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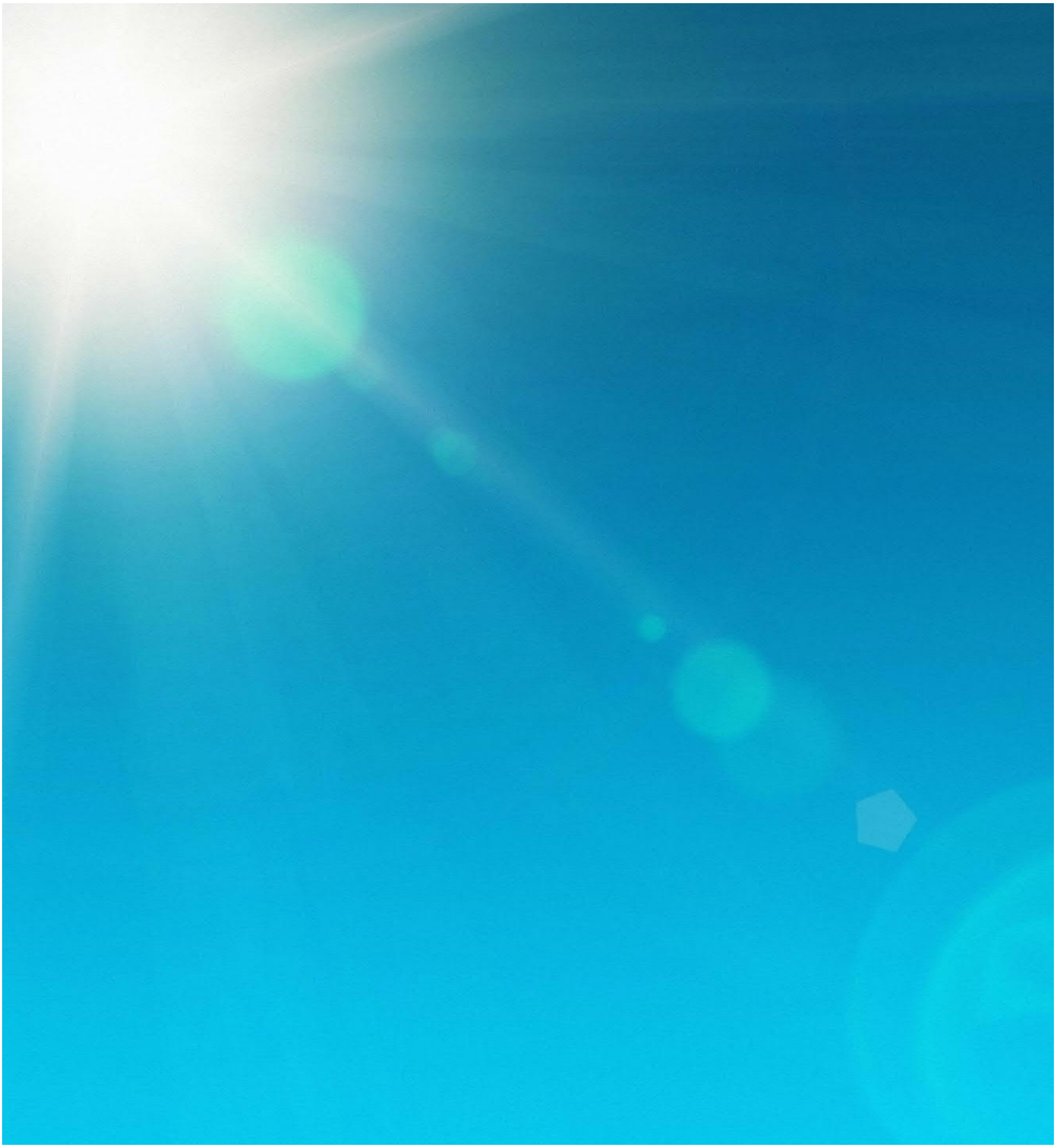
Chapter 6 – Hydrological Processes

Australia-Asia PowerLink Environmental Impact Statement



Chapter 6 – Hydrological Processes

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Revision history

Revision	Date	Purpose	Reviewed by	Approved by
0	18/03/2022	Draft EIS submission	Joe Sheridan	Mark Branson

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6 Hydrological Processes

The NT EPA's objective for the Hydrological processes factor is:

> *"Protect the hydrological regimes of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are maintained."*

This chapter describes and assesses the significance of potential impacts to the hydrological regimes of surface water and groundwater associated with the Australia-Asia PowerLink (AAPowerLink) proposal.

The potential impacts to hydrological regimes considered in this chapter were identified with reference to the EIS Terms of Reference (TOR) issued by the NT Environment Protection Authority (NT EPA) (Appendix A), issues raised by stakeholders, and professional judgement of the EIS team (Appendix D) based on their knowledge and understanding of the AAPowerLink components and activities described in Chapter 2 Proposal Description. Potential impacts were then assessed using the Environmental Impact Assessment (EIA) methods described in Chapter 3 Impact Assessment. This chapter presents the findings of the EIA process undertaken for the Hydrological processes factor.

Closely related environmental factors are covered elsewhere in this EIS – Chapter 7 Inland Water Environmental Quality, Chapter 8 Aquatic Ecosystems, and Chapter 9 Marine Environmental Quality.

6.1 Information sources

This chapter has been informed by:

- Review of existing studies and information available in relation to the water resources present within and proximate to the proposal footprint
- Surface water hydrology investigation and static flood modelling prepared for the Solar Precinct site, and
- Field observations made by the ecology survey team at watercourses crossed by the Solar Precinct access roads, the section of the OHTL in the Utilities Corridor, and the seasonal swamp south-west of the Darwin Converter Site.

The climate and meteorological conditions of the proposal footprint and surrounds was determined from Bureau of Meteorology data and historical records (BoM 2021a). Information on climate change as it relates to hydrological processes, and surface water and groundwater in general, has been sourced from the Bureau of Meteorology, the CSIRO, and the Northern Territory Government Report *Climate Change in the Northern Territory, state of the science and climate change impacts* (NESP ESCC Hub 2020).

Hydrologic modelling was undertaken for the Solar Precinct by Surface Water and Erosion Solutions (SWES, 2022) (Appendix N). Information used in the modelling, as well as model outputs, have informed this chapter. Information on the location, scale, and flow conditions of surface water along the OHTL, and at Murrumujuk (location of the Darwin Converter Site and Cable Transition Facilities) has been determined from datasets available on the Northern Territory Government databases NR Maps (DEPWS 2021a), the Water Data Portal (DEPWS 2021b), and field observations made during ecological surveys (see Appendix P)

Groundwater systems and aquifers that underlie the Solar Precinct are described by Chapman (2019) and Fulton and Knapton (2015). The groundwater systems underlying the Darwin Converter Site and Cable Transition Facilities are described by Woltmann (2020), as part of the NT Government's *Mapping the Future* project. General groundwater information, including the location of aquifers, registered bores, bore reports and water extraction licences have been sourced from NR Maps (DEPWS 2021a), Water Data Portal (DEPWS 2021b) and Water Licencing Portals (DEPWS 2021c).

Information on environmental values, including declared beneficial uses, land use, and water licencing has been determined from NR Maps (DEPWS 2021a), Water Licencing Portal (DEPWS 2021c) and DEPWS water resources information (DEPWS 2021d). Information on the cultural values of water features has been informed by the Cultural Heritage Impact Assessments undertaken for the proposal components by Earth Sea Heritage (see Appendix V and W). Journal articles have been used to inform aspects of this chapter and are referenced throughout.

6.2 Relevant policies and guidelines

The EIA for the Hydrological processes factor references the following policies and guidelines:

- *NT Water Allocation Planning Framework* (DENR 2020)
- *Declaration of Daly Roper Beetaloo Water Control District* (Northern Territory Government 2019)
- *Katherine Tindall Limestone Aquifer Water Allocation Plan* (DENR 2019)
- *Northern Territory Land Clearing Guidelines* (DEPWS 2021)
- *Guide to Road Design Part5: Drainage* (Austroads, 2021)
- *Standard Specifications for Roadworks* (DIPL 2020)
- *Best Practice Erosion and Sediment Control Guidelines* (IECA 2008)
- *Darwin Harbour Water Quality Objectives* (DEPWS 2022)
- *Darwin Harbour Water Quality Protection Plan* (DLRM 2014)

6.3 Environmental values

This section describes the climate conditions, surface watercourses and groundwater aquifers encountered within the proposal footprint and surrounding areas, and the supported environmental values and land uses.

6.3.1 Solar Precinct

The Solar Precinct site is located in the Barkly region in the Lake Woods catchment and overlies the Cambrian Limestone (groundwater) Aquifer. The sections below provide an overview of the surface water features and groundwater aquifers that occur in proximity to the Solar Precinct and in surrounding areas. Areas that hold permanent or semi-permanent water, such as springs and Lake Woods, are significant features in the semi-arid landscape and are identified as having environmental and cultural value. The limited availability of surface water means that groundwater is relied upon as a water supply for domestic and commercial uses.

6.3.1.1 Climate and weather

The Solar Precinct is in the Barkly Region, an area that experiences a semi-arid climate which is characterised by hot dry summers and cool dry winters, with low average annual rainfall (~590 mm/year; see BoM 2021a, station number 015131). Significant rainfall and flooding can occur during the summer months, with influences from the wet season and monsoonal activity across northern Australia, but the likelihood of cyclones is low because it is many hundred kilometres inland (Geoscience Australia 2018). Climate and weather conditions experienced in the region are described in Chapter 2, along with details of how these have been taken into consideration to avoid and minimise impacts to hydrological regimes as part of the site selection and design process.

Significant[1] rainfall events can produce high velocity flows in watercourses and drainage structures, and extended periods of rainfall can cause widespread flooding. The modelled flood extent around the Solar Precinct is shown on Figure 6-1 and illustrates that the vast majority of the footprint is outside of any mapped flood extents, including in the modelled extreme flood event (i.e., 1 in 1,000-year event). Watercourse crossings (along the access roads) and stormwater drainage infrastructure will be designed in accordance with good practice in relation to drainage design criteria for local conditions.

6.3.1.2 Surface water

The Solar Precinct footprint lies within the Lake Woods catchment and is located approximately 10 km south-south-west of the Lake Woods Site of Conservation Significance boundary (see Figure 6-2). There are no surface water courses within the footprint, but there are several drainage depressions that hold water for periods following rainfall. Surface water runoff will generally flow, via overland flow, towards drainage depressions locally, but more broadly drainage across the Solar Precinct footprint is towards the east and north, discharging to the floodplains around Lake Woods. The access tracks traverse several watercourses that flow north-east and discharge to the floodplains around Lake Woods, and a number of springs have been identified on these watercourses. The location of surface water features within and surrounding the Solar Precinct is show in Figure 6-2.

Lake Woods

Lake Woods is the largest ephemeral lake in the Northern Territory, located south of Elliott and west of the Stuart Highway. The lake is classified as an endorheic drainage basin (De Caritat et al. 2019) – i.e., one that accumulates and retains water, and does not discharge to other drainage systems. Instead, its losses are due to evaporation or seepage into the underlying groundwater aquifer.

Lake Woods has three main catchments: the Lake Woods catchment, Newcastle Creek catchment and Newcastle Waters catchment. The Solar Precinct, which is south of Lake Woods, is within the Lake Woods catchment, whilst Newcastle Creek and Newcastle Waters catchments are both north and upstream of Lake Woods. The total drainage area of Lake Woods combined is approximately 40,000 km^2, which covers approximately 2.6 % of the Northern Territory's land area. The Solar Precinct footprint, at 120 km^2, covers approximately 0.3 % of Lake Woods' catchment area.

Lake Woods is ephemeral, and fills with water following rain events, generally occupying an area of approximately 350 – 500 km^2. The normal extent of Lake Woods is over 10 km north of the Solar Precinct; however, during times of flooding and consistent heavy rainfall, Lake Woods can expand to occupy an area of over 1,300 km^2. The Solar Precinct is mostly located outside of the maximum modelled flood extent of Lake Woods[2], except for the north-eastern corner, which is modelled to be inundated in very rare events (i.e., the 0.1 %AEP flood event; 1 in 1,000 year). The modelled extent of the flood events covers ~4.3% of the Solar Precinct footprint (see Figure 6-1 and Appendix N). Climate change projections for the region indicate uncertain changes to rainfall overall, but an increased likelihood of extreme rainfall events (CSIRO and BoM 2021). Climate scenarios were modelled which show that there is likely to increased flows into Lake woods as a result of more extreme rainfall events (see Appendix N). The modelled AEP levels increased by 1.5 mAHD by 2140 (i.e., extreme flood levels are likely to be higher); however, the surface water elevation of Lake Woods did not change in the models and there were indications that perhaps excess water flows back

[1] Although the area is semi-arid, it does experience periods of significant rainfall often associated with monsoonal activity. For example, the total rainfall for 2014 was 839 mm, 404 mm of which fell in the month of February alone (see BoM 2021a, station no. 015131). Refer to Chapter 2 Section 2.3 for additional detail on climate.

[2] The hydrologic modelling (presented in Appendix N) assessed the likelihood of flooding at the Solar Precinct under various Annual Exceedance Probability (AEP) events. The Annual Exceedance Probability (AEP) is the probability of a flood event occurring in any given year, expressed as a percentage. For example, a 1% AEP is a 1 in 100-year flood event, while a 0.5% AEP is a 1 in 200-year flood event.

out of Newcastle Waters Creek. Design of the Solar Precinct will ensure that infrastructure that is flood sensitive will be located outside of mapped flood extents and/or on raised pads, for climate change resilience.

Drainage depressions

Drainage depressions were mapped and assessed as part of the ecological surveys undertaken at the Solar Precinct (see Appendix O) and are described as relatively isolated areas of loamy sands (i.e., not claypans) where the vegetation present includes species which are tolerant of inundation or waterlogged soils for periods of time but are not considered riparian vegetation. The location of drainage depressions within the Solar Precinct is shown in Figure 6-2 and photographic examples of the drainage depressions are provided in Figure 6-3 and Figure 6-4.

Watercourses

The access road corridors from the Solar Precinct to the Stuart Highway traverse the alluvial plain land system (Gosse land system) and several watercourses that drain north into the floodplains surrounding Lake Woods. The watercourses crossed are, from west to east, Gleeson Creek, Billy Creek, Bull Creek, and some minor unnamed tributaries of Powell Creek (see Figure 6-2). All are ephemeral at the proposed crossing locations and are generally a narrow channel with sandy or rocky bottom, and with a narrow band of riparian vegetation along the banks. Photographic examples of watercourses crossed by the access roads are provided in Figure 6-5 and Figure 6-6 from the *Terrestrial Ecology Report – Solar Precinct* (Appendix O).

Springs

Springs[3] occur at several locations downstream of the access road crossings and in the Ashburton, Ranges as shown on Figure 6-2. These semi-permanent surface water features were identified by field survey and from review of aerial imagery and are mapped and described in the *Terrestrial Ecology Report - Solar Precinct* (Appendix O). Springs or areas of permanent water are of high ecological value in arid environments (Duguid et al. 2005) and are groundwater dependent ecosystems (GDEs). The closest spring to the proposal footprint is located approximately 800 m downstream of the gravel access road – along Bull Creek. All other springs are located several kilometres from the proposal footprint and are outside the predicted area of impact or influence from the proposal activities.

6.3.1.3 Groundwater systems

Groundwater systems within the region are wide reaching basins which cover huge expanses of the NT. These values are important as they support a broad range of uses and users, as well as supporting a variety of groundwater dependent ecosystems[4] (e.g., groundwater fed waterbodies).

Geologically, the Solar Precinct footprint is in the Wiso Basin (Tickell 2003). There are two major aquifers in the Wiso Basin; the Hooker Creek Formation dominated by siltstone, which overlays the Montijinni Limestone dominated by limestone (Chapman 2019). The Solar Precinct footprint overlies the Montijinni Limestone aquifer, which is referred to as the Tindall Limestone (in the Daly Basin) and the Gum Ridge Formation (in the Georgina Basin). These aquifers are collectively referred to by some authors (Chapman 2019, Fulton & Knapton 2015) as the Cambrian Limestone Aquifer (CLA) which extends over 320,000 km^2 (Figure 6-7).

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[3] Springs are defined as areas of surface expression of groundwater (i.e., surface water bodies fed by groundwater).

[4] See Chapter 5 – Terrestrial Ecosystems, and Chapter 8 – Aquatic Ecosystems, for more detailed discussion of groundwater dependent ecosystems.

The CLA is a regional aquifer, meaning that the distance that groundwater travels between where it enters the aquifer to where it discharges back to the surface is greater than 50 km (Tickell 2008). Key characteristics of the aquifer are summarised below:

- Regional groundwater flow direction is to the north and then north-east, likely into the Tindall Limestone Aquifer in the Daly Basin (de Caritat et al. 2019).
- Aquifer depth according to 'water level' depths on bore logs for Powell Creek station is between 36 metres below ground level (mbgl) and 60 mbgl (DEPWS 2021a). Refer to the geological cross-section including Powell Creek Station bores RN002350, RN000218 and RN005690 (Figure 6-8).
- Recharge is poorly characterised but is mainly dominated by infiltration through sinkholes and preferential recharge through soil cavities (de Caritat et al. 2019 and Fulton & Knapton 2015). The area's arid climate makes recharge very sporadic and in the order of only a few millimetres per year (Tickell & Bruwer 2019). Notably, Lake Woods is a known recharge zone (de Caritat et al. 2091).
- It is a significant water supply aquifer (Tickell 2003). Around 80% of bores drilled in the area utilise this aquifer, with some bores yielding up to 100 L/s, although average yields are 2-5 L/s (Tickell 2003). New groundwater bore/s will be drilled, targeting the CLA, to supply water for the construction and operation of the Solar Precinct.

The access roads traverse two other aquifers within the Tennant Creek geological region; a relatively narrow band of the Kalkarindji Province, and then the Tennant Creek Block to the Stuart Highway. Both are local scale fractured and weathered rock aquifers, with lower yields than the Wiso Basin. Construction and operation of the access roads will not result in impacts to these groundwater aquifers because groundwater extraction for construction will target the CLA (not these aquifers) and springs along the watercourses (which are an area of groundwater-surface water interaction) will be avoided.

6.3.1.4 Water control districts and water allocation plans

Powell Creek Station is within the Daly Roper Beetaloo Water Control District (WCD) which replaced the Daly Roper Water Control District on the 20 July 2018. The WCD covers 175,580km^2 and includes the Beetaloo Sub-basin which is highly prospective for shale gas (see Figure 6-7). WCDs are declared in areas where there is high competition for water resources, or water resources require close management. Within a WCD, bore construction permits and water extraction licences are required, with some exceptions (e.g., for stock watering and construction). Powell Creek Station (and, therefore, the Solar Precinct) are at the southern extent of the WCD, the boundary of which follows the boundary of the station.

Water Allocation Plans (WAP) are developed for specific regions within designated WCDs to protect the environment, ensure an equitable share of water, and to ensure the sustainability of a water resource. WAPs are in place for a number of areas within the Daly Roper Beetaloo WCD, including the Katherine Tindall Limestone Aquifer WAP and the Oolloo Dolostone Aquifer WAP. No WAPs cover the Solar Precinct footprint or surrounds. Groundwater use in the region surrounding the Solar Precinct is predominantly for stock watering, with the nearest water extraction licence over 100 km to the north.

6.3.1.5 Beneficial uses

Licenced use is limited in proximity to the Solar Precinct – there are no surface water extraction licences, and the closest groundwater extraction licence is located at Elliott, approximately 100 km north of the Solar Precinct (see Figure 6-7), which licences extraction of 300 ML/year for the public potable water supply of the township (DEPWS 2021c). The declared beneficial uses of the Daly Roper Beetaloo WCD are agriculture, aquaculture, public water supply, environment, cultural, industry, rural stock and domestic, mining activity and petroleum activity (NT Government Gazette 2019). These uses are dependent on groundwater availability, with limited consumptive use of surface water occurring in the region due to the seasonal variation in rainfall, and lack of perennial water.

Near the Solar Precinct, groundwater is used as a domestic water supply and for stock watering. Rates and volumes of extraction are unknown as these uses do not require a licence under the *Water Act*. Fulton and Knapton (2015) estimated pastoral water use across the Beetaloo Sub-basin, an area of ~60,000 km^2 which includes the north-eastern portions of Powell Creek Station and Newcastle Waters Station, as 4,380 – 5,475 ML/year. Table 6-1 lists the properties adjacent to the Solar Precinct and Powell Creek Station which contain registered bores and so are assumed to be users of groundwater in the region. Registered bores proximate to the Solar Precinct are shown on the inset map in Figure 6-7.

Table 6-1. Groundwater users on properties adjacent to the Solar Precinct

Perpetual pastoral lease (parcel number)	Powell Creek station (2094) Newcastle Waters (2093) Helen Springs (1512) Tandyidgee (2095, 4278, 1764 & 4280)
Freehold (parcel number)	Karlantijpa North Aboriginal Land Trust (2845) Gurungu Aboriginal Land Trust (3720) Pamayu Aboriginal Corporation (6154) Parcels (928, 868 & 832) Muckaty Aboriginal Land Trust (5173)

Surface watercourses proximate to the Solar Precinct are ephemeral and episodic, and do not support significant aquatic ecosystems or habitat; however, the limited surface water features that do occur in the arid landscape have been identified as having ecological value and/or cultural value as summarised below:

- Springs that occur along watercourses traversed by the access routes to the Solar Precinct are GDEs that have ecological value as refuge habitats for fauna, which is discussed in Chapter 5 Terrestrial Ecosystems and Chapter 8 Aquatic Ecosystems and are also likely to hold cultural value.
- Drainage depressions that occur in the Solar Precinct have cultural heritage value. Cultural heritage surveys have identified archaeological sites and isolated artefacts in and around some of the depressions and impacts to these areas are further considered in Chapter 14 Culture and Heritage.
- Regionally, Lake Woods is a Site of Conservation Significance (SOCS) which has significant environmental values, including providing habitat for high numbers of waterbirds and shorebirds during periods of flood and inundation. Lake Woods and the permanent waterholes along Newcastle Creek upstream (and north) of Lake Woods are recreational areas for bird watchers and there are day use areas used by locals and travellers passing through. The area also holds significant cultural value. Values associated with Lake Woods are discussed further in Chapter 5 Terrestrial Ecosystems, Chapter 8 Aquatic Ecosystems, and Chapter 13 Community and Economy.

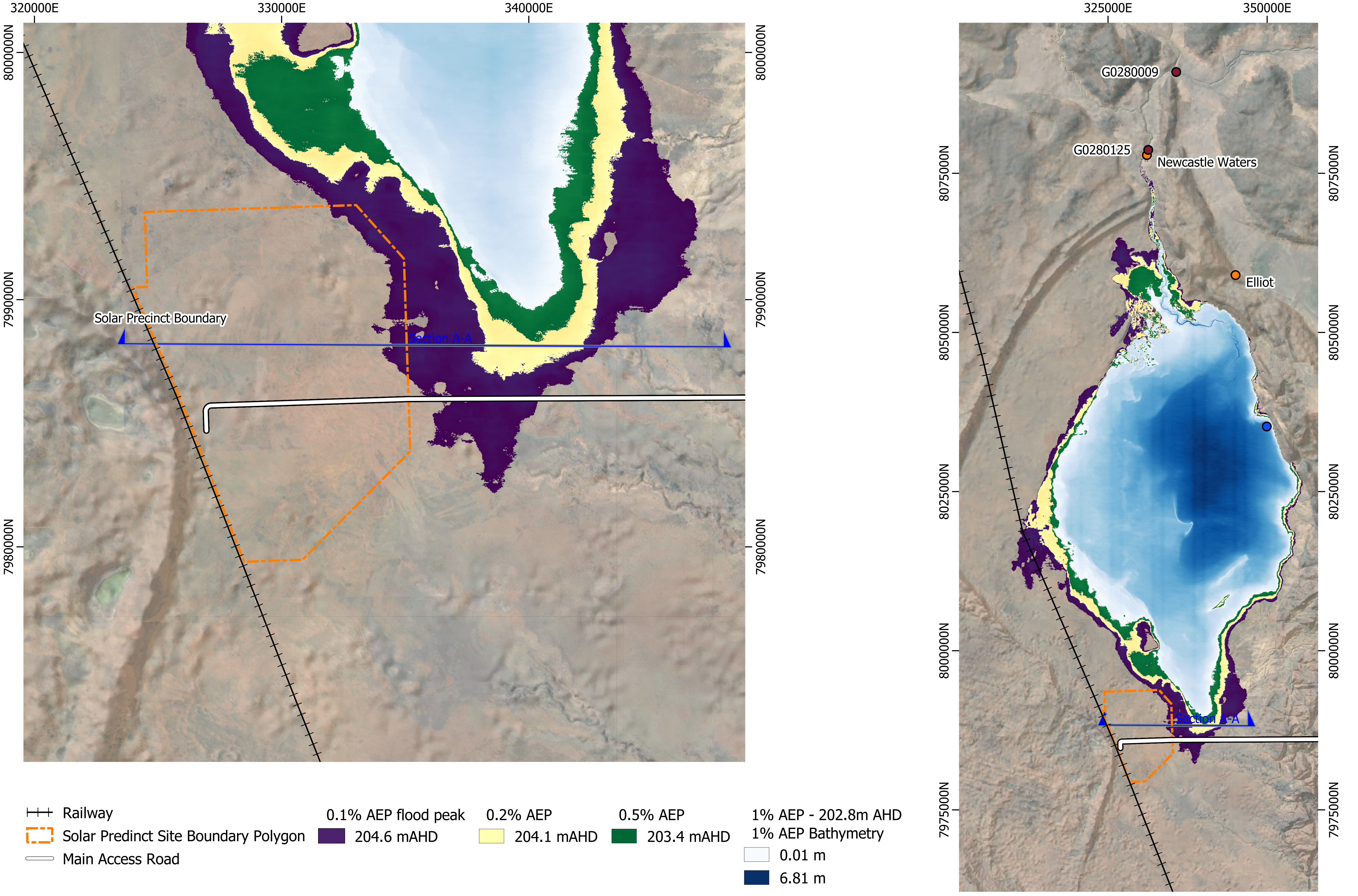

Figure 6-1	SUN CABLE / SURFACE WATER & EROSION SOLUTIONS	Map of Lake Woods modelled flood extents (Source: Surface Water Erosion Solutions 2022)	Title: 1%, 0.5%, 0.2%, 0.1% AEP Flood Inundation Levels	Designed	Drawn	Checked	Sheet size
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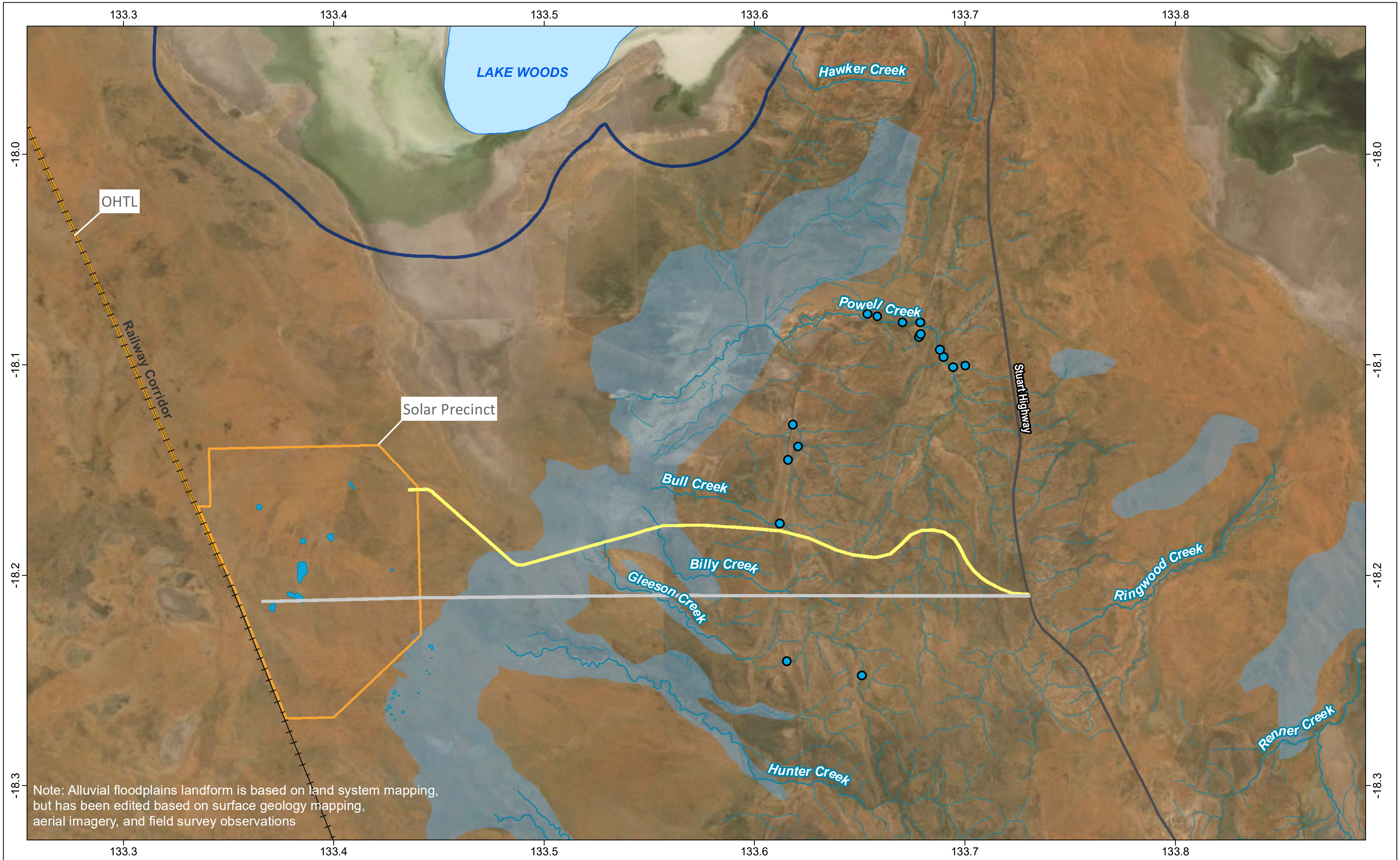


Legend

AAPowerLink infrastructure	Landform class	Lake Woods
Main access road (sealed)	alluvial floodplains	Lake Woods SOCS
All-weather access road (unsealed)	Watercourses	Railway
Inferred spring locations	Shallow depressions (revised from fieldwork)	Principal road

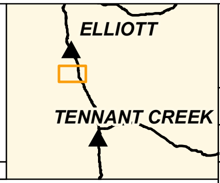


Figure 6-2: Map of surface water features Solar Precinct and access corridors

Project: Australia-Asia PowerLink | Reference: M-Files ID 198726 | Revision: 1

Projection: GDA2020 | Date: 9/03/2022

0 2 4 6 8 Kilometres | Scale: 1:250,000 | A4

N

SUN CABLE

Source: Sun Cable, EcOz, NTG (NR Maps)

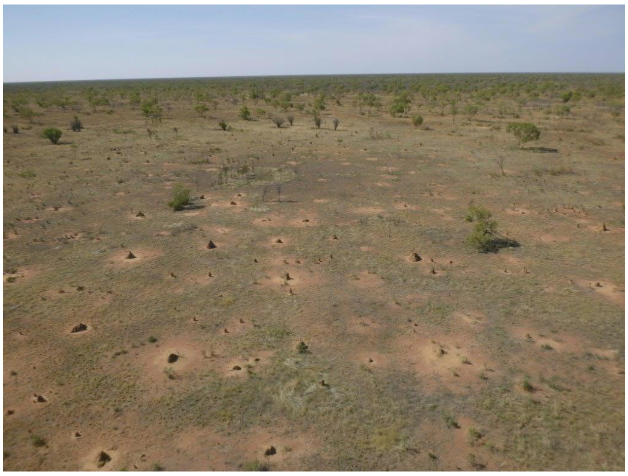


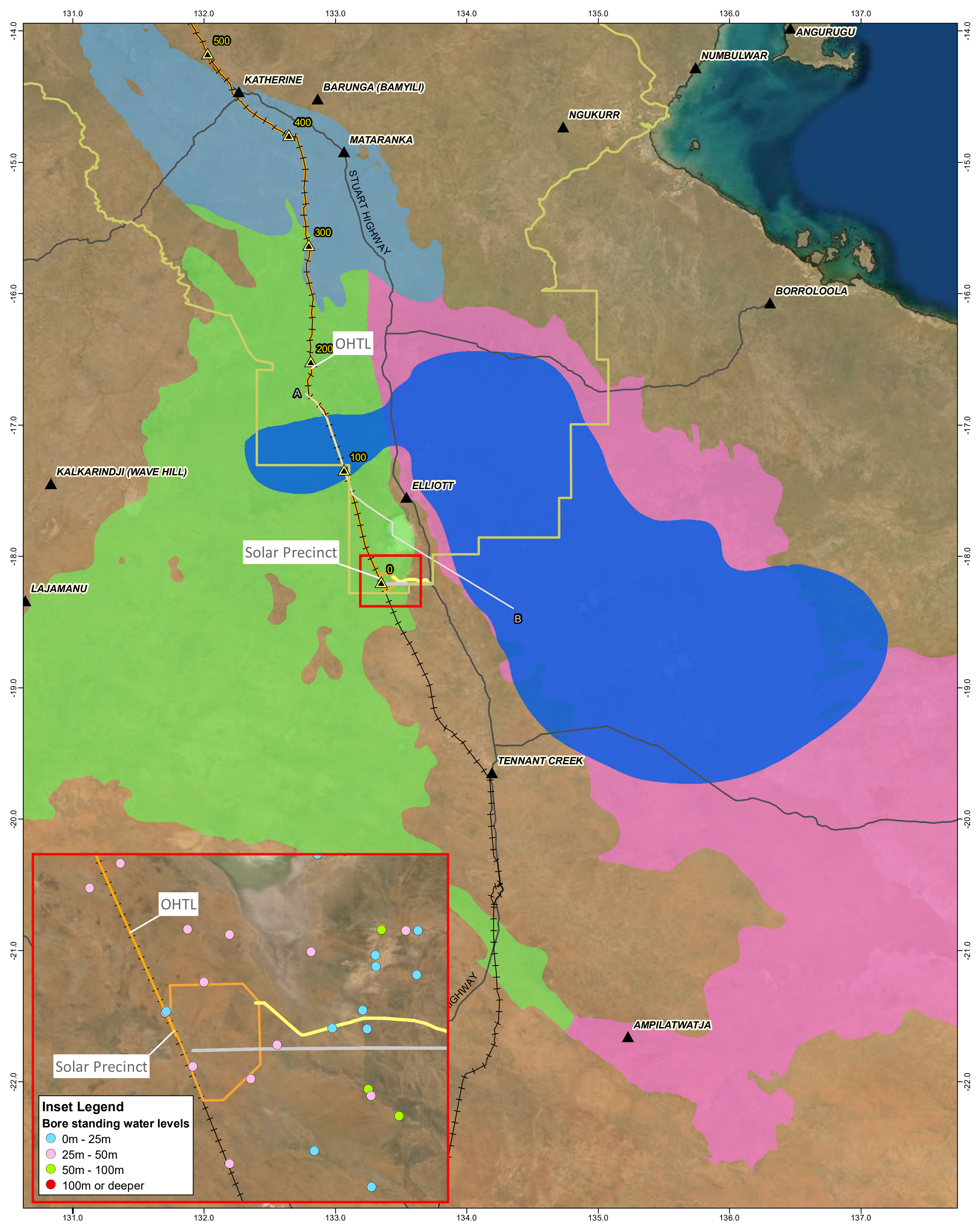
Figure 6-3. Photograph of depression in Solar Precinct

Figure 6-4. Example of soils and vegetation within depressions in Solar Precinct

Figure 6-5. Photograph of Gleeson Creek near access road crossing

Figure 6-6. Photograph of unnamed tributary in Ashburton Range, near access road crossing

Note: All photographs were taken in November 2020.



Legend

- AAPowerLink infrastructure
- Principal Road
- Geological cross section
- Railway
- Main access road (sealed)
- All-weather access road (unsealed)
- OHTL Kilometre Points
- Daly Roper Beetaloo Water Control District

Cambrian Limestone Aquifer

- Tindall Limestone
- Gum Ridge Formation
- Montijinni Limestone
- Anthony Lagoon/Hooker Creek Formation

Source: Sun cable, EcOz, NTG (NR Maps)

Figure 6-7: Map of extent of the CLA in the Daly, Wiso and Georgina Basins (Tickell and Bruwer 2017)

Bores proximate to the Solar Precinct shown in inset

Project: Australia-Asia PowerLink

0 30 60 90 120 Kilometres

Scale: 1:4,000,000

Coordinate System: GDA2020

A4

Reference: M-Files ID 198726

Date: 09/03/2022

Revision: 1

SUN CABLE

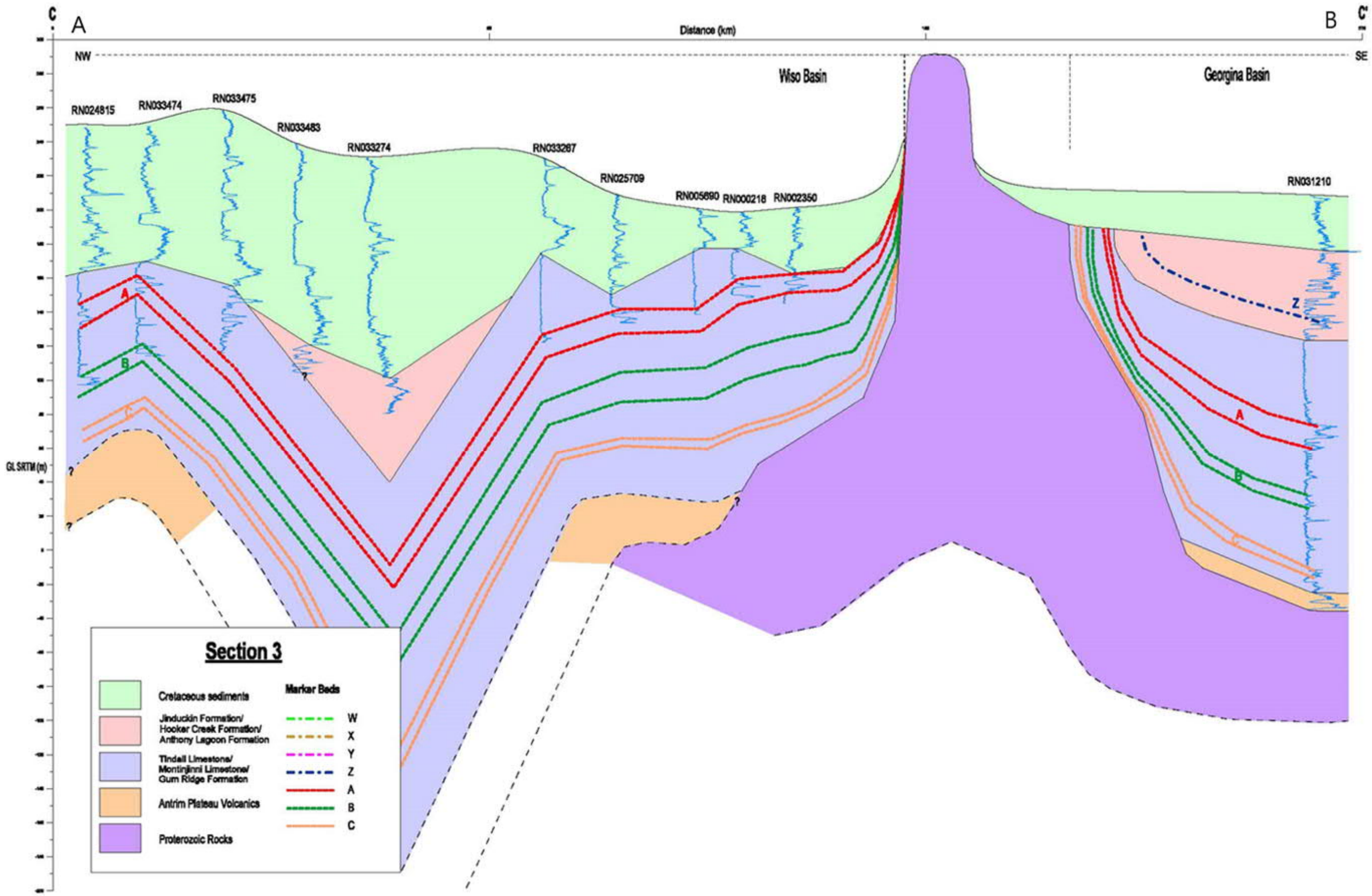


Figure 6-8. Geological cross-section including Powell Creek station (Source: Chapman 2019)

6.3.2 Overhead Transmission Line (OHTL)

The sections below provide an overview of the climatic conditions and surface water features present in proximity to the OHTL corridor, which extends for ~800 km from the Solar Precinct to Murrumujuk, near Darwin. Numerous groundwater systems underlie the corridor over its length; however, these are only considered briefly below as the proposed activities within the OHTL are unlikely to impact groundwater.

6.3.2.1 Climate and weather

The OHTL traverses two distinct climate zones: the arid zone in the south and the humid zone in the north[5]. Climate and weather conditions experienced across the proposal footprint are described in Chapter 2, along with details of how these conditions have been taken into consideration to avoid and minimise impacts to hydrological regimes as part of the site selection and design process.

Through the arid zone the OHTL services corridor crosses mainly minor drainage lines that flow only after heavy and/or sustained rainfall. The frequency of creeks and river crossings increases in the humid zone (north of Katherine), and many of the larger watercourses crossed are perennial (i.e., hold permanent water). The OHTL design allows for the powerlines to span major surface water features without disturbing the beds or banks.

Significant rainfall and flooding can occur during the wet season months (November to April), and for the northern portion of the OHTL services corridor, the likelihood of being affected by cyclones is relatively high, with numerous cyclones forming each year in the region (Geoscience Australia 2018). The OHTL infrastructure is designed to withstand the high windspeeds that can occur. Localised flooding is likely to occur at locations along the OHTL corridor but is not a concern for the OHTL infrastructure.

6.3.2.2 Surface water

The OHTL will cross a total of 154 watercourses and drainage lines over the planned route, the vast majority of which are minor streams or drainage lines of stream order 1; see Table 6-2. Stream order refers to the hierarchy of watercourses. Watercourses with no tributaries are first order streams; two first order streams merge to form a second order stream, and so on (DEPWS 2021). First and second order streams are usually intermittent watercourses (high in the catchment), third and fourth order streams are usually creeks, and stream orders of five and above are rivers. Generally, the higher the stream order, the larger the watercourse, the more frequent the flow, and the more significant the riparian vegetation and aquatic ecosystem potential.

The frequency of watercourse and drainage line crossings increases as the OHTL moves north from the Solar Precinct towards Murrumujuk, and the climate changes from arid to humid (see Figure 6-13 and Figure 6-14). The OHTL traverses the following river basins – from south to north – Wiso, Roper, Daly, Mary, Adelaide, Darwin/Blackmore, and the Finniss/Elizabeth/Howard River basins. In the south, watercourses are typically ephemeral and episodic, whilst the north is a combination of ephemeral and perennial watercourses (DEPWS 2019). Twelve named watercourses (stream order 3 and above) are crossed by the OHTL; their stream orders and approximate crossing locations are provided in Table 6-3 and their locations are shown on Figure 6-13 and Figure 6-14. Unnamed tributaries of major rivers are also crossed including those of the Elsey Creek, McKinlay River, Coomalie Creek and Manton River (these tributaries are generally narrow and ephemeral at the point of the OHTL crossing). The major perennial watercourse crossings are the Katherine River, Edith River, Fergusson River and Adelaide River, all of which are generally wide, defined channels with significant riparian vegetation.

[5] Within the Northern Territory there are two distinct climate zones; the arid zone in the south and the humid zone in the north, with the boundary defined along the ~600 mm average annual rainfall line (NTG 2016).

From KP722 to the Darwin Converter Site the OHTL deviates from the Railway Corridor and will follow a largely uncleared Utilities Corridor. Within this portion of the OHTL there are 28 watercourse crossings (note this is included in the total 154 above). Most watercourses crossed in this section are minor drainage lines of stream order 1, as the alignment avoids major watercourses and wetlands. The route does cross the upper reaches of the Elizabeth River, which is stream order 3 at the crossing location, with an approximately 180 m wide vegetated riparian zone. The Elizabeth River ceases to flow at the crossing location (Alverly Road) during the dry season, as observed during the ecology survey of the Utilities Corridor portion of the OHTL, which was conducted in September and October 2021 (see Appendix P). The route also crosses some small patches of wetland, including Howard sand plain habitat (discussed further in Chapter 5 Terrestrial Ecosystems).

Photographs from the ecology survey (taken September and October 2021), provided in Figure 6-9 and Figure 6-10, shows the two most significant watercourse crossings along the OHTL utilities corridor. Both are dry (in the late dry season) and narrow, but with a clearly defined channel and riparian vegetation.

Table 6-2. Stream order and number of watercourses crossed by the OHTL

Stream order	No. of crossings
1	98
2	28
3	14
4	10
5	3
6	1

Table 6-3. Named watercourse crossing locations, stream orders and GDE status

Watercourse	KP[6] of OHTL crossing	Stream order	Aquatic GDE status[7]
King River	414	3	Known GDE
Katherine River	456	6	Known GDE
Edith River	498	5	High potential GDE
Fergusson River	513	5	High potential GDE
Cullen River	519	4	High potential GDE
Saunders Creek	596	4	High potential GDE
Margaret River	598	3	High potential GDE
Howley Creek	624	4	High potential GDE
Bridge Creek	628	4	Moderate potential GDE
Burrell Creek	652	3	High potential GDE
Adelaide River	657	5	High potential GDE

[6] KP refers to kilometre point – along the OHTL (0 being at the commencement of the OHTL at the Solar Precinct). KPs for watercourse crossings are approximate (i.e., rounded to the nearest kilometre).

[7] Refer to Section 6.3.2.3 for a discussion of GDE.

Watercourse	KP[6] of OHTL crossing	Stream order	Aquatic GDE status[7]
Elizabeth River	728	3	High potential GDE

Figure 6-9. Photograph of Elizabeth River at OHTL crossing location (KP 728)

Figure 6-10. Photograph of drainage line crossed by OHTL at KP754

6.3.2.3 Groundwater systems

The OHTL from the Solar Precinct north to around Katherine overlies the regional scale Cambrian Limestone Aquifer (Figure 6-7). From this point north it traverses several local scale aquifers within the Pine Creek Oregon, before arriving at the Darwin Converter Site described in Section 6.3.3.3 below. As the construction and operation of the OHTL is not expected to result in impacts to groundwater (see Section 6.4) the groundwater systems are not described in detail.

Groundwater Dependent Ecosystems

The Bureau of Meteorology Groundwater Dependant Ecosystems (GDEs) Atlas maps GDEs across Australia (BoM 2021d). Aquatic (areas of groundwater expression e.g., springs) and terrestrial (ecosystems reliant on sub-surface groundwater) GDEs are mapped for the Northern Territory. Aquatic GDEs in particular provide important aquatic habitat as they are usually permanent or near permanent waterbodies which provide ecological functions and habitat for both aquatic and terrestrial species. Along the OHTL, aquatic GDEs generally align with watercourses, and the GDE status is provided in Table 6-3 above. Two watercourses are known GDEs; the Katherine River and King River, while the majority of other creeks and rivers (i.e., stream order 3+) crossed are considered highly likely to be GDEs. Subterranean GDEs (e.g., caves) have not been mapped within the NT, but two sinkholes are within 100 m of the OHTL corridor around the Katherine region which are considered subterranean GDEs.

GDEs are more common around the Utilities Corridor portion of the OHTL, associated with swamps, lagoons and springs in the Darwin Rural area and Gunn Point (BoM 2021d; see Chapter 8 for locations). The OHTL alignment avoids known GDEs; Black Jungle Swamp is approximately 1 km east of the alignment, and the Howard River is >6 km west. Two high potential GDEs are crossed by the OHTL: the Elizabeth River, and an unnamed swamp at KP770. Numerous other swamps and springs are considered high potential GDEs in the region, but the OHTL alignment avoids these areas. GDEs are discussed in more detail in Chapter 5 – Terrestrial Ecosystems and Chapter 8 – Aquatic Ecosystems. Impacts to GDEs are captured in assessment of impacts to watercourses and wetland features.

6.3.2.4 Water control districts and water allocation plans

The majority of the OHTL corridor, from the Solar Precinct to Pine Creek, is within the Daly Roper Beetaloo Water Control District (discussed in Section 6.3.1.4 above). From just south of Manton Dam, the OHTL corridor then enters the Darwin Rural Water Control District, which was declared in 1999 due to a high level of competition for water resources for land uses such as rural living blocks, agriculture, and horticulture. The WCD includes 13 significant aquifers, including the Koolpinyah Dolostone, Berry Springs Dolostone, Palmerston Dolostone and Coomalie Dolostone. The majority of the OHTL Utilities corridor footprint overlies the Koolpinyah Dolostone aquifer (discussed in Section 6.3.3.3 below).

The OHTL corridor crosses one declared WAP area; the Katherine Tindall Limestone Aquifer WAP, and two WAPs in progress; the Mataranka Tindall Limestone Aquifer WAP and the Howard WAP. The Howard WAP is discussed below in relation to the Darwin Converter Site (see Section 6.3.3.4). The Katherine Tindall Limestone WAP stipulates requirements for extraction within the Katherine River catchment of the Tindall Limestone Aquifer, with the aim of providing water to users as well as maintaining river flows. The construction and operation of the OHTL will not require significant water extraction and is not expected to impact on the values protected by the WCD and WAP.

Any water extraction within a WCD or subject to a WAP will be undertaken in accordance with a water extraction licence, subject to proposed extraction volumes, as per the requirements of the *Water Act.*

6.3.2.5 Values of water resources

Water users along the OHTL route include pastoral properties and agriculture, public water supply (e.g., at Elliot, Katherine, Pine Creek and Adelaide River), and industry. Most water extraction licences are clustered around Katherine and the Darwin Rural area and are mostly for agriculture (DEPWS 2021a). However, stock, and domestic uses do not require a water extraction licence and it would be expected that a significant number of water users are stock and domestic users.

The declared beneficial uses of the Daly Roper Beetaloo WCD, which covers most of the OHTL corridor were described earlier in Section 6.3.1.5. The OHTL corridor crosses several other declared beneficial use areas as summarised in Table 6-4.

Table 6-4. Declared beneficial uses along OHTL route

Waterway/catchment	KP[8] of OHTL crossing location	Declared beneficial uses
Daly Roper Beetaloo WCD	KP0 (start)-KP86 KP104-550	agriculture, aquaculture, public water supply, environment, cultural, industry, rural stock and domestic, mining activity and petroleum activity
Copperfield Creek	KP519-KP522 KP526-541	aquatic ecosystem protection
Mary River	KP545-KP598	environment, riparian, cultural and agricultural (surface water and groundwater)
Coomalie Creek	KP672-KP689	aquatic ecosystem protection, recreational water quality and aesthetics, and agricultural water use
Darwin Rural WCD	KP689-KP788 (end)	agriculture, aquaculture, public water supply, environment, cultural, industry, rural stock and domestic, mining activity and petroleum activity
Darwin Harbour Region	KP759-KP788 (end)	aquaculture, environment, cultural (for surface water and high-water mark), plus rural stock and domestic (surface water).
Vernon Island Area Waterways	KP786-KP788	environment and culture[9]

Water quality objectives for aquatic ecosystem protection are declared for the McKinlay River, which is crossed by the OHTL north of Pine Creek, and for Darwin Harbour where the shore-crossing is located (refer Section 6.3.3.1 below).

Several of the watercourses crossed by the OHTL have environmental and cultural values. The major watercourses (the Katherine, Edith, Fergusson, and Adelaide Rivers) provide water for industry and agriculture, support significant biodiversity, and are also used recreationally (e.g., fishing, swimming, tourism). The watercourses also have significant cultural values. These values are further considered in Chapter 8 Aquatic Ecosystems and Chapter 14 Culture and Heritage.

6.3.3 Darwin Converter Site and Cable Transition Facilities

The sections below provide an overview of the climatic conditions, surface water features and groundwater aquifers present in proximity to the Darwin Converter Site and Cable Transition Facilities located at Murrumujuk at the base of the Gunn Point Peninsula.

6.3.3.1 Climate and weather

The Darwin Converter Site and Cable Transition Facilities are located on the coast in an area that experiences a humid climate, which is characterised by hot wet summers and cool dry winters. Significant rainfall can occur during the wet season months (November to April); however, the footprint is unlikely to experience flooding as there are no watercourses present. Storm surge mapping available on NR Maps shows that the infrastructure is located outside of the mapped extent for storm surge in 2100 (including 1 in 100 year and 1 in 1,000-year events), therefore inundation is not predicted to occur. The likelihood of being affected by

[8] KP refers to kilometre point – along the OHTL (0 being at the commencement of the OHTL at the Solar Precinct). KPs for watercourse crossings are approximate (i.e., rounded to the nearest kilometre).

[9] No surface water runoff from the proposal footprint will flow north toward the Vernon Islands and so declared beneficial uses in this area will not be impacted by the proposal.

cyclones is relatively high, with numerous cyclones forming each year in the region (Geoscience Australia 2018). As a result, the infrastructure is designed to withstand the high windspeeds that can occur. Climate and weather conditions experienced in the region are described in Chapter 2, along with details of how these have been taken into consideration to avoid and minimise impacts to hydrological regimes as part of the site selection and design process.

6.3.3.2 Surface water

The Darwin Converter Site and Cable Transition Facilities are situated in the northern part of the Shoal Bay catchment in the outer Darwin Harbour. There are no defined watercourses within the footprint. Rainfall/runoff produces overland flows that discharge towards the south and west entering localised depressions (seasonal swamps) and the floodplains and coastal creeks within the Shoal Bay and Tree Point Conservation Areas.

Drainage from the Darwin Converter Site will flow, via overland flow, to the south into adjacent vegetated areas, and towards the seasonal swamp[10] located to the south-west of the footprint. Figure 6-11 shows the condition of the swamp during the dry season, while Figure 6-12 shows the condition during the wet season. The swamp is a Melaleuca Forest to woodland (a tree swamp) with no open water; instead, water pools between the Melaleuca stands during the wet season, and the swamp is dry during the dry season. The extent of the swamp (i.e., usual extent of inundation) is shown on Figure 6-15, based on field survey of soils, vegetation, landform, and extent of wetted area during the wet season. Land unit mapping for the swamp is provided in Appendix P.

The swamp fills during the wet season and discharges to the south-west into a minor drainage line that flows into the coastal floodplains in Tree Point Conservation Area. The construction of infrastructure at the Darwin Converter Site is predicted to cause localised changes to overland flow paths and it is possible that this could alter the hydrological regime of the swamp as discussed in Section 6.4.2.1. Potential impacts to water quality associated with erosion and sedimentation are considered in Chapter 7 Inland Water Environmental Quality.

Drainage from most of the Cable Transition Facilities footprint will report to adjacent vegetated areas. Drainage from the Shore Crossing Site will report directly to the beach and intertidal areas of Shoal Bay, via erosion and sediment controls. The proposal is predicted to cause localised changes to overland flow paths during construction but will not alter hydrological regimes as there are no watercourse present and the land will be reinstated following construction as described in Chapter 2. Potential impacts to marine water quality associated with drainage from the proposal footprint are further considered in Chapter 9 Marine Environmental Quality.

[10] Swamps are a common type of wetland in the Darwin region and are characterised as shallow vegetated depressions within which water pools. They are generally palustrine (i.e., dominated with trees, shrubs and emergent) as opposed to open bodies of water, and can be perennial or ephemeral (Aquatic Ecosystems Task Group 2012). Perennial swamps are generally GDE’s as they are fed, in part, by groundwater to sustain water during the dry season. Water quality is usually fresh (i.e., good) during the wet season, as it is reflective of rainfall, but can deteriorate during the dry season due to evaporation (see Chapter 7). Swamps do provide habitat and aquatic ecosystem values; see Chapter 8.

Figure 6-11. Photograph of seasonal swamp adjacent to Darwin Converter Site (dry - October 2021)

Figure 6-12. Photograph of seasonal swamp adjacent to Darwin Converter Site (wet – February 2022)

6.3.3.3 Groundwater systems

The Darwin Converter Site and Cable Transition Facilities overlie the central portion of the Howard Groundwater System (the extent of which is shown in the inset map in Figure 6-15). The system covers an area of 1,462 km^2, and extends from south of the Arnhem Highway, west of the Howard River, east to the Adelaide River, and across all of Gunn Point peninsula in the north (DENR, n.d.).

Groundwater resources of Gunn Point were investigated as part of the Mapping the Future project (see Woltmann 2020). There are two main aquifers underlying Gunn Point:

- Upper (shallow) seasonal aquifer, hosted in lateritic rock, which is unconfined and recharges every wet season, discharging to springs, wetlands, and the coast over the dry season
- Lower productive aquifer, mostly within the Koolpinyah Dolostone formation. Aquifer thickness, lithology and yields vary. The aquifer is confined in the north as the Wangarlu Formation increases in thickness; and is confined underlying the Darwin Converter Station and Cable Transition Facilities.

The NT Government drilled several investigation and monitoring bores across Gunn Point; the closest to the Darwin Converter Site is approximately 1 km to the north-east (see Figure 6-15). Groundwater contour data shows that during the wet season groundwater flow in the Koolpinyah Dolostone formation (i.e., the deeper aquifer which is confined under the Darwin Converter Site) is toward the north (see Woltmann 2020). During the dry season, this hydraulic gradient inverts and groundwater flows toward the south; however, there does not appear to be discharge or significant movement from the confined aquifer. The Howard Koolpinyah Dolostone Aquifer recharges through diffuse infiltration of rainfall in the southern region of the aquifer, on Koolpinyah Station and around Melacca Swamp (Woltmann 2020), which is over 14 km from the proposal area.

Existing groundwater bores in the vicinity of the Darwin Converter Site have yields ranging from 0 - 20 L/s, with the closest bore (~1km to the north-east) having a yield of >2 – 5 L/s (Woltmann 2020). The maximum depth to the Koolpinyah aquifer (i.e., the productive aquifer) underlying the Darwin Converter Site is 50-60 mbgl and there is limited seasonal variation in groundwater levels (<1 m) as the groundwater aquifer is confined and there are few groundwater users.

Water resource mapping indicates that the aquifer in the region of the Darwin Converter Site has moderate yields, but quality is fresh to brackish, and saline impacted (Woltmann 2020). Just to the east of Gunn Point Road, approximately 1 km east of the Darwin Converter Site, the water quality is fresh, but resources are minor[11] due to limited annual recharge. These observations indicate that the capacity of the local aquifer to supply water to the site may be limited by either low yields or poor water quality (saline impacted) and further investigations are required to identify a suitable water supply as indicated in Chapter 2. There are currently no other groundwater users within 4 km of the Darwin Converter Site, and the nearest groundwater extraction licence is over 10 km away, and so groundwater use for construction and operation of the Darwin Converter Site is unlikely to impact other users (discussed in Section 6.4.2.2 below).

6.3.3.4 Water control districts and water allocation plans

The Darwin Converter Site and Cable Transition Facilities are located within the Darwin Rural Water Control District declared under the *Water Act*. The aquifers in the Darwin Rural WCD rely on wet season recharge to replenish groundwater levels, and water availability in the dry season can be significantly impacted by a poor wet season (DENR 2018). They are also known as fill and spill systems; once the aquifer is full the extra water pools on land surfaces (e.g., in wetlands) or flows into watercourses. A water allocation plan (the Howard Water Allocation Plan) is currently being developed for this groundwater system and aims to ensure the

[11] Bore yields range from 0 L/s to 2-5 L/s (Woltmann 2020).

sustainable use of this water resource (DENR 2019); the extent is show in the inset on Figure 6-15. Sun Cable are required to apply for bore permits and groundwater extraction licences to establish a water supply for construction and operation of the Darwin Converter Site and Cable Transition Facilities.

6.3.3.5 Values of water resources

Groundwater is a highly valued resource in the Darwin Rural Water Control District where the Darwin Converter Site and Cable Transition Facilities are located, and is under pressure from over-allocation, which has flow on effects to land uses and environmental values. The aquifers within the Howard Groundwater System that underlies the proposal footprint also underlie a large portion of the Darwin Rural Area, with the main water users being pastoral/agriculture/horticulture, rural lots, and Power Water supply bores for town water (SKM 2012). The proposal footprint is in the northern most portion of the central water management zone of the Howard Groundwater System, which is overallocated, with overextraction occurring because of increasing demands from rural living blocks and horticulture in the Darwin Rural Area (SKM 2012). The vast majority of groundwater extraction occurs in the Darwin Rural Area, over 20 km south of the Darwin Converter Site. There are no known major water users in the area surrounding the Darwin Converter Site and Cable Transition Facilities; the nearest licensed extraction is located over 12 km south-east.

The closest registered bores to the Darwin Converter Site are located ~2 km north-west, which were used as part of the now disused Gunn Point prison farm which operated until 1995 (NT Land Corporation 2021). Other bores in close proximity (i.e., 2-3 km from the proposal footprint) are NT Government monitoring bores and a bore installed for water supply for roadworks in 2018-2019 (see Figure 6-15). None of these bores are current water supply bores.

There are several surface water ecosystems which are fed by groundwater from the Howard Groundwater System, including the Howard River, Black Jungle and Melacca Creek (DENR, n.d.). These are significant GDEs, however none of these are proximate to the proposal footprint; the closest is the Howard River, the mouth of which is approximately 10 km to the south; see Chapter 8.

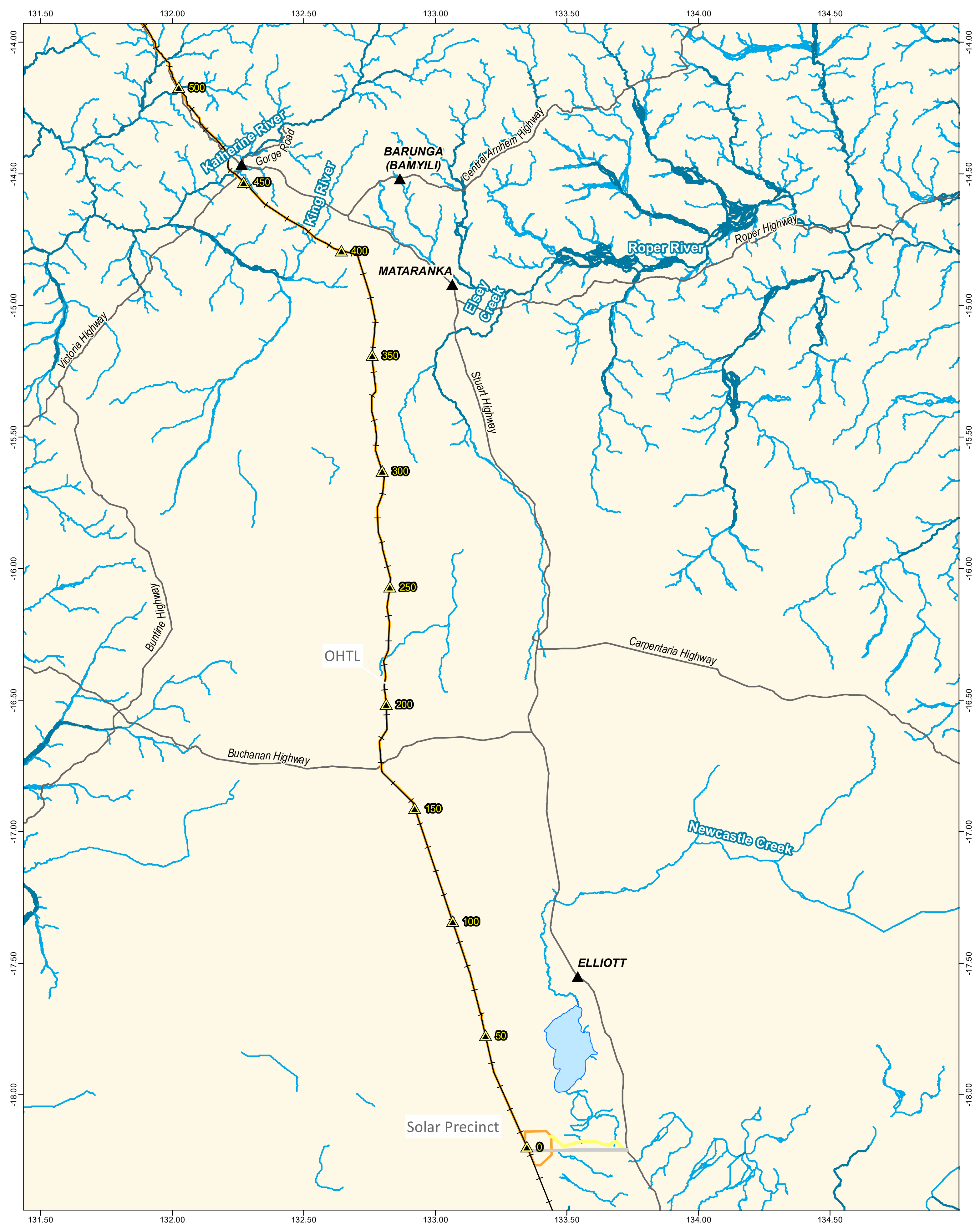
While there are few existing water users at Gunn Point, the area has been identified for future development under the NT Governments Mapping the Future program (Woltman 2020). The development prospects include strategic infrastructure, primary production and horticulture, rural and residential development. While demand for water is currently low, future development will rely on water availability from groundwater aquifers. The closest proposed future development is the Project Sea Dragon prawn hatchery adjacent to the Darwin Converter Site, although this development will use seawater, rather than groundwater, as a water supply (C02 Australia 2017).

The Darwin Converter Site and Cable Transition Facilities are located within three beneficial use areas (DEPWS 2021a) as summarised in Table 6-5.

Table 6-5. Declared beneficial uses relevant to Murrumujuk location

Waterway/catchment	Declared beneficial uses
Darwin Rural WCD	agriculture, aquaculture, public water supply, environment, cultural, industry, rural stock and domestic, mining activity and petroleum activity
Darwin Harbour Region	aquaculture, environment, cultural (for surface water and high-water mark), plus rural stock and domestic (surface water).
Vernon Island Area Waterways	environment and culture[12]

[12] No surface water runoff from the proposal footprint will flow north toward the Vernon Islands and so declared beneficial uses in this area will not be impacted by the proposal.



Legend

- AAPowerLink infrastructure
- OHTL Kilometre Points
- Towns
- Roads
- Railway
- Main access road (sealed)
- All-weather access road (unsealed)
- Major waterourse (stream order 5+)
- Minor watercourse (stream order 3-4)
- Lake Woods

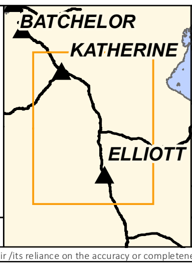


Figure 6-13: Map of major watercourses crossed by the OHTL - southern end

N

Project: Australia-Asia PowerLink

0 20 40 60 Kilometres

Reference: M-Files ID 198726

Date: 09/03/2022

Revision: 1

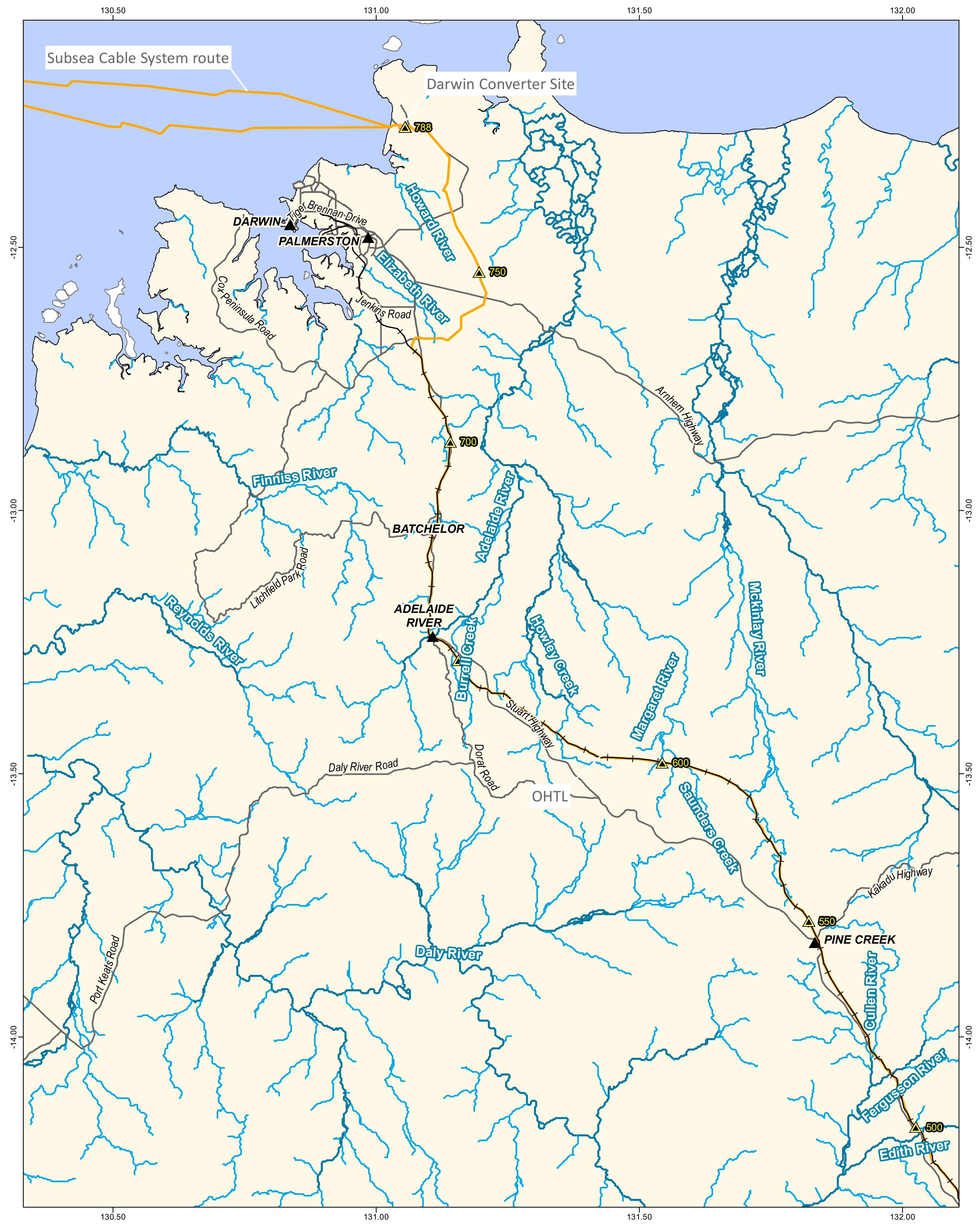
Scale: 1:2,000,000

Coordinate System: GDA2020

A4

SUN CABLE

Source: Sun Cable, EcOz, NTG (NR Maps)



Legend

- AAPowerLink infrastructure
- OHTL Kilometre Points
- Towns
- Railway
- Roads
- Watercourses (stream level 5+)
- Watercourses (stream level 3-4)

Source: Sun Cable, EcOz, NTG (NR Maps)

Figure 6-14: Map of major watercourses crossed by the OHTL - northern end

N

Project: Australia-Asia PowerLink

0 15 30 Kilometres

Scale: 1:1,000,000

Coordinate System: GDA2020

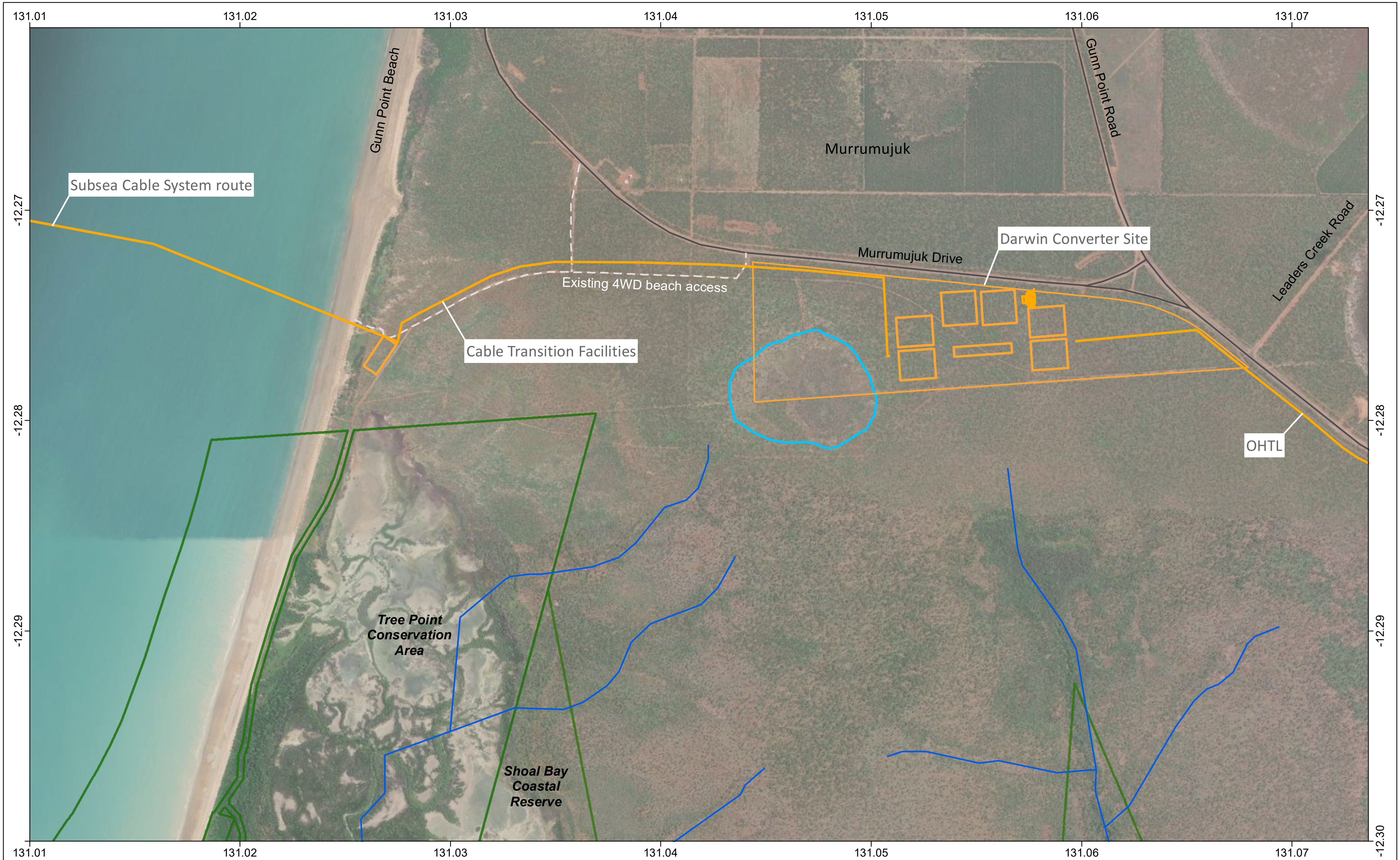
A4

Reference: M-Files ID 198726

Date: 09/03/2022

Revision: 1

SUN CABLE



Legend

- AAPowerLink Infrastructure
- 4WD beach access
- Road
- Streams
- Seasonal swamp
- NT Parks and Reserves
- Howard Water Allocation Plan (inset)

Source: Sun Cable, EcOz, NTG (NR Maps)

Figure 6-15: Map of water features within the area of influence Darwin Converter Site and Cable Transition Facilities

Project: Australia-Asia PowerLink | Reference: M-Files ID 198726 | Revision: 2

Coordinate System: GDA2020 | Date: 09/03/2022

0 — 1 Kilometres | Scale: 1:25,000 | A4

N

SUN CABLE

6.4 Potential impacts

The potential impacts to surface water and groundwater hydrological regimes associated with construction and operation of the AAPowerLink have been assessed using the EIA methodology described in Chapter 3 – Impact Assessment. The EIA identified and assessed the following impacts that could occur during construction and/or operations:

- Alteration to surface water flows in watercourse and wetlands caused by land development
- Changes to groundwater levels associated with extraction of groundwater and/or reduced recharge.

The EIA considered the impact avoidance and mitigation measures detailed in Section 6.5 below and assessed the residual impacts to hydrological processes assuming these measures are effectively implemented. A residual impact rating was then assigned taking into consideration the scale, magnitude and duration of the impacts, the presence/absence of environmental values and/or sensitive receptors and the level of certainty with respect to the intensity of the impact and the effectiveness of the mitigation measures. The residual impact ratings adopted in the assessment are provided in Table 6-6.

The outcomes of the EIA are summarised in Table 6-7 and Table 6-8 below from the *Impact Assessment Register* provided at Appendix E and discussed in the subsequent sections.

Table 6-6. Residual impact ratings adopted for the AAPowerLink EIA

Ratings and Description
Minor: A minor residual impact is unlikely to be significant.
A minor impact generally has two or more of the following characteristics: Scale: Limited/Localised Magnitude: Negligible/Minor Duration: Short-term/ Medium-term/Reversible. **OR** There are no sensitive receptors or land uses present, and the environment does not contain any aspects that are valuable or otherwise important or unique (i.e., Very Low/Low rating), and there is moderate to high degree of certainty about the likelihood and intensity of the impact, and the effectiveness of proposed mitigation measures.
Moderate: A moderate residual impact has potential to be significant. The significance depends on the acceptability of the impacts and the effectiveness of mitigation measures.
A moderate impact generally has two or more of the following characteristics: Scale: Localised/Regional **Magnitude**: Moderate Duration: Medium-term/Long-term **AND/OR** There are sensitive receptors or land uses present, or environmental aspects that are valuable or otherwise important or unique (i.e., Medium-High value rating), and there is a low degree of certainty about the impact, and the effectiveness of proposed mitigation measures.
Major: A major residual impact is likely to be significant. The level of acceptability will depend on offsets or benefits compensating for the impact.
Impact generally has two or more of the following characteristics: Scale: Regional/ Widespread Magnitude: Moderate/Major Duration: Long-term/Permanent **AND** There are sensitive receptors or land uses present, or environmental aspects that are valuable or otherwise important or unique (i.e., Medium-High value rating).

Table 6-7. Summary of EIA results - Hydrological processes factor – Construction

Impact	Location	Likelihood	Scale	Duration	Magnitude	Value rating	Certainty	Residual impact
Alteration to surface water flows in water courses or wetlands Section 6.4.2.1	Solar Precinct	**Possible** Altered flow paths possible in watercourses and alluvial floodplains crossed by access roads.	**Limited** Altered surface water flow paths limited to direct disturbance footprint at crossings.	**Short-term** Once crossings are installed surface water flows will be unimpeded due to road and drainage design.	**Negligible** Watercourses are minor ephemeral drainage lines. Watercourse crossings will not be constructed during periods of flow.	**Medium** Hydrology supports aquatic ecosystems and other beneficial uses of watercourses	**High** Roads and crossings will adhere to Austroads, which is proven effective in mitigating impacts to surface water flows. Temporary drainage as per ESCP developed in accordance with IECA guidelines.	**Minor**
	OHTL	**Possible** OHTL crosses 154 watercourses. Lower order drainage lines will be crossed by the access track. Pole placement will avoid disturbance to watercourses and wetlands.	**Limited** Altered surface water flow paths limited to within the direct disturbance footprint.	**Short-term** Minor changes to overland flow paths could occur intermittently during significant rainfall events.	**Negligible** No offsite impacts to hydrological regimes in watercourses or wetlands.	**Medium** Hydrology supports aquatic ecosystems and other beneficial uses of watercourses.	**High** Construction design avoids disturbance of major watercourses. Temporary drainage as per ESCP developed in accordance with IECA guidelines.	**Minor**
	Darwin Converter Site	**Possible** Overland flows progressively altered within direct disturbance footprint (~55ha) over construction period.	**Localised** No watercourses present in footprint but seasonal swamp present 150 m south-west.	**Long-term** Hydrology will be altered for the construction and operational phases.	**Moderate** No watercourses present in footprint but seasonal swamp present immediately south-west.	**Medium** Hydrology supports aquatic ecosystem in seasonal swamp.	**Low** Stormwater management plan yet to be developed and could result in increased or decreased flows to the swamp.	**Moderate**

Impact	Location	Likelihood	Scale	Duration	Magnitude	Value rating	Certainty	Residual impact
	Cable Transition Facilities	**Unlikely** Footprint is small; there are no watercourses present and the area is outside of storm surge zone.	**Limited** Flows may be altered in direct disturbance footprint.	**Short-term** Construction activities will take place over a single dry season and footprint will be reinstated.	**Negligible** No alteration of flows in watercourses as none present.	**Low** No watercourses supported by flows from Cable Transition Facilities	**High**	Minor
Changes to ground water levels caused by groundwater extraction Section 6.4.2.2	Solar Precinct	**Likely** Groundwater extraction to supply 1,000 ML/year during construction will result in drawdown around bores.	**Regional** Drawdown may affect up to kilometres around bores, location, and extent currently unknown.	**Med-term** Extraction of large volumes of water only required for construction (up to 5 years). Groundwater levels will take time to recover following extraction.	**Minor** Due to remote location, few existing water users, and distance to springs and GDEs, impact from drawdown expected to be minor.	**Medium** Groundwater in the region support pastoral uses and, in the broader aquifer, many beneficial uses.	**Low** Locations for construction water extraction bores are currently unknown, and so certainty is low about impact to other users.	Moderate
	OHTL	**Possible** Extraction of minor volumes (9.2 ML/year spread over the ~800 km length) from existing bores	**Limited** Drawdown may occur around bore but will be limited by minor volumes and short duration of use.	**Short-term** OHTL will be constructed as a moving workfront, with water use spread across the route.	**Negligible** Drawdown unlikely to be detectable or impact other users or GDEs.	**High** Groundwater supports numerous other users across the region, and GDEs.	**High** Water will be extracted from existing bores under agreement with landholders and in accordance with any existing licences.	Minor
	Darwin Converter Site	**Possible** Groundwater extraction to supply 33 ML/year during construction could result in drawdown around bores.	**Limited** Drawdown may occur around bore, but impacts limited by lack of other users.	**Med-term** Extraction for construction may occur for 5 years. Groundwater levels may take years to recover.	**Minor** Drawdown may be measurable but unlikely to impact other users or the environment.	**Low** No existing consumptive users within 4 km or GDEs fed by Koolpinyah aquifer	**High** Extraction of proposed volumes at Darwin Converter Site unlikely to impact other users or GDEs as none are present within area of	Minor

Impact	Location	Likelihood	Scale	Duration	Magnitude	Value rating	Certainty	Residual impact
							influence.	
	Cable Transition Facilities	Unlikely	**Not assessed.** No groundwater extraction proposed at this location. Construction water to be supplied from bore at Darwin Converter Site				High	None

Table 6-8. Summary of EIA results - Hydrological processes factor – Operations

Impact	Location	Likelihood	Scale	Duration	Magnitude	Value rating	Certainty	Residual impact
Alteration of flows in surface watercourses or wetlands Section 6.4.3.1	Solar Precinct	Possible The Solar Precinct will alter overland flow paths across ~12,000 ha	Limited No watercourses within Solar Precinct and Lake Woods >10 km away.	Long-term Overland flow paths will be altered for the duration of operations.	Negligible Alteration of overland flow paths within Solar Precinct will have negligible impact on hydrological regime of Lake Woods.	High Lake Woods is a nationally important wetland which provides numerous ecosystem values, particularly during times of flood.	High Hydrological modelling has been undertaken. See Appendix N.	Minor
	OHTL	Unlikely Majority of OHTL will be reinstated following construction with drainage as required to manage overland flows and maintain hydrological regime.	Limited Overland flows may be altered in limited areas due to erosion.	Short-term Erosion would be identified and rectified.	Negligible No impacts to flows in watercourses or wetlands.	Medium OHTL does cross watercourses and wetland which support numerous beneficial uses.	High OHTL will be reinstated, and drainage as per an ESCP developed in accordance with IECA guidelines.	Minor
	Darwin Converter Site	Possible Overland flows altered within direct disturbance footprint ~55ha.	Localised Potential for increase or decrease in discharges to seasonal swamp located 150 m south-west.	Long-term Overland flow paths will be altered for the duration of operations.	Moderate Potential for increase or decrease in swamp levels.	Medium Hydrology supports aquatic ecosystem in seasonal swamp.	Low Stormwater management plan yet to be developed and could result in increased or decreased flows to the swamp.	Moderate
	Cable Transition Facilities	Unlikely Footprint will be reinstated following construction.	Limited Some isolated erosion may occur, with no impacts to hydrology in surrounding	Short-term Any erosion would be identified and rectified.	Negligible No impact to watercourses from altered hydrology.	Low No watercourses present in footprint.	High Footprint will be reinstated. ESCP developed in accordance with IECA guidelines.	Minor

Impact	Location	Likelihood	Scale	Duration	Magnitude	Value rating	Certainty	Residual impact
			watercourses.					
Changes to ground water levels caused by groundwater extraction Section 6.4.3.2	**Solar Precinct**	**Unlikely** Groundwater extraction to supply 10 ML/year	**Limited** Drawdown may occur immediately surrounding the bore.	**Long-term** Extraction will occur for duration of operations	**Negligible** Remote location, few other users, no proximate GDEs.	**Medium** Groundwater in the region supports pastoral uses and, in the broader aquifer, many beneficial uses.	**High** Although extraction locations not known, volumes are low, and aquifer is a regional aquifer with significant supply.	**Minor**
	OHTL	**Unlikely** Very limited groundwater may be required for maintenance.	**Limited** Drawdown may occur immediately surrounding the bore.	**Short-term** Groundwater extraction would only occur for short maintenance works.	**Negligible** Short term use of minor volume unlikely to impact levels or other users.	**High** Groundwater supports numerous other users across the region, and GDEs.	**High** If required, water will be extracted from existing bores under agreement with landholders and in accordance with any existing licences.	**Minor**
	Darwin Converter Site	**Unlikely** Groundwater extraction to supply 0.05 ML/year	**Limited** Drawdown may occur immediately surrounding the bore.	**Long-term** Extraction will occur for duration of operations.	**Negligible** Low volumes, few other users, no GDEs.	**Low** No existing consumptive users within 4 km or GDEs fed by Koolpinyah aquifer.	**High** Extraction of proposed volumes at Darwin Converter Site unlikely to impact other users or GDEs as none are present within area of influence.	**Minor**
	Cable Transition Facilities	**Unlikely**	**Not assessed.** No water use as part of routine operations. Any water requirements for maintenance activities would be met by extraction from bores at Darwin Converter Site.				**High**	**None**

Impact	Location	Likelihood	Scale	Duration	Magnitude	Value rating	Certainty	Residual impact
Changes to groundwater levels caused by reduced recharge Section 6.4.3.3	Solar Precinct	**Unlikely** Reduced recharge to the regional aquifer at Solar Precinct unlikely to impact groundwater levels.	**Limited** Reduced recharge within direct disturbance footprint only.	**Long-term** Reduced recharge will occur for duration of operations.	**Negligible** Site is not located in identified groundwater recharge area. Aquifer is a broad, regional scale aquifer.	**Medium** Groundwater in the region supports pastoral uses and, in the broader aquifer, many beneficial uses.	**High** A localised decrease in infiltration is unlikely to affect recharge. Flows to Lake Woods (which is a recharge area) will be unimpacted.	**Minor**
	OHTL	**Unlikely**	**Not assessed.** No impervious surface created, so no impact on recharge.				**High**	**None**
	Darwin Converter Site	**Unlikely** No change in recharge to deep productive aquifer. Recharge to shallow aquifer may be reduced by hardstand areas, but unlikely to impact shallow aquifer levels.	**Limited** Reduced recharge within direct disturbance footprint only.	**Long-term** Reduced recharge will occur for duration of operations	**Negligible** Productive aquifer is confined under the Darwin Converter Site. Site is not located in identified recharge area.	**Low** No known GDEs which would be impacted by reduced recharge to shallow aquifer in operational footprint.	**High**	**Minor**
	Cable Transition Facilities	**Unlikely**	**Not assessed.** No impervious surface created, so no impact on recharge.				**High**	**None**

6.4.1 Areas of potential impact

6.4.1.1 Proposal footprint (direct disturbance)

The area within which hydrological regimes may be directly impacted is limited to locations where the proposal footprint intersects surface water features and areas where groundwater will be used as a water supply. At the Solar Precinct the direct disturbance footprint encompasses several drainage depressions that hold water after wet season rains and several seasonal watercourses that are crossed by the access roads (these are shown on Figure 6-2). Along the OHTL corridor numerous rivers, creeks and minor drainage lines are crossed (as shown on Figure 6-13 and Figure 6-14). At the Darwin Converter Site and Cable Transition Facilities, there are no surface watercourses present in the direct disturbance footprint.

Groundwater resources could be impacted in the vicinity of proposed groundwater extraction bores used during construction and operation, which will be at the Solar Precinct, Darwin Converter Site, and potentially at designated points along the OHTL (during construction only). The remainder of the proposal footprint does not directly impact surface water features or groundwater aquifers.

6.4.1.2 Area of influence (indirect disturbance)

Indirect impacts to surface water flows in watercourses outside of the direct disturbance footprint are unlikely to occur because the construction and operational activities do not involve any surface water extraction or activities that would alter discharges to watercourses. At the Darwin Converter Site, it is possible that the nearby seasonal swamp could be indirectly affected by localised changes to overland flows within the catchment. The area of influence to surface water hydrological regimes therefore extends to the seasonal swamp at the Darwin Converter Site, the location of which is shown on Figure 6-15. Elsewhere across the proposal footprint impacts to hydrological regimes are limited to the areas where direct disturbance will occur (as described above).

Groundwater extraction at the Solar Precinct could result in groundwater drawdown which could impact on existing station bores, and the area of influence at the Solar Precinct therefore includes the proximate bores which are shown on Figure 6-7. Groundwater drawdown is not expected to impact on other users, or GDEs, along the OHTL or at the Darwin Converter Site. Groundwater extraction locations along the OHTL are currently unknown, but existing bores may be used under arrangement with the landholder and in accordance with relevant licence conditions. At the Darwin Converter Site, there are few bores located close to the facility (as shown on Figure 6-15), but groundwater extraction is not expected to impact these bores as proposed extraction volumes are low and the proximate bores are not currently in use as production bores.

Activities will not alter groundwater recharge to the underlying productive aquifers; the Solar Precinct overlies a large-scale regional aquifer and is not in a known recharge area, and the productive aquifer underlying the Darwin Converter Site is confined at that location.

6.4.2 Construction

The potential for impacts to hydrological regimes will be greatest during the construction phase, when catchment conditions are altered due to land clearing and development (e.g., earthworks and installation of hardstand areas), and project water demand from groundwater extraction will be greatest due to construction water requirements and the accommodation camps servicing a large construction workforce. The sections below discuss the potential impacts of construction activities at each proposal location to the hydrological regimes of surface water and groundwater.

6.4.2.1 Changes to surface water flows

During the construction phase there is the potential to alter surface water flows via the creation of hardstand areas (which could increase runoff), and ground disturbance causing changes to relief and drainage (which could modify flow directions).

Solar Precinct

Land clearing and development at the Solar Precinct will progressively alter overland flow paths across the ~12,000 ha footprint. During construction, rainfall and runoff will be managed in accordance with Erosion and Sediment Control Plans (ESCPs), with water discharged into the surrounding vegetated areas as overland flows. Changes to overland flow paths over the construction phase will not alter flows in any watercourses or drainage lines as there are none within or in proximity to the direct disturbance footprint.

Within the direct disturbance footprint of the Solar Precinct, drainage will be altered such that the localised drainage depressions (see Figure 6-2) will likely be filled in and will no longer receive surface water runoff. These features are not connected to any watercourses and are not groundwater recharge features, and therefore their loss will not impact hydrological regimes outside of the immediate area. The drainage depressions do not contain significant vegetation, riparian vegetation, or ecological but they have been identified as having cultural heritage value and impacts to these values associated with the loss of these depressions are considered in Chapter 14 – Culture and Heritage.

The access roads to the Solar Precinct cross alluvial plains and drainage lines as shown on Figure 6-2. Crossings will be constructed at these drainage lines, which will involve disturbance of the beds and banks and can only be undertaken during no flow conditions. Crossing locations will have erosion and sediment controls installed in accordance with ESCPs, which is expected to ensure that existing drainage patterns are maintained, and it is unlikely that flows will be altered in the downstream environment. Access road watercourse crossings will be constructed when watercourses are dry to minimise impacts to water quality and water flows, as well as aquatic biota (e.g., fish) passage.

Overhead Transmission Line

Construction of the OHTL may result in alteration of overland surface water flow paths in isolated areas, where the cleared corridor or infrastructure may divert flows or become a preferential flow path. This impact is more likely to occur within the section of the OHTL located within the Utilities Corridor (from KP 722 to the Darwin Converter Site), which is mostly greenfield and so will require more clearing than the portion of OHTL within the railway corridor. Within the Utilities Corridor, the beds and banks of minor watercourses will be disturbed by the establishment of OHTL access track crossings. The OHTL is not predicted to alter flow regimes in any watercourse because placement of poles and construction pads will avoid these areas as described in Chapter 2, and only lower order drainage lines will be crossed by the OHTL access track.

Minor changes to overland flow paths will occur intermittently over the construction phase, when construction activities coincide with significant rainfall events, but will reduce post construction as the OHTL construction pads and construction access track are progressively reinstated (see Chapter 2). Drainage, erosion, and sediment controls will be installed along the OHTL in accordance with the *Best Practice Erosion and Sediment Control Guidelines* (IECA, 2008), which have been effectively implemented on other linear projects in the NT to minimise changes to surface water flows and erosion. Minor alteration of overland flows paths could cause isolated areas of erosion as discussed in Chapter 4 Terrestrial Environmental Quality but is unlikely to alter surface water flow regimes in any watercourse or impact environmental values or other uses.

Darwin Converter Site

Land clearing and development at the Darwin Converter Site will alter overland flow paths across the 55-ha footprint. It is possible that the seasonal swamp immediately to the south-west could be affected by the permanent localised changes to surface water flow pathways that will occur once the site is constructed, and this impact is further considered in Section 6.4.3.1 below. During construction, drainage, erosion, and sediment controls will be installed in accordance with the *Best Practice Erosion and Sediment Control Guidelines* (IECA, 2008), with rainfall and runoff discharged into the surrounding vegetated areas as overland flows. Changes to overland flow paths over the construction phase will not alter flows in any watercourses or drainage lines as there are none within the direct disturbance footprint or immediate surrounds.

Cable Transition Facilities

Construction of the Cable Transition Facilities is unlikely to alter surface water flow regimes because the footprint is small, there are no watercourses within the construction footprint and it is outside of mapped storm surge zones, and construction activities will be completed over a short period of time (weeks to months), in the dry season where practicable. Minor changes to overland flow paths will occur intermittently over the construction phase, when construction activities coincide with significant rainfall events, but will reduce post construction as the footprint is progressively reinstated (see Chapter 2). Drainage, erosion, and sediment controls will be installed within the construction footprint in accordance with the *Best Practice Erosion and Sediment Control Guidelines* (IECA, 2008), which have been effectively implemented on other linear projects in the NT to minimise changes to surface water flows and erosion. Minor alteration of overland flows paths could cause isolated areas of erosion as discussed in Chapter 4 Terrestrial Environmental Quality but is unlikely to alter surface water flow regimes in any watercourse or impact environmental values or other uses.

6.4.2.2 Changes to groundwater levels

Extraction of groundwater to supply the construction water requirements could possibly impact groundwater levels around existing water bores at the Solar Precinct. There are no other activities that are likely to impact groundwater hydrological regimes.

Solar Precinct

It is likely that extraction of groundwater to supply the construction camps and construction water requirements at the Solar Precinct could lower groundwater levels in the area around water supply bores. It is estimated that up to 1,000 ML/year of water will be required during construction for dust suppression, wash downs, concrete batching and to service the construction camps. A demand of 1,000 ML/year is equivalent to ~30 L/second (assuming 24-hour extraction year-round), which is a high rate of extraction and will likely require a bore field (i.e., more than one bore) to achieve required water supply volumes.

The location, depth and construction of any new groundwater bores will be subject to investigation and recommendations from a hydrogeologist to ensure that bores can meet project water demand within sustainable yields. Specific groundwater extraction locations are currently unknown, but the aquifer underlying the Solar Precinct is a large regional scale aquifer with significant supply. Fulton and Knapton (2015) state that the CLA contains a significant water resource with estimated sustainable yields from the Georgina Basin (the geological province which includes the CLA) of approximately 100,000 ML/year, and current use within the Beetaloo Sub-basin is approximately 6,000 ML/year. Therefore, bores drilled in the CLA underlying the Solar Precinct are likely to be able to achieve required extraction volumes within sustainable yields, but this will be confirmed via hydrogeological studies.

There are no existing bores within the Solar Precinct, but a number of registered bores are located in the surrounding area, as shown on Figure 6-7 (see inset). All bores are station bores, presumably used for stock watering, except for two bores on the north-western side of the Solar Precinct, adjacent to the railway line, which were drilled for use by the railway, and are assumed to be infrequently used. Groundwater used for stock watering does not require a licence, and so current usage and extraction volumes from proximate bores are unknown. Fulton and Knapton (2015) estimated stock water usage as 50 litres/head[13]/day when undertaking an assessment of current water usage in the Beetaloo Sub-basin. Based on this, and a stocking rate of 4-5 head per km^2, Fulton and Knapton estimated pastoral water use across the study area (~60,000 km^2) as 4,380 – 5,475 ML/year[14]. Therefore, proposed Sun Cable extraction volumes represent approximately one fifth of estimated pastoral groundwater usage volumes in the Betaloo region.

A hydrogeological assessment will be undertaken to determine sustainable yields and inform bore locations to avoid potential drawdown impacts on existing users. Sun Cable will locate groundwater extraction bores away from existing bores to minimise potential drawdown impacts and will consult with the landholders of Powell Creek Station to ensure proposed water usage has minimal impact on pastoral activities.

Bore construction will be subject to a Bore Work Permit and a Water Extraction Licence will be required because the Solar Precinct is within the Daly Roper Beetaloo WCD. The Water Extraction Licence Application requires an assessment of sustainable yields and potential impacts of proposed extraction, and the licence will include conditions to ensure sustainable rates of extraction and detection of any lowering of groundwater levels.

GDEs, in the form of groundwater fed springs, are known to occur along the watercourses crossed by the access roads. Based on available aquifer boundary mapping[15] the springs are fed from different groundwater aquifers to that which would be targeted for Solar Precinct water supply, associated with the Kalkarindji Province and Tennant Creek Block. The springs are also > 18 km east of the boundary of the Solar Precinct, and it is therefore considered highly unlikely that groundwater extraction at the Solar Precinct will impact on GDEs. However, given the ecological and cultural values associated, water quality sampling and analysis will be undertaken to compare water chemistry from the springs and bores within the CLA proximate to the Solar Precinct. This will assess whether the GDEs are fed by the same aquifer that Sun Cable will target for groundwater extraction, and therefore ensure proposed extraction will not impact on water levels in the springs.

Overhead Transmission Line

Extraction of groundwater to support construction along the OHTL is unlikely to lower groundwater levels because relatively minor volumes of water will be required. A total of 9.2 ML/year is estimated to be required for dust suppression, washdowns, concrete batching, and to supply the fly camps (kitchen, ablutions, potable water); see Chapter 2. Water will be sourced from existing bores under agreement with landholders along the OHTL, or trucked to site, and water extraction will comply with any existing and applicable water extraction licences. As the OHTL will be constructed on a rolling basis using a series of mobile work fronts, water extraction will be spread across multiple locations and will occur for a short period of time at each location, which is unlikely to cause drawdown that would affect other users or the environment.

13 Head of cattle – i.e., 50L/cow/day

14 The study area covered the Beetaloo Sub-basin of ~ 21,000 km2, extending from ~ 50 km north of Daly Waters, to 55 km south of Elliot, and west to cover the eastern portions of Powell Creek and Newcastle Waters stations. The study area extends east to cover the majority of pastoral properties Beetaloo and Tanumbirini, ~ 200 km east of Daly Waters; see Fulton and Knapton 2015.

15 Northern Territory Groundwater – Aquifers 1:2,000,000 dataset created in 2008 and last updated in 2015 (available at NR Maps, DEPWS 2021a). Aquifer boundaries were derived from geology and modified with bore information and known aquifer boundaries where available.

Darwin Converter Site

Groundwater extraction for construction of the Darwin Converter Site could possibly lower groundwater levels surrounding the extraction bore but would be unlikely to impact on other users or GDEs. Estimated groundwater use for construction of the Darwin Converter Site is 33 ML/year, which is equivalent to ~1 L/second (assuming 24-hour extraction year-round). Groundwater is required for dust suppression, washdowns, concrete batching and for the staff amenities (see Chapter 2); there is no accommodation camp onsite. It is proposed that water supply will either be from a bore/s drilled onsite or nearby or sourced from existing Power and Water supplies under agreement. The location, depth and construction of any new groundwater bores will be subject to investigation and recommendations from a hydrogeologist to ensure that bores can provide a sustainable yield that will meet the project needs.

Groundwater extraction from the Koolpinyah Dolostone formation could result in drawdown impacts at the bore and immediate surrounds. As reported in Woltmann (2020), historic groundwater use in the Gunn Point area[16] did result in lowered groundwater levels in nearby bores, which took five years to recover after extraction stopped as the aquifer in confined, recharge is ~14 km to the south, and the aquifer is somewhat compartmentalised, which influences connectivity. However, given the relatively low proposed extraction volumes, and the fact that there are no other consumptive groundwater users within 4 km of the Darwin Converter Site, any drawdown impacts would be unlikely to impact other groundwater users. The proposed extraction location is over 20 km from the Darwin Rural Area, where competition for groundwater is high.

A Water Extraction Licence will be required because the site is within the Darwin Rural WCD. The licence will include conditions to minimise potential impacts to other users or the environment associated with groundwater extraction. Extraction of low volumes under licenced conditions is unlikely to result in a reduction in groundwater levels such that other users or supported values[17] would be impacted.

The seasonal swamp to the south-west of the Darwin Converter Site may be fed, in part, by groundwater from the shallow lateritic aquifer (noting that the Koolpinyah dolostone aquifer is confined and so is unlikely to be connected to surface water features). Any groundwater bores drilled will target the deeper Koolpinyah dolostone aquifer, and so groundwater extraction for the Darwin Converter Site will not impact on groundwater feeding the swamp.

Cable Transition Facilities

Water required for construction of the Cable Transition Facilities will be sourced from bores constructed for the Darwin Converter Site. Refer above for discussion of impacts.

6.4.3 Operation

Once the infrastructure is installed, during operations there will be ongoing localised impacts to overland flows within the Solar Precinct and Darwin Converter Site as incident rainfall and runoff on the sites is captured in stormwater drainage systems. There is not predicted to be any ongoing impacts to surface water flows along the access roads, OHTL corridor or Cable Transition Facilities as these areas will be reinstated following construction or, where not reinstated (e.g., along the access roads) appropriate engineered drainage will ensure flows are unimpeded. Groundwater extraction will continue to occur at the Solar Precinct and Darwin Converter Site, but the water demand is minor and unlikely to alter groundwater levels.

[16] Groundwater pumping for the Gunn Point prison in the 1980's – just north of the proposed Darwin Converter Site location – impacted nearby monitoring bores. Pumping occurred from 1985-1996, and groundwater levels in RN008373 (monitoring bore) recovered after five years. Further south at RN022296 (located adjacent to Gunn Point Road, 10.5 km south-east of the Darwin Converter Site), historical records indicate drawdown during pumping, but immediate recovery once pumping ceased, indicating variable recharge and recovery rate, with recovery of groundwater levels slower in the northern portion of Gunn Point. See Woltmann (2020).

[17] Noting that there are no significant GDEs within 10 km of the Darwin Converter Site.

The sections below discuss potential impacts to hydrological regimes of surface water and groundwater during operations at each proposal location.

6.4.3.1 Changes to surface water flows

Solar Precinct

Construction of the Solar Precinct will permanently alter overland flow paths across a large area (~12,000 ha) but the impact to surface water flow regimes will be localised due to the absence of watercourses and because the design criteria for the Solar Precinct drainage network is to discharge at similar rates to pre-construction condition. Although flow paths within the Solar Precinct footprint will be altered to manage stormwater, ultimately all water captured in the drainage network will be discharged as overland flows, and there is not expected to be any reduction in water volumes reporting to the alluvial plains and floodplains surrounding Lake Woods.

The access roads to the Solar Precinct cross alluvial plains and drainage lines as shown on Figure 6-2 The access roads will be designed in accordance with Austroads Road Design Standards, which will include standard drainage measures to maintain natural drainage patterns. Installation of drains, culverts, and spillways in accordance with good practice guidelines is predicted to ensure that existing drainage patterns are maintained, and it is unlikely that flows will be altered in the downstream environment.

Overhead Transmission Line

It is unlikely that operation of the OHTL will result in impacts to surface water flows because the poles will be placed away from watercourses and the majority of the OHTL footprint will be reinstated following construction as described in Chapter 2. During operations, a 6 m wide permanent maintenance track will be maintained and a cleared area of 6 m x 12 m around each pole. An ESCP will be implemented, and controls will be maintained, to ensure drainage is not impeded and to minimise the risk of erosion along the OHTL. Isolated occurrences of erosion will possibly occur along the OHTL each wet season and will require remediation to limit the impact. Erosion may be more frequent in the first two years following construction whilst the disturbed areas are stabilising. Isolated occurrences of erosion can be readily rectified by routine inspection and maintenance works, and erosion would not be expected to occur to the extent that surface water flows within the operational footprint, or downstream watercourses, would be impacted.

Darwin Converter Site

Development of the Darwin Converter Site will permanently alter overland flow paths across the 55-ha footprint. A stormwater drainage system will be installed to divert overland flows around the facilities and to capture and discharge rainfall and runoff that occurs internal to the site as described in Chapter 2. Stormwater will be discharged to the south and west of the site, via erosion controls and level spreaders, such that surface water runoff reports to surrounding vegetated areas as overland flows. The design criteria for the stormwater drainage system are for discharges from the area to be similar to pre-construction conditions. Sun Cable has designed and located infrastructure to minimise impacts to surface water features, including avoiding development near the swamp in the south-western corner of the site.

It is possible that the seasonal swamp could be affected by localised changes to surface water flow pathways as flows are diverted around works areas and/or concentrated at discharge points from the stormwater drainage system. The change in the catchment could lead to the swamp filling faster or slower than under pre-development conditions; however, the likelihood and magnitude of change is uncertain until the drainage design is finalised. The implications of this change for the ecological functioning of the wetland are considered in Chapter 5 Terrestrial Ecosystems and Chapter 8 Aquatic Ecosystems. Any change is predicted to be localised to the swamp and is unlikely to affect the hydrological regimes in the catchment more broadly as the Darwin Converter Site footprint comprises a small portion of the catchment area[18] reporting to the coastal floodplains within the Tree Point Conservation Area and Shoal Bay Coastal Reserve.

Cable Transition Facilities

There is not predicted to be any ongoing impacts to surface water flows in the Cable Transition Facilities footprint as these areas will be reinstated following construction; trenches will be backfilled, and the area will be allowed to revegetate as described in Chapter 2.

6.4.3.2 Changes to groundwater levels caused by water extraction from bores

Extraction of groundwater for operational water uses at the Solar Precinct and Darwin Converter Site is unlikely to alter groundwater levels in the aquifer because the water demand is low. The forecast operational water demand at the Solar Precinct is approximately 10 ML per year and at the Darwin Converter Site is 0.05 ML per year. For context, the average Darwin household uses ~600 KL (0.6 ML) per year, while the average rural domestic user uses ~3.5 ML/year (Water Resources, n.d.).

Water will be supplied either from an onsite bore/s (drilled during construction) or trucked to site as described in Chapter 2. No water will be required for routine operation of the OHTL, and minor volumes of maintenance water (if required), will be supplied from existing bores and other water supplies, subject to agreement with the landholder and existing licence conditions.

The location, depth and construction of any new groundwater bores will be subject to investigation and recommendations from a hydrogeologist to ensure that bores can provide a sustainable yield that will meet the project needs, and groundwater extraction will be subject to the requirements of the *Water Act,* including obtaining a groundwater extraction licence for extraction within the Daly Roper Beetaloo WCD and the Darwin Rural WCD. As discussed in Section 6.4.2.2, there are no existing water extraction licences, and very few existing water users, proximate to the Solar Precinct and Darwin Converter Site, and so the proposed extraction volumes are unlikely to impact groundwater levels or other users. There are also no GDEs close to the Solar Precinct or Darwin Converter Site which would be impacted by water extraction.

6.4.3.3 Changes to groundwater levels caused by reduced recharge

Construction of the Solar Precinct and Darwin Converter Site will create impervious surfaces (infrastructure and hardstand areas) that will increase run-off and reduce infiltration of incident rainfall within a localised area at both locations. Across most of the Solar Precinct footprint, rainfall will continue to infiltrate the soils underlying the solar fields as runoff from the panels will report to the underlying soils. As the proposal footprints are not located in identified groundwater recharge areas, a localised decrease in infiltration is unlikely to affect recharge of the underlying productive aquifers.

At the Solar Precinct, the underlying Cambrian Limestone Aquifer is a regional scale aquifer and the proposal footprint of 120 km^2 covers approximately ~0.3 % of the catchment. Decreased infiltration of rainfall in parts of the developed footprint is predicted to have negligible impact on aquifer recharge. Additionally, the proposal is not predicted to affect flows into Lake Woods, a known area of groundwater recharge, because the design criteria for the site stormwater drainage system is to maintain surface water flows at similar volumes to pre-construction conditions.

The Darwin Converter Site will not result in impacts to groundwater recharge in the productive Koolpinyah dolostone aquifer as the aquifer is confined where it underlies the proposal footprint, and the main recharge area is known to occur over 14 km south. Reduced recharge to the shallow lateritic aquifer will occur across most of the 55-ha footprint. The shallow lateritic aquifer recharges each wet season and drains laterally throughout the dry season, discharging to lower elevation areas along the coast, and springs and wetlands.

[18] The catchment area surrounding the Darwin Converter Site reports to the Tree Point Conservation Reserve to the south-west and the Shoal Bay Coastal Reserve to the south. The catchment area south of Murrumujuk Drive is ~18 km^2. The construction footprint for the Darwin Converter Site is 0.55 km^2, ~3% of the broader catchment area.

Discharge areas are known to occur in the watercourses south of the Darwin Converter Site (near the boundary of the Shoal Bay Coastal Reserve; see Woltmann 2020). Groundwater dependence of vegetation and supported values in these areas are unknown. However, the lateritic aquifer recharges broadly across the region, and as the Darwin Converter Site covers ~55 ha in a largely undeveloped area[19], reduced recharge in the direct disturbance footprint is unlikely to impact on the recharge or discharge regimes of the shallow aquifer more broadly.

6.5 Avoidance, mitigation, and monitoring

Sun Cable is committed to applying the environmental decision-making hierarchy. Consistent with Section 26 of the *EP Act* this involves applying the following approaches in order of priority:

1. Avoid – Ensure that actions are designed to avoid adverse impacts on the environment.
2. Mitigate – Identify management options to mitigate adverse impacts on the environment to the greatest extent practicable.
3. Offset – If appropriate, provide for environmental offsets for residual adverse impacts on the environment that cannot be avoided or mitigated.

The environmental management framework that will be adopted for the construction and operation of the AAPowerLink is detailed in Chapter 17 Environmental Management. The framework comprises a Construction Environmental Management Plan (CEMP) and Operations Environmental Management Plan (OEMP) that sit within an overarching Environmental Management System (EMS).

For each of the impacts to hydrological regimes discussed in this chapter, Table 6-9 summarises the actions that will be taken to avoid environmental impacts (through site selection and design) and actions proposed to minimise impacts during construction, operation and decommissioning of the proposal. The measures provided in this chapter, along with any additional measures required to address conditions of approvals, permits and licences, will be integrated into the CEMP and OEMP prepared for the AAPowerLink.

[19] To demonstrate this; the watercourse immediately south of the Darwin Converter Site has a surface catchment area of ~1,000 ha, from south of Murrumujuk Drive. The recharge zone for the shallow lateritic aquifer may be broader than this, but as a conservative measure the surface catchment will be used to represent the approximate recharge area. The Darwin Converter Site, at 55 ha, covers ~ 5% of the catchment (and inferred shallow aquifer recharge zone), and the remainder of the catchment is undeveloped naturally vegetated areas where recharge would remain unchanged.

Table 6-9. Hydrological processes – Commitments

Impact	Avoidance	Mitigation	Monitoring	Reporting
Changes to surface water flows from land clearing and development	Solar Precinct and Darwin Converter Site footprints located on flat land above the maximum modelled flood extent (0.1 % AEP/1-in-1000-year flood event) and outside of mapped storm surge zones. Solar Precinct and Darwin Converter Site selection process included avoidance of major watercourses. OHTL poles will not be placed in watercourses or drainage lines. Only minor drainage lines will be crossed by the OHTL access track. Major drainages will be approached from either side to avoid the need for constructing crossings. Roadside drainage and culverts will be designed and installed in accordance with accepted Austroads standards. Groundwater used as water supply – no surface water extraction.	Watercourse crossings along access roads and OHTL installed during the dry season when no flow present. Drainage, erosion, and sediment controls installed and maintained in accordance with Erosion and Sediment Control Plans (ESCP) that align with the *Best Practice Erosion and Sediment Control Guidelines* (IECA, 2008). Reinstatement of OHTL construction corridor and Cable Transition Facilities footprints post-construction. Design criteria for engineered stormwater management systems installed at the Solar Precinct and Darwin Converter Site is to discharge water to similar locations and at similar volumes to pre-development conditions.	During construction, visual inspections of disturbed areas and erosion and sediment controls as per ESCP (after significant rainfall events, at a minimum). Annual post wet season monitoring of revegetation success until disturbed areas are stabilised. Visual inspections of drainage structures, discharge points and site boundaries following rain events. Post-wet season inspections of all project locations and rectification of emerging erosion issues.	Internal records of ESCP inspections, as stipulated in ESCPs. Internal reporting on environmental performance. External reporting in accordance with environmental approval conditions.
Changes to groundwater levels caused by groundwater extraction	Groundwater extraction sites will be located away from existing groundwater bores in use. Engagement with landowners at Solar Precinct and along OHTL to identify bores that can be used as a water source without affecting other uses.	Bore locations and sustainable yields to be determined subject to investigation and recommendations from a hydrogeologist. Bore work permits and water extraction licences obtained under the *Water Act*.	Monitoring of standing water levels and water extraction volumes, as required under water extraction licence conditions. Water quality sampling and analysis of springs near Solar Precinct and aquifer targeted for groundwater extraction to ensure there is no connectivity.	Internal records of water usage and water extraction. External reporting of water extraction in accordance with water extraction licence and environmental approval conditions.

Impact	Avoidance	Mitigation	Monitoring	Reporting
Changes to groundwater levels caused by reduced recharge	Solar Precinct and Darwin Converter Site footprints are not located in identified groundwater recharge zones for the underlying productive aquifers. Ground under the solar fields will not be compacted, allowing rainfall to infiltrate soils. Design criteria for engineered stormwater management systems installed at the Solar Precinct and Darwin Converter Site is to discharge water to similar locations and at similar volumes to pre-development conditions.	None required	None required	None required

6.6 Residual impact

As stated at the start of this chapter, the NT EPAs objective for the Hydrological processes factor is to:

'*Protect the hydrological regimes of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are maintained'*.

The residual impact of the AAPowerLink to hydrological process is summarised below, assuming the adoption of the impact avoidance, mitigation and monitoring measures described in this chapter.

Each impact to hydrological processes was assigned a residual impact rating taking into consideration the scale, magnitude and duration of the impacts, the presence/absence of environmental values and/or sensitive receptors and the level of certainty with respect to the intensity of the impact and the effectiveness of the mitigation measures. The residual impact ratings adopted in the assessment were provided earlier in Table 6-6. The combined residual impact to hydrological processes from all components of the AAPowerLink construction and operations is summarised in Table 6-10.

Table 6-10. Residual impact ratings for impacts to Hydrological processes

Impacts	Residual Impact Rating
Construction	
Alteration to surface water flows in water courses or wetlands	Moderate
Changes to ground water levels caused by groundwater extraction	Moderate
Operations	
Alteration to surface water flows in water courses or wetlands	Moderate
Changes to ground water levels caused by groundwater extraction	Minor
Changes to groundwater levels caused by reduced recharge	Minor

The results of the EIA undertaken for the Hydrological processes factor indicate the proposal will have a Minor-Moderate residual impact to surface water flows in water courses or wetlands across the AAPowerLink footprint during construction and operations. The Moderate residual impact rating applies to the Darwin Converter Site where the hydrological regime of the seasonal swamp located immediately south-west of the site could possibly be altered by clearing and development of most of the catchment area, with implications for the ecological functioning of the wetland, which are considered in Chapter 5 Terrestrial Ecosystems and Chapter 8 Aquatic Ecosystems. As there is some uncertainty in relation to changes in discharges that will occur and the subsequent response of the swamp and the potential for cumulative impact, the residual impact has been rated as Moderate, but this could be reduced if the stormwater management system design can demonstrate no significant change to discharge volumes. Across the remainder of the footprint, the residual impact was assessed as Minor; land clearing and development is predicted to alter overland surface water flows but will not impact on flow regimes in any watercourses.

The residual impact associated with reduced groundwater levels in the vicinity of bores used as a water supply was assessed as Minor to Moderate. The extraction volumes are minor except for at the Solar Precinct, where larger volumes of water will be extracted during construction. The aquifer that will be targeted for extraction at the Solar Precinct is a significant regional aquifer which is currently underdeveloped, which indicates it has capacity to supply the water demand. However, there is a possibility that groundwater drawdown at the Solar Precinct could impact on existing station bores. This impact will be minimised by Sun Cable locating bores away from existing pastoral use bores where possible; however, until extraction locations and volumes are further refined as project planning progresses, the precautionary principle has been adopted in assessing impacts and the residual impact rating is Moderate. Sun Cable has committed to undertaking further hydrogeological assessment to inform the site water planning and ensure impacts are reduced to ALARP, and this information will be provided for assessment through the bore permit applications and extraction licences required under the *Water Act*.

The residual impact associated with reduced groundwater recharge was assessed as Minor. Reduced recharge to the regional aquifer at Solar Precinct unlikely to impact groundwater levels. No change in recharge to deep productive aquifer. At the Darwin Converter Site recharge to shallow aquifer may be reduced by hardstand areas, but unlikely to impact shallow aquifer levels. At all other locations there is no residual impact to groundwater recharge.

6.7 Cumulative impacts

The framework used to assess cumulative impacts is described in Chapter 3. The process involves considering the cumulative or combined impacts to terrestrial ecosystems associated with the residual impacts from the AAPowerLink, residual impacts from existing activities, and impacts associated with reasonably foreseeable developments described in Chapter 3. Through the EIA process, the following areas of potential cumulative impacts to hydrological processes were identified:

- Combined land clearing and development at Murrumujuk, Gunn Point, from the AAPowerLink Darwin Converter Site and Sea Dragon Hatchery, will alter surface water flows, discharges, and infiltration to the shallow aquifer across approximately 200 ha of land within the catchment of the coastal swamps and floodplains of the Tree Point Conservation Area and Shoal Bay Coastal Reserve. The sub-catchment area south of Murrumujuk Drive reporting to the Tree Point Conservation Area is ~7 km^2 and the combined construction footprint for the Darwin Converter Site and Sea Dragon Hatchery is ~2 km^2, which is ~30% of the sub-catchment area. Note that this assumes the entire land parcels will be cleared, when in fact a portion of each parcel will be cleared and developed, and so the actual development footprint will be less than 200 ha. At a local level, most of the catchment area that feeds the seasonal swamp that lies between the two sites will be cleared and replaced with impermeable surfaces, and it is possible that this could affect the hydrological regimes of the swamp. More broadly, assuming stormwater drainage systems are designed to replicate pre-development flows off-site, surface water flow regimes into the Tree Point Conservation Area are unlikely to be affected.
- Groundwater extraction to meet construction water demand could contribute to cumulative impacts if extraction occurs from bores that also supply other uses. The locations of bores are yet to be identified; however, Sun Cable has made a commitment to engage with landowners at the Solar Precinct and along the OHTL to identify suitable water sources, and to engage a hydrogeologist to identify bore locations and sustainable yields for production bores at the Solar Precinct and Darwin Converter Site. Any extraction within Water Control Districts will be in accordance with licence conditions. These measures are expected to effectively avoid cumulative impacts to groundwater resources from the combined impacts of the proposal and other uses.
- The Solar Precinct is located ~70 km south of the Beetaloo Sub-basin and is underlain by the regional scale Cambrian Limestone Aquifer (CLA) which forms the principal water resource in the Beetaloo Sub-basin. Cumulative impacts to water associated with hydraulic fracturing are of great concern to the community. Groundwater extraction will be significant during the construction phase at the Solar Precinct (1,000 ML/year for up to 5 years) but will be minor during operations. The AAPowerLink is unlikely to contribute to cumulative impacts to groundwater levels in the CLA as large volumes of water will only be extracted for 5 years, the Solar precinct will extract from the Montijinni Formation, while the gas exploration areas generally overlie the Gum Ridge and Anthony Lagoon/Hooker Creek Formations, and current fracking activities are focussed a significant distance from the Solar Precinct (e.g. Amungee and Glyde located ~200 km north and ~360 km to north-east of the Solar Precinct respectively; see DITT 2021). Fulton and Knapton (2015) estimate that current groundwater extraction and projected demand for gas development in the Beetaloo Basin represents 7% of the available water resource from the CLA in the Georgina Basin. They estimate the sustainable yield of the Georgina Basin component of the CLA to be 100,000 ML/year, of which approximately 6,000 ML/year is currently used. The construction water use for the Solar Precinct (1,000 ML/year) represents 1% of the estimated sustainable yield.
- The Darwin Converter Site overlies a groundwater aquifer which is known to be overallocated, resulting in impacts to the groundwater resource. However, the site is at the northern extent of the

aquifer (down-gradient of the groundwater flow paths) and over 20 km from the major groundwater users within the Darwin Rural area. There are no other groundwater users close to the Darwin Converter Site; bores within 4 km are no longer in use, or are monitoring bores, and the nearest groundwater extraction licence is over 10 km away. Given this, minor volumes of groundwater extraction from a bore at the Darwin Converter Site would be unlikely to contribute to cumulative impacts to other users or supported values such as GDEs.

- Future development of other land uses at Gunn Point would rely on groundwater as a water supply. The northern zone of the Howard groundwater system (located to the east of the Darwin Converter Site) is largely undeveloped and Woltmann (2020) estimated the sustainable yield of the northern zone to be 3,800 ML/year (20 % of median annual recharge). Currently it is estimated that 143 ML/year is used in the northern zone and so over 96% of the estimated sustainable yield in this zone is still available for future use. Based on this, groundwater extraction for the operation of the Darwin Converter Site will not impede future development at Gunn Point, assuming most of the water for future developments is obtained from the northern zone of the Howard groundwater system.
- The renewable energy generated by the AAPowerLink has potential to drive economic development in the NT, by providing a significant source of secure and affordable electricity. The type and scale of development that could occur is difficult to predict, but it is reasonably foreseeable that mining and manufacturing-based industries could be made more feasible by having access to this resource. Where these activities involve extraction of water resources, there is potential for cumulative impacts.

6.8 Offsets

The EIA did not identify any significant residual impacts to hydrological processes that require offsets.

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