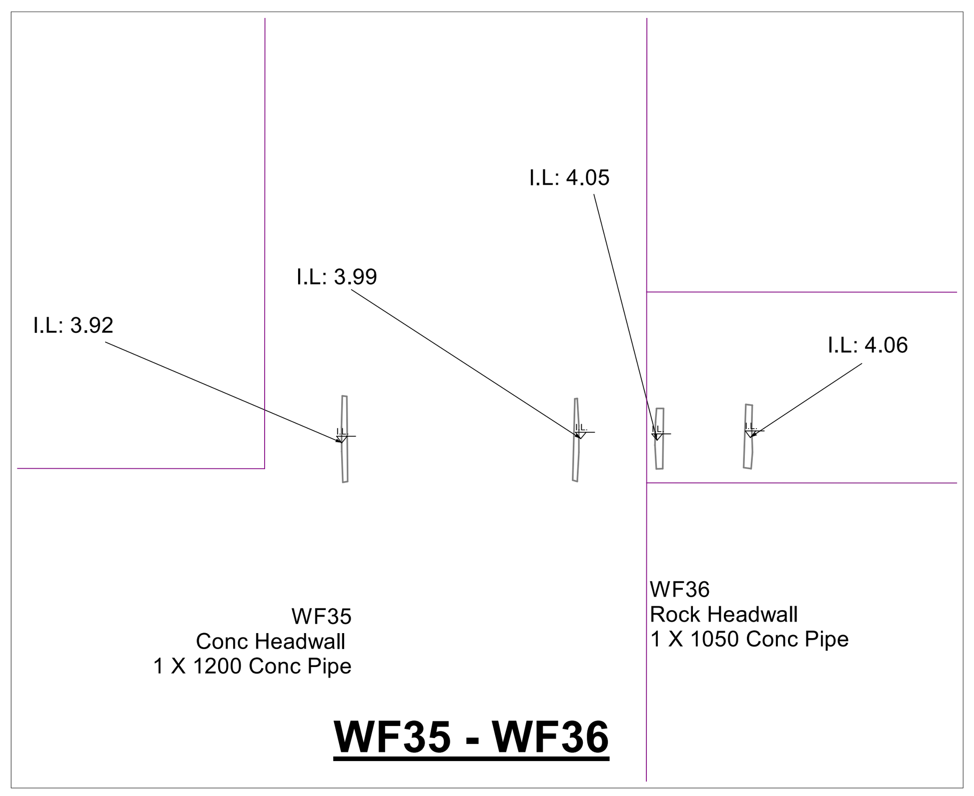


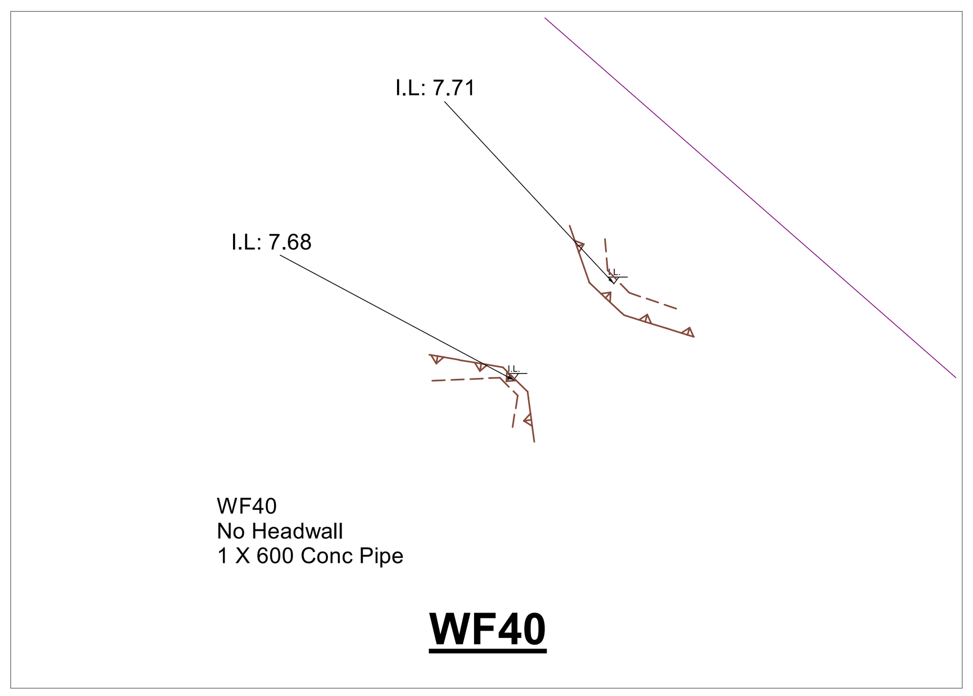












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MUNDIJONG
SURVEY LOCATIONS - (Sheet 5 of 5)
Culverts and Bridge Surveys

CLIENT:
STOCKLAND DEVELOPMENT PTY LTD

Project Mngr. Trevor Veen | Datum PCG94 / AHD

101097 - DE - 007 - A
Job Number / Type / Plan Number / Revision

ROAD FEATURES
- Traffic Junction Box
- Traffic Signals - 1 Aspect
- Traffic Signals - 2 Aspect
- Traffic Signals - 3 Aspect
- Traffic Signals - 4 Aspect
- Pedestrian Signals
- Sign On One Pole
- Sign Multiple Poles
- Overhead Sign
- Traffic Controller Box
- Finger Sign
- Traffic Earth Pit
- Police Traffic Camera
- Guide Post
- Km Marker
- Traffic Count

ELECTRICAL
- Earth Pit
- Electrical Pillar
- Electrical Dome
- Light Pole - Directional
- Power Pole
- Transformer Single Pole
- Stay Pole
- Steel Wire Anchor
- High Mast Lighting
- Electrical Cable Marker
- MRWA Cable Marker
- MRWA Electrical Cable Box
- Electrical Cable Pit/Box
- MRWA Distribution Board
- High Tension Power Pole
- Electrical Supply Pole
- Ground Floodlight
- MRWA Electrical Manhole
- Meter Box
- Power Meter Box
- Electrical Transformer
- MRWA Light Pole
- MRWA Multiple Light Pole

COMMUNICATION
- Telstra Pit
- Telstra Pillar
- Telstra Marker
- Telstra Pole
- Telephone Booth
- Emergency Phone
- Antenna
- Telstra Elevated Joint
- Cable Marker (Optus)
- Telstra Tower
- Communication Manhole

WATER
- Water Meter
- Water Stop Valve
- Hydrant (Ground Level)
- Hydrant (Pillar)
- Water Bore
- Stand Pipe
- Reticulation Sprinkler
- Reticulation Control Valve
- Well
- Water Main Marker
- Water Tap
- Flushing Point
- Air Valve
- Peizometer
- Hydrant Booster Box

GAS
- Gas Marker
- Gas Valve
- Gas Test Valve
- LPG Tank
- Gas Test Pit
- Gas Manhole

DRAINAGE
- Invert Level
- Overt Level
- Flood Level
- Water Line
- Flood Level Indicator
- Storm Water Grate
- Drainage Gully
- Drainage Manhole
- Drainage Headwall

SEWER
- Sewer Vent
- Sewer Line Marker
- Sewer Inspection Shaft
- Sewer Inspection Opening
- Sewer Manhole

RAIL
- Rail Traffic Signals
- Rail Traffic Control Box
- Rail Telephone Box
- Rail Cable Pit
- Rail Cable Marker
- Rail SLK Post
- Manhole - Rail Cable

STRUCTURE
- Deck Level
- Floor Level
- Column Centre

GENERAL
- Clothes Hoist
- Air Conditioner
- Marker Unk/Undefined
- Undefined Manhole
- Control Of Access Sign
- Count Station
- Advertising Sign
- Windmill
- Stock Trough
- Litter Bin
- Mail Box
- Parking Meter
- Bus Stop
- Ticket Machine
- Borehole
- Flag Pole
- Bollard
- Fuel Bowser
- Underground Filler
- Diesel Tank
- Oil Main Marker
- Security Post
- Tank

GROUND FEATURES
- Natural Surface
- Aerial Survey Marker

VEGETATION
- Tree Details - Canopy & Trunk
- Tree 0.1m-0.3m Trunk Diameter
- Tree 0.3m-0.5m Trunk Diameter
- Tree 0.5m-1.0m Trunk Diameter
- Tree > 1.0m Trunk Diameter
- Bush
- Die Back Area - Marker
- Nesting Tree
- Tree Trunk/ Stump
- Grass Tree

SURVEY CONTROL
- Star Iron Picket
- Trig Point
- SSM
- Bench Mark
- Photo Point
- Cadastral Peg/Post
- Reference Peg
- Alignment Control
- Spring Head Nail
- Spike
- TBM
- Peg Placed / Found

ROAD FEATURES
- Edge Of Bitumen
- Road Shoulder
- Edge Of Unsealed Road
- On Road
- Centre Of Road
- Kerb Top
- Kerb Bottom
- Cattle Grid
- Centre Of Driveway
- Edge Of Driveway
- Pedestrian Ramp
- Pedestrian Crosswalk
- Track
- Parking Bay
- Line Markings 1m Line & 1m Gap
- Line Markings 1m Line & 3m Gap
- Line Markings 3m Line & 9m Gap
- Lane Marking (9m*3m GAP)
- Lane Markings - Audible
- Shared Pathway - Guide Line 900mm*300mm GAP
- Footpath/Shared Path - Give Way 200mm*200mm GAP
- Giveway/Hold/Turn Lines 600mm*600mm GAP
- Double Barrier Line
- Overtaking Lane Left
- Overtaking Lane Right
- Single Solid Line
- Arrow Straight
- Arrow Straight/Left
- Arrow Straight/Right
- Arrow Left
- Arrow Right
- Arrow 3 Ways
- Arrow Right & Left
- Arrow U-Turn
- Arrow Merge
- Painted Lettering On Seal
- Painted Bicycle Traffic Signal Detector
- Guardrail - W Beam
- Guardrail - Thrie
- Barrier Concrete
- Barrier Steel Rope
- Barrier - Single Rail
- Barrier - Double Rail
- Barrier Triple Rail
- Bridge Barrier - (All Types)
- Bridge Expansion Joints
- Bridge - Outside Of Deck
- Soffit String

STRUCTURE
- Bridge
- Abutment
- Columns
- Piers
- Underpass
- Ramp
- Steps/Stairs
- Edge Of Concrete
- Bus Shelter
- Memorial
- Ruin
- Building / Structure
- Awning
- Shed
- Verandah
- Door Opening
- Window
- Roof Gutter Line
- Roof Ridge Line
- Top Of Wall
- Brick Wall
- Concrete Wall
- Livestock Grid

GENERAL
- Swimming Pool
- Tank Perimeter
- Mine Shaft
- Mine Workings
- Koppa Logging Fence
- Fence/Gate
- Wall
- Top Of Barrier / Wall etc
- Retaining Wall
- Boundary Line
- Footpath
- Gas Cylinder/Tank
- Brick Paving
- Bike Rack
- Bench Seating
- Handrail

GROUND FEATURE
- Major Contour
- Minor Contour
- Bank Bottom
- Bank Top
- Line Of Levels
- Levee Top
- Levee Bottom
- Rock Outcrop
- Ridge Line
- Borrow Pit
- Earthworks Area
- Ground Subsidence
- Rock Pitching

VEGETATION
- Tree Line/Canopy
- Bush Line
- Hedge
- Garden Bed
- Lawn Area
- Vineyard
- Plantation
- Orchard
- Nursery
- Market Garden
- Recreational Area
- Trunk Circumference Circle
- Tree-line Face Of Trunks

ELECTRICAL
- Varible Message Sign
- Electrical Structure String
- Overhead Powerlines - Null Height
- Overhead Powerlines - True Height
- High Tension Power Lines - Null Height
- High Tension Power Lines - True Height

COMMUNICATION
- Unidentifed Service Pit
- Telstra Cable
- Amcom Cable

WATER
- Water Pipe

GAS
- Gas Line

DRAINAGE
- Drainage Pipe
- Drainage Culvert
- Floodway
- Drain
- Edge Of Drain
- Sump
- Waters Edge
- Swamp
- Dam
- Edge Of Creek Water
- Centre Of Channel
- Wet Area
- Flood Level Line
- Waterways Cross Section

SEWER
- Sewer Pressure Main
- Sewer Pipe

RAIL
- Railway Platform
- On Rail
- Rail Boom Gate
- Rail Underground Cable
- Dual Gauge Rail
- Narrow Gauge Rail
- Cross Setion - Rail
- Standard Gauge Rail
- Rail U/G Cable

UNDERGROUND SERVICES - DIRECT MEASUREMENT - CLASS A
(CAD)	Spatial Cadastral Database - SCDB (WA)
(PQA)	Underground Amcom Cable
(PQC)	Underground Drainage Pipe
(PQE)	Underground Electrical Cable
(PQF)	Underground Western Power Comms
(PQG)	Underground Gas Line
(PQH)	Underground MRWA Comms
(PQI)	Underground MRWA Power
(PQN)	Underground Next Gen Comms
(PQP)	Underground Optus Fibre_Optic
(PQR)	Underground Rail Services
(PQS)	Underground Sewer Pipe
(PQT)	Underground Telstra Copper
(PQU)	Underground Unknown Service
(PQV)	Underground Telephone
(PQW)	Underground Water Pipe
(PQX)	Underground Reticulation Pipe

UNDERGROUND SERVICES

(MAIN ROADS - SURFACE LOCATION) - CLASS B
(HA)	(0.4)	AMCOM Cable - Surface Location - (Depth Below)
(HC)	(0.4)	Drainage Pipe / Stormwater - Surface Location - (Depth Below)
(HE)	(0.4)	Electrical Cable - Surface Location - (Depth Below)
(HF)	(0.4)	Western Power Communication - Surface Location - (Depth Below)
(HG)	(0.4)	Gas Line - Surface Location - (Depth Below)
(HH)	(0.4)	MRWA Communication - Surface Location - (Depth Below)
(HI)	(0.4)	MRWA Power - Surface Location - (Depth Below)
(HN)	(0.4)	Next Gen Communication - Surface Location - (Depth Below)
(HO)	(0.4)	Optus Copper - Surface Location - (Depth Below)
(HP)	(0.4)	Optus Fibre Optic - Surface Location - (Depth Below)
(HR)	(0.4)	Rail Services - Surface Location - (Depth Below)
(HS)	(0.4)	Sewer Pipe - Surface Location - (Depth Below)
(HT)	(0.4)	Telstra - Surface Location - (Depth Below)
(HU)	(0.4)	Unknown Service - Surface Location - (Depth Below)
(HV)	(0.4)	Telstra Fibre Optic - Surface Location - (Depth Below)
(HW)	(0.4)	Water Pipe - Surface Location - (Depth Below)
(HX)	(0.4)	Reticulation - Surface Location - (Depth Below)

(MAIN ROADS - UNVERIFIED, NO MEASURMENT) DBYD COMPILED - CLASS C AND D
(CAD)	Spatial Cadastral Database - SCDB (WA)
(QA)	AMCOM Cable - Unverified, No Measurement
(QC)	Drainage Pipe / Stormwater - Unverified, No Measurement
(QE)	Electrical Cable - Unverified, No Measurement
(QF)	Western Power Communication - Unverified, No Measurement
(QG)	Gas Line - Unverified, No Measurement
(QH)	MRWA Communication - Unverified, No Measurement
(QI)	MRWA Power- Unverified, No Measurement
(QN)	Next Gen Communication - Unverified, No Measurement
(QO)	Optus Copper - Unverified, No Measurement
(QP)	Optus Fibre Optic - Unverified, No Measurement
(QT)	Telstra Copper - Unverified, No Measurement
(QV)	Telstra Fibre Optic - Unverified, No Measurement
(QR)	Rail Services - Unverified, No Measurement
(QS)	Sewer Pipe - Unverified, No Measurement
(QU)	Unknown Service - Unverified, No Measurement
(QW)	Water Pipe - Unverified, No Measurement
(QX)	Reticulation - Unverified, No Measurement

Rev.	Description	Drawn	Date	Checked
B	Feature Codes Revised	SAH	22/08/2017	MNG
A	Initial Issue	SAH	30/06/2016	MNG

SCALE 1:1000 @ A3
0 25 50
ALL DISTANCES ARE IN METRES
For a true to scale reproduction of this plan, plot it to A3 with the Paging Scaling set to None.

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McMULLEN NOLAN GROUP
FEATURE SURVEY - GENERAL LEGEND

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Surveyor:- MNG
Survey Date:- 22/08/2017
Precal/Cad:- N/A

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MNG.

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Offices in: Broome, Bunbury, Kununurra, Newman, Port Hedland

CLIENT: N/A

Project Mngr: MNG | Datum: LOCAL

95465 - DE - 012 - B
Job Number | Type | Plan Number | Revision

Appendix F: Landscape concept

2.0 LANDSCAPE MASTER PLAN

LANDSCAPE STRATEGY

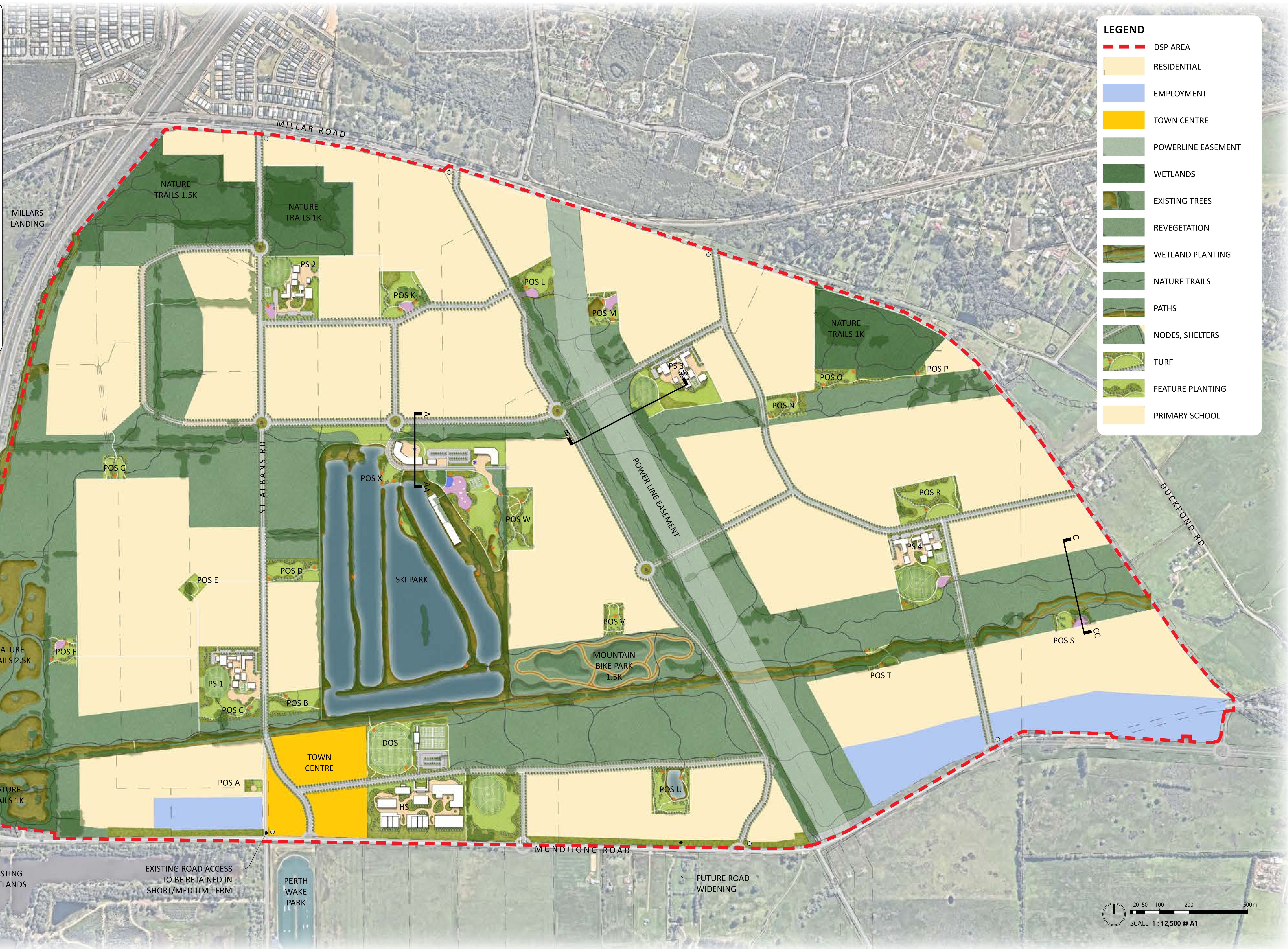
The landscape strategy for the project consists of a variety of approaches for different zones and areas. In broad terms the project site is divided into the following areas:

- Public open space precincts
- Town Centre and commercial precinct
- Floodway, Drainage Swales and Retention Basins within POS areas
- District Open Space
- Natural Trails
- Major Streetscape corridors

In terms of practical implementation of the above this will translate into the following:

Retention of existing paddock trees where levels and provision allows.

- Creation of native wetland habitat within the drainage swales and retention basins corridors.
- Development of character and promotion of local identity across the different landscape precincts.
- Definitive planting palette with an emphasis on native plant and tree species.
- Delineated cycle network throughout the development site and beyond.



Appendix G: Earthworks concept

LEGEND

DESCRIPTION	SYMBOL
LSP AREA	
EARTHWORKS AREA	
FINISHED SURFACE CONTOUR MAJOR	
FINISHED SURFACE CONTOUR MINOR	
EXISTING SURFACE CONTOUR	
SPOT HEIGHT	4x99

1:5000 0m 100 200 300

P:\6489 Wellard Farms\6489-00\Acad\Sketches\6489-00-SK01.dwg, 28/03/2023

REV	DATE	DRN	CKD	APP	AMENDMENT
H	28.03.23		-	[signature]	ISSUED FOR INFORMATION
F	06.09.22	ARH			LAYOUT AND EARTHWORKS MODEL (REV'D') UPDATED
E	15.07.22	ARH			UPDATED LOT LEVELS
D	26.05.22	ARH			UPDATED PLANNING LAYOUT AND LEVELS
C	07.05.22	ARH		M. WALLIS	EARTHWORKS LEVELS UPDATED

Cossill & Webley CONSULTING ENGINEERS
Mailing Address PO Box 680 Subiaco WA 6904
Street Address B12 (Level 2) 431 Roberts Road Subiaco WA 6008
T (08) 9422 5800 F (08) 9422 5801 E admin@cosweb.com.au

CLIENT: Stockland
APPROVED: [signature]
DESIGNED: AMC
SCALE: AS SHOWN
PROJECT: WELLARD FARMS
TITLE: 000 - GENERAL EARTHWORKS CONCEPT
WAPC No.
DRAWING No. 6489-00-SK01
REVISION: H
ORIGINAL SIZE: A0

Appendix H: Flood modelling report

PENTIUM WATER

FLOOD MODELLING REPORT

North-east Baldivis District Structure Plan

STOWELL_02

10 November 2023

Document Status

Version	Purpose of document	Authorised by	Reviewed by	Review Date
Draft A	Draft for Review	DanWil	ShaMcS	24/03/2023
Rev 0	Final for issue	DanWil	ShaMcS	29/06/2023
Rev 1	Final for issue	DanWil	ShaMcS	10/11/2023

Approval for Issue

Name	Signature	Date
Shane McSweeney		10/11/2023

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Prepared By

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Author: Dan Williams

Reviewer: Shane McSweeney

Approved by: Shane McSweeney

Version: Rev 1

Date: 10 November 2023

Prepared For

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Contact: Jacob Abbott

Table of Contents

Table of Appendices

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1. Introduction

1.1. Background

Stockland Property Group ('Stockland') are undertaking District Structure Planning for a large group of landholdings located in the suburb of North-east Baldivis, within the City of Rockingham. The subject land is comprised of the lots listed below (Table 1) and is referred to hereafter as 'the site'.

The site falls within the 'East of Kwinana' planning investigation area (PIA) which was recently assessed by the State Government as part of the Perth and Peel@3.5million Sub-regional Planning Frameworks. The outcome of that assessment was released in a Planning Investigation Areas Update (WAPC 2022) and included support from the Western Australian Planning Commission (WAPC) for a change of the land use classification (for the portion of the PIA that relates to the site) under the framework to Urban Expansion.

Pentium Water have been commissioned by Stockland to prepare a District Water Management Strategy (DWMS) to support rezoning of the site from Rural to Urban land use. The purpose of the DWMS is to demonstrate that the site is capable of supporting the proposed land use from a water management perspective. As noted in the Planning Investigations Area Update (WAPC 2022), one of the key considerations for the site is "flooding and drainage". The site is located on a regionally significant floodplain area that provides an important flood storage and attenuation function under the existing conditions.

1.2. Purpose of modelling assessment

This report has been prepared (as an appendix to the DWMS) to document the detailed hydraulic modelling that has been undertaken by Pentium Water to assess and quantify the flood management requirements associated with the proposed rezoning and development of the site. The modelling was undertaken to inform the District Structure Plan (DSP) layout and the associated conceptual engineering and flood management designs which underpin the DWMS.

As described in detail in subsequent sections, the modelling has been informed by the significant amount of flood assessment and hydraulic modelling undertaken at a regional scale by the Department of Water and Environmental Regulation and, in particular, the two associated reports which were prepared by DWER in 2021 (DWER 2021a and DWER 2021b).

2. Site description

2.1. Location and landuses

The site is located 35 km south of Perth within the City of Rockingham and encompasses an area of approximately 760 ha between Mundijong road to the south, Millar road to the north, Kwinana Freeway to the west and Duckpond road to the east. The site location is shown in Figure 1.

Current land uses and infrastructure across the site include rural residential, stock grazing, sheep feedlot and holding yards, a water ski facility, aquaculture ponds, function centre and temporary accommodation, high voltage overhead powerlines and former clay excavation pit lakes.

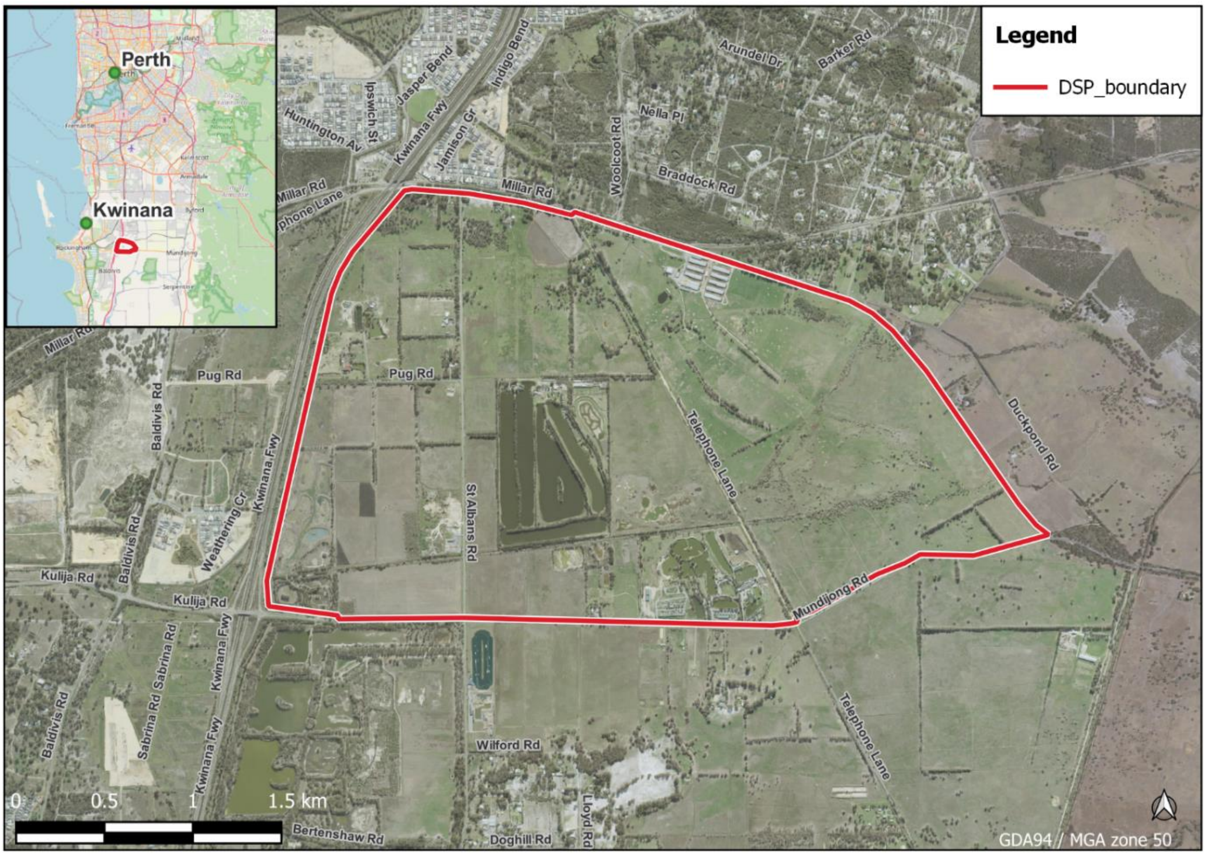


Figure 1: Site location

2.2. Topography

The site is quite flat with a gentle slope from east to west, with natural surface levels ranging from approximately 9 to 5 m AHD at the eastern and western boundaries, respectively. Figure 2 illustrates the topography of the subject site and surrounds, with 2m contours.

Section 4 discusses more detailed aerial survey that was collected for the subject site and used to create a high-resolution Digital Elevation Model (DEM) to support the hydraulic modelling. The existing conditions DEM is shown in Figure 11 (Section 4.2).

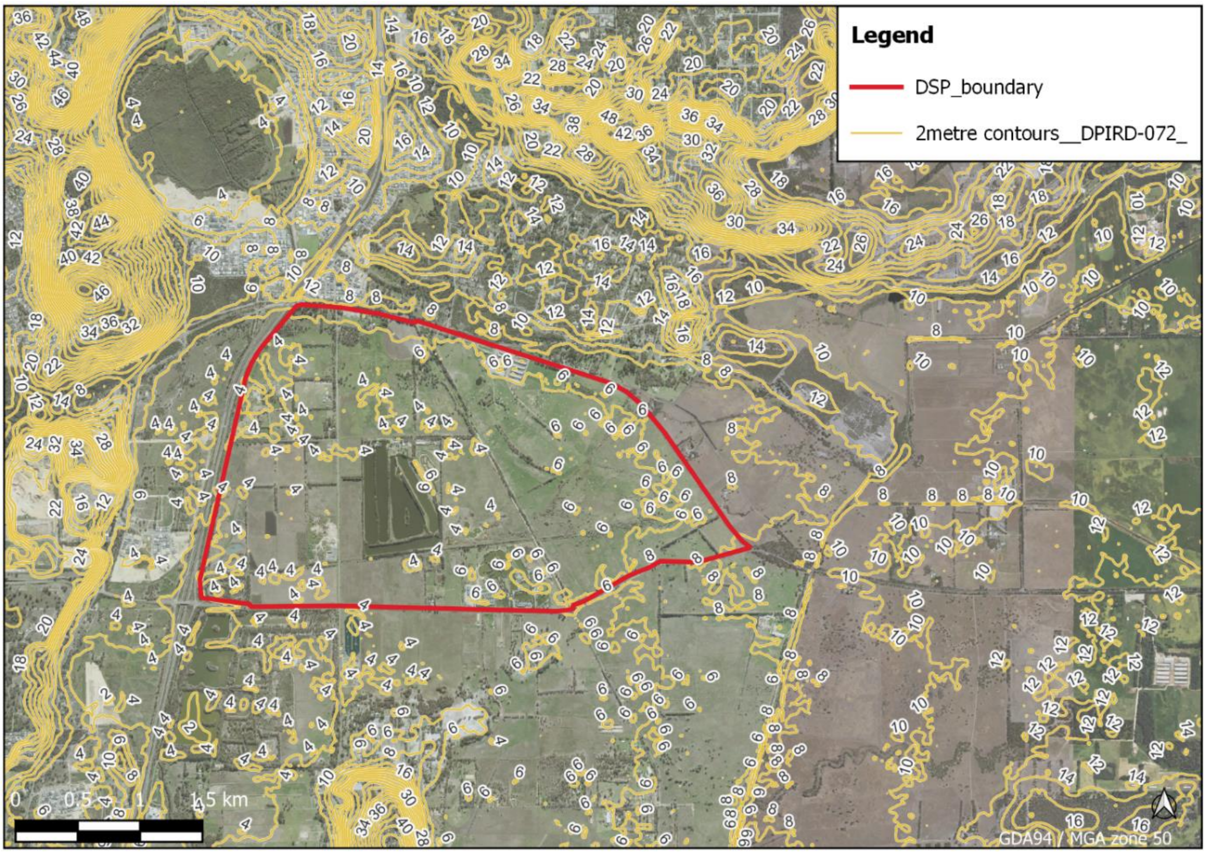


Figure 2: Existing topography

2.3. Geology and soils

2.3.1. Regional soil mapping

The site is located on the low-lying Swan Coastal Plain and regional mapping indicates that the surficial geology across the majority of the site consists of the Guildford formation which is described as alluvial sand and clay with shallow-marine estuarine lenses and local conglomerate (Davidson 1995). The Northern part of the site is mapped as part of the Bassendean Sands formation, described as basal conglomerate overlain by dune quartz sand with heavy mineral concentrations (Davidson 1995). Regional surficial geology mapping is shown in Figure 3.

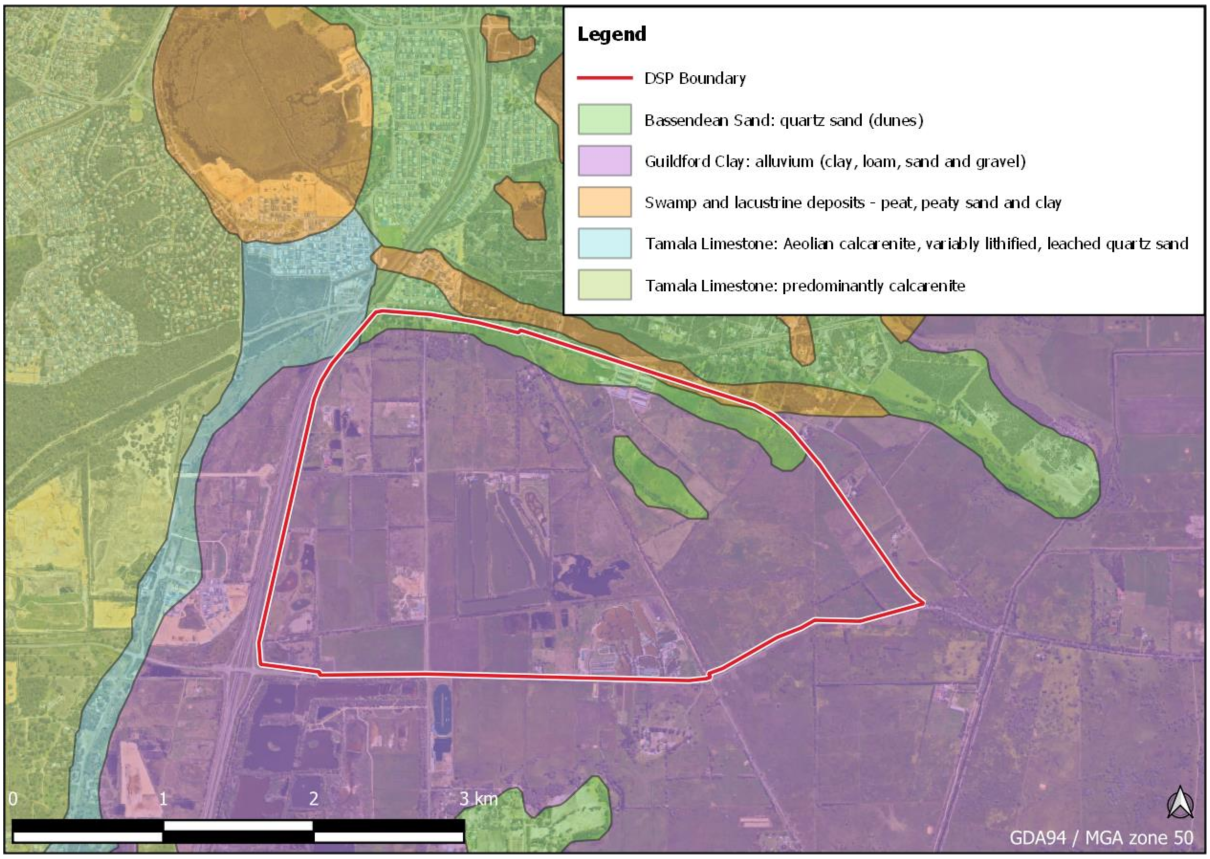


Figure 3: Regional soil mapping

2.3.2. Site investigations

Stockland commissioned Cardno to undertake ongoing surface water and groundwater monitoring at Lots 1 – 3, 100, 201, 451 and 454 Telephone Lane, Baldivis from April 2018 to December 2020 (2021). The assessment included the installation and monitoring of 12 nested groundwater monitoring bores and installation and monitoring of four surface water sites. The key findings included:

- Surface water flows increased from the upstream surface water monitoring sites (located to the east) to the downstream sites (to the west)
- Runoff coefficient across the catchment ranged from 1.0% to 2.1% indicating the soils at site absorbed a large portion of rainfall
- Clay layers were encountered at majority of the groundwater bore locations
- Shallow groundwater bore winter elevations ranged from 2.2 mAHD to 7.88 mAHD with an inferred groundwater flow to the west/southwest.
- Deep groundwater bore winter elevations ranged from 4.39 mAHD to 7.86 mAHD with an inferred groundwater flow to the west/southwest

Golder Associates completed a geotechnical investigation of Lots 456 to 458 Pug Road and Lots 465, 466 and 1261 Mundijong Road, Baldivis in 2010. The investigation included a broad assessment of subsurface soil and groundwater conditions on site as well as a number of other geotechnical assessments. The key findings include:

- Subsurface soil conditions included sand overlain by clay overlain by silty clay topsoil.
- The clayey organic topsoil was encountered to be up to 0.4 m thick and underlain by a typically firm to stiff soft organic plasticity clay.
- Groundwater was encountered at approximately 1.0 and 2.2 m below ground level at the north and south ends of the site respectively and is considered likely to be close to ground surface during wet periods.

A summary of the ground conditions encountered across the site during the geotechnical investigations, Cardno groundwater bore installation and from publicly available data (obtained via the DWER WIR database) is presented in Figure 4. Bassendean Sands exist at the northern site boundary to depths of greater than 3m below existing ground surface, however the majority of the site encounters low permeability upper Guildford Formation soils (sandy clays, clays and clayey sands) from shallow depths. Deeper bores and CPTs have penetrated into the lower Guildford Formation which is comprised of higher permeability sands, with most locations indicating the coarser material exists at depths greater than 5m below ground surface.

Figure 4: Depth of encountered soil types

2.4. Hydrogeology

2.4.1. Local hydrogeology and drainage

The site lies within the Stakehill groundwater area and the Maramanup and Stakehill Confined groundwater subareas. The site is underlain by the following hydrogeological units (aquifers):

- Perth – Superficial Swan aquifer (unconfined)
- Perth - Leederville aquifer (confined)
- Perth - Yarragadee North aquifer (confined).

The surficial geology across the majority of the site consists of interfingering alluvial and lacustrine sands and clays of the Guildford Formation, with sands of the Bassendean Formation occurring in shallow dunes to the north. Although the vertical distribution of sands and clays is variable across the site, drilling and test pit logs across the site indicate there is typically a shallower sand or clayey sand layer above a lower permeability more clay rich layer, grading back into a sandier unit at depth. To the north where the Bassendean sands occur the clay layer is generally not present, however a lower permeability layer of coffee rock often occurs around the water table level. The site is relatively flat and poorly draining, therefore several artificial drainage channels have been constructed to manage groundwater and surface water across the site.

2.4.2. Groundwater levels

Twenty-eight bores were installed across the site and monitored monthly by Cardno from June 2018 to December 2020, including three annual peaks. Several of the bores were nested "shallow" and "deep" bores installed above and below the low permeability layers. Monitoring results indicate there is a perched system sitting on top of the clays across most of the site. The water level in the perched aquifer is shallow and intersects ground surface in some areas in winter. Water levels show the regional flow direction is towards the west and southwest, likely controlled by the invert of the Peel Main Drain. Refer to the DWMS (Pentium Water 2023) for full details of the monitoring program.

Pre-development Average Annual Maximum Groundwater Level (AAMGL) and Maximum Groundwater Level (MGL) were calculated for the DSP area and surrounds using a combination of groundwater data, drain AAMGL elevations, and topography. The objective of calculating the AAMGL is to provide an understanding of the pre-development hydrology at the site. The AAMGL is not the critical factor in the establishment of the controlled groundwater level (CGL), which is the level at which groundwater is controlled, generally by the installation of a subsoil drainage system. Rather the CGL will be set according to DoW (2013) Water Resource Considerations when Controlling Groundwater Levels. As specified in DoW (2013), the CGL will be set with consideration of infrastructure protection, catchment and nearby land use constraints, a free-flowing drainage outlet, groundwater quality and protection of water dependent ecosystems.

The long-term AAMGL and MGL for each site bore were calculated by correcting the measured annual peaks in each bore against the calculated AAMGL and MGL of nearby longer-term monitoring records in DWER registered bores. Six DWER bores within the vicinity of the site provided a longer-term record for the corrections. The estimated typical winter baseflow level along the alignment of the Peel Main Drain (PMD) (taken from monitoring data for nearby projects) was included for the interpolation of the AAMGL surface to control the AAMGL on the western side of the site. The AAMGL surface across the site was also corrected for topography, to prevent mapped AAMGL from exceeding ground level. Full details of the AAMGL calculations are provided in the DWMS (Pentium Water 2023).

AAMGL contours and depth to AAMGL across the DSP area, are shown in Figures 4 and 5, respectively. The contour surfaces were interpolated from the estimated AAMGLs for the shallow bores across the site and the PMD. The shallow AAMGL contours range from approximately 3.5 mAHD to 8.0 mAHD and indicate a west/southwest groundwater flow direction.

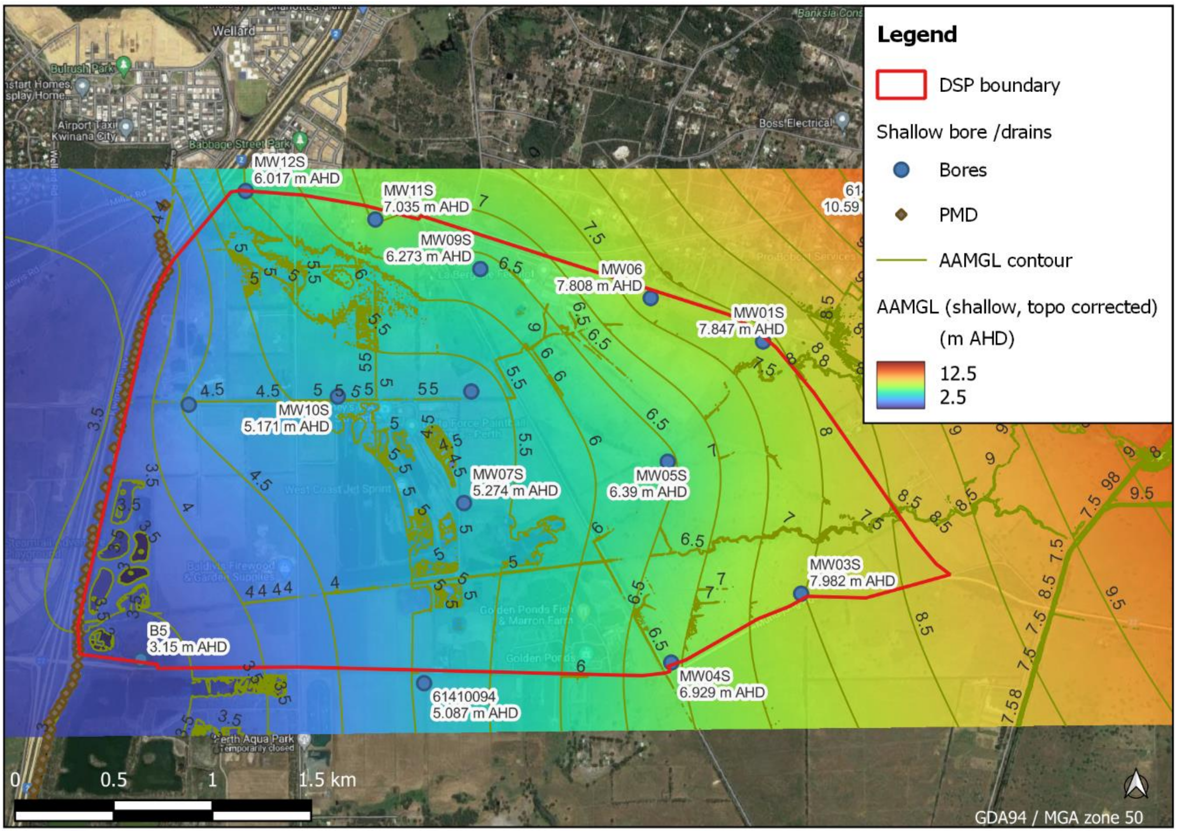


Figure 5: Shallow bore AAMGL

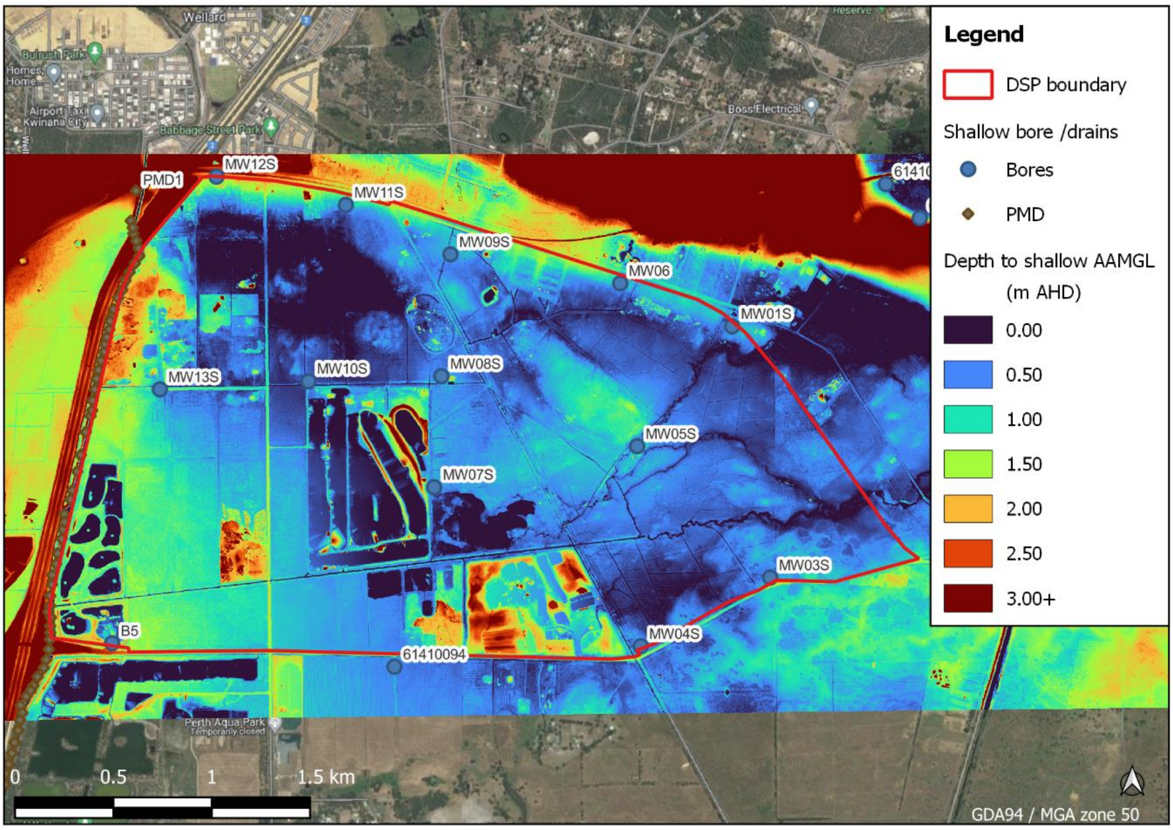


Figure 6: Depth to shallow bore AAMGL

2.5. Hydrology

2.5.1. Surface water drainage

The subject site is located within the Peel-Harvey Coastal Plain catchment and drains via the Peel Main Drain to the Peel Inlet which is located approximately 30 km downstream of the site to the south-southwest.

The site itself comprises relatively flat and low-lying land between the Peel Main Drain (adjacent to the west) and the Birrega Main Drain (approximately 500 m to the east). These main drains were constructed to control groundwater and drain surface water from rural land and they have a very low grade, eventually discharging to the Peel Inlet. Surface water at the site drains to the Peel Main Drain through a network of small agricultural drains that dissect the site, as well as two Water Corporation drains that run through the site from east to west. The main drainage channels through and in the vicinity of the site are shown in Figure 7.

The upstream catchment area to the site is quite small, comprising the land extending several hundred metres from the eastern site boundary of the site as far as Birrega Main Drain to the east and a dunal ridge to the north-east. The construction of Birrega Main Drain (BMD) effectively altered the drainage catchments in the region such that runoff from land upstream (east) of the BMD, which would previously have drained through the site, is now intercepted by the BMD and conveyed south. However, major flood events may result in discharge of floodwater from the upstream catchment into the subject site, via either overflow or breach/failure of the BMD spoil bank. This is discussed further in Section 3.2.

Within the site is the Bonney's Ski Park which comprises a series of large lakes totalling approximately 55 ha in area. The ski lakes are bounded on the north and south by the two Water Corporation drains. It is understood that surface water can be diverted from the southern Water Corporation drain (under licence) during periods of high-flow, and similarly can be discharged to the southern Water Corporation drain during high lake water conditions, though there is no record of discharge from the lake occurring.

A number of structures (ie. culverts and small bridges) have been installed along the drains within the site. A feature survey to measure the elevations and dimensions of these structures identified included approximately 36 culverts and 4 bridges across the DSP area. Many of these culverts were found to be blocked and/or buried, rendering them ineffective in a major flood event.

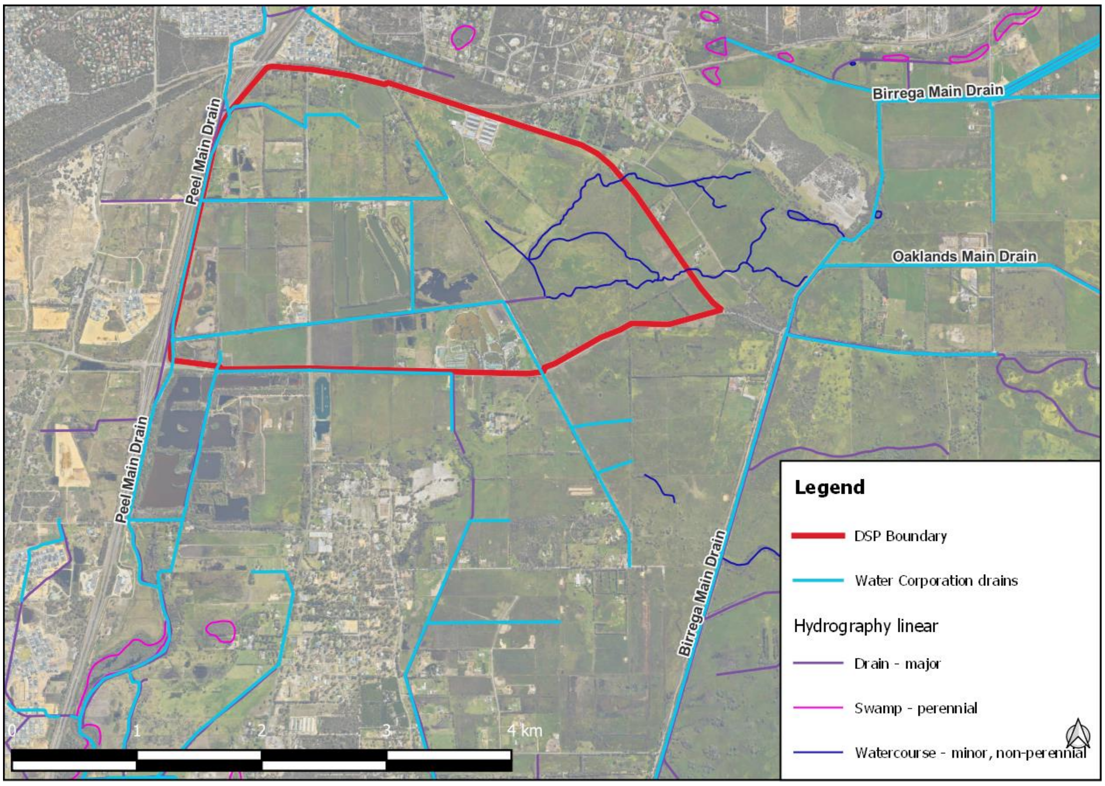


Figure 7: Watercourses and drains

2.5.2. Wetlands

The majority of the site is mapped as Multiple Use Wetland (MUW), with several small Resource Enhancement Wetlands (REW) located within the northern portion of the site and one Conservation Category Wetland (CCW) located adjacent to the eastern boundary of the site. Wetland mapping is shown in Figure 8.

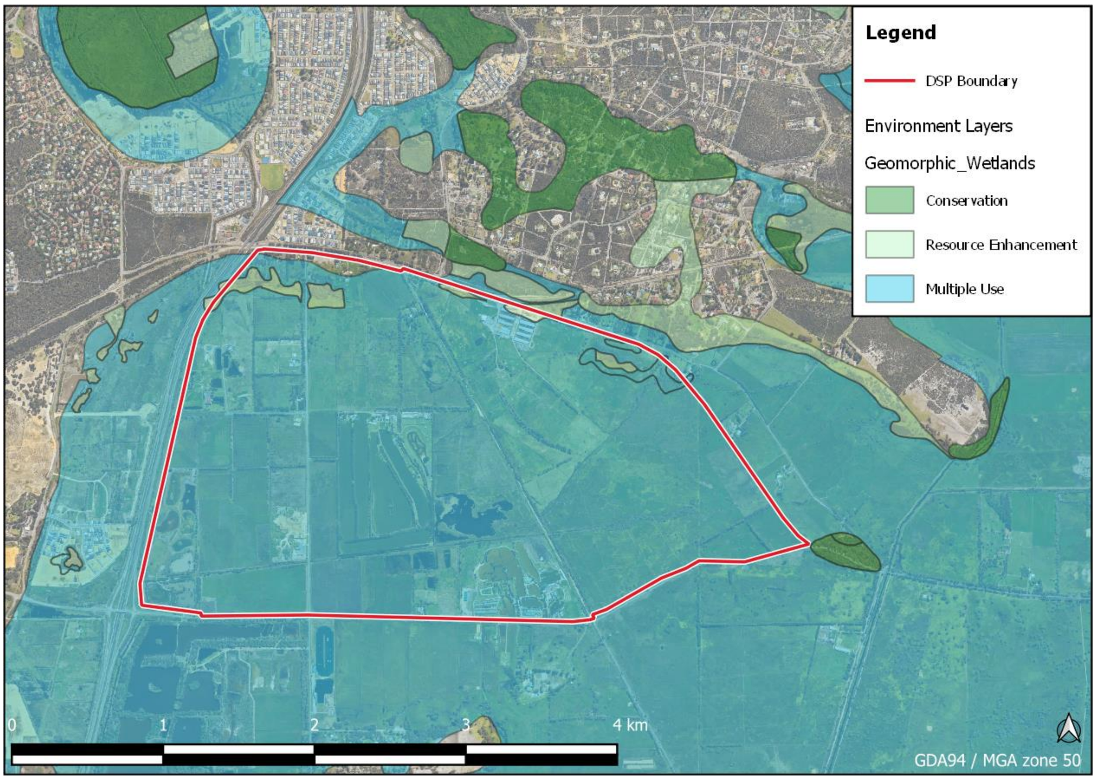


Figure 8: Geomorphic wetland mapping

3. Existing flood conditions

3.1. Flooding context

The DSP area is situated on flat, low-lying land with a shallow water table and surface soils generally comprising clayey material with relatively low infiltration potential. The site is located between the Birrega and Peel main drains. These main drains are characterised as having extremely low grades, having originally been constructed to assist with surface and groundwater drainage from poorly-drained low-lying agricultural land. The upstream catchment areas for the two main drains are also very large, at approximately 65 km^2 ha and 220 km^2 for the Peel Main Drain and Birrega main drains, respectively. The overall catchment area for the Serpentine River and the regional topography are illustrated in Figure 9, which provides some context to the site setting and potential sources of flooding.

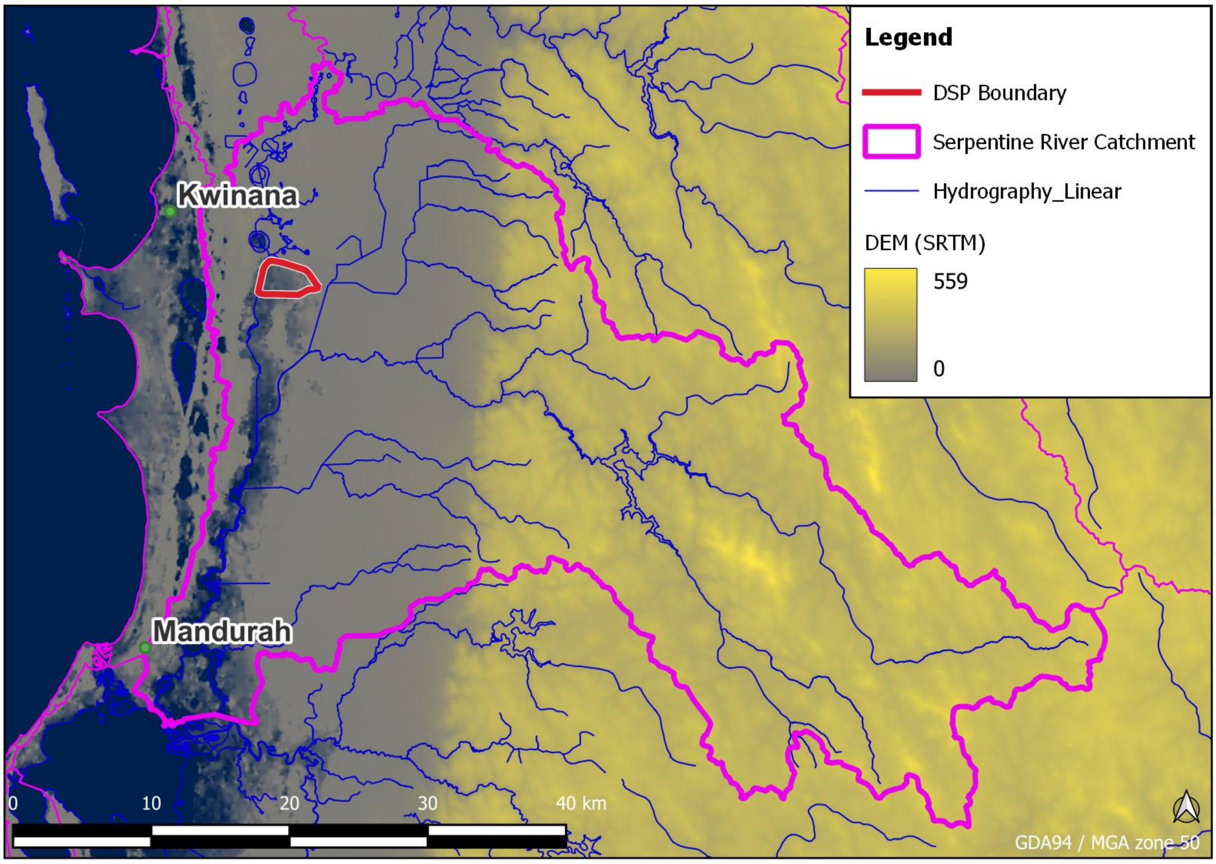


Figure 9: Regional hydrological setting

The construction of the Berriga Main Drain (BMD) effectively altered the drainage catchments in the region such that runoff from land to the east of the subject site, which would previously have flowed through the site, is now intercepted by the BMD and conveyed south. It is understood that the BMD was constructed primarily to drain inundated rural land in accordance with the Water Corporation's 72 hour of inundation drainage service provision for rural land, rather than being intended for major rainfall event flood protection of land down-gradient. Regardless of that being the primary purpose, the BMD and associated spoil bank does effectively control surface water runoff in large rainfall events. However, major flood events may result in discharge of floodwater from the upstream catchment into the subject site, via either overflow or breach/failure of the BMD spoil bank.

A number of flood studies relating to the site have been commissioned or undertaken by the Department of Water and Environmental Regulation, the main findings of which are summarised in the following sections.

3.2. Department of Water and Environment flood assessments

3.2.1. Overview

The Department of Water and Environment (DWER) have completed a number of flood studies over the project area since 2015, including:

- Birrega and Oaklands flood modelling and drainage study (DoW 2015a)
- North-east Baldivis flood modelling and drainage studies (DoW 2015b)
- East of Kwinana flood modelling and drainage study (DWER 2021a)
- East of Kwinana and Pinjarra and Ravenswood planning investigation areas flood risk management land capability assessment (DWER 2021b)

The first study listed above focused on the upstream catchments of the Birrega Main Drain and Oaklands Main Drain and extended as far downstream as the subject site. The second study listed above focused on the Peel Main Drain and Serpentine River catchments, which are fed by the Birrega and Oaklands Main Drains, and the upstream boundary of that study incorporated the subject site. Therefore, the subject site represents a small area of overlap between these two studies, for which the modelling approach was consistent.

More recently, DWER has undertaken a review of the modelling of the 2015 studies which has involved creating a single regional model for the combined catchments and updated the modelling approach for consistency with Australian Rainfall and Runoff 2019 (Ref) as well as increased resolution in parts of the model. The outcomes of this modelling were documented in the latter two reports listed above which address, respectively, details of the modelling process and the land capability assessment outcomes of the modelling.

3.2.2. Birrega Main Drain spoil bank failure

Both the 2015 and the more recent 2021 flood studies undertaken by DWER identify the potential for significant volumes of floodwater to break out of the Birrega Main Drain (BMD) adjacent to the DSP area and flow through the subject site. Broadly, there are two mechanisms by which floodwater from the BMD might impact the subject site; overtopping or failure of the western bank of the BMD. Whilst various terminology has been used in previous flood studies in reference to the structure (ie. levee versus spoil bank), DWER (2021) has stated that the structure should be considered a spoil bank rather than a levee. The preference for the term spoil bank reflects a structure formed by the placement of excavated material during the construction of the BMD, the purpose, design and construction of which is not necessarily consistent with an engineered flood protection levee.

DWER (2021a) includes extensive discussion on this topic and describes the assessment undertaken by DWER to assess the condition of the existing spoil bank, the mechanisms of potential failure and the methodology for modelling various failure scenarios and the resulting impact (ie. flow rates and volumes) on the subject site.

A summary of the main findings of the DWER flood study, with respect to the impacts of failure of the BMD spoil bank on the DSP area, are as follows:

- Failure of the western BMD spoil bank adjacent to the DSP area is considered likely to occur in a 1% AEP or greater event. Whilst no quantitative description of this likelihood is provided in DWER (2021a), due to the complexity of failure mechanisms and significant uncertainty associated with these, it is stated that in a 1% AEP event the spoil bank adjacent to the DSP area has an equal or greater likelihood of experiencing failure compared to several locations which were observed to fail in a 1987 flood event of 2% AEP magnitude.
- The estimated 1% AEP flow rate associated with failure of the spoil bank along the section of BMD adjacent to the subject site is 73 m3/s. This estimate is based on sensitivity testing of multiple spoil bank failure locations and “represents the median risk position that recognises the likelihood of spoil bank failure and provides a reasonable balance between the economic use of the land and the risk to property damage and human life”.

3.2.3. Flood dynamics of the DSP area

DWER (2021a) provides a thorough assessment of the floodplain hydraulics to characterise volumes of floodwater that would move through and be temporarily stored within the "North East Baldivis north of Mundijong Road" precinct (which roughly corresponds to the DSP area) under existing conditions. The assessment identified that the DSP area comprises a significant floodplain storage area which influences the flooding dynamics downstream through the attenuation of a large proportion of the flood volume. The DWER modelling tested several development scenarios to demonstrate that maintaining the same volume of flood storage within the developed site is critical to mitigating impacts (ie. increased flood risk) to downstream properties.

Some of the key findings of the DWER (2021a) modelling are as follows:

- The adopted spoil bank failure scenario (100% failure of approximately 1 km length of spoil bank) results in a peak 1% AEP flow from the BMD towards the DSP area of 73.1 m^3/s (for the critical duration, which was identified as 18 hours).
- The total volume of discharge from the BMD towards the DSP area is 4.02 GL in the 1% AEP event
- The combined (Peel Main Drain plus flow over Mundijong Road) peak discharge from the DSP area is 65.9 m^3/s in the 1% AEP event (with this number increasing to 73.3 m^3/s in DWER's "local" model which focused more specifically on the DSP area)
- The combined discharge volume from the DSP boundary via Peel Main Drain and over Mundijong Road is 3.65 GL in the 1% AEP event
- The 1% AEP flood storage volume within the "North East Baldivis north of Mundijong Road" precinct is 3.61 GL.

The modelled flood extent and depth from DWER (2021a) is shown below in Figure 10. As can be seen in the modelled flood depths, the flow regime and mechanics of flood storage and discharge are largely controlled by existing topographic features including the embankments associated with St Albans Road and Mundijong Road. Floodwater backs up behind these features, which has a controlling effect on storage volume as well as the timing and rate of discharge from the site.

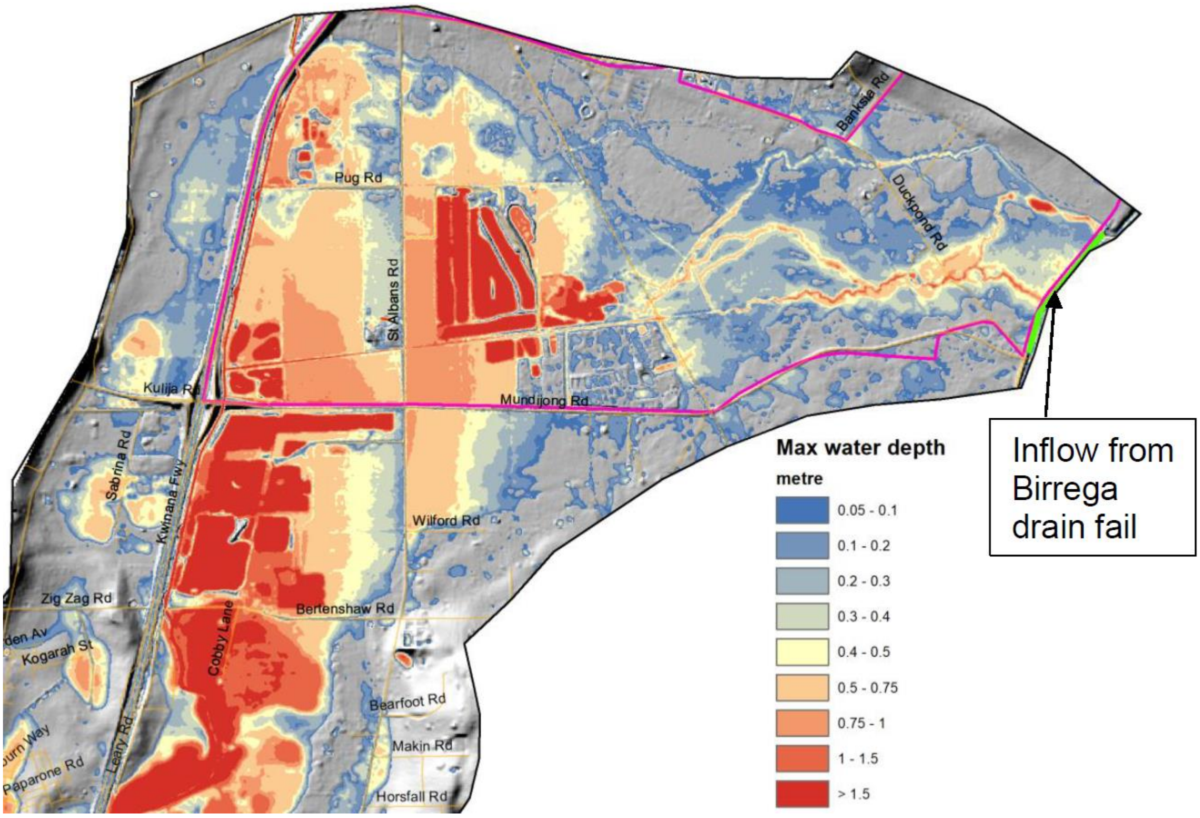


Figure 10: DWER flood modelling results (source: Figure 6-16 of DWER, 2021a)

3.2.4. DSP response to flooding risk

The DWMS (Pentium Water 2023) and this modelling report recognise that, given the potential magnitude of flow rates and volumes impacting the DSP area in the event of spoil bank failure, development of the site will need to consider such an eventuality and provide an urban form and engineering response which manages the flooding to prevent any impact to upstream or downstream areas and to mitigate risk to the community.

Consistent with the recommendations of DWER (2021b) the DSP has been developed with a focus on maintaining the existing conditions floodplain storage volume and has been supported by the post-development modelling and flood mitigation concept design (described in later sections of this report) to maintain the flood storage and flow regime through the site (ie. to maintain the timing and volume of flows discharging from the site) as much as possible.

3.2.4.1. Spoil bank failure assumption

It is acknowledged that the DWER-modelled soil bank failure scenario is appropriate to adopt as the base-case assumption for the DSP area, noting that this represents the more conservative assumption (ie. opposed to “spoil bank intact”) and therefore needs to be considered and planned for. It is also acknowledged that DWER (2021b) does not, in-principle, support the upgrading of existing spoil bank infrastructure or construction of a new levee for the purpose of increasing the developable area within the DSP. Therefore, the current DSP and DWMS (Pentium Water 2023) have been prepared on the basis of no new levee infrastructure being proposed and adopting spoil bank-failure as the base-case conditions to be managed within the DSP.

4. Existing conditions modelling

4.1. Overview

Whilst comprehensive modelling of the existing conditions has already been undertaken by DWER as part of the East of Kwinana flood study, a local-scale flood model for the site has also been developed by Pentium Water to simulate existing flooding conditions for this study. The purpose of the modelling is not to challenge or verify the DWER modelling, which is considered to be comprehensive and robust. Rather, the purpose was to enable the testing of various development scenarios with direct (ie. like-for-like) comparisons between existing and post-development conditions within the same modelling environment. The existing conditions modelling provides the baseline against which post-development scenarios are tested for the purpose of optimising the layout and earthworks design, and demonstrating that the site is capable of supporting the proposed land uses.

The (existing and post-development conditions) modelling described herein is heavily based upon the findings, assumptions and outputs of the DWER (2021a and 2021b) modelling. For example, the design rainfall event (duration and temporal pattern) and inflow hydrographs to the local model have been adopted from the DWER modelling outcomes. Therefore, this assessment focuses mainly on an assessment of how the subject site and downstream floodplain dynamics respond to potential development scenarios rather than characterising the broader catchment, which has been done in detail by DWER (2021a and 2021b).

4.2. Model setup

Aerial survey (LiDAR) was flown for the subject site and immediate surrounds by MNG Survey in 2017. From the high resolution and high accuracy (±0.07 m) LiDAR data, a 0.5m horizontal resolution Digital Terrain Model (DTM) was created. A minor southern portion of the 2D model domain (outside of the DSP area) was outside of the aerial survey area and utilised publicly available LiDAR data (sourced from Department of Water and Environmental Regulation).

Figure 11 illustrates the DTM as well as the hydraulic model domain, which extends east of the subject site to BMD and the dunal ridge which forms a catchment divide, west to the freeway and south to include the ponds (former clay excavations) within the Alcoa-owned land south of Mundijong Rd before terminating immediately south of Bertenshaw Road. Figure 11 also shows key elements of the model configuration including culverts that were explicitly modelled as 1D elements and boundary conditions (including inflow locations and outflow locations). The downstream model boundary adopted a head-flow rating curve derived from the terrain model slope, to simulate tailwater level at the model boundary.

The model explicitly simulates existing culverts and small bridge structures as 1D elements linked to the 2D model. These features were surveyed for accurate invert elevations and dimensions and the location of the features included in the model as 1D elements are shown on Figure 11.

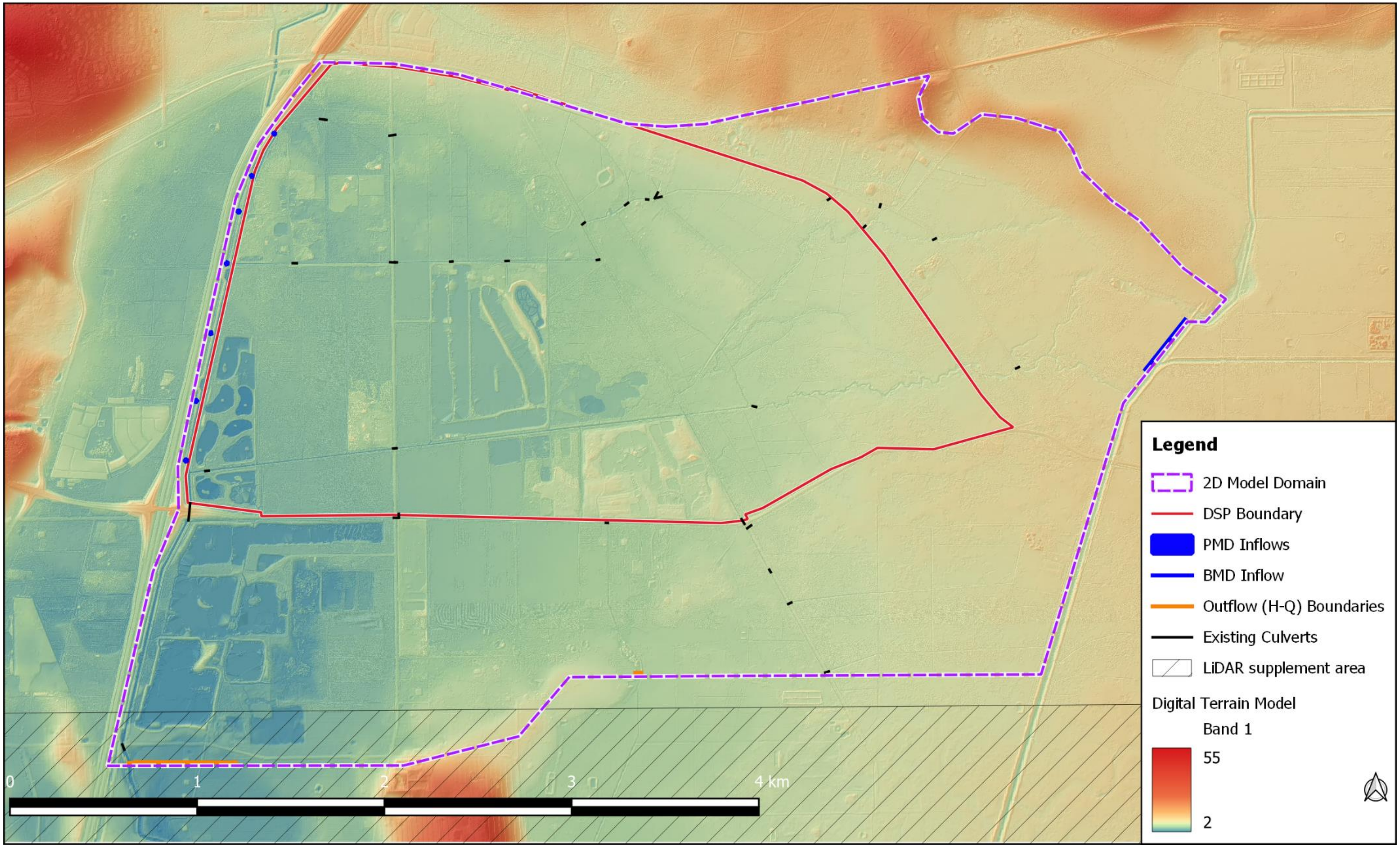


Figure 11: Existing conditions model setup and DTM

4.2.1. External catchment design inflows

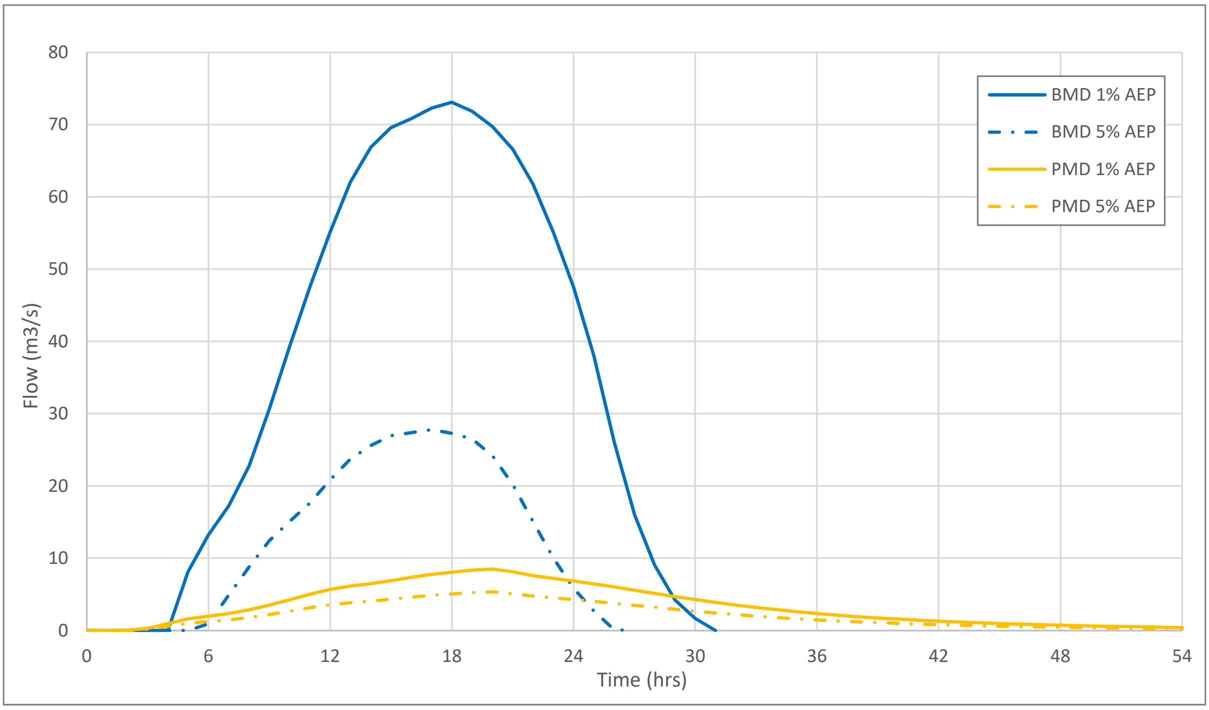
As described above, the model is primarily a hydraulic simulation of the flow of floodwater through the DSP and surrounds, to understand how the proposed development impacts the storage, flow and inundation height of floodwater within the model domain. Design inflows to the model domain from external catchments have been adopted from the DWER (2021a) East-of-Kwinana modelling, and the two key inflow locations (BMD and PMD) are illustrated in Graph 1 below.

The design inflow to the model from the Birrega Main Drain spoil bank failure location is the key driver of the 1% AEP flooding within the model domain, representing approximately three times the volume of rainfall that falls on the DSP area and its upstream catchment extent (as far east as the BMD) in an 18 hour-1% AEP event. This is due to the base-case assumption that the BMD spoil bank will fail during a 1% AEP event, causing a large proportion of the BMD flow to discharge in a westerly direction towards the DSP area. As shown in Graph 1 below, the peak inflow at the BMD spoil bank failure location is 73 m^3/s, as taken from the DWER (2021a) model.

The purpose of this section is to demonstrate that the proponent has reviewed and understood the Departments flood modelling. The BMD discharge hydrograph represents the "median" result from several spoil bank failure scenarios (locations and extents of spoil bank failure) tested by DWER. DWER (2021a) also notes that whilst several scenarios were tested, exhaustive testing of possible spoil bank failure scenarios and combinations thereof (ie. a probabilistic analysis of potential spoil bank breakout flow rates) was not undertaken due to the impracticality of doing so. Therefore, there remains some uncertainty regarding the exact likelihood and nature of spoil bank failure and associated flow volumes and rates into the DSP area. However, the following is noted with respect to this uncertainty:

- The floodplain storage volume within the DSP area is relatively insensitive to the magnitude of breakout flow, due to the controlling influence of the topographic surface and existing structures / roads.
- Therefore, a large increase in the volume and rate of BMD breakout flow into the site would not result in a proportional increase in floodplain storage volume, ie. floodplain storage volume would increase only slightly whilst peak discharge through / from the site would increase significantly.
- The implication of this is that the adopted design criteria (to replicate the existing conditions floodplain volume) and design response (ie. the DSP layout and flood storage area design) are likewise not particularly sensitive to the design breakout flow from the BMD.
- The main implications of a potentially larger peak discharge from the BMD into the site is the safe conveyance of that flow and the separation from flood levels to house pads and critical infrastructure levels. These factors have been tested though the hydraulic modelling (herein) which demonstrates that the typical 0.5 m freeboard requirement for major floodplain areas is adequate to cater for this uncertainty, in the context of the pre-development spoil bank failure base case as per the DWER East of Kwinana and Pinjarra and Ravenswood Planning Investigation Area flood risk management and land capability assessment.
- The other consideration in terms of discharges from the BMD in a spoil bank failure scenario is the potential for a sudden / instantaneous failure of a section of spoil bank and the associated high flow rates and velocities that could occur immediately downstream of the failure location. However, this risk factor is not considered high in relation to the DSP area given it is located approximately 600 m downstream of the BMD spoil bank. It can generally be expected that the hazards will diminish further downstream, however, given the downstream hydraulic constraints NE Baldivis site this may not be the case.

Multiple inflow locations along the Kwinana Freeway (relating to small catchments on the western side of the freeway) were also input to the model as shown in Figure 11, using flow hydrographs sourced from DWER. These inflows are significantly smaller than those associated with the BMD and PMD.



Graph 1: External catchment design inflows to 2D model

4.2.2. Hydrology

Hydrological modelling of runoff from within the model domain area was handled via direct rainfall onto the 2D surface and spatially distributed losses. Loss rates were based on land coverages which were delineated based on information sources including aerial imagery and geological mapping. The design rainfall event applied to the model domain was selected to match that used in the DWER East-of-Kwinana model, ie. the 18-hour rainfall event with temporal pattern no. 1.

For other AEPs that were modelled besides the 1% AEP, various rainfall event durations were tested to confirm the critical duration. However, it should be noted that the external catchment design inflows used in these simulations were constant between the various durations and based on the relevant AEP DWER-modelled discharge as described in Section 4.2.1.

For the non-1% AEP simulations, the adopted temporal pattern was selected based on a high-level assessment of which temporal patterns were likely to produce the majority of runoff during the latter part of the storm (ie. back-loaded temporal patterns which are more likely to coincide with peak inflows from external catchments). This method was adopted due to the impracticality of simulating multiple temporal patterns for various combinations of rainfall event durations and AEPs, given the very significant 2D model run time. Whilst being non-exact, this approach is considered reasonable because it is conservative in that it aims to select the worst-case or close to worst-case temporal pattern, whereas a more typical approach (where practical computationally) would be to simulate all temporal patterns and adopt the median.

Table 1 below provides the modelled loss rates whilst Table 2 identifies which temporal pattern was modelled for each design rainfall event along with which duration was identified as critical for each AEP.

Table 1: Rainfall loss rates

Soil type	Initial loss (mm)	Continuing loss (mm/hr)
Clay	0	0.21
Sand	0	2.92
Water / Inundated	0	0
Road	0	0

Table 2: Design storm temporal patterns and critical durations

	Modelled temporal pattern number				Critical duration
AEP	6 hours	12 hour	18 hour	24 hour	
0.5% AEP	NA	NA	TP1	NA	18 hours
1% AEP	NA	NA	TP1	NA	18 hours
5% AEP	TP10	TP10	TP9	TP9	24 hours
20% AEP	TP9	TP1	TP9	TP10	18 hours

4.2.3. Roughness coefficient

Figure 12 below illustrates the existing conditions land coverages that were used to assign loss rates (discussed in previous section) and roughness parameters. The adopted Manning's roughness values are provided in Table 3.

Table 3: Manning's roughness values

Coverage	Manning's roughness
Pasture	0.05
Vegetated	0.08
Water / Inundated	0.02
Road	0.025

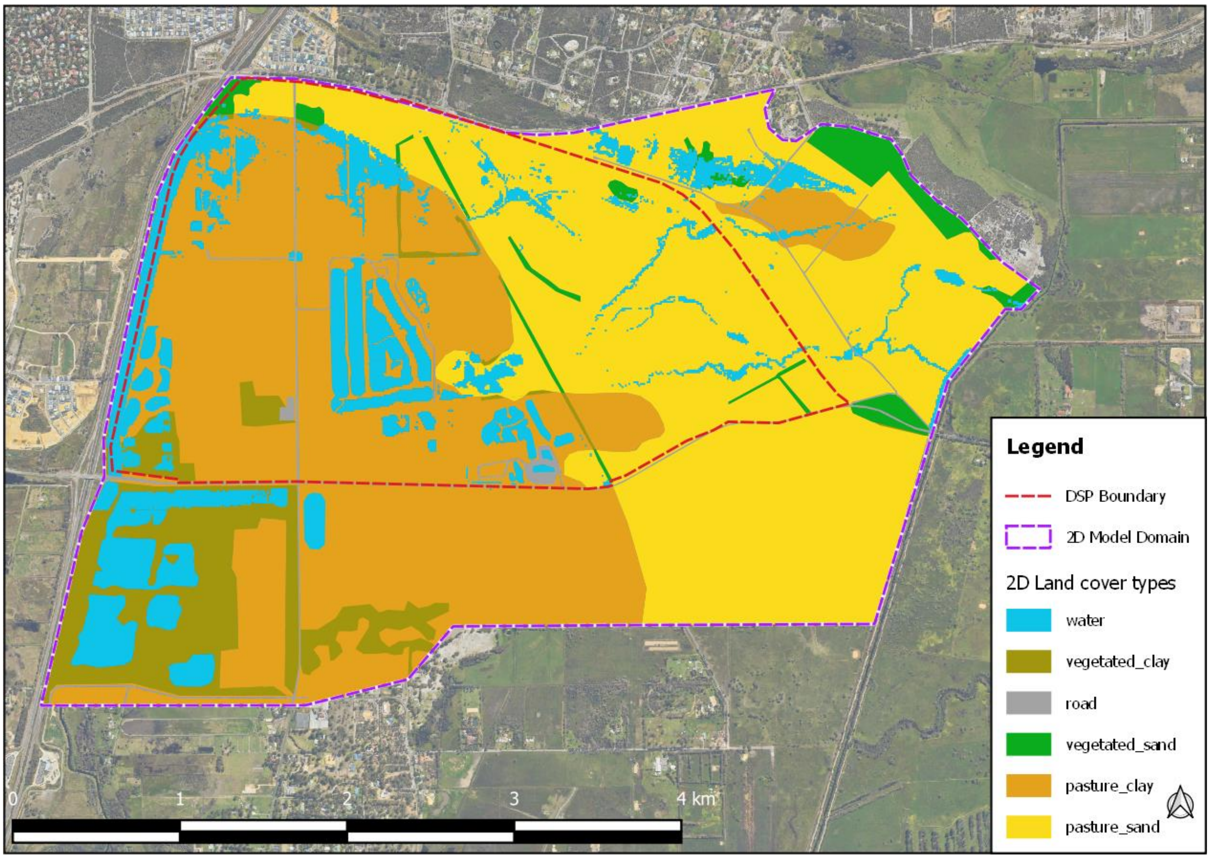


Figure 12: **Existing conditions 2D land coverages**

4.3. Existing conditions model results

The results of the existing conditions modelling are consistent with those of the DWER East-of-Kwinana modelling in terms of the following key parameters:

- Inundation extent and approximate depths
- Floodplain storage volume within the DSP area
- Peak discharge rate and hydrograph shape at Mundijong Rd ("outlet" from the DSP area)

The existing conditions 1% AEP flood extent and maximum inundation depth is shown in Figure 13 (which is also provided as a larger format flood map in Appendix A). The results indicate wide spread inundation within the DSP area, with depths between approximately 0.5 and 1.0 metres in many places (and deeper within watercourses, drains and waterbodies). The results also demonstrate large volumes of storage associated with the low-lying flat areas in the western portion of the DSP where floodwater backs up behind the existing embankments associated with St Albans Road, Mundijong Road and the Kwinana Freeway.

The significant storage volume provided within the site, owing to its flat nature and the controlling affect of the existing roads, was identified by DWER (2015 and 2021a) as a significant feature of the flood dynamics of the broader region. The movement of water through the site and the significant temporary storage within it has an influence on downstream flooding by reducing and delaying the peak discharge rates to downstream areas.

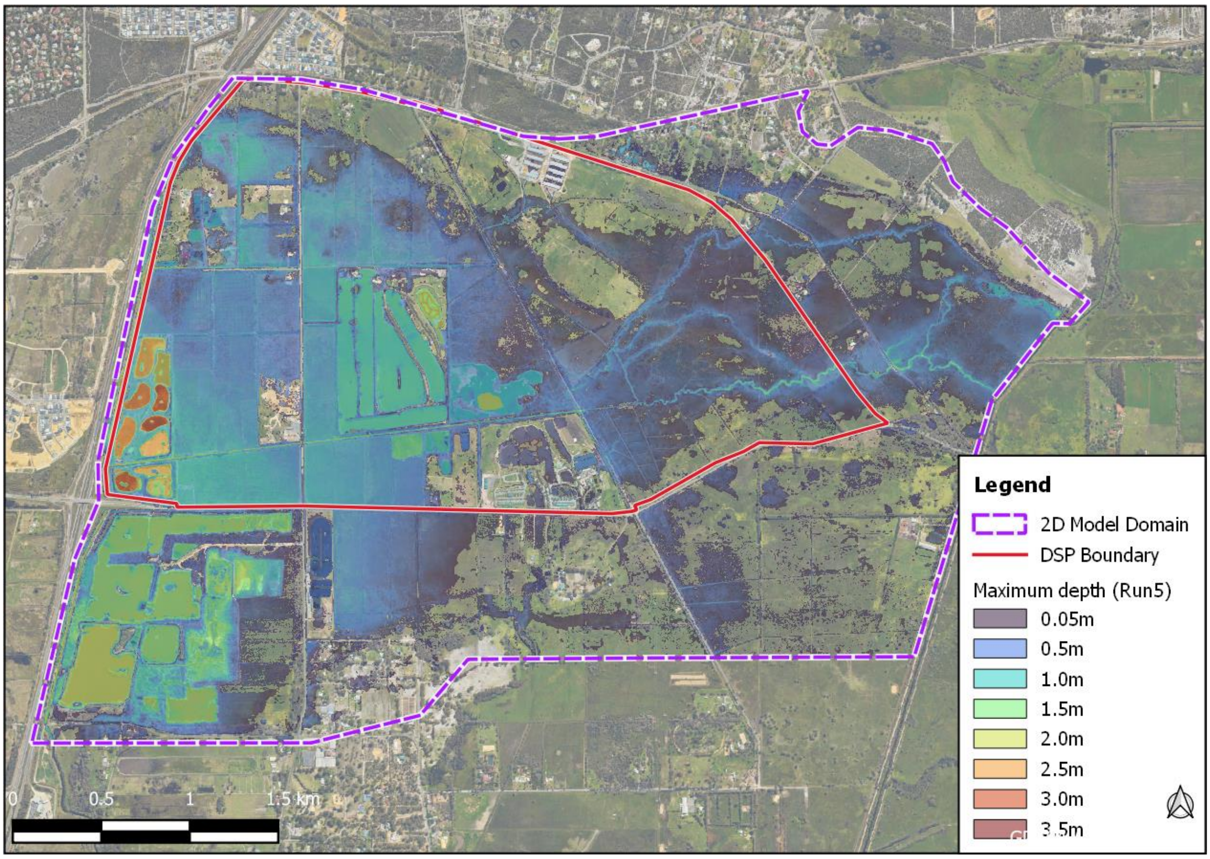


Figure 13: Extent and depth of flooding – 1% AEP existing conditions

The modelled storage volume within the DSP area is provided in Table 4 below and compared to that modelled by DWER (2021a). The DWER-modelled volume for the corresponding area has been approximated as the total of DWER "cells" 2 to 7, which as shown in Figure 14 closely align to the DSP boundary.

Table 4: Existing conditions 1% AEP storage volumes

Coverage	Total 1% AEP storage volume
Pentium Water model - DSP area	3.38 GL
DWER model – Cells 2 to 7	3.41 GL

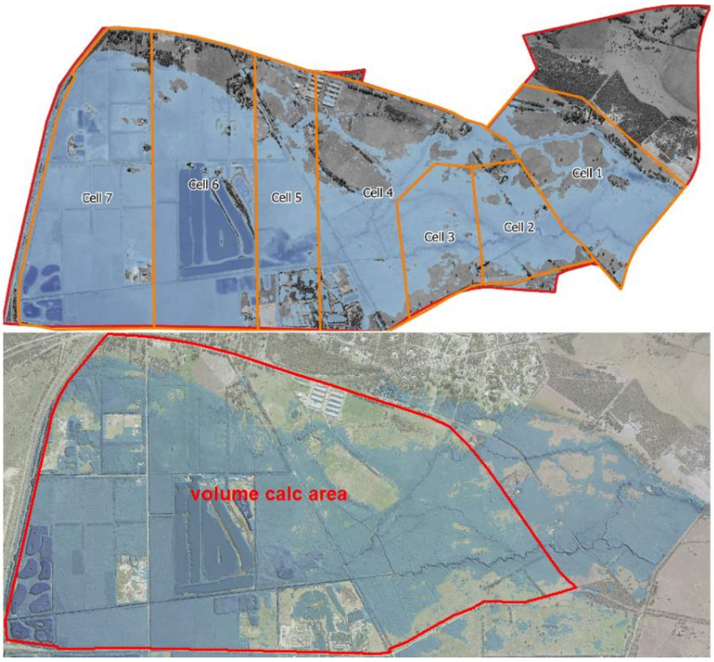
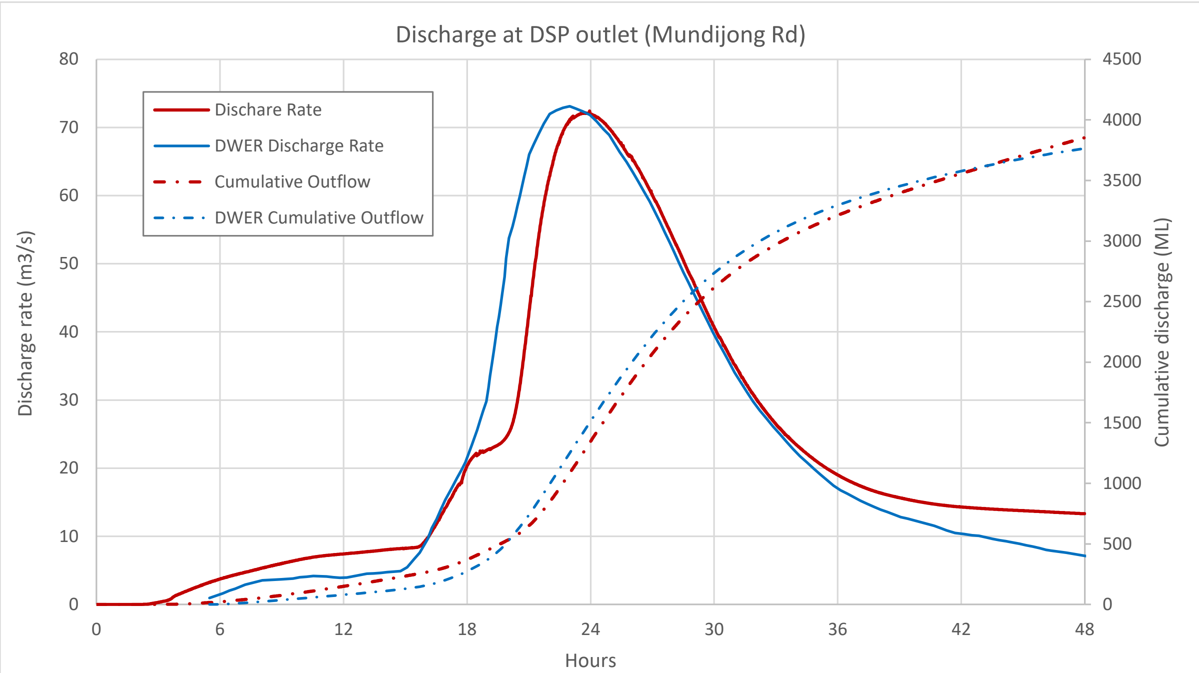


Figure 14: Storage volume assessment areas (DWER at top)

Graph 2 below provides the modelled discharge rate (and cumulative discharge volume) at the south-western DSP boundary and compares this to the results of the DWER 2021 modelling. The results plotted in Graph 2 represent the combined discharge via the existing Peel Main Drain culverts beneath Mundijong Road and flow over the top of Mundijong Rd, which occurs across an approximately 1 km length of the road to the east of Peel Main Drain.



Graph 2: Comparison to DWER modelled existing conditions (at Mundijong Road)

In summary, the existing conditions model developed as part of this assessment simulates flood conditions that are very consistent with those of the DWER (2021a) modelling and therefore provides an appropriate "baseline" against which to compare proposed development scenarios.

5. Developed conditions model setup

5.1. Overview

The purpose of the developed conditions modelling is to understand how the floodplain dynamics (particularly in relation to detention storage volumes, and rates and timing of discharge at various locations) respond to the proposed development of the site. The primary mechanism by which development will impact the floodplain behaviour is the necessary filling of portions of the site to provide dwellings and infrastructure with suitable flood protection, thereby removing floodplain storage and potentially redistributing / redirecting flows.

As has previously been demonstrated by DWER (2021a and 2021b) the floodplain behaviour, in terms of discharge volumes and rates downstream of the site, is sensitive to changes in the storage volume within the site. This has been re-confirmed through the modelling described herein, and requires the post-development flood management design to conserve total flood storage volume as well as control the way in which water moves through the flood storage areas, to avoid significant changes to the rate and timing of discharge from the site.

5.2. Model setup

The XPSWMM 1D-2D hydraulic model described in the previous section was modified using a DTM developed to represent the developed site conditions. Other key model parameters including external catchment inflows, boundary conditions, grid size, design rainfall, and losses and roughness coefficients (where land uses are unchanged in the Developed scenario) were unchanged from the existing conditions model. The developed conditions model focuses on the same design rainfall event (1% AEP, 18 hour, temporal pattern 1) that was adopted as the critical duration design event in both the DWER (2021a) and Pentium Water existing conditions modelling.

5.2.1. Model domain

The developed conditions model adopted a slightly smaller 2D model domain compared to the existing conditions model. The area of 2D domain that was removed is the area south of Mundijong Road and east of Saint Albans Road where it is south of Mundijong Road. This change to the 2D domain (relative to the existing conditions model) was adopted due to the large number of developed conditions model simulations undertaken as part of the DSP design and modelling process (ie. numerous revisions to layouts, earthworks levels, design of hydraulic controls etc). From a practicality perspective, the reduced model domain allowed model run times to be reduced without impacting the ability to assess flood conditions upstream, within or downstream of the site.

Flows generated via rain-on-grid over the excluded portion of the existing conditions model were input to the developed conditions model as boundary conditions, as shown in Figure 17.

5.2.2. Digital terrain model and 1D features

The developed scenario terrain model reflects the DSP layout and the concept earthworks plan which is provided as Appendix B. Both the layout and earthworks concept underwent multiple revisions as part of the modelling process, ie. these designs were heavily informed by the hydraulic modelling.

The concept earthworks plan (and developed conditions model terrain) incorporate the following key features:

- Large flood storage corridors, which range from 100 to 150 m wide, are typically graded at ~1:1000 longitudinally, and generally have a deign level similar to natural surface level.
- Smaller flow channels within the flood corridors, which are intended to convey baseflows (ie. groundwater discharge under high groundwater conditions and subsoil drainage

discharge) and the majority of rainfall events (ie. these channels are typically capable of conveying all flow generated by the site in the absence of large inflows from a BMD spoil bank failure). These have been modelled as typically 0.9 m deep and 15 m wide at the top of banks.

- Developed areas are raised to provide separation from the flood levels (as well as providing groundwater separation and grade for sewer and stormwater services). The design levels presented in the earthworks concept and the DTM are preliminary only; in terms of the hydraulic modelling, the developed areas simply represent removal of floodplain storage and the modelled design levels are not relevant to the model outcomes.
- Minor open drains within the developed area footprint. These small drains are included in the earthworks concept (and DTM) simply to provide some local conveyance of flow towards the flood corridors and to represent the potential use of open drains (ie. median swales or living streams) through the site reduce sub-catchment sizes and fill requirements. In terms of the hydraulic modelling, these minor drains also better represent the channelisation and connectivity of flows generated from the developed area. However, the influence of the drains on the model outcomes is negligible as the storage volume provided within these drains represents only 0.5% of the total modelled storage within the site.

The following features are not reflected on the concept earthworks plan but were incorporated in the hydraulic model and DTM (ie. were added within the model environment). These features are all described in more detail in Section 5.3.

- Major bunds and culverts. These are significant features of the flood management design. These will likely be associated with the alignments of roads crossing the flood corridors and will incorporate large banks of culverts which may provide some attenuation of peak discharge rates as the flood moves through the site but are primarily intended to pass the 1% AEP flow whilst maintaining vehicular / emergency access in flood events (ie. these bunds are not intended to overtop during a 1% AEP event).
- Minor bunds and culverts. These are also significant features of the flood management design; however, their purpose and function are very different to the major bunds described above. Whilst the major bunds and culverts assist with controlling peak flow rates and flood levels through the flood corridors, the minor bunds influence the timing of peak flows and control the discharge of stored water. The function of these bunds will include significant overtopping during a 1% AEP (spoil bank failure) event and as such these bunds are not proposed to be associated with roads but rather are likely to be landscaped features within the flood corridors.
- Public open spaces. Some of the proposed POS areas within the DSP are located within the flood corridors. These were modelled as being raised (typically by 0.4-0.6 m) above the general flood corridor elevation due to the possibility that some of these POS areas will be elevated with fill to facilitate subsoil drainage and turfed active space. Modelling the POS areas as uniformly raised ensures that the potential flood storage over these areas is not overestimated.
- Interceptor drains along the eastern / upstream boundary of the DSP. These will be required to assist with the collection and conveyance of floodwater from the upstream floodplain into the proposed flood corridors, to avoid any increase in flood levels upstream of the site. These features would likely be temporary if the adjoining land to the east was also developed, in which case flows through the adjoining land would become channelised within corridors and tie directly into the subject site's flood corridors (thus negating the requirement for these interceptor drains).
- Mundijong Road culverts. The developed conditions model includes the future upgrade of Mundijong Road which, given its importance as a major regional road, would be required to provide it with flood immunity and ensure emergency access. Therefore, the existing conditions flood route, which is overtopping of a long section of the road, will need to be redesigned to utilise culverts beneath the road. The hydraulic model has incorporated culverts (at the location shown in Figure 17) as well as an associated inlet structure (ie. bund) to maintain the existing conditions discharge (ie. frequency, rate and timing) at Mundijong Road as much as possible.
- Proposed bund along Peel Main Drain to increase the achievable flood storage height. The purpose of this feature is to facilitate storage of the required flood volume within the western portion of the DSP more efficiently, by allowing a flood height approximately 0.4m higher than that in the adjacent PMD. The bund isolates the PMD and any external

properties which are connected to the PMD from the higher flood level to prevent any flood impacts to those areas.

The above features and how these are configured within the developed conditions model are further discussed in Section 5.3 and illustrated in Figure 17.

5.2.3. Golden Ponds site

The Golden Ponds aquaculture and accommodation site (Lot 470 Mundijong Road located centrally along the southern DSP boundary) is identified in the DSP plan as being approximately 45% occupied by flood corridor, in line with the general approach to distribute flood storage areas as equitably as possible between landholdings. Given the Golden Ponds site has previously been filled (the existing aquaculture ponds sit approximately 0.5-1.0m higher than natural surface levels to the north of Golden Ponds and the constructed ground levels surrounding the ponds are a further 1 m or more higher) and contains significant improvements / infrastructure, it has been assumed for the purpose of the flood modelling that the site will not be developed or modified. The Golden Ponds site has therefore been omitted from the modelled flood corridor extent to avoid overestimating flood storage volume within the DSP.

5.2.4. 2D land coverages

Land use coverages in the model were only changed over the development footprint area. Upstream and downstream areas were unchanged as well as the flood corridors which for the most part are intended to be subject to only minor earthworking / change of levels and therefore the existing soil types and infiltration losses remain appropriate. As discussed in the DWMS, the future land uses and landscape design of the flood corridors is unconfirmed at this stage, with various options having been identified for further investigation. It is possible that future uses and landscape management within the corridors will impact the infiltration and roughness characteristics. These potential changes are addressed as part of the model sensitivity analysis (Section 6.5).

The modelled land use types within the development footprint are shown in Figure 15 and the associated values adopted for model parameter are provided in Table 5.

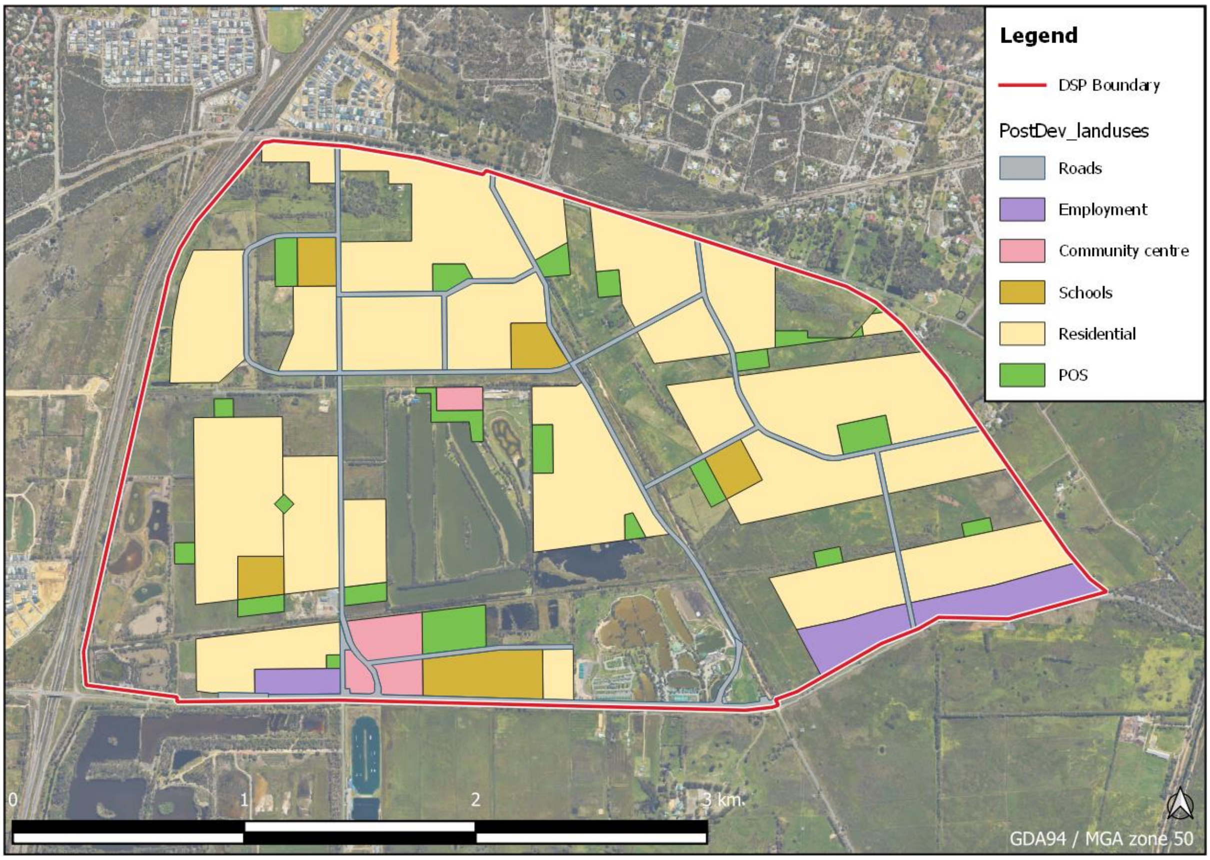


Figure 15: Developed conditions coverages (where different to existing conditions)

The loss rates (applied as infiltration from the 2D grid) that were adopted for the developed portions of the model are provided in Table 5. Initial and continuing loss values for "residential" areas are based on the anticipated breakdown of road reserve and private lots, as follows:

- 35% road reserve
- 30% Class A lots (with soakwells)
- 30% Class S lots (with direct connections)
- 5% POS

The weighted average approach is reasonable at this stage of planning and also incorporates conservative loss rates for each land use to account for uncertainty around final proportions of land uses.

An initial loss of 15 mm is expected to apply to both of these areas given runoff from roads will need to be treated in bioretention basins (which are not represented in the model terrain) and lots will either use soakwells to contain runoff onsite or will be connected into the road reserve drainage system and be accounted for in the sizing of bioretention basins. Despite this, a conservative value of 10 mm initial loss has been used which accounts for the possibility that portions of the site may discharge directly into the flood corridors for in-line treatment rather than off-line bioretention basins (ie. adjacent sections of road reserve may utilise flush kerbing if appropriate).

The continuing loss value of 1.6 mm/hr is similarly a weighted average for residential areas and considers the following assumed (conservative) continuing loss rates for the various land uses:

- Road reserve (assumed 35% of development footprint) – 1 mm/hr loss based on minimal infiltration losses through verge area
- Class A lots (assumed 50% of lots / 32.5% of development footprint) – 4 mm/hr loss based on losses through soakwells

- Class S lots (assumed 50% of lots / 32.5% of development footprint) – 0.21 mm/hr loss based on minimal loss, equivalent to existing conditions losses on clayey soils.

Losses for other land coverages are based on the following assumptions:

- Employment and community centre areas will need to retain / treat the first 15 mm on site (eg. Treatment swales or soakage structures within car parks etc). Minimal continuing losses conservatively assumed for these areas.
- Schools assumed to largely manage stormwater onsite. Continuing loss rate reflects infiltration in landscaped areas of the school / oval etc.
- POS loss rates reflect at-source infiltration within the mostly pervious areas of POS and the likely use of import fill to achieve groundwater separation (thus more effective infiltration) for POS areas.

Table 5: Roughness and loss values adopted for developed areas

Soil type	Manning's roughness	Initial loss	Continuing loss
Residential	0.025	10 mm	1.6 mm/hr
Employment	0.025	15 mm	0.21 mm/hr
Community Centre	0.02	15 mm	0.21 mm/hr
Schools	0.06	15 mm	2.9 mm/hr
POS	0.05	15 mm	3.5 mm/hr

5.3. Flood management concept design

5.3.1. Flood corridors

The primary purposes of the flood corridors are the conveyance and storage / detention of floodwater in the occurrence of a large rainfall event and associated failure of the BMD spoil bank. The size of the proposed corridors is significantly greater than would typically be necessary (in terms of their dimensions and proportion of the overall site) due to the requirement to allow for potential breakout flows from the BMD. In the event of a BMD spoil bank failure, the magnitude of potential flow volumes and rates through the site is very large.

The main governing criterion for the size and design of the corridors is the provision of equivalent flood storage volume to the existing conditions, which is one of the key design principles outlined by DWER (2021b) for the potential development of the site. The modelling undertaken by both DWER (2021a) and Pentium Water (discussed in next section), indicates that the downstream floodplain behaviour and discharge characteristics are sensitive to the timing and volume of discharge from the site (not just the peak discharge rate). Therefore, the flood corridor design has been based on achieving an overall flood storage volume equal to that of the floodplain under existing conditions (refer to Section 4.3).

Within the flood corridors are smaller flow channels which will convey the vast majority of rainfall events without overtopping into the broader flood corridor area. The channels have been preliminarily modelled as approximately 0.9m deep and 15 m wide at the top of banks, and are adequate to convey the 5% AEP event (assuming no breakout flow from the BMD) without overtopping into the flood corridor except for immediately upstream of road crossings and bunds where flow is controlled by culverts and some minor inundation / detention within the flood corridor occurs (these inundation areas can be seen in the flood maps provided in Appendix A).

These lower flow channels are also likely to provide the controlled groundwater level being the likely point of discharge for subsoil drains installed beneath the proposed development and usable open space. The remaining / broader portions of the flood corridors, on the other hand, will generally remain above the groundwater level and not be subject to groundwater inundation and, therefore, can be useable and provide a year round amenity function.

5.3.2. Hydraulic structures

5.3.2.1. Major bunds

The 'major' bunds shown in the model setup (Figure 17) are associated with the locations of key roads crossing the flood corridors. The two purposes of these bunds are to; 1) accommodate trafficable emergency access routes with immunity from the 1% AEP flood, and 2) assist with the attenuation of peak flows through the site. These bunds will be designed with large banks of culverts sized to pass the 1% AEP flood beneath road pavements and will provide some attenuation of peak flow rates.

Details for the numbers and dimension of culverts at each of these major bund / road crossing locations are shown in Figure 18 but are preliminary at this stage of planning. The design of these structures and culverts will be refined through further modelling at structure planning and detailed design phases of development.

5.3.2.2. Minor bunds

Besides the flood storage corridors themselves, which provide for the conveyance and attenuation of flows through the site, the key aspects of the flood management concept design are the hydraulic structures which have an important role in controlling the detention time for stored floodwater and the discharge hydrograph shape.

As noted in DWER (2021a), the site is not sufficiently close to the final catchment outlet (ie. to the Peel Inlet / ocean) that it would be reasonable to discharge floodwater from the site earlier in the storm than would occur under existing conditions. Locations near the final catchment outlet can potentially do so without impacting flood levels, however for locations higher in the catchment, earlier discharge of water can create or exacerbate flooding downstream due to the concentration of flows.

The hydraulic model domain was extended to approximately 1.4 kilometres downstream of the site boundary in order to assess any impacts that development of the site may have to areas further downstream through changes in the timing and volume of discharge of floodwater from the site. It was determined that the discharge rate further downstream of the site (near the model outlet / boundary condition) is highly sensitive to the shape of the site discharge hydrograph. Through the process of modelling numerous post-development designs, it was evident that even when the discharge rate at the site boundary (ie. Mundijong Road) was controlled to below existing conditions, the discharge rate further downstream could experience significant increases resulting from changes to the site's discharge hydrograph shape.

In particular, when peak discharge conditions from the site are extended over a longer period of time (ie. flatter, broader hydrograph compared to existing conditions), the greater cumulative discharge volume results in a significantly higher downstream discharge rate. This finding led to the inclusion of one of the key aspects of the post-development flood management design, which is the inclusion of 'minor bunds' within the flood corridors. The characteristics of these 'minor bunds; are as follows;

- primary purpose is to provide an extended detention time for a large portion of the stored floodwater (ie. as opposed to allowing the floodwater to discharge rapidly via large culverts following the peak of the flood)
- the extended detention time behind these bunds effectively mimics the existing conditions whereby most of the flood storage is provided behind roads which act as barriers, forcing stored floodwater to recede slowly through relatively small culverts
- in order to effectively 'hold' the water back for extended periods, these minor bunds will be designed with culvert capacity much lower than the peak flood discharge rate; therefore, the bunds will overtop during a 1% AEP (spoil bank failure) event
- the stored water behind these bunds is intended to discharge over a period of ~3-4 days following the peak flow for a 1% AEP event (emptying times would be quicker for more frequent events and would be much quicker for rainfall events in which the BMD spoil bank does not fail).

- given the requirement for these bunds to overtop, they are less likely to be associated with road crossings, or they could be associated with lower order roads that are not essential for emergency access in the event of a major flood event.

Figure 15 below illustrates the function of the two types of flood storage bunds discussed above.

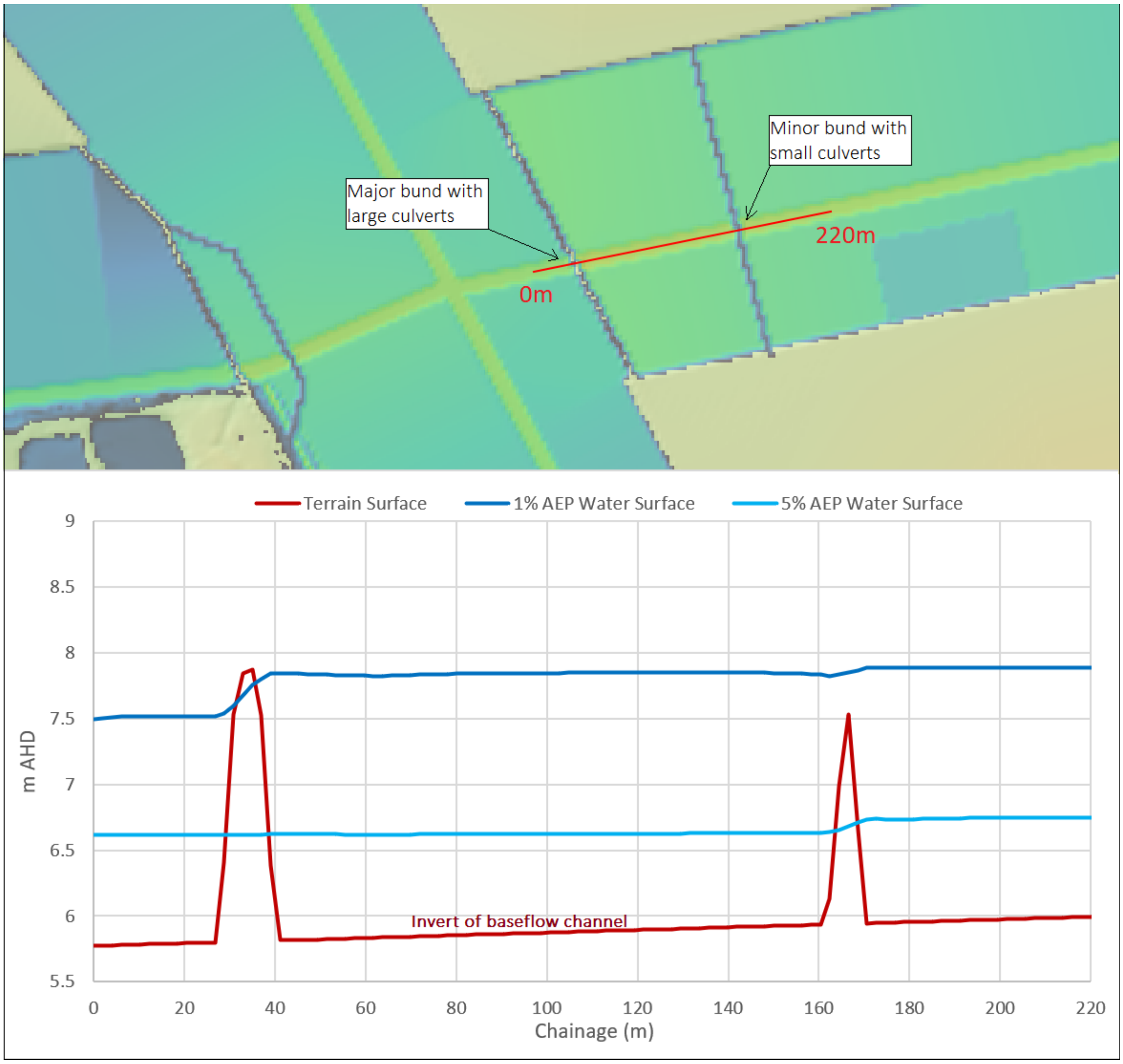


Figure 16: **Conceptual long-section of major and minor bund functions**

5.3.2.3. Mundijong Road outlet

The conveyance of flood water across Mundijong Road is a key aspect of the existing conditions flood dynamics and an important consideration for proposed development of the site and/or upgrading of Mundijong Road. Approximately 79% of the 1% AEP discharge from the DSP flows over a broad section of Mundijong Road under existing conditions, as described in Section 4.3.

It is understood that Mundijong Road as a key regional transport route will need to be upgraded to support both the proposed DSP but also broader development and increasing traffic volumes. It is anticipated that any upgrade to Mundijong Road will include raising the profile of the road to provide it with flood immunity as a major transport route. This will require a large set of culverts (or bridge) to convey the large 1% AEP flow (~55 m3/s) which would flow over the roadway in the existing conditions. Given the magnitude of flow (which under existing conditions is modelled as flowing over an approximately 1 km length of Mundijong Road), a floodway is not considered feasible.

The developed conditions model has been set up with the following configuration for the Mundijong Road culverts which has been determined to provide a reasonable match for the existing conditions discharge characteristics at Mundijong Road:

- 11x 1.8mx1.2m box culverts
- 120 m long bund immediately upstream of the culverts, with crest at 5.8 mAHD to control flow through the culverts to match existing conditions.

5.3.2.4. Peel Main Drain bund

A bund alongside the Peel Main Drain (PMD) is proposed in order to increase the achievable storage height / depth without impacting flood levels in the PMD (and subsequently impact external properties via increased tailwater levels and the potential for floodwater to back up into those properties). The proposed maximum flood height is 6.2 mAHD which is equal to the approximate lowest elevation of the adjacent Kwinana Freeway carriageway. Whilst the proposed flood storage within the DSP is isolated from the PMD and the freeway via the proposed bund, the adoption of this maximum design flood height further protects the adjacent infrastructure from impacts in the unlikely event of a bund failure etc.

Assuming the bund is constructed with 300 mm freeboard above the design flood height, the top of the bund would be at approximately 6.5 mAHD. The top of the existing PMD eastern levee / spoil bank is generally between 5.5 and 6.0 mAHD with the general ground level to the east of the level typically at approximately 5.0 mAHD. Therefore, the height of the proposed bund is approximately 0.5-1.0m above the existing levee / spoil bank. It is acknowledged that the bund would need to be appropriately designed and constructed from a structural integrity perspective, and that this would likely require geotechnical testing and remediation / modification of the existing levee bank if that were proposed to be used as part of the new bund structure (as opposed to constructing the new bund on a separate alignment further east of the existing levee bank).

The DSP flood storage areas will be connected to the PMD via culverts through the proposed bund. These culverts will be designed to maintain connectivity for baseflow (ie. to maintain the ability to control groundwater levels within the DSP) and minor rainfall events / local stormwater flows, whilst also being sized to restrict flows into the PMD in the event of a BMD spoil bank failure event during which flood storage up the maximum 6.2 mAHD may occur. The developed conditions modelling has identified preliminary sizing for these culverts as a 1.8m x 1.2m box culvert at each of the two proposed connection locations depicted in Figure 17 below.

5.3.3. Developed conditions model configuration

Figures 17 and 18 below illustrate the developed conditions model setup. The post-development terrain model (ie. design surface levels) is illustrated in Figure 17 and has been created from the conceptual engineering earthworks design along with some manual modification where required to superimpose POS areas (which have been modelled as raised with fill for enhanced groundwater separation) and additional drainage features (eg. bunds and interceptor drains on the upstream boundary etc). Required culverts at the bund locations have been modelled explicitly as 1D features and the preliminary numbers and dimensions of these are provided in Figure 18.

Rainfall (as rain-on-grid) and boundary conditions (outflow locations and external catchment inflows) are modelled in the same manner as the existing conditions model, with the exception of additional inflow boundary conditions in the south-eastern part of the model domain which replace a portion of the model domain outside of the DSP. Inflows to these locations were taken from the existing conditions model and the corresponding part of the model domain excluded because it is outside of the proposal area and thus is the same for the existing and developed conditions.

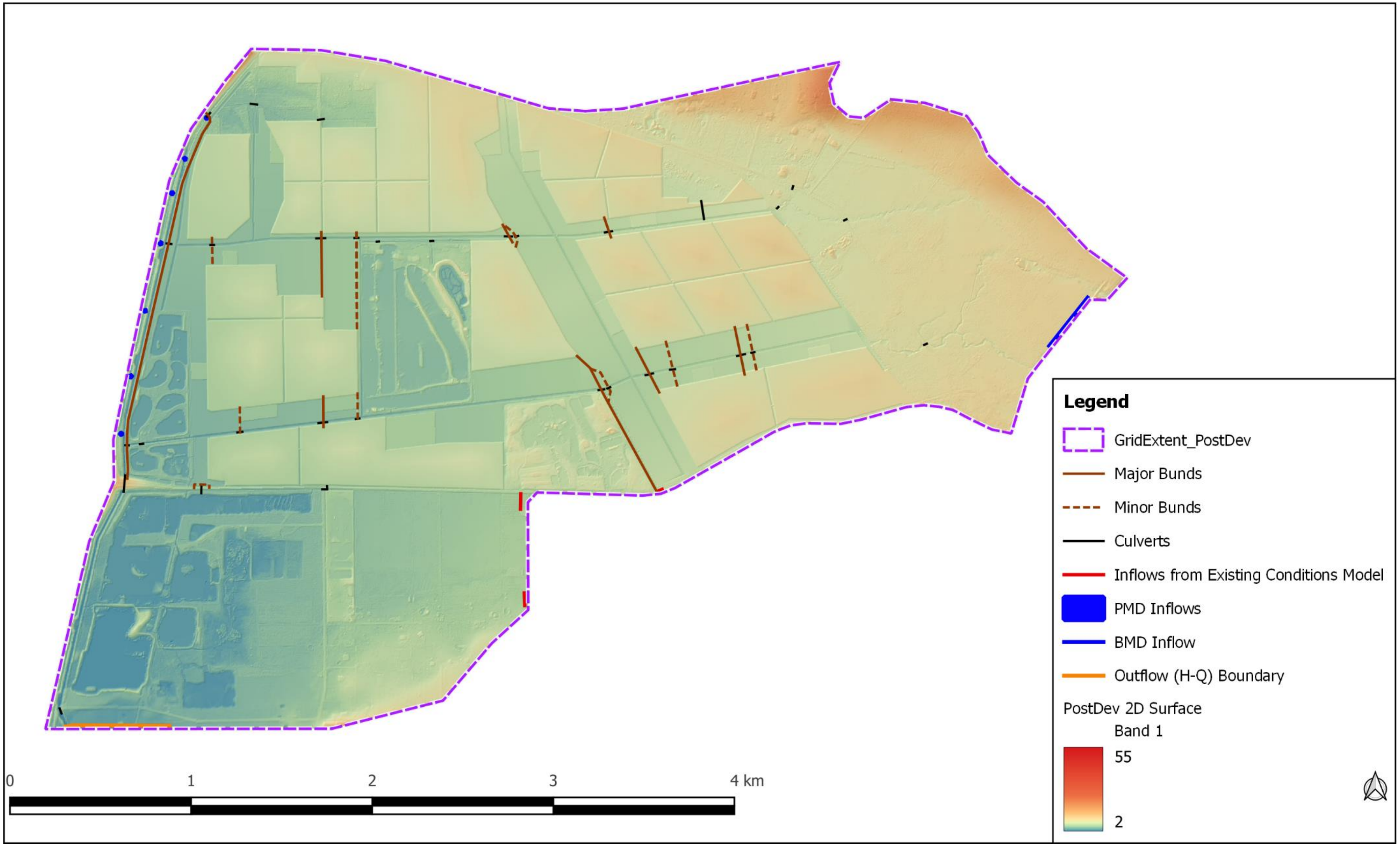


Figure 17: Developed Conditions Model Configuration

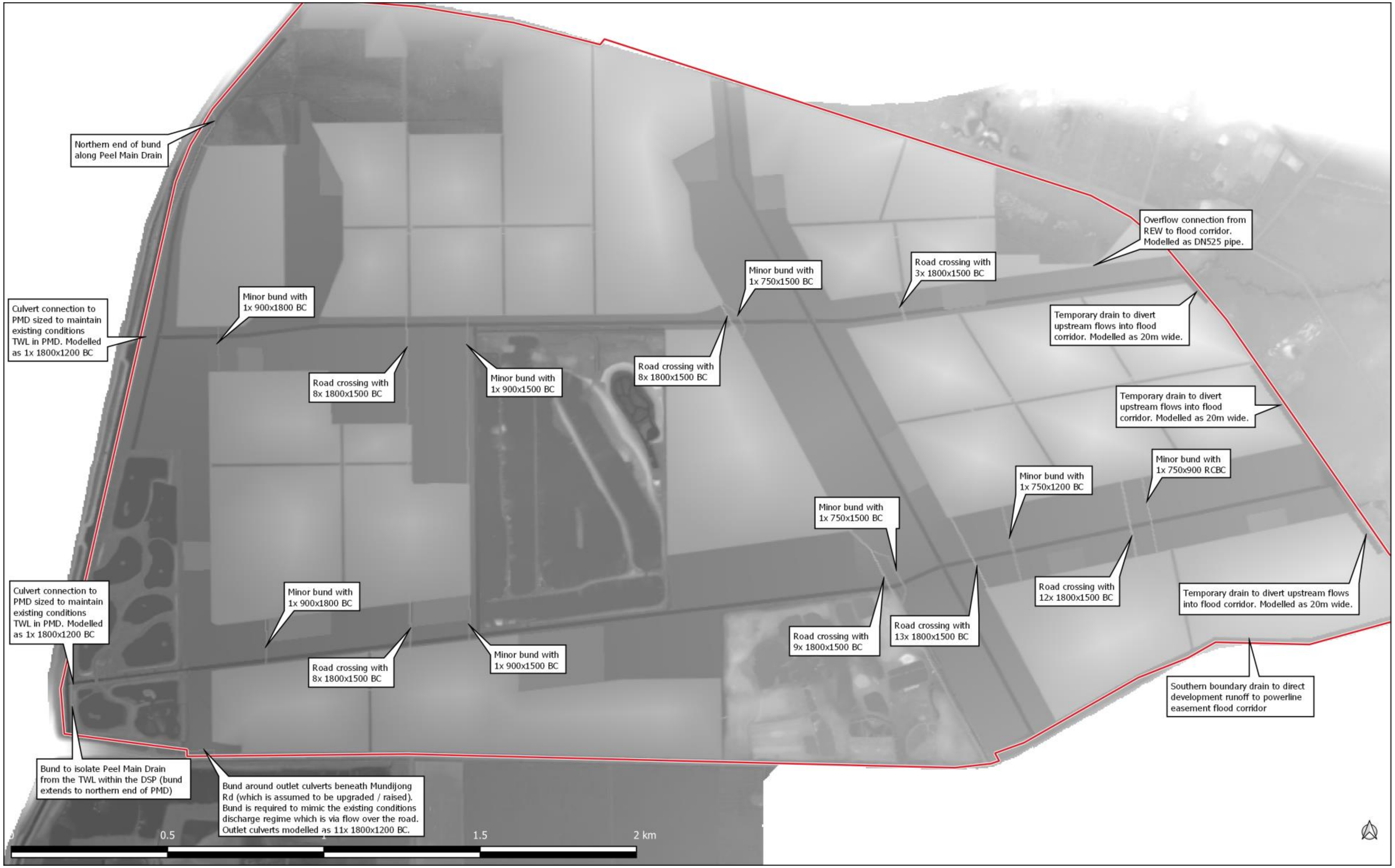


Figure 18: Preliminary design details for hydraulic structures

6. Developed conditions model results

6.1. Optimisation of storage and discharge

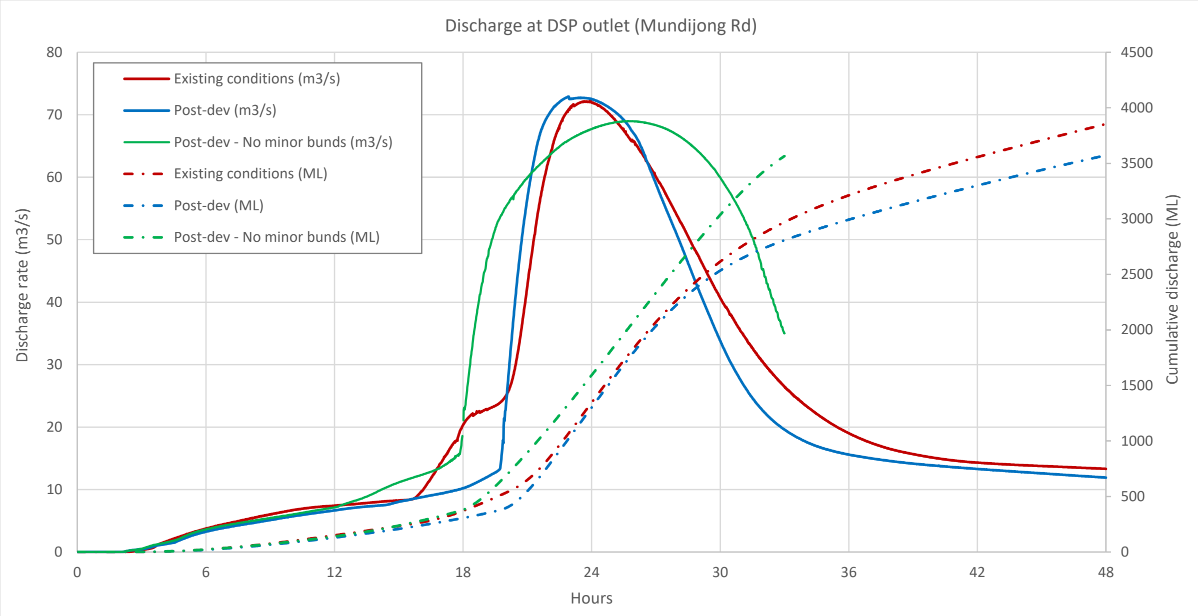
As discussed extensively through this report, a key parameter of the flood mitigation design is the replication of the flood storage volume that occurs across the site under existing conditions, to prevent adverse impacts downstream in terms of flow rates and flood levels. Another key aspect of the flood mitigation design is to control the movement of water through the site to mimic the function of the existing floodplain in terms of the retention time of water within the DSP area (ie. as occurs behind road embankments under existing conditions).

It is not suitable to simply provide an equivalent storage volume without any consideration for the means and timing of discharge of the stored water to downstream. This is particularly relevant given the site's location near the top of the hydrological catchment, meaning earlier discharge of floodwater from the site has the potential to coincide with / exacerbate peak flooding conditions downstream (ie. as opposed to locations nearer the catchment outlet where it might be acceptable or even advantageous to discharge water earlier to avoid coinciding peak flows).

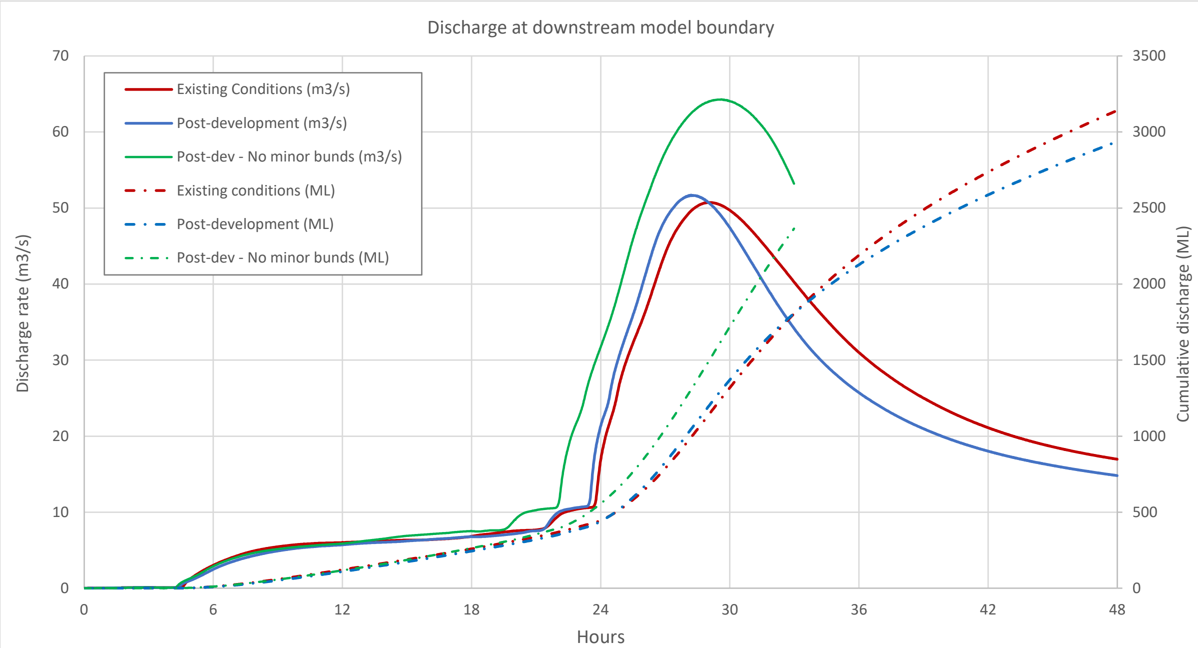
This point is well illustrated in Graphs 3 and 4 below which show the modelled discharge rate at two locations; the DSP boundary at Mundijong Road and further downstream at the model boundary (immediately south of Bertenshaw Rd). The graphs compare the existing conditions discharge hydrograph to that of the developed conditions under two scenarios; the first representing the proposed DSP flood mitigation design inclusive of proposed minor bunds and the second representing omission of the proposed minor bunds. As described in Section 5.3.2, the minor bunds are proposed specifically to mimic the existing floodplain dynamics by temporarily holding large volumes of floodwater behind these structures to be released over an extended period by appropriately sized culverts.

Under both scenarios the volume of flood storage has been matched to that of the existing conditions and the peak discharge rate is controlled so as not to exceed that of the existing conditions. However, the minor bunds and associated culverts have a significant influence on the timing of discharge from the site (ie. the discharge hydrograph shape). The results show that under the scenario with the minor bunds omitted, the cumulative discharge volumes are much higher owing to the earlier rising limb and broader hydrograph. The impact of the increased discharge volumes are significant at the downstream model boundary where peak discharge increases by about 25%.

Graphs 3 and 4 demonstrate how the hydraulic modelling has been used to inform not only the DSP layout but also the conceptual flood mitigation design (including critical elements such as bunds and culverts) to ensure that the current function of the floodplain is maintained by the proposed flood corridors following development.



Graph 3: **Modelled discharge at Mundijong Road**



Graph 4: **Modelled discharge at downstream model boundary**

6.2. Modelled storage volumes and discharge rates

Table 6 summarises the modelled flood storage volume within the DSP boundary and peak discharge rates at Mundijong Road as well as the downstream model boundary, for a range of AEPs under existing and developed conditions. The results demonstrate that the proposed DSP and flood mitigation concept are capable of maintaining the existing conditions flood regime to prevent impacts to downstream properties.

Table 6: Modelled storage volumes and discharge rates

AEP	Scenario	DSP Storage	Discharge from DSP	Discharge at model boundary
1% AEP (spoil bank fail)	Existing	3.38 GL	72.4 m^3/s	50.7 m^3/s
	Developed	3.35 GL	72.9 m^3/s	51.7 m^3/s
5% AEP (spoil bank fail)	Existing	1.90 GL	10.9 m^3/s	6.9 m^3/s
	Developed	1.83 GL	8.9 m^3/s	6.3 m^3/s
5% AEP (spoil bank intact)	Existing	0.63 GL	7.3 m^3/s	6.4 m^3/s
	Developed	0.68 GL	6.5 m^3/s	6.1 m^3/s
20% AEP (spoil bank intact)	Existing	0.42 GL	5.7 m^3/s	5.2 m^3/s
	Developed	0.46 GL	5.2 m^3/s	4.9 m^3/s

6.3. Flood levels and depths

Appendix A provides detailed flood maps which provide the extent and depth of inundation as well as the peak flood height at various reference locations. The flood maps demonstrate that whilst the distribution and depth of flooding within the DSP area changes as a necessary consequence of development of the site, the upstream and downstream flood extents and depths / heights are not adversely impacted. The maximum increase in flood height modelled for the areas upstream and downstream of the DSP are 0.04 m and 0.01 m respectively. These changes are within the range of impact described as being acceptable by DWER (2021a) which are 0.05 m and 0.03 m for the Birrega Main Drain (upstream of DSP) and Peel Main Drain (downstream of DSP) floodplains, respectively. However, it should also be noted that these very minor modelled “impacts” can be further reduced or completely negated at subsequent stages of design through slight optimisation of hydraulic controls etc.

The only area outside of the DSP where flood depths significantly change in the developed conditions model is around the cable ski park, to the east of St Albans Rd and south of Mundijong Road. This area experiences a significantly (~0.2m) decreased flood depth / height in the 1% AEP event. This is due to the assumed / modelled upgrade to Mundijong Road which would prevent floodwater overtopping the road into this area. In the developed conditions model, all discharge via Mundijong Rd is assumed to be directed via culverts to the Alcoa-owned lakes to the west of St Albans Road (which is where the vast majority of overflow goes in the existing conditions).

The flood maps in Appendix A also show the proportion of the flood corridors and associated POS areas (ie. POS areas within the flood corridors) that are inundated during various AEP events. All of the POS areas (which were modelled as being slightly raised above the general flood corridor level, as described in Section 5.3.3) remain free of inundation in the 20% AEP and 5% AEP (spoil bank intact) scenarios, whereas several of the POS areas are inundated during the 5% AEP (spoil bank fail) scenario and all POS areas are inundated in the 1% AEP event. In terms of the broader flood corridor areas, these are mostly dry in the 20% AEP event, about half inundated in the 5% AEP (spoil bank intact) event, almost completely inundated in the 5% AEP (spoil bank fail) event and completely inundated in the 1% AEP event.

The modelled inundation depths shown in the flood maps can be summarised as follows:

- 1% AEP depths typically between 1.0 and 1.4 m (and up to 1.5 m) in the general flood corridor areas and typically between 1.5 and 2.0 m in the baseflow channels (up to approximately 2.5 m near the Peel Main Drain).
- 5% AEP (spoil bank fail) depths typically between 0.4 and 1.0 m (and up to 1.2 m) in the general flood corridor areas and between 1.2 and 1.8 m in the baseflow channels.
- 5% AEP (spoil bank intact) between 0 and 0.4 m in the general flood corridor areas and between 0.4 and 1.3 m in the baseflow channels.

- 20% AEP depths between 0 and 0.2 m in the general flood corridor areas and between 0.3 and 1.1 m in the baseflow channels.

The maximum inundation depths modelled for the developed conditions 1% AEP event are fairly consistent with those for the existing conditions. The main watercourse through the eastern portion of the DSP area was modelled with 1% AEP depths up to 1.6 m in existing conditions and further downstream the open drain was modelled with depths up to 2.1 m upstream of St Albans Rd and 2.4 m downstream of St Albans Rd, near the Peel Main Drain. The Peel Main Drain itself was modelled as having 1% AEP depths of up to approximately 2.7 m in existing conditions. Therefore, whilst the conceptual flood mitigation design includes inundation depths greater than the typical 1.2 m adopted for urban stormwater systems, this is generally reflective of the major regional watercourses and significant flood depths that occur in this locality (ie. these depths are largely unavoidable).

Figure 19 illustrates how the modelled 1% AEP flood level and depth varies along the east-west flood corridor through the southern portion of the DSP and demonstrates that water depths in the general flood corridor area are typically less than 1.2m except for immediately upstream of bund locations where floodwater is deliberately backed up behind those structures.

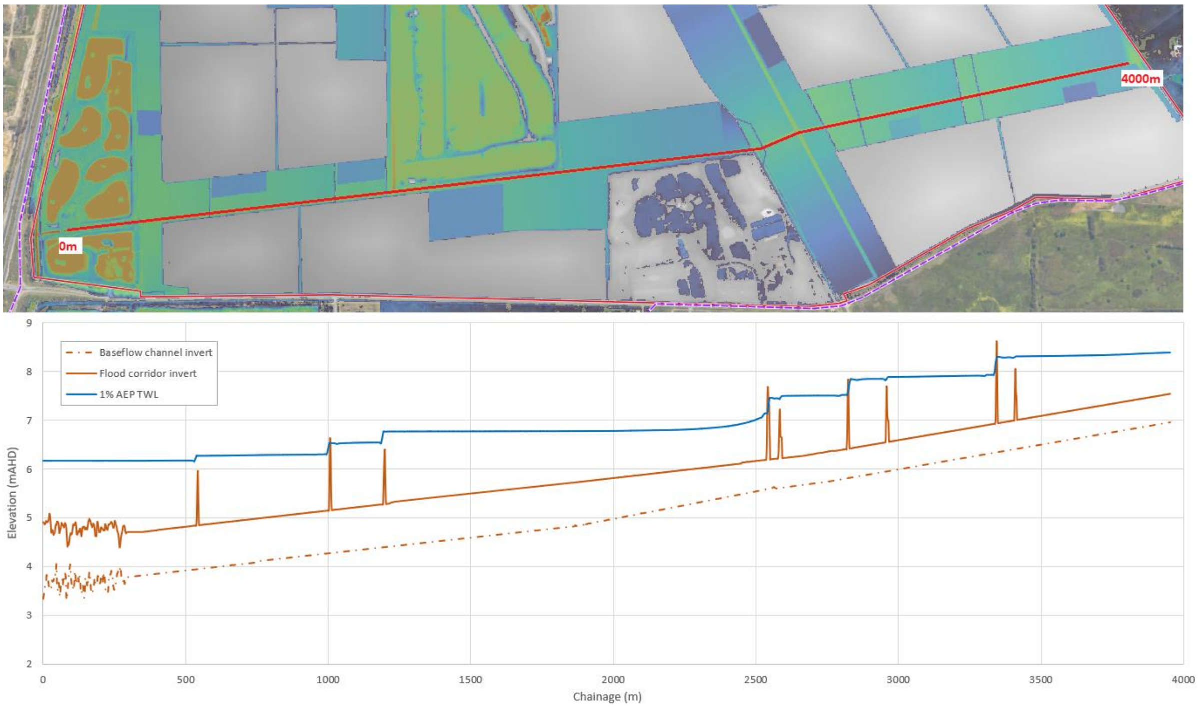


Figure 19: Long-section of 1% AEP flood level

6.4. Velocities and hazard

As discussed in the previous section, maximum inundation depths within the general flood corridor areas slightly exceed the typical urban stormwater design standard of 1.2 m depth, with 1% AEP (spoil bank fail) inundation depths of up to 1.5 m within the flood corridor areas (and greater within the baseflow channels). Safety risk in floodplain areas is related to both depths and flow velocity. The velocity-depth product (ie. velocity multiplied by depth) is often used to categorise risk in various parts of the floodplain based on these two factors. Figure 20 below indicates VxD values of 0.6, 0.8 and 1.2 relate to hazard levels for adults of moderate, high and extreme, respectively. The graph also shows that these values are valid up to a limiting depth of 1.2m which is considered the maximum depth for stability for adults.

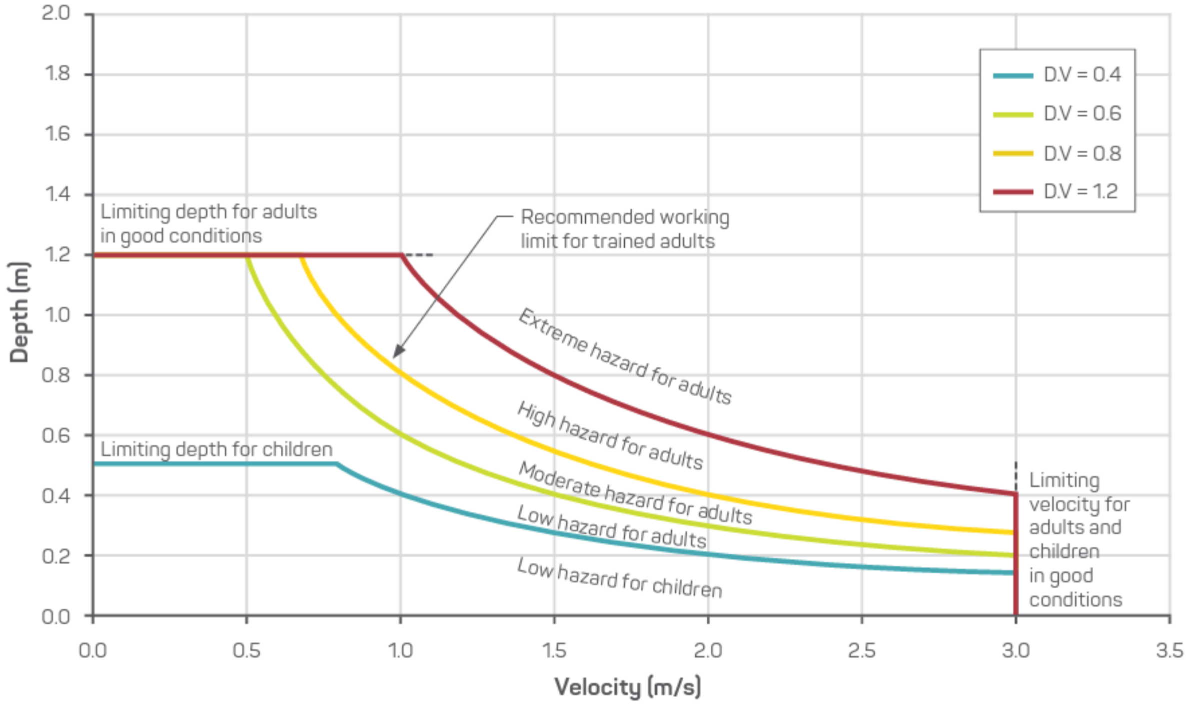


Figure 20: Velocity and depth risk ratings (source: Australian Rainfall and Runoff)

Figures 21 and 22 below provide the modelled VxD values for the developed conditions, for the 1% AEP (spoil bank fail) and 5% AEP (spoil bank intact) scenarios, respectively. The results show that the VxD is low (<0.3 m^2/s) throughout the general floodplain corridor area in the 1% AEP (spoil bank fail event). This is to be expected due to the very low velocities that occur within the general flood corridor area (typically 0.2-0.3 m/s in the 1% AEP spoil bank fail event) and indicates that whilst the depth may exceed 1.2m in areas, the general hazard level is otherwise low, owing to the low velocities.

VxD values within the baseflow channels are higher, these are generally about 0.6 m^2/s but up to about 1.0 m^2/s through some sections where the velocity is slightly higher due to more constrained / narrower corridor width (eg. on the southern side of the ski lakes where the southern portion of the corridor is raised to accommodate public open space). The higher VxD values through the baseflow channels are partially due to the greater depth in these channels but more so to the higher velocity through these baseflow channels. The highest VxD values are associated with very localised areas where velocities are high as water overtops the minor bunds (ie. weir-like flow conditions).

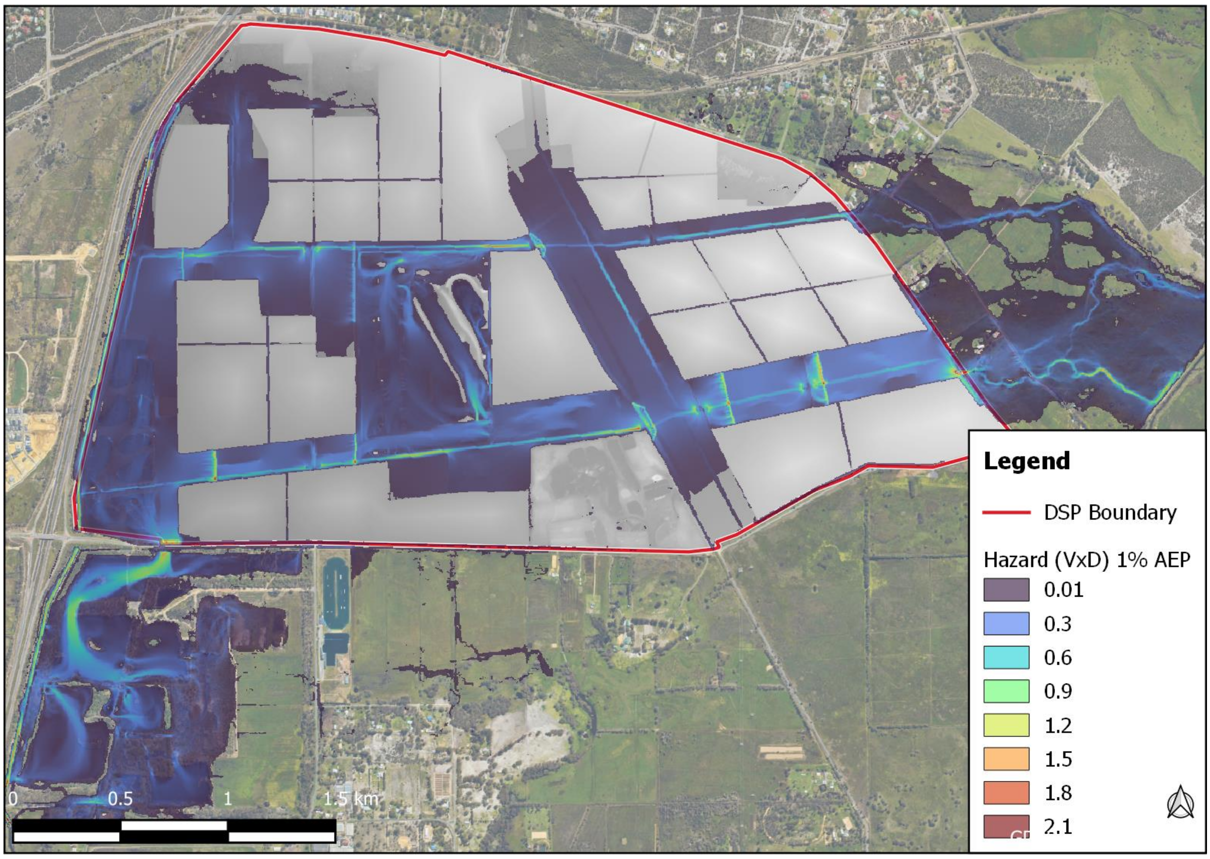


Figure 21: Velocity-depth product – 1% AEP developed conditions

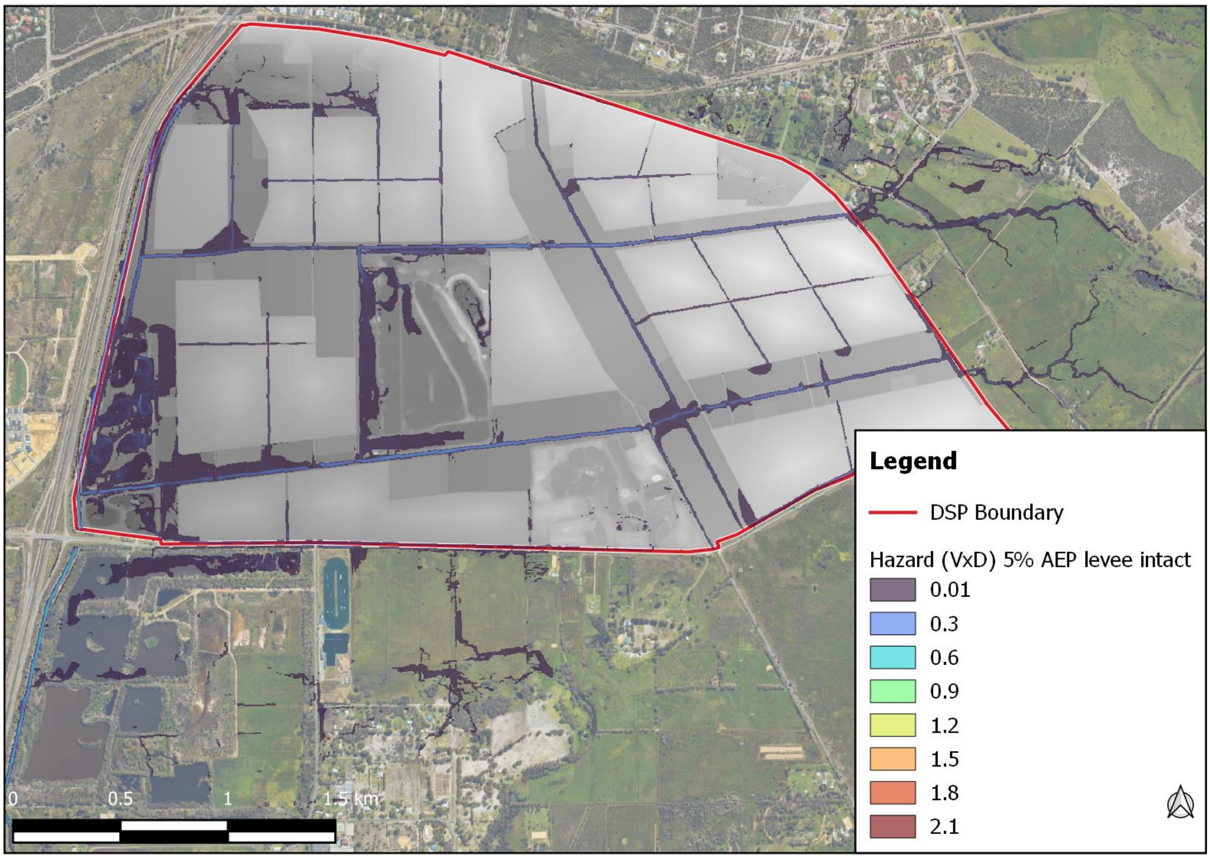


Figure 22: Velocity-depth product – 5% AEP (spoil bank intact) developed conditions

Except for some sections of the baseflow channels and the minor bunds, the hazard classification based on the VxD values discussed above would be considered low to moderate, notwithstanding some localised areas where the depth in the flood corridors exceeds 1.2 m.

As discussed in Section 6.3, the >1.2m water depths for the developed conditions 1% AEP spoil bank fail event are consistent with the existing conditions modelled water depths in sections of open drains through the DSP area as well as the Peel Main Drain. Hazard levels for areas the interface with the proposed development footprint are generally low, with the exception of where baseflow channels or minor bunds abut the development area. It is anticipated that further optimisation of the drainage layout (ie. aligning baseflow channels more centrally within the flood corridors to provide some separation to developed areas) will be undertaken at LSP stage to further reduce public safety risks. Where required for localised areas of higher depth or velocity floodwater, other controls such as landscape treatments or balustrading to limit public access could also be considered.

It should be noted that all of the VxD values and hazard classifications discussed above relate to the 1% AEP spoil bank fail scenario and are driven entirely by the large inflow assumed to occur from the BMD. Under the 5% AEP (spoil bank intact) scenario, the VxD values are substantially lower and are <0.4 m^2/s in all areas of the DSP, as shown in Figure 21.

6.5. Sensitivity analysis

Sensitivity testing was undertaken to quantify how sensitive various model outputs are to input parameters. The model inputs that were tested include Manning's roughness coefficients and infiltration / loss rates applied to the 2D model domain (ie. the rain-on-grid simulation of rainfall-runoff hydrologic processes).

Table 7 provides the base-case and the sensitivity test values adopted in the modelling, which are based on ±15% variation around the base-case input values. Table 8 provides the results of the sensitivity testing which were assessed from the modelled peak flow rate and top water level ("TWL") at several locations as described in Table 8. The results indicate that the hydraulic model and its findings are not very sensitive to the range of input parameter values tested. This finding indicates that the model parameterisation is robust reflects the fact that the majority of flow through the model is related to upstream catchments, the design flows for which have been taken from DWER's (2021a) flood modelling.

Table 7: Sensitivity test input values

	Mannings n			Initial loss (mm)			Continuing loss (mm/hr)		
Soil / cover type	Low	Base	High	Low	Base	High	Low	Base	High
Residential	0.022	0.025	0.029	8.7	10.0	11.5	1.39	1.60	1.84
Community Centre	0.017	0.020	0.023	13.0	15.0	17.3	0.18	0.21	0.24
Schools	0.052	0.060	0.069	13.0	15.0	17.3	2.54	2.92	3.36
POS	0.043	0.050	0.058	13.0	15.0	17.3	3.04	3.50	4.03
Pasture	0.043	0.050	0.058	-	-	-	-	-	-
Vegetation	0.070	0.080	0.092	-	-	-	-	-	-
Sand	-	-	-	0.0	0.0	0.0	2.54	2.92	3.36
Clay	-	-	-	0.0	0.0	0.0	0.18	0.21	0.24

Table 8: Sensitivity test results (1% AEP)

		Manning's n		Loss rates	
Model output	Base Case	Low	High	Low	High
Peak flow in PMD (m^3/s)	15.4	15.7	15.0	15.4	15.3
Peak flow at Mundijong Rd (m^3/s)	57.6	57.6	57.0	58.0	56.8
Peak flow at model boundary (m^3/s)	51.7	52.0	51.1	53.1	50.2
TWL in powerline easement (mAHD)	7.51	7.49	7.53	7.51	7.50
TWL at Mundijong Road (mAHD)	6.16	6.14	6.17	6.16	6.15
TWL at model boundary (mAHD)	3.82	3.81	3.83	3.82	3.82

Two further sensitivity tests were undertaken as follows;

- A 0.5% AEP (200 year ARI) simulation using the BMD spoil bank failure flow from DWER (2021a) and the IFD2019 0.5% AEP-18 hour design rainfall for the model domain (rain-on-grid). The purpose of this sensitivity test was to understand how sensitive the TWLs through the DSP flood corridors are to increased inflow from BMD. The 0.5% AEP peak inflow from the BMD was modelled by DWER (2021a) as 96 m^3/s (compared to 73 m^3/s for the 1% AEP).
- A scenario with an even higher Manning's n applied to the flood corridor areas, to reflect a potential outcome in which the corridors are densely vegetated. In this scenario a Manning's n value of 0.15 was applied to the flood corridors.

The results of these two tests are provided in Tables 9 and 10, respectively. Table 9 shows the flood levels within the DSP (extracted at the powerline easement in the centre of the site and at Mundijoing Rd in the downstream portion of the site) experience only a fairly minor increase of 0.07 m and 0.04 m, respectively, from the increased roughness through the corridors. Flow rates and TWLs downstream of the DSP are not adversely impacted.

Table 10 shows that the TWLs through the flood corridors increase by between approximately 0.18 m and 0.36 m as a result of the higher design inflow from BMD in the 0.5% AEP event. It is also noted that the highest increase (0.36 m) occurs at the upstream end of the site where flow is restricted by the modelled road crossings over the flood corridor, with flood level difference further downstream being generally less due to some attenuation of flow in the upstream area. These road crossings are modelled with an arbitrary height above the 1% AEP flood level; however, at detailed design stage these road crossings would be designed and modelled in more detail, with an elevation that provides an overland flow path for flows in exceedance of the design culvert capacity. Therefore, the flood height from water backing up behind these road crossings as a result of the 0.5% AEP design flow would actually be less than described above and in Table 10. Standard urban flood protection measures include providing 0.5m separation between the 1% AEP flood level and habitable floor levels; based on the sensitivity testing, this standard freeboard requirement is considered adequate to cater for any uncertainty in the design inflows from BMD.

Table 9: Flood corridor roughness sensitivity test

Model output	Base Case	Manning's n 0.15
Peak flow in PMD (m^3/s)	15.4	15.5
Peak flow at Mundijong Rd (m^3/s)	57.6	55.3
Peak flow at model boundary (m^3/s)	51.7	51.4
TWL in powerline easement (mAHD)	7.51	7.58
TWL at Mundijong Road (mAHD)	6.16	6.20
TWL at model boundary (mAHD)	3.82	3.82

Table 10: BMD inflow sensitivity test

Model output	1% AEP	0.5% AEP
Peak inflow from BMD (m^3/s)	73.1	96.3
TWL in eastern portion of flood corridor (mAHD)	8.34	8.70
TWL in powerline easement / central portion of flood corridor (mAHD)	7.50	7.68
TWL at Mundijong Road / western portion of flood corridor (mAHD)	6.16	6.44

7. References

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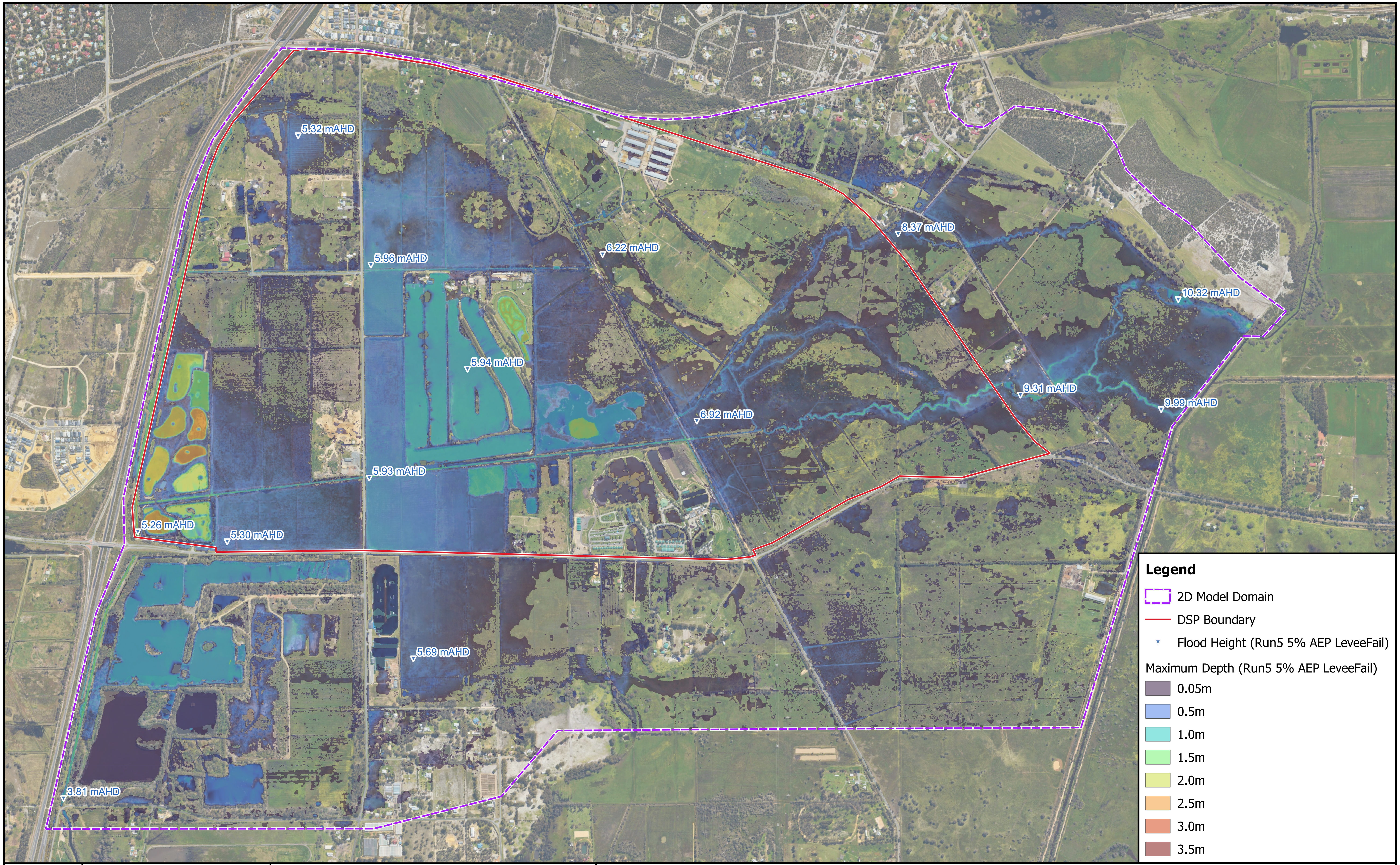
Appendix A: Flood maps

PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

Existing Conditions - 1% AEP flood map



PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

Existing Conditions - 5% AEP (levee fail) flood map

PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

0 0.25 0.5 0.75 1 km

GDA94 / MGA zone 50

Existing Conditions - 5% AEP flood map

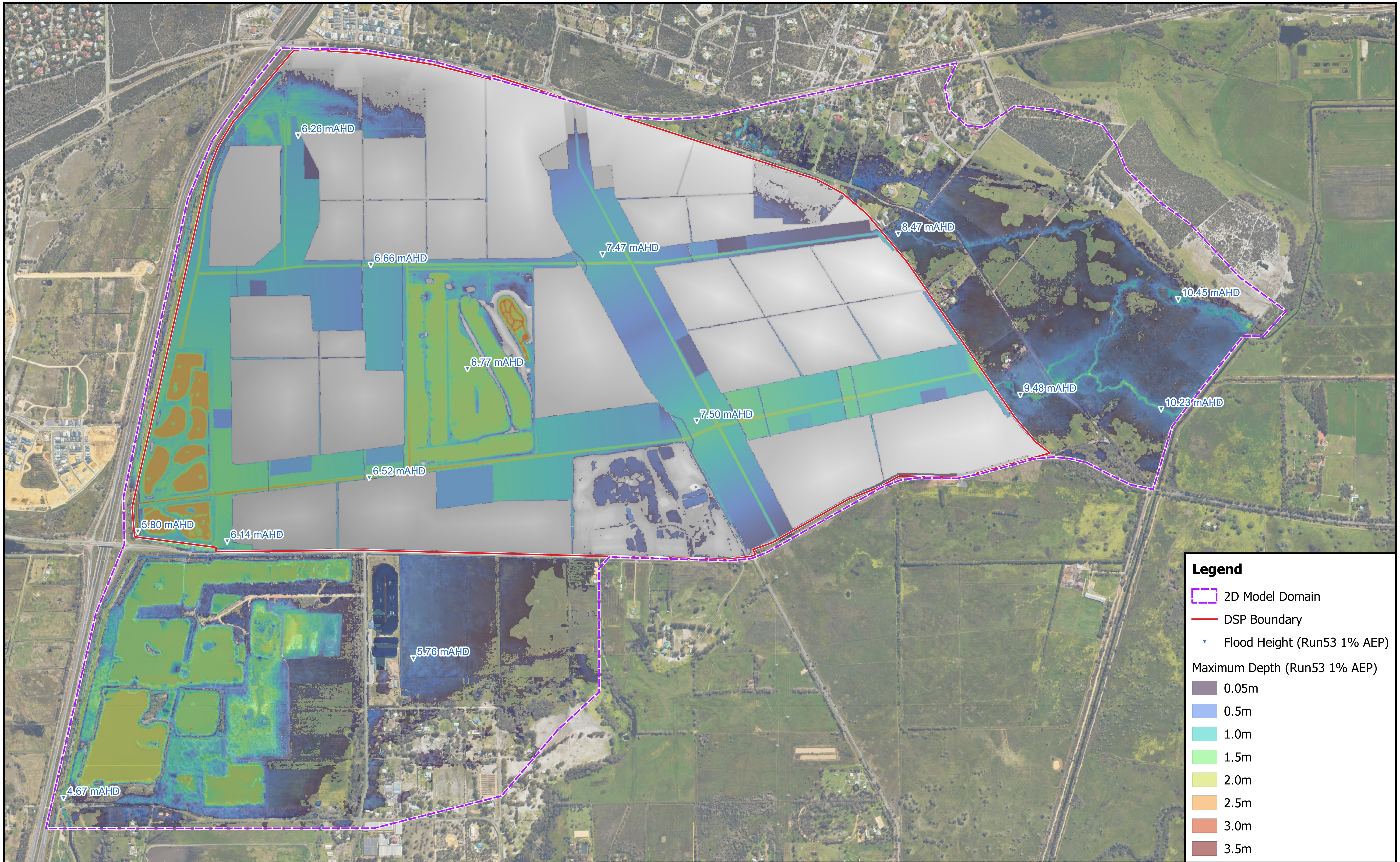
PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

0 0.25 0.5 0.75 1 km

GDA94 / MGA zone 50

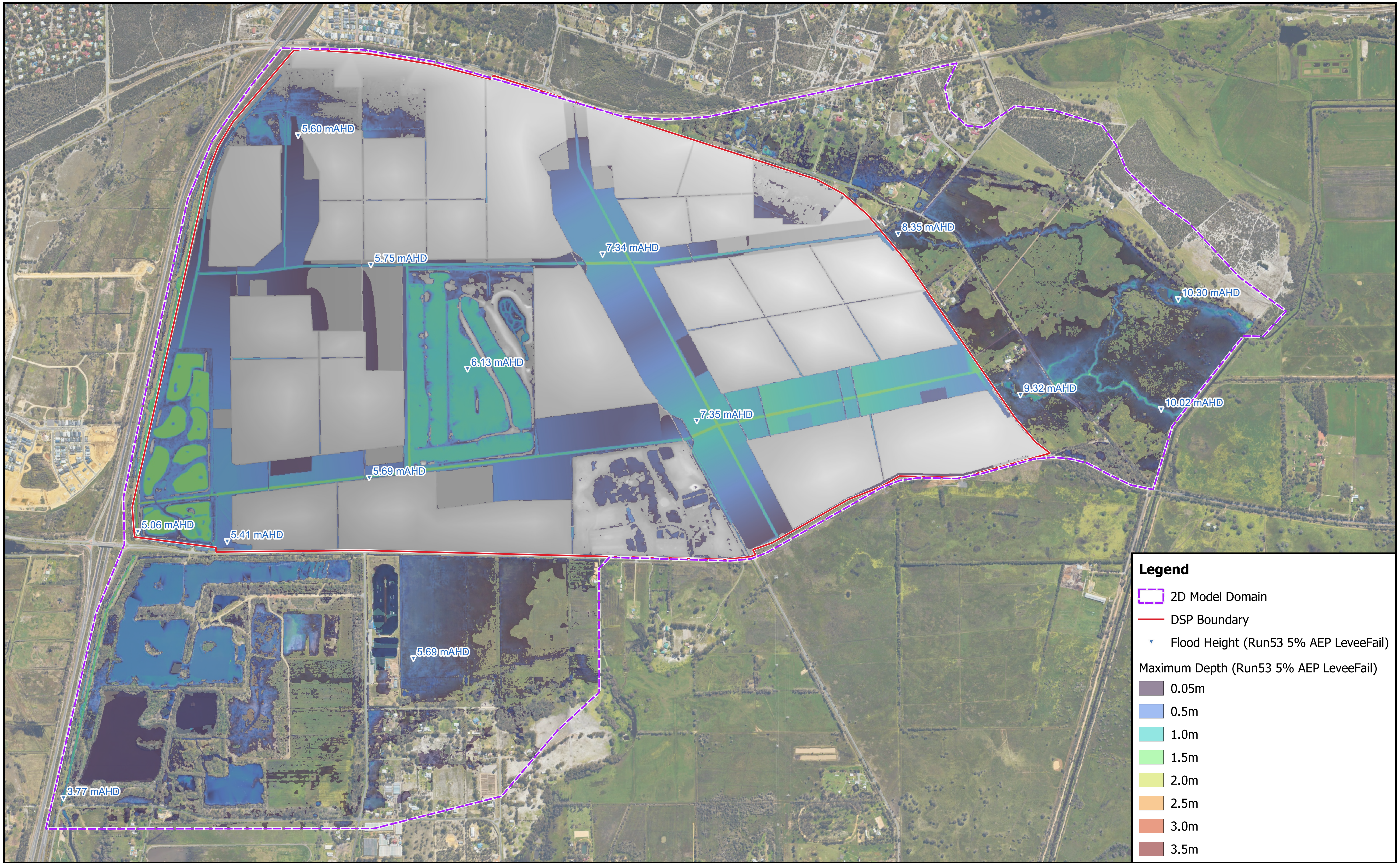
Existing Conditions - 20% AEP flood map



PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

Developed Conditions - 1% AEP flood map



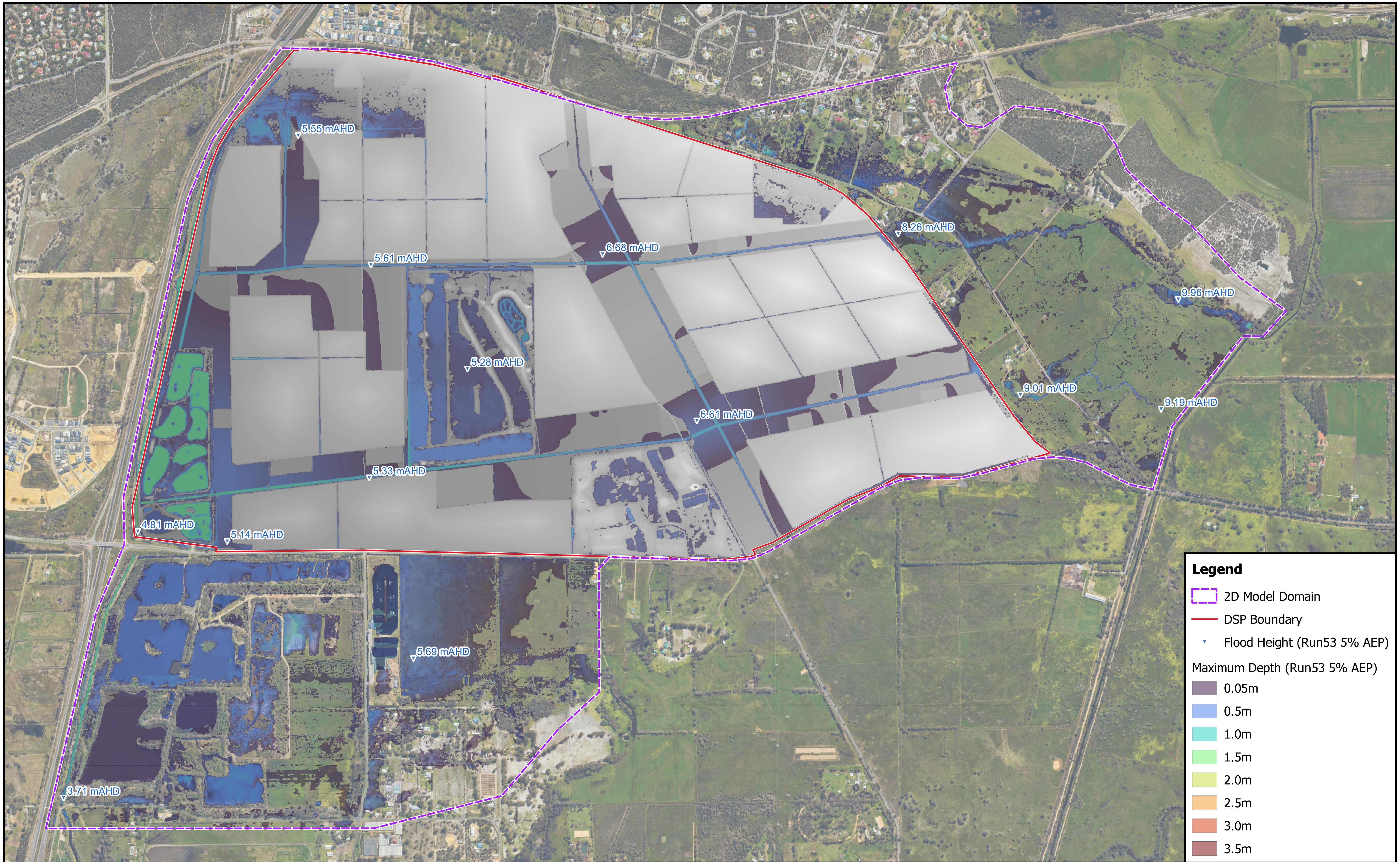
PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

0 0.25 0.5 0.75 1 km

GDA94 / MGA zone 50

Developed Conditions - 5% AEP (levee fail) flood map



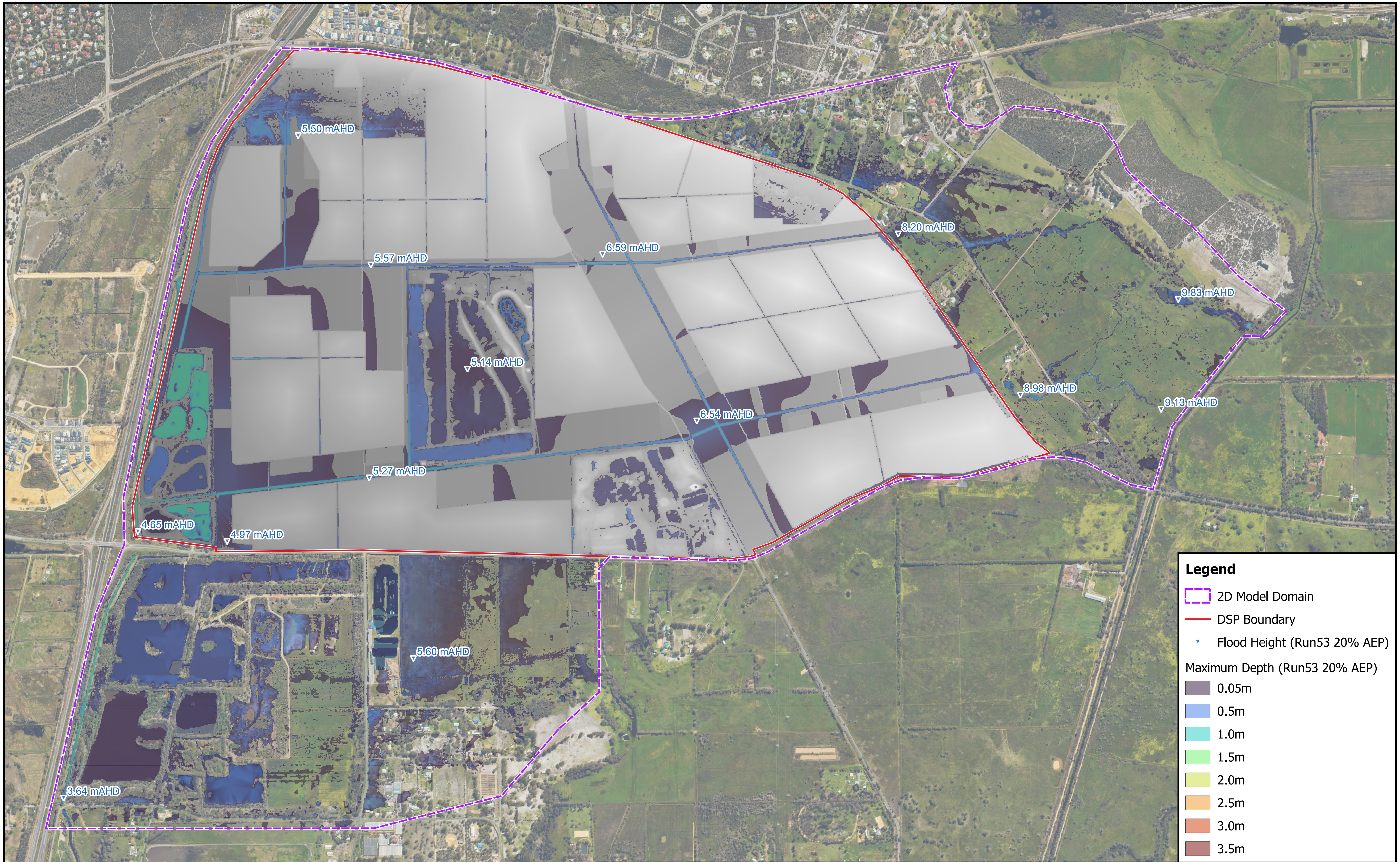
PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

0 0.25 0.5 0.75 1 km

GDA94 / MGA zone 50

Developed Conditions - 5% AEP flood map



PENTIUM WATER

Project code: STOWELL_01
Drawn by: Daniel Williams
Date: 17/03/2023
Scale: 1:17000
Page size: A3
Sources: data.gov.au, landgate

Developed Conditions - 20% AEP flood map

Appendix B: Earthworks concept

LEGEND	
DESCRIPTION	SYMBOL
LSP AREA	
EARTHWORKS AREA	
FINISHED SURFACE CONTOUR MAJOR	
FINISHED SURFACE CONTOUR MINOR	
EXISTING SURFACE CONTOUR	5
SPOT HEIGHT	4x99

0m 100 200 300
1:5000

REV	DATE	DRN	CKD	APP	AMENDMENT
H	28.03.23		-	[signature]	ISSUED FOR INFORMATION
F	06.09.22	ARH			LAYOUT AND EARTHWORKS MODEL (REV'D') UPDATED
E	15.07.22	ARH			UPDATED LOT LEVELS
D	26.05.22	ARH			UPDATED PLANNING LAYOUT AND LEVELS
C	07.05.22	ARH		M. WALLIS	EARTHWORKS LEVELS UPDATED

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CLIENT: Stockland

APPROVED: [signature]

DESIGNED: AMC

SCALE: AS SHOWN

PROJECT: WELLARD FARMS

TITLE: 000 - GENERAL EARTHWORKS CONCEPT

WAPC No.

DRAWING No. 6489-00-SK01

REVISION: H

ORIGINAL SIZE: A0