

Appendix 12.1 – Land Based Electrode Technical Report

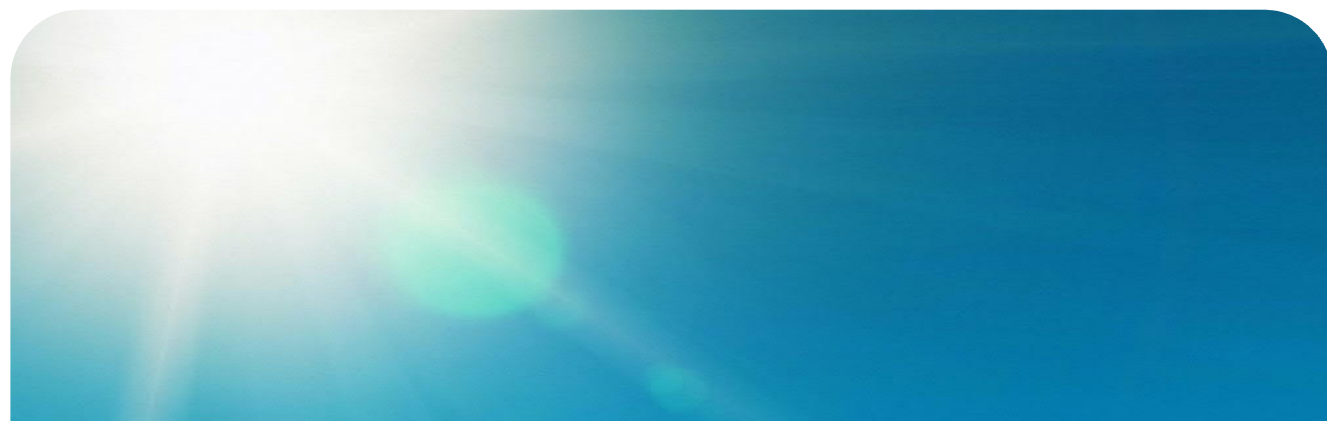


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Land Based Electrode Technical Report

AAP01-000-GEG-GGEN-00002

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Document revision history and tracking

Document Preparation

Rev	Status	Date	Prepared by	Position	Reviewed by	Position
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Revision history tracking record (Use after Rev 00)

Rev	Date	Description	Prepared by	Approved by

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1 Introduction

This technical memo was prepared in support of the SEIS for the Proponent's Australia-Asia PowerLink (the Project). It explains how Electrode Infrastructure operates and sets out the potential environmental impacts associated with operating this infrastructure as part of the Project.

Electrodes have been in use since 1965 in HVDC systems globally and provide a ground return for the power current. In bipolar HVDC configurations, the ground return is generally only utilised during HVDC faults (transiently) or outages. The Project will be installing a bipole HVDC system, which may require the installation of two Electrodes (one near each converter station) within the Australian jurisdiction area. The Nelson River BP1, BP2 and BP3 HVDC Systems are examples of HVDC Systems using earth Electrodes.

This technical memo describes the Electrode configurations associated with HVDC, the process used for site selection, environmental constraints considered during this selection process and the potential environmental impacts associated with Electrode operation.

2 Infrastructure

Most electrical systems, regardless of size, are required to be grounded and it is commonly referred to as a grounding system. A bipole HVDC system, such as the Powell Creek–Murrumujuk HVDC Transmission System, requires a grounded electrical current return path in the event of a fault. The Electrodes for the Project are considered to be 'low duty' or 'no requirements for continuous or long-time operation' Electrodes.

Earth Electrodes are an important part of any grounding system. The Electrode provides a zero-volt reference for an electrical system. The Electrode is used to dissipate current into the ground, which can accept excess current during fault mitigation and remain electrically neutral. The ground, if properly selected and designed, has the capacity to accept electrons from a charged object to neutralise that object.

2.1 Ground Electrode

A Ground Electrode is comprised of a metallic grid or rods (or other conductive material), that is buried in the ground at a prescribed depth and connected externally to the grounding system by ground wire (usually copper wire). The purpose is to connect the HVDC grounding system with the groundmass at a point where the soil offers very low resistivity, thus allowing safe passage of direct current.

2.2 Types of Ground Electrodes

The type of Electrode and material required to construct the Electrodes is dependent on the soil resistivity profile and surrounding infrastructure. The Electrode north-east of the Darwin Converter Site will be in an upper shallow seasonal aquifer, which is unconfined and recharges over the wet season. It is likely that this shallow aquifer experiences saltwater intrusion due to its proximity to the sea and is likely to have increased salinity.

The Electrode proposed to be constructed to the west of the Solar Precinct has a contrasting geological profile and is unlikely to have saline groundwater profile. These factors can influence the efficiency at which the Electrode dissipates current.

The materials used for HVDC Electrodes are a combination of the following and are dependent on the type and design of the electrode, and the resistivity of the surrounding soil:

- Silicon-iron/high silicon iron alloys
- Electrode (SiCrFe) (high resistance to corrosion and but, brittle)
- Steel or mild steel
- Copper
- Titanium
- Coated mesh electrodes or graphite (not commonly used because of low mechanical strength) electrode.

All land electrodes are surrounded by coke¹ to ensure good contact to soil.

Soil resistivity testing will provide the basis for the initial design of the two Electrodes. The design is expected to be completed by quarter one (January to March) 2023.

2.2.1 Shallow Horizontal Electrode

This type of Electrode is generally buried in a shallow trench which is deeper than 1 m. It consists of a coke filled ground bed to surround the element and then is backfilled with soil. This type is installed by excavating a trench and then backfilling with the excavated soil as depicted in Figure 2-1. It requires a larger surface footprint than other types and is generally fenced. Multiple configurations for these types of Electrodes exist. However, for this Project, if a shallow Electrode is selected, the circular or irregularly shaped arrangement is likely to be used. Figure 2-2 shows a general arrangement for a shallow ground Electrode Site.

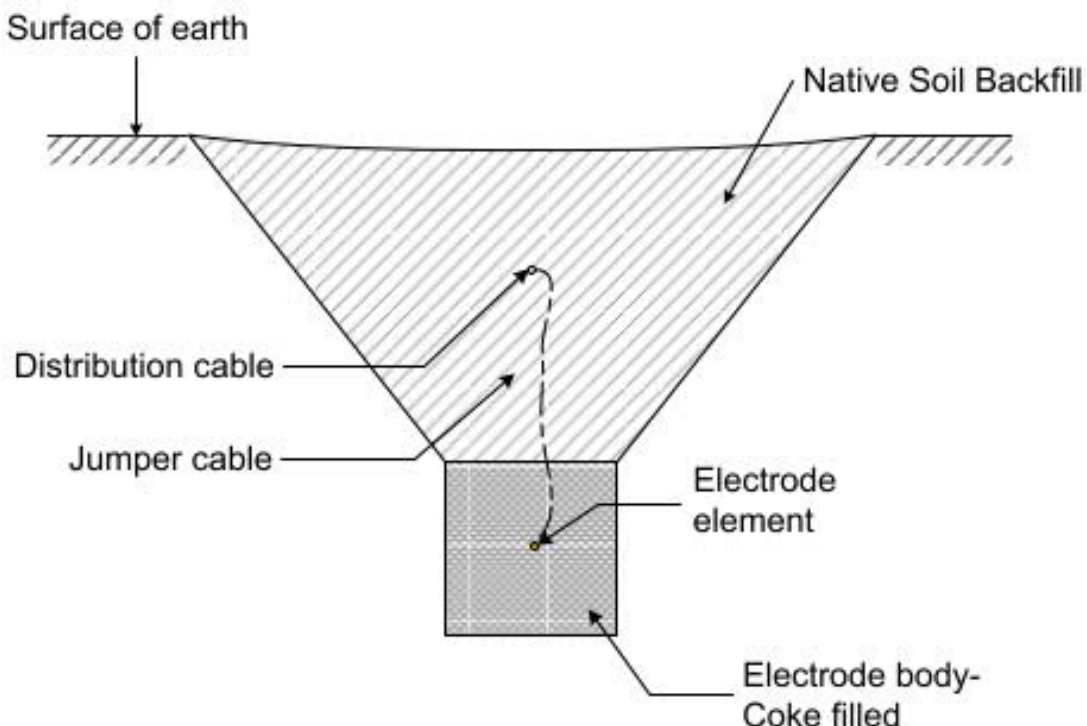


Figure 2-1: Cross section of electrode installation (CIGRE, 2017)

¹ A porous fuel generated by heating certain grades of coal in anaerobic conditions, typically used as a raw material in the production of steel.

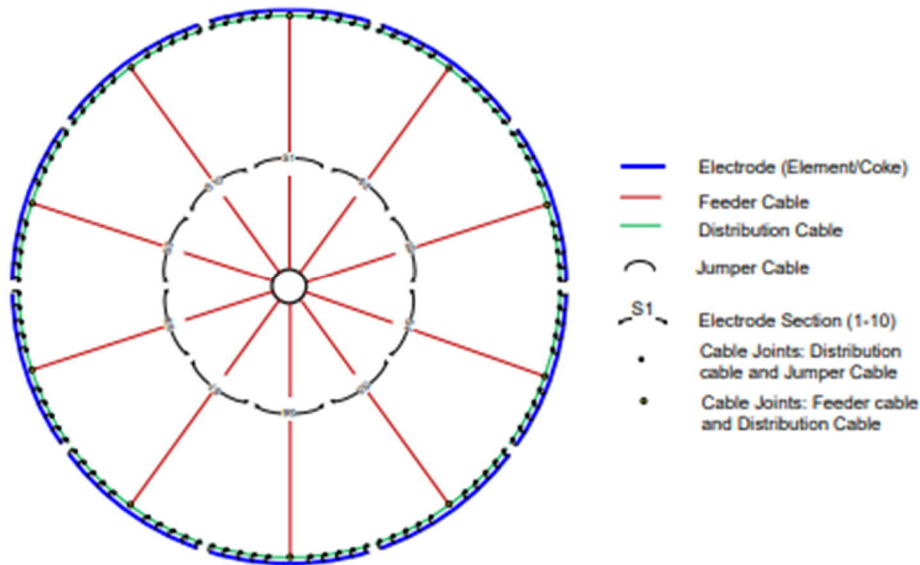


Figure 2-2: Aerial view of the shallow electrode arrangement (CIGRE, 2017)

2.2.2 Vertical Electrodes

This type of Electrode can be buried to depths of up to 200 m deep to reach a layer of low resistivity and higher moisture content than near the surface. It is constructed in wells and backfilled with coke, or a mixture of graphite and bitumen as shown in Figure 2-3. A Vertical Well Electrode could be selected for the Electrode design if, during the detailed resistivity surveys phase, lower resistivity soil is found at deeper depths.

Existing Vertical Well Electrodes in other HVDC systems around the world are most frequently built at depths of 40 m or more. A Vertical Electrode would consist of an array of approximately 80-90 wells equally spaced and arranged in a circle and would require a site similar in size to that identified for a shallow ring electrode. Vertical Electrodes have a smaller surface footprint than a Shallow Electrode.

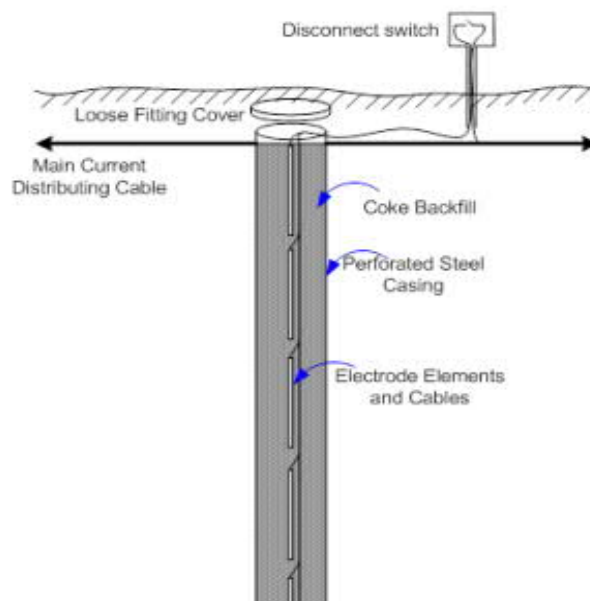


Figure 2-3: Cross section of vertical Electrode (CIGRE, 2017)

2.2.3 Deep Well Electrodes

This type of Electrode is buried at depths of up to 1 km deep to reach a layer of lower resistivity and consists of steel and coke which are used as the electrode bar material. Petroleum coke is used to provide the electrical interface between the metallic elements and the soil as shown in Figure 2-4. Well-cementing concrete and steel tube are used to prevent borehole collapse during installation. After borehole drilling works the electrode bar is installed in a steel tube and backfilled with coke. Typically, three to five deep well electrodes would be connected in parallel arranged either a line or a polygonal.

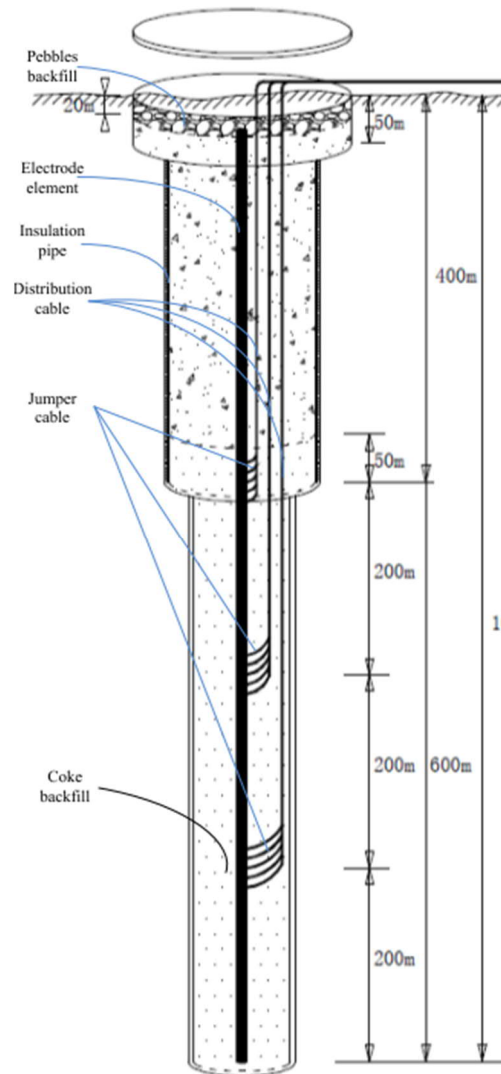


Figure 2-4 Cross section of a Deep Well Electrode (CIGRE, 2017)

2.3 Site Requirements

When selecting a site for the placement of a Ground Electrode, there are a number of factors which were taken into consideration. It is important to select a site which is safe, reliable, feasible, and limits potential for impact to environment. The following factors were considered during this process:

- The distance between the Converter Station and the prospective Electrode Site
- The predominant soil resistivity in the vicinity of the Electrode Site
- Operational duties of Electrodes
- Operation and maintenance philosophy

- Expected cost
- Possible limitations on land use
- Safety at the Electrode Site
- Total number of infrastructure elements that could be adversely affected.

For this Project, a 2 ha area was considered when identifying potential locations for the Electrodes. The selection of the Electrode design will determine the disturbance footprint within this area, as a Horizontal Electrode will have a greater surface footprint than a Deep Electrode will.

The second siting requirement was placement approximately 10 kilometres from the associated Converter Site. This is required in order to ensure no interference on the HVDC system during electrode operation (specifically related the Voltage Source Converter grounding grid).

2.4 HVDC Electrode Line

The Electrode is connected to the Converter Site through a low-voltage distribution line known as a HVDC Electrode Line. The function of the low voltage electrode line is to provide a low resistance connection between the Converter Site and the ground electrode site.

This will be designed in accordance with AS7000: 2016 Overhead Line Design and is comparable in scale, height and appearance to conventional overhead distribution lines and poles. The height of these poles is approximately 12 m.

The HVDC Electrode Line connecting the Darwin Converter Site to the Electrode will cross the road at Gunn Point and continue along distribution poles. Design will consider the best pathway and will consider the potential to make use of an easement adjacent to the existing access road. Following this alignment provides access to assist with the construction effort and simultaneously reduce the environmental impacts by limiting vegetation clearing associated with the construction effort. The areas of interest identified for the Electrode locations are approximately 10 km away from each of the Powell Creek Solar Precinct and the Darwin Converter Site Voltage Source Converters.

2.5 Operations

The Electrodes installed as a part of this system are intended to be utilised in fault or outage situations and are not operated continuously. Industry wide, Electrodes are noted to be in operation for 40 hours in a year to less than 500 hours a year. A survey of Electrode operators indicated that the earth return operating time for a bipolar system was less than 3% and almost entirely related to controlled maintenance periods (HVDC Ground Electrode Overview, 2010.)

The longest utilisation of a Ground Electrode would be during an extended partial OHTL repair. This time required will depend on the type and location of the repair but is unlikely to cause the utilisation to exceed the estimated range of operation. If there is a failure of the HV overhead line (which is a very rare event), one cannot bypass the Electrode and outage and subsequent operation of the Electrode will be as long as is required in order to repair the line. If the failure is in the Converter Station, the Electrode can be bypassed as soon as local operations and maintenance staff determine it is safe to do so (approximately two to six hours).

In a planned outage, which is used to complete routine maintenance once a year, the Electrode is likely to be used for one to two hours to transition the system. The system will be designed to have high reliability with approximately 98.5% system availability at the Converter Station required to meet this reliability target.

Given the design reliability target, the incidence of unplanned outages (and the resulting Electrode utilisation) should be low. The system designers indicate that if the system is affected by a fault, the Electrode may be in use for up to 48 hours or the time needed to repair the fault.

However, general operating practice dictates that after six hours, the system is typically reconfigured from electrode-return to using the other pole as a metallic return if the fault was not on the OHTL.

3 Site Selection

To confirm the preferred locations of the Electrodes and the associated HVDC Electrode Line connecting them to the respective Voltage Source Converters, the following steps were undertaken in accordance with industry best practice (CIGRE, 2017):

- Environmental and social constraints mapping exercise to refine disturbance area (completed).
- Initial desktop and field investigations including the following which are underway:
 - Flora and fauna surveys
 - Heritage surveys
 - Geological reconnaissance mapping
- Soil Resistivity testing.

3.1 Constraints Mapping

Several locations were identified as being suitable for the Electrode sites. To refine these areas, a review of the sites against constraints identified in earlier field studies and previous desktop studies was undertaken. This included a review of the proposed locations against the following aspects:

- Sacred site and cultural heritage area information
- Environmental values and constraints
- Geological and hydrogeological data
- Hydrology, inundation and flooding
- Geoscientific data
- Land tenure, land uses and zoning
- Other notable features.

3.2 Constraints Mapping Conclusions

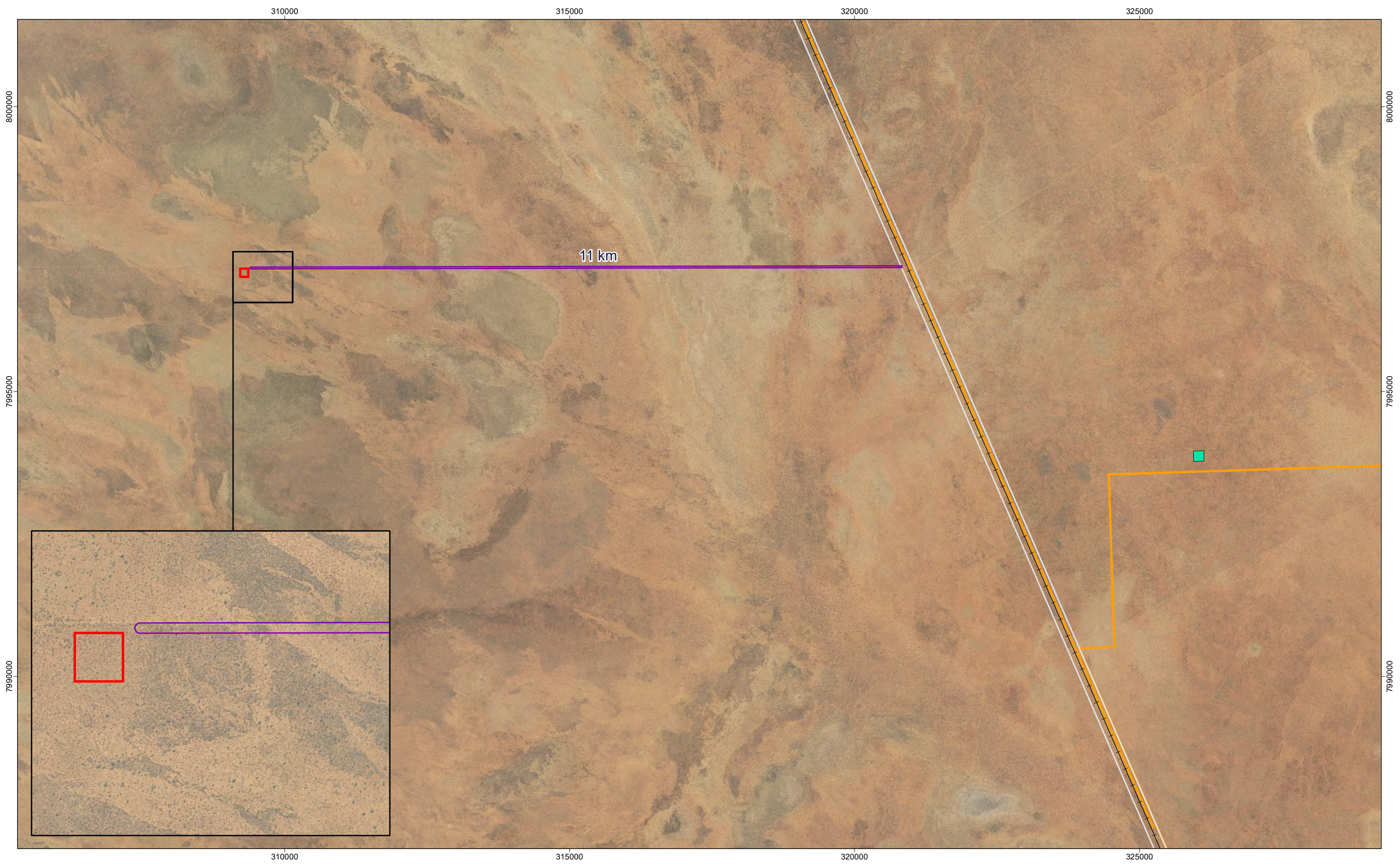
A constraints mapping workshop was undertaken, which was based on a desktop review of the available information and mapping layers.

Table 3-1 sets out the conclusions drawn from this workshop.

Table 3-1: Constraints Mapping Conclusions

Values	Electrode	
	Murrumujuk Electrode	Solar Precinct Electrode
Land Access	Located within Crown land, no known constraints for access to site. Other land users to consider.	Located within the Powell Creek Station tenure parcel of land. Required to cross the rail line.
Heritage	Based on desktop mapping, no known heritage sites within the two hectare footprint and overhead connection. Ground truthing of area required to confirm prior to construction.	Based on desktop mapping, no known heritage sites within the two hectare area. Ground truthing of area required to confirm prior to construction.
Ecological values	Based on desktop mapping, no mapped areas of significant flora and fauna habitats within the two hectare area. Desktop review of the area is required. Ground truthing of area may be required.	Based on desktop mapping, No mapped areas of significant flora and fauna habitats within the two hectare area. Desktop review of the area is required. Ground truthing of area required to confirm.
Water courses	Over five km to Leader Creek. Approximately 10 km to the mouth of Adelaide River.	Over 25 km to Tomkinson Creek.
PASS	CSIRO acid sulphate soils mapping layers indicates the area on which the potential electrode site is located has a high risk of acid sulphate soils in watercourses. Sampling would be required to confirm this.	CSIRO acid sulphate soils mapping layers indicates acid sulphate soils were identified as a low risk at the solar precinct. Sampling would be required to confirm this.
Geology	Gunn Point peninsula is predominately dolomite and has a number of sink holes. The potential Electrode Site is not near any known sinkholes. Engineers indicate that the presence of sink holes will not impact Electrode.	No sink holes in the site location. Black clays in the area may affect the access road to the Electrode.
Groundwater	Groundwater is expected to be saline. Consideration of Electrode materials to ensure fit for use in saline environments.	No impacts on groundwater quality are expected.

The location of the HVDC Electrode Lines linking the Electrode to the main OHTL was identified based on the above constraints mapping and, where possible, follows the roads as areas of existing disturbance to minimise the impact of additional clearance. At the Solar Precinct, the HVDC Electrode Line will require clearing of the disturbance footprint and the installation of an access road along that corridor. This will be approximately 20 m to 30 m wide and 10 km in length.



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




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Legend

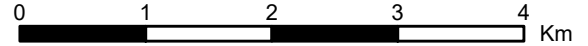
-  OHTL Corridor
-  Railway Line
-  HVDC Electrode Line Corridor
-  Solar Precinct Electrode
-  Ancillary Infrastructure
-  Solar Precinct



Powell Creek Solar Precinct Electrode

Project: **Australia-Asia PowerLink** Reference #: AAPL_GNR_CTA_GEN_MAP_0370 Figure: 1 of 1 Revision: A

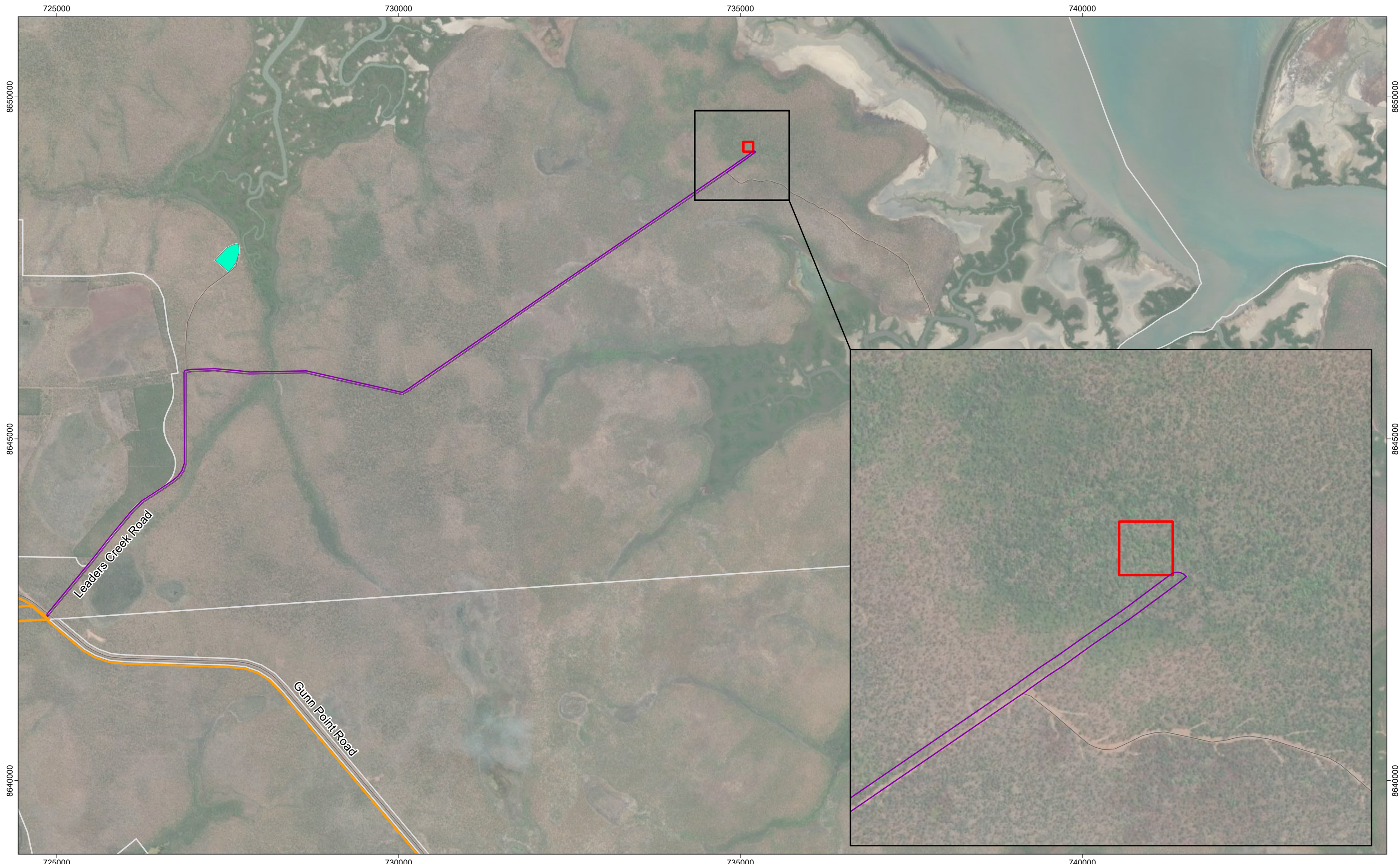
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Legend

Road	Cadastre
HVDC Electrode Line Corridor	Darwin Converter Site Electrode
AAPowerLink Infrastructure	Leaders Creek Fishing Base



Darwin Converter Site Electrode

Project: Australia-Asia PowerLink		Reference #: AAPL_GNR_CTA_GEN_MAP_0371	Figure: 1 of 1	Revision: A
Coordinate System: MGA Zone 52		Datum: GDA2020	Date: 06/11/2022	
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4 Environmental Impacts

At this time, a high-level review of the potential environmental impacts was completed. Table 4-1 sets out the environmental impacts typically associated with land-based Electrodes and their potential relationship to the Project. Detailed review and impact assessment of the Electrodes and associated locations will be completed as a part of the SEIS.

The construction methodologies required for installing the Electrodes are comparable to the activities required to install the OHTL and were not examined separately in this document.

Table 4-1: Potential Environmental Impacts

Receptor	Potential Impact	Factors affecting severity of impact	Mitigation Measures	Residual impact of proposed electrodes
Third Party Infrastructure	Ground rise potentials causing electrical interferences in telecommunication s circuits, telephone, railway signalling systems.	Electric Potential and ripple magnitude affecting grounding systems. Number of hours of operation of Electrode.	Distance from infrastructure used to identify initial constraints mapping. Where distance cannot be achieved the following will be used: <ul style="list-style-type: none"> Use cathodic protection/plastic shielding for telecommunications equipment. 	There are no known utilities or significant fixed infrastructure within a 10 km buffer of the proposed Electrode locations at either Powell Creek or Murrumujuk. There are small structures such as boat ramps, diesel generators and fishing camps within this 10 km buffer. Due to the intermittent nature of operations (< 500 hours per year expected and < five hours in a single operation event) there is minimal impact expected as a result of Electrode operation.
Third Party Infrastructure	Current through metallic infrastructure causing corrosion (e.g. pipelines, cables, fences, railway tracks, bridges, buried tanks, electrical infrastructure).	Current Density through metallic infrastructure. Number of hours of operation of electrode.	<ul style="list-style-type: none"> Insulating joints for piping Sectionalise fences Create electrical isolation gaps in railway tracks Passive or active cathodic protection systems. Limited electrode operation 	Future infrastructure developments in the area can easily be adapted to prevent potential impacts using cathodic protection and sectionalising infrastructure (creating electrical isolation gaps) as the degree of interference is proportional to the length of infrastructure (Guofei et al., 2019).
Safety of public and fauna	Ground rise potentials may cause dangerous touch potential due to long potential transference.	Electric potentials between two points.	<ul style="list-style-type: none"> Sectionalise fences Restrict size or sectionalising large radial irrigation systems. 	The Electrodes will be designed to ensure there is no risk to public or fauna safety from touching ground or conductive surfaces (such as fences) outside a securely fenced compound.
Safety of public and fauna	Potential for the Electrode to generate current at surface presenting	Electrical potential and/or	<ul style="list-style-type: none"> Adjust the physical size of the Electrode or the burial depth to achieve acceptable 	The Electrodes will be designed to ensure there is no risk to public or fauna safety from touching ground or

Receptor	Potential Impact	Factors affecting severity of impact	Mitigation Measures	Residual impact of proposed electrodes
	a danger to humans or animals on this area.	electric field in soil.	<p>levels of 'step and touch potentials' based on soil resistivity data</p> <ul style="list-style-type: none"> Design to ensure a low current density (by increasing the size / surface area of Electrode). 	conductive surfaces (such as fences) outside a securely fenced compound.
Flora and Soil Biota	<p>Potential for heating of soil by the Electrode and impact of electro-osmosis causing drying of the soil.</p> <p>Soil drying and heating also impacts the effectiveness of the Electrode.</p>	<p>Electrical current density.</p> <p>Maximum operation time of the Electrode.</p> <p>Temperature and pressure parameters.</p>	<ul style="list-style-type: none"> Burial of Electrode beneath groundwater table (hydraulic inflow) will balance electro-osmotic flow of water. Irrigation of the soil to prevent drying out and heating. Management of the Electrode may involve wetting of the soil profile to reduce the risk of electrode failure which in turn will prevent environmental impacts because of soil drying. Limit the electrical current density on Electrode surface according to local condition (a commonly adopted limit is 1 Ampere per m2). Burial of the Electrode in a coke bed to ensure current transfer by conduction through the coke to the soil leading to low current densities in the ground. 	Soil drying and heating impacts require a period of time to develop and is unlikely to result due to the intermittent and short-term use of the Electrode proposed for AAPowerLink's operation. No information is available on the timeframe required for this impact to occur.
EMF – Public	Exposure to EMF from Electrode station equipment.	N/A	<ul style="list-style-type: none"> ICNIRP guidelines for limiting exposure to time-varying EMF are ICNIRPLFgdl.pdf. ARPANSA references ICNIRP guidelines. 	There is no scientific evidence which indicates that this impact would occur with the proposed arrangement in place.

5 Future work

Selection of the sites for Electrode installation has been completed however development of the design of the Electrodes is ongoing. This design will be reliant on the resistivity of the soil and its ability to dissipate electrical current quickly and efficiently. The following studies will be completed over the next six months and will provide additional information for consideration when placing the preferred Electrode design within the area of interest. These are:

- Field survey if required (to be completed)
 - Targeted ecology field surveys
 - Heritage field survey.
- Detailed field investigations (to be completed)
 - Boreholes to conduct deeper resistivity measurements and validate the resistivity model developed
 - Geological logging of bores, groundwater information (including pump testing), soil sampling and thermal response tests.

6 References

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