CopperString 2.0

Geology and soils

Volume 2 Chapter 6

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6. Geology and soils

6.1 Introduction

6.1.1 Project overview

The Project involves the construction and operation of approximately 1,060 km of extra high voltage overhead electricity transmission line that would extend from Mount Isa to the Powerlink transmission network, via a new connection point near Woodstock, south of Townsville.

The Project involves construction of seven new substations at Woodstock, Hughenden, Dajarra Road (Cloncurry), Mount Isa, Selwyn, Cannington Mine and Phosphate Hill Mine.

The CopperString transmission network is divided into the following eight sections as shown in Figure 6-1.

1. Woodstock Substation
2. Renewable Energy Hub
3. CopperString Core
4. Mount Isa Augmentation
5. Southern Connection
6. Cannington Connection
7. Phosphate Hill Connection
8. Kennedy Connection (option).

6.1.2 Objectives

This chapter of the EIS aims to ensure that the construction and operation of the Project:

- Minimises impacts on the environment and improves environmental outcomes
- Protects the environmental values of land including soils, subsoils, landforms and associated rural activities and ecological habitats.

6.1.3 Purpose of chapter

This chapter assesses the potential impacts of the Project on topography, geology and soils in the study area and surrounding environment. The assessment is required to address the Terms of References as detailed in Volume 3 Appendix A Terms of reference with cross-reference table.

The scope of this report is defined by the following:

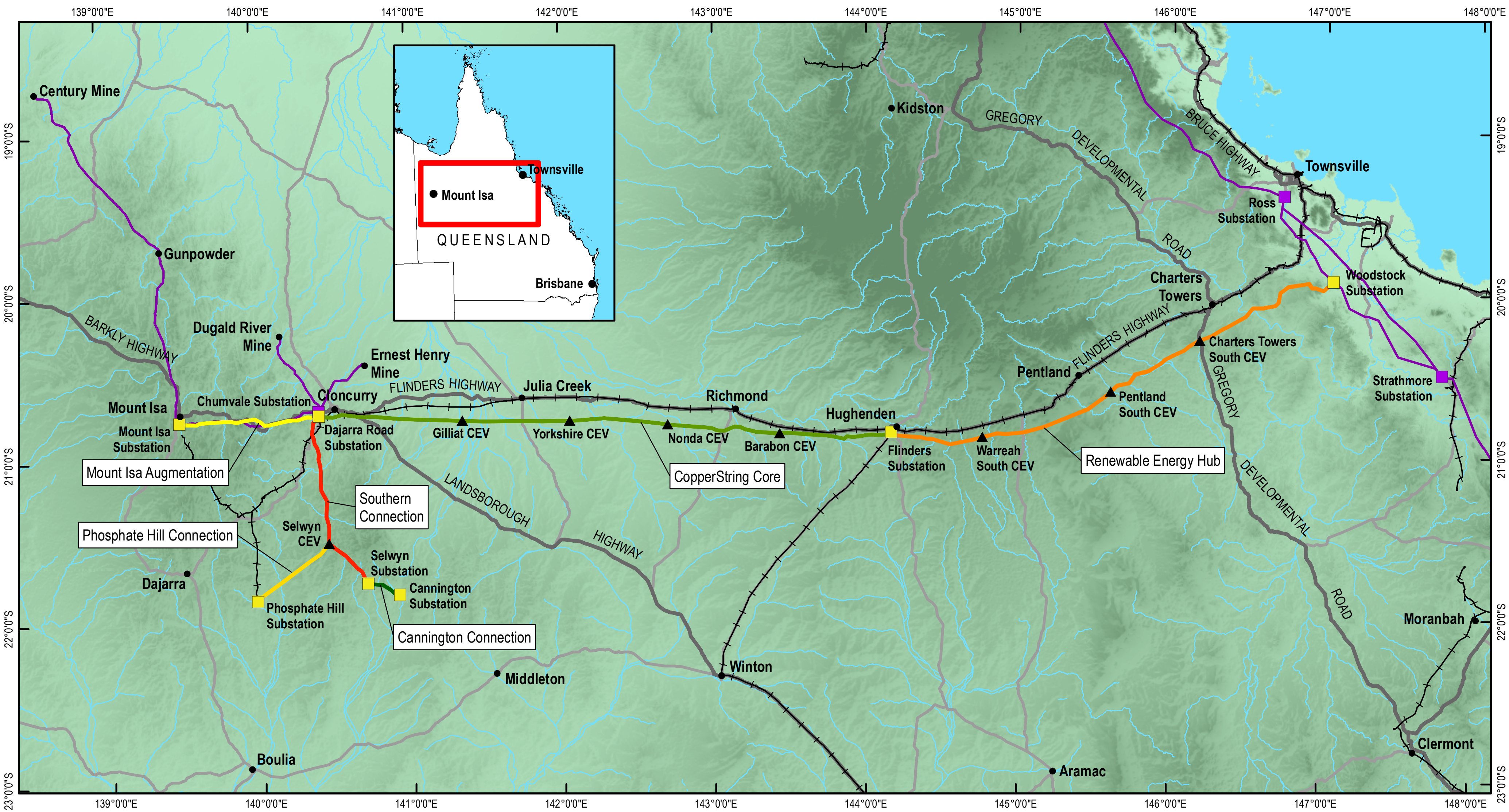
- Assessment of impacts to topography, geology and soils where significant earthworks are proposed.
- Discussion of the Project's impacts on important agricultural areas.
- Identification of potential areas of salinity, sodic, dispersive and cracking clay soils and actual areas of acid sulfate soils.
- Identification of potentially contaminated land.
- Identification of activities likely to impact on existing erosion control works and any soil conservation plans.

- Propose measures to avoid or mitigate Project impacts to soil values, existing conservation works and erosion control works.

6.1.4 Defined terms

The following key terms are used throughout this chapter:

- 'The Project' – means the CopperString 2.0 EIS Project
- 'CuString' – means CuString Pty Ltd, the proponent
- 'Corridor selection' – means the baseline investigation corridor of the transmission line (a nominal 1,060 km long corridor). The corridor selection is 120 m wide from Woodstock to Dajarra Road, and 60 m wide from Dajarra Road to Mount Isa, Dajarra Road to Selwyn, and Selwyn to Phosphate Hill and Cannington. The 4 km long section of the corridor selection from Dajarra Road Substation to Chumvale Substation is 60 m wide and a 3 km long section from Dajarra Road Substation to the Dugald River 220 kV overhead line is 80 m wide.
- 'Study area' – means the study area defined specifically for this chapter of the EIS, included in Section 6.2.2.



Legend

- ● Town/City
- ▲ CEV Hut Site
- Proposed Substation
- Existing Substation
- Existing Transmission Line (>= 220kV)
- Railway
- Highway
- Secondary Road
- Major Watercourse

0 20 40 60 80 100
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
Original page size: A4 landscape

Disclaimer

WKSP Project_Overview_RevD

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Figure 6-1 - Project overview

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6.2 Methodology

6.2.1 Overview of methodology

Coffey Geotechnics Pty Ltd conducted a topography, geomorphology, geology, and soils assessment for the EIS undertaken for the CopperString 1.0 Project in 2010. The technical report from that assessment formed the basis of the Topography, Geology and Soils chapter of the 2010 EIS.

A review of the Coffey Geotechnics (2010) report and the 2010 EIS chapter (RLMS, 2010) has been undertaken and used to inform the existing environment, impact assessment, and mitigation measures of this chapter.

A current desktop study has been undertaken, involving collation and assessment of available mapping, studies and data from the following sources:

- Queensland Globe – biogeographic regions spatial layer
- Queensland Globe –detailed surface geology spatial layer
- Queensland Globe – agricultural land audit spatial layer
- Australian Soil Resource Information System (ASRIS)
- Queensland Agricultural Land Audit (2017)
- Ipswich Soil Management Guidelines (2014).

6.2.2 Study area

For the purpose of the geology and soils assessment, the study area for the Project is 50 km either side of the proposed corridor selection. This wider geology and soils study area has been selected because broader context is important for understanding the impacts and mitigation associated with project infrastructure both within and outside the corridor selection.

6.2.3 Legislative contexts and standards

This assessment has considered the following key statutory regulations related to land management:

- Queensland *Soil Conservation Act 1986*
- Queensland *Environmental Protection Act 1994*
- Queensland *Vegetation Management Act 1999*
- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
- State Planning Policy 2017 (SPP).

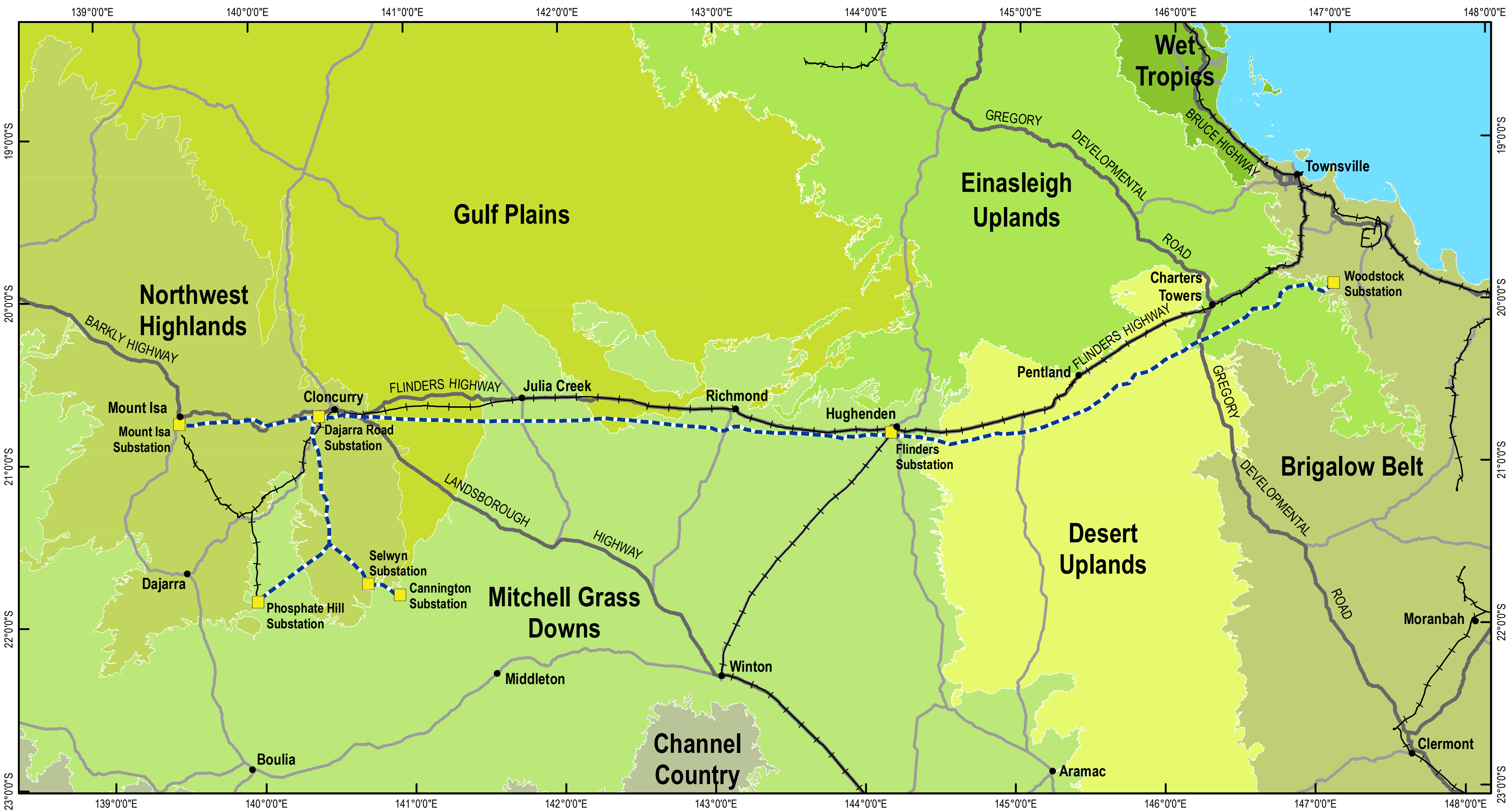
6.3 Existing environment

6.3.1 Bioregions

The corridor selection traverses six different bioregions, that are characterised by broad, landscape-scale natural features and environmental processes that influence the functions of ecosystems. Bioregions capture large-scale geophysical patterns across the land. For this assessment, aspects of geology, topography and soils are discussed using bioregions as regional areas that are within the study area.

These bioregions are shown in Figure 6-2, and summarised in Table 6-1, in terms of topography, geomorphology, geology and soils. These characteristics are described in further detail in the subsequent sections.

The eastern extent of the Renewable Energy Hub crosses into the northern Brigalow Belt bioregion however, the characteristics of this zone along the corridor selection are broadly similar to the Einasleigh Uplands area. For the purposes of this study, therefore, the Brigalow Belt section has been included within the Einasleigh Uplands.



Legend

- Town/City
- Proposed Substation
- CopperString Alignment
- Railway
- Highway
- Secondary Road

Biogeographic Region

- Brigalow Belt
- Channel Country
- Desert Uplands
- Einasleigh Uplands
- Gulf Plains
- Mitchell Grass Downs
- Northwest Highlands
- Wet Tropics

0 20 40 60 80 100
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
Original page size: A4 landscape

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Figure 6-2 - Biogeographic regions

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Table 6-1 Summary of environmental characteristics

Landscape characteristics	Physiographic area				
	Einasleigh Uplands*	Desert Uplands	Mitchell Grass Downs	Gulf Plains	Northwest Highlands
Surface geology	Palaeozoic granite with some intermediate to mafic intrusions and volcanic rocks. 'Country rock' may be dominated by quartzose sandstone	Sedimentary sequences of the Cretaceous age Rolling Downs Group			Proterozoic and Palaeozoic metamorphic rocks intruded by mafic to felsic igneous rocks. Some younger sedimentary rocks.
Relief	Relief is strongly linked to the structural geology and ancient nature of the landscape. Key are zones of intense folding, faulting, uplift and igneous intrusion, associated with periods of mountain building. In the west, the Northwest Highlands comprise relatively low height, resistant ridges that are remnant of denuded ancient mountains. Towards the east, the Einasleigh Uplands are part of the Great Dividing Range mountains, dominated by granite intrusions that extend into sequences of volcanic and metamorphosed sedimentary rocks. The vast tract of the Gulf Plains, Mitchell Grass Downs and Desert Uplands, that make up the majority of the Renewable Energy Hub and CopperString Core sections of the Project, comprises gently up-warped sedimentary rocks that formed within a vast marine basin.				
Landform	Steeply undulating "granite country", with tors and steep hills rising above an undulating plain	Characterised by upland landforms, dominated by sandstone ranges and sand plains	Consists of largely treeless plains with some occasional ridges, rivers and gorges.	Flat to gently undulating plain crossed by networks of anastomosing channels	Ridges, pyramidal hills and tors rising above an undulating plain
Dominant vegetation	Eucalypt woodlands	Eucalypt woodlands, acacia woodlands, and spinifex understorey	Mitchell grass tussocks	Eucalypt and tee-tree open woodland	Low open woodlands with spinifex hummock grass groundcover

Landscape characteristics	Physiographic area				
	Einasleigh Uplands*	Desert Uplands	Mitchell Grass Downs	Gulf Plains	Northwest Highlands
Soils	Generally shallow, sodic texture contrast soils in valley bottoms, patches of sandy soil where granites have weathered in situ and rudosols on ridge and hilltops	Moderate to deep grey cracking clays.			Generally rudosols on ridges and sloped with shallow dermosols or ferrosols in valley bottoms. Broad expanses of deep gilgai cracking clays.
Land-use	Predominantly grazing, with some mining, cropping and horticulture	Predominantly grazing			Limited grazing, mining
Erosion	Gullying and rilling of clearing and disturbed areas, particularly in areas of sodic/dispersive soils.				

* Einasleigh Uplands includes Brigalow Belt.

6.3.2 Geology

Surface geology

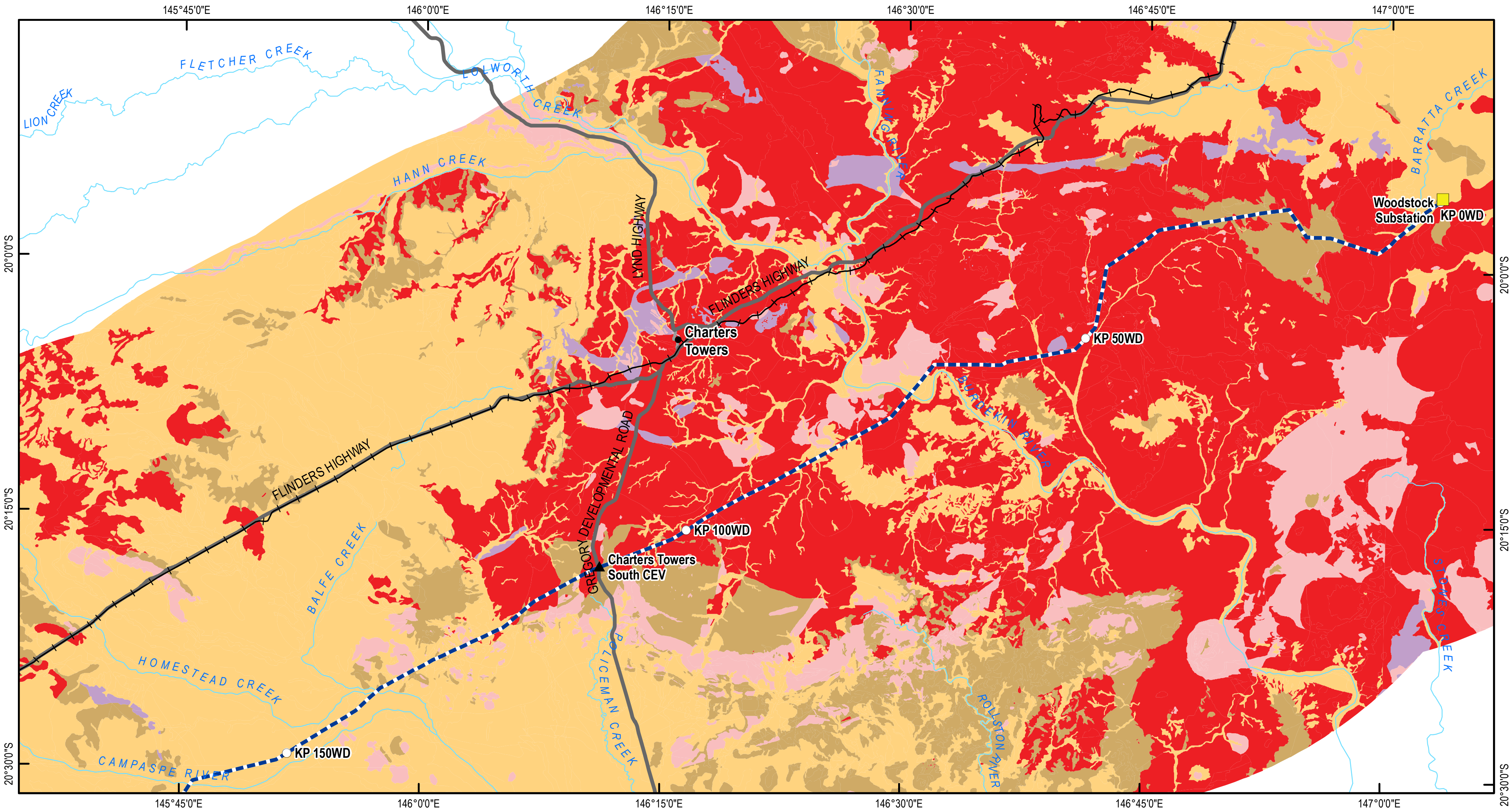
Geology across the study area is highly complex. Table 6-2 summarise the surface geology of the study area. The simplified geology of the study area is shown in Figure 6-3. Geological cross-sections that are representative of the landscape are shown in Figure 6-4. Whilst not all the cross sections intersect the proposed corridor selection, they provide an indication of the geological distribution throughout the study area.

Table 6-2 Surface geology of bioregions

Bioregion	Description of surface geology
Einasleigh Uplands (and Brigalow Belt)	
 *Einasleigh Uplands*  *Brigalow Belt*	Resistant basement rocks, comprising of granite and a mix of volcanic rocks including tuff and 'welded' air-fall pyroclastic types as well as lavas, dominate the Einasleigh Uplands region. To the south east of Charters Towers alluvial and colluvial plains associated with large river systems prevail.

Bioregion	Description of surface geology
Desert Uplands	
	The majority of this bioregion passes over the broad colluvial and alluvial plains associated with the Cape and Campaspe Rivers. Here, the underlying Tertiary age Campaspe Formation comprises muddy sandstone. This area has been subject to intense tropical weathering. Geological maps indicate that the higher topography in this region is made up of a highly varied range of rocks.
Mitchell Grass Downs	
	The Mitchell Grass Downs bioregion is a flat landscape that comprises river-borne and wind-blown (alluvial and aeolian) soils that overlie almost horizontal sequences of relatively young sandstone, muddy sandstone and limestone rock types. These sedimentary sequences are gently up-warped rocks that formed within a vast marine basin. The strata are locally incised by rivers, exposing tropical weathering characteristics. This region represents a relatively stable zone of sedimentary accumulation and basin formation.

Bioregion	Description of surface geology
Gulf Plains	
	The Gulf Plains bioregion has similar geology to the Mitchell Grass Downs bioregion, with a flat landscape overlying sequences of sedimentary rock types. Typically, there is a thickening of the overlying sedimentary deposits to the west (between Julia Creek and Cloncurry). The corridor selection traverses areas of volcanic and metamorphic stratified rock units associated with Toolebuc Formation.
Northwest Highlands	
	The Northwest Highlands area is known for its complex geology. It comprises an area of relatively low, steep-sided ridges and hills comprising resistant igneous rock types interspersed within metamorphosed (predominantly sandstone and mudstone) sediments. Flat land between the ridges may comprise ancient colluvium, intermixed clay, sand gravel and cobbles, partially reworked by river action.



Legend

- ● Town/City
- ▲ CEV Hut Site
- Proposed Substation
- Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Major Watercourse

Simplified Geology

- Superficial Deposits
- Sedimentary Rocks
- Igneous and Volcanic Rocks
- Granitic Rocks
- Metamorphic Rocks

0 5 10 15 20

Kilometres

Coordinate System

MGA1994 Zone 54\55

Notes/Data Sources

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CopperString 2.0 EIS

Figure 6-3A - Geology

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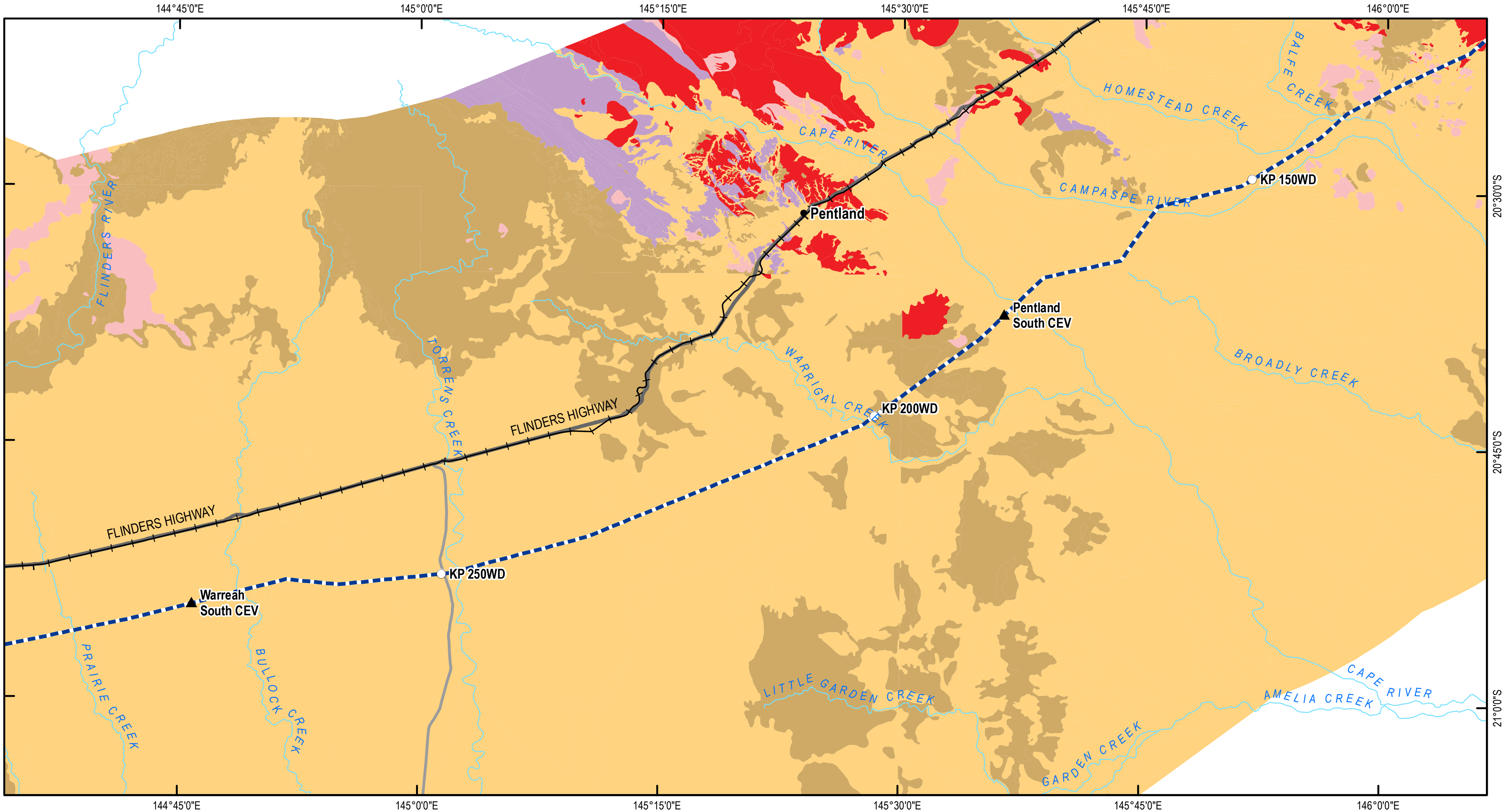

Legend

- ● Town/City
- ▲ CEV Hut Site
- ○ Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Major Watercourse

Simplified Geology

- Superficial Deposits
- Sedimentary Rocks
- Igneous and Volcanic Rocks
- Granitic Rocks
- Metamorphic Rocks

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
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Figure 6-3B - Geology

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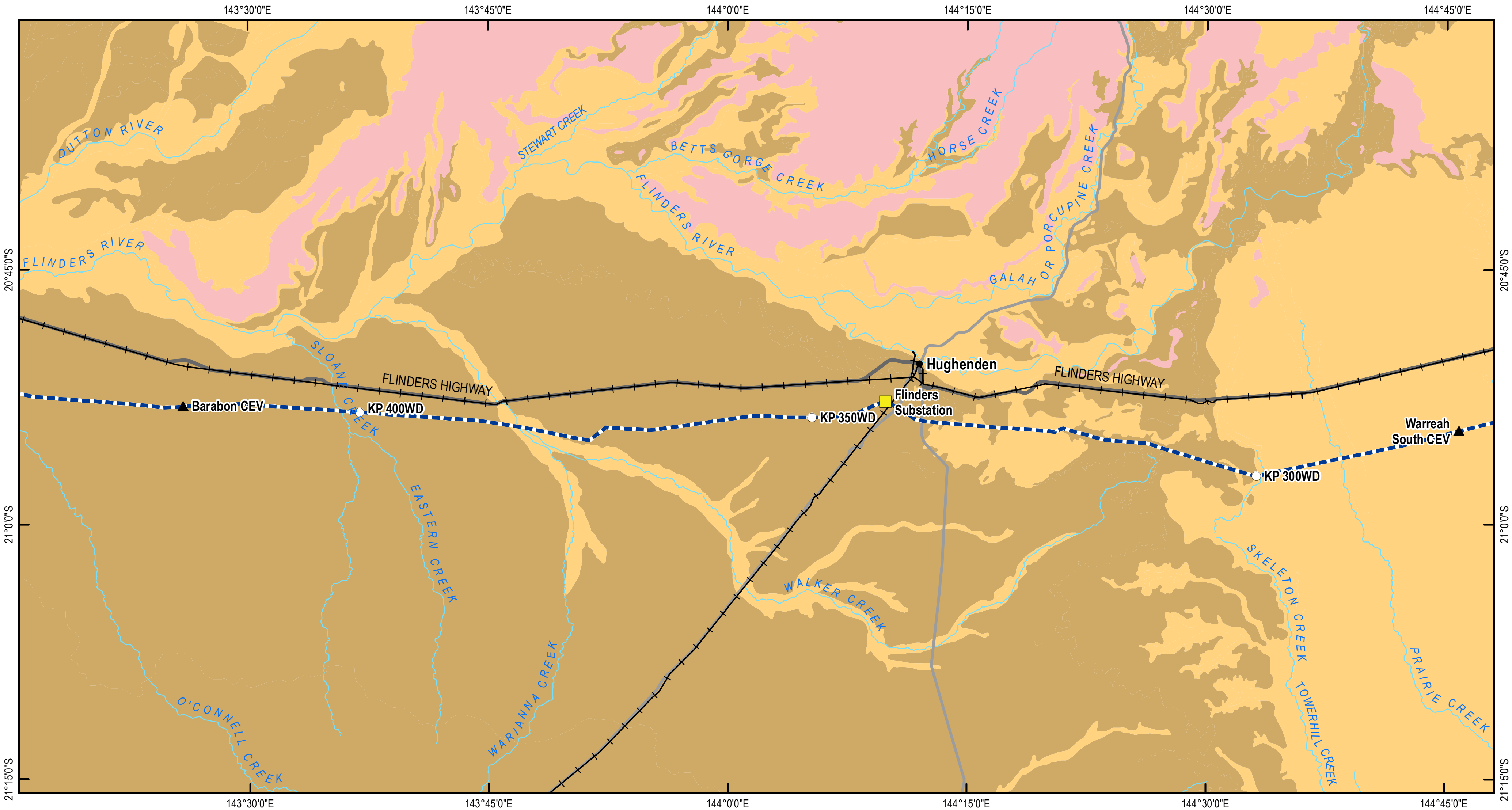
CopperString 2.0 EIS

Figure 6-3C - Geology



Legend

- Town/City
- CEV Hut Site
- Proposed Substation
- Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Major Watercourse

Simplified Geology

- Superficial Deposits
- Sedimentary Rocks
- Igneous and Volcanic Rocks

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

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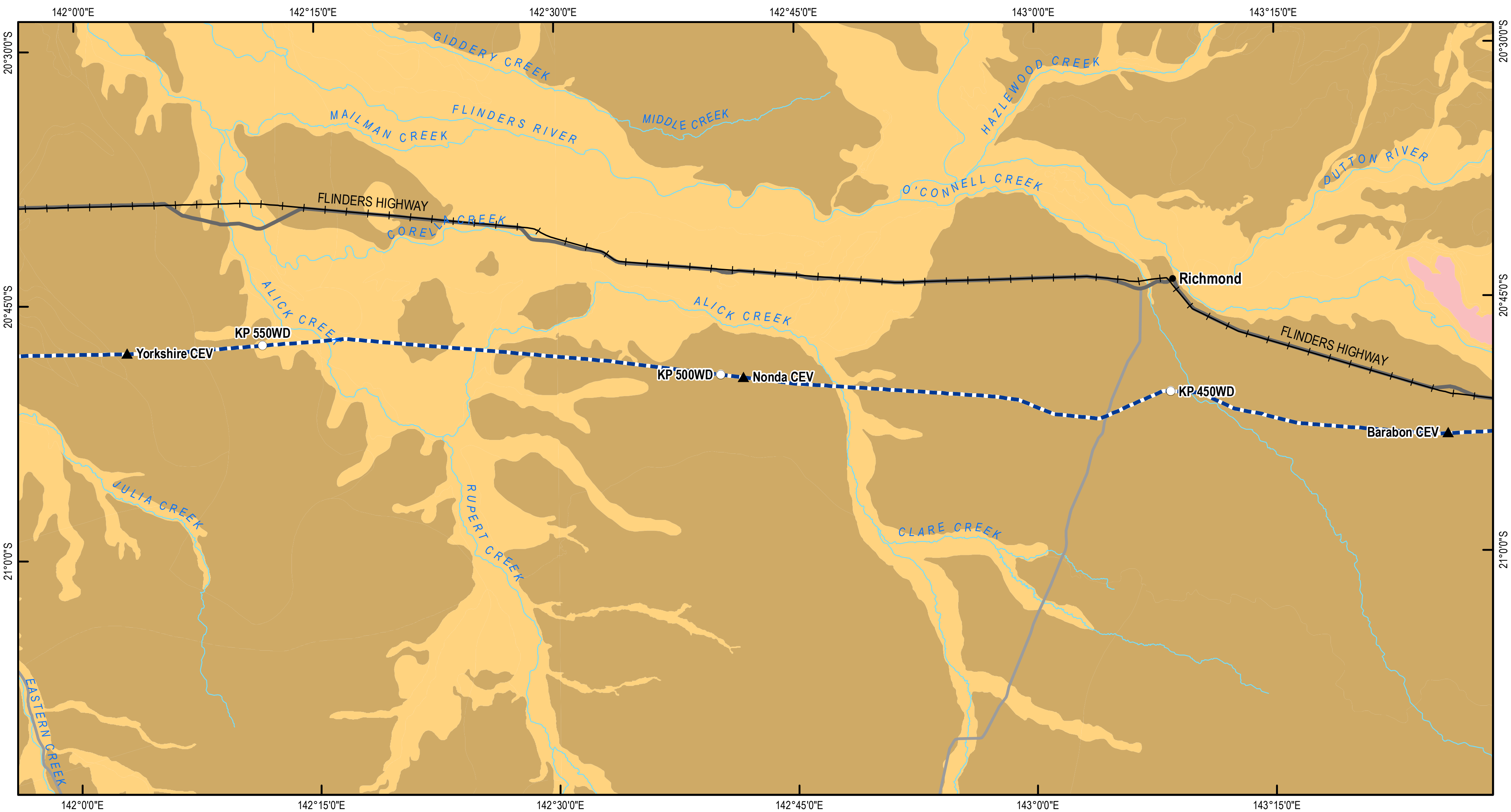

Legend

Town/City	Railway	**Simplified Geology**
CEV Hut Site	Highway	Superficial Deposits
Kilometre Post	Secondary Road	Sedimentary Rocks
CopperString Alignment	Major Watercourse	Igneous and Volcanic Rocks

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

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CopperString 2.0 EIS

Figure 6-3D - Geology

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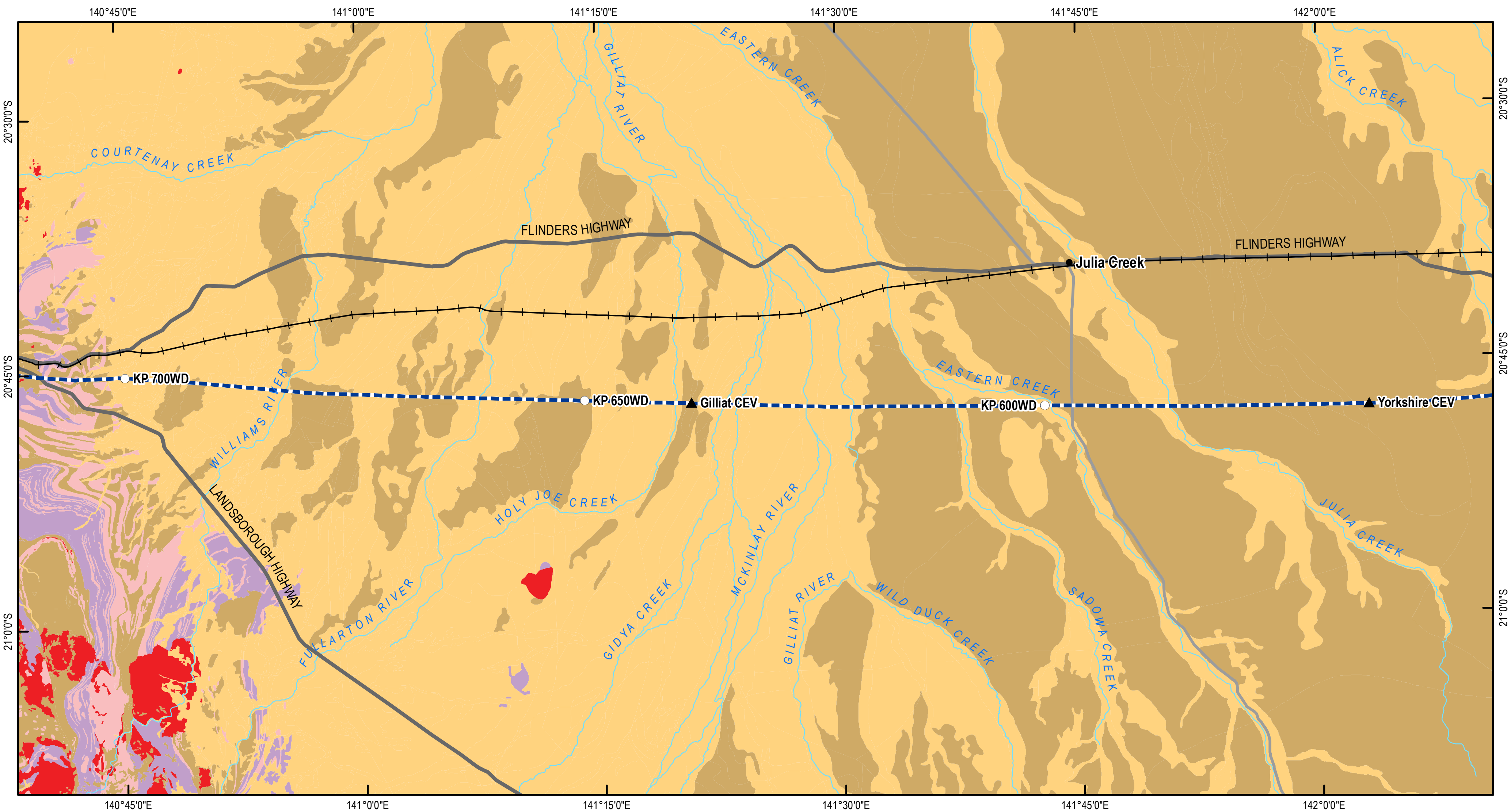

Legend

- ● Town/City
- ▲ CEV Hut Site
- ○ Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Major Watercourse

Simplified Geology

- Superficial Deposits
- Sedimentary Rocks
- Igneous and Volcanic Rocks
- Granitic Rocks
- Metamorphic Rocks

0 5 10 15 20

Kilometres

Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources

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WKSP Geology_RevB

CopperString 2.0 EIS

Figure 6-3E - Geology

COPPERSTRING 2.0

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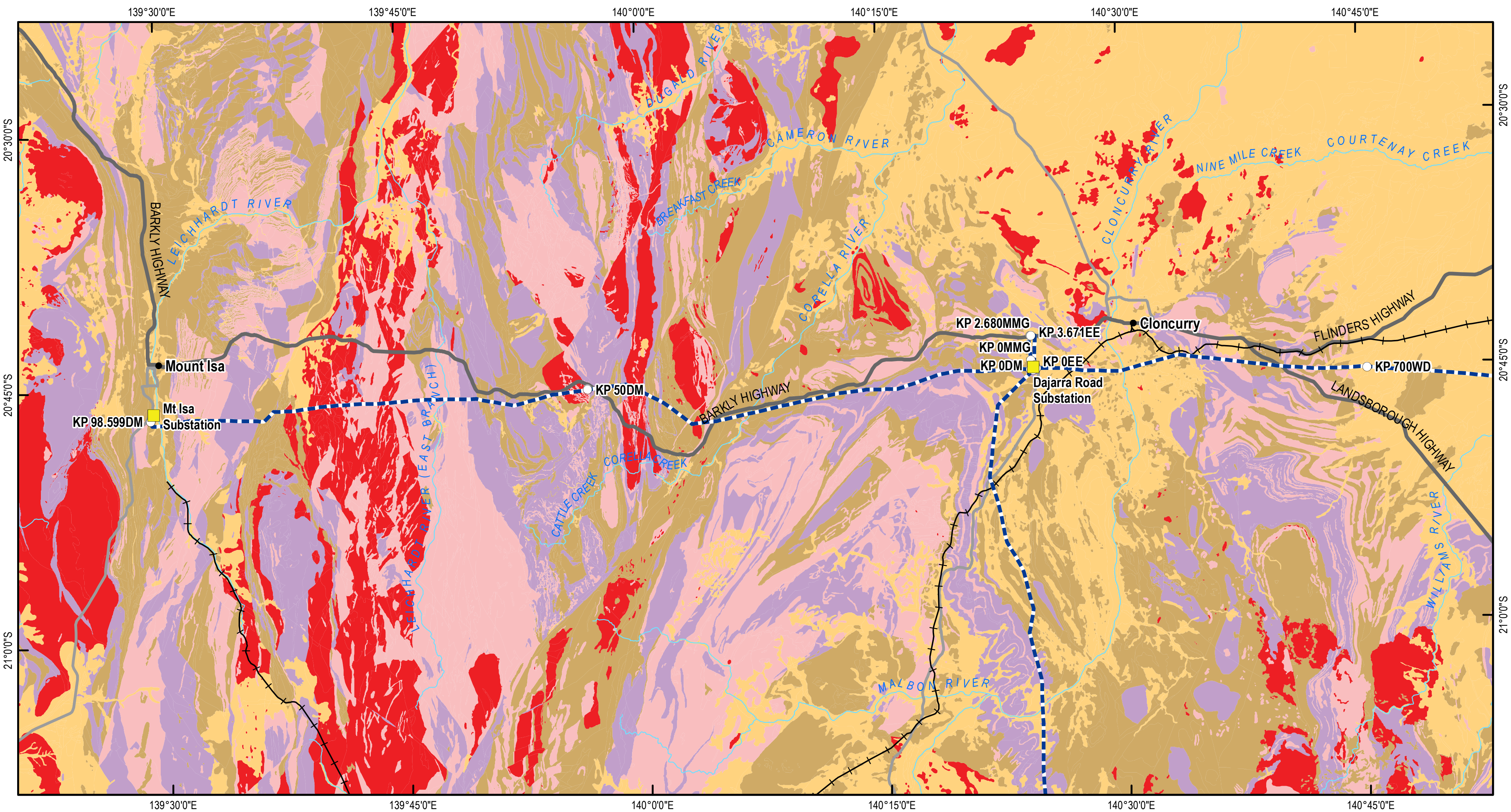

Legend

- Town/City
- Proposed Substation
- Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Major Watercourse

Simplified Geology

- Superficial Deposits
- Sedimentary Rocks
- Igneous and Volcanic Rocks
- Granitic Rocks
- Metamorphic Rocks

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

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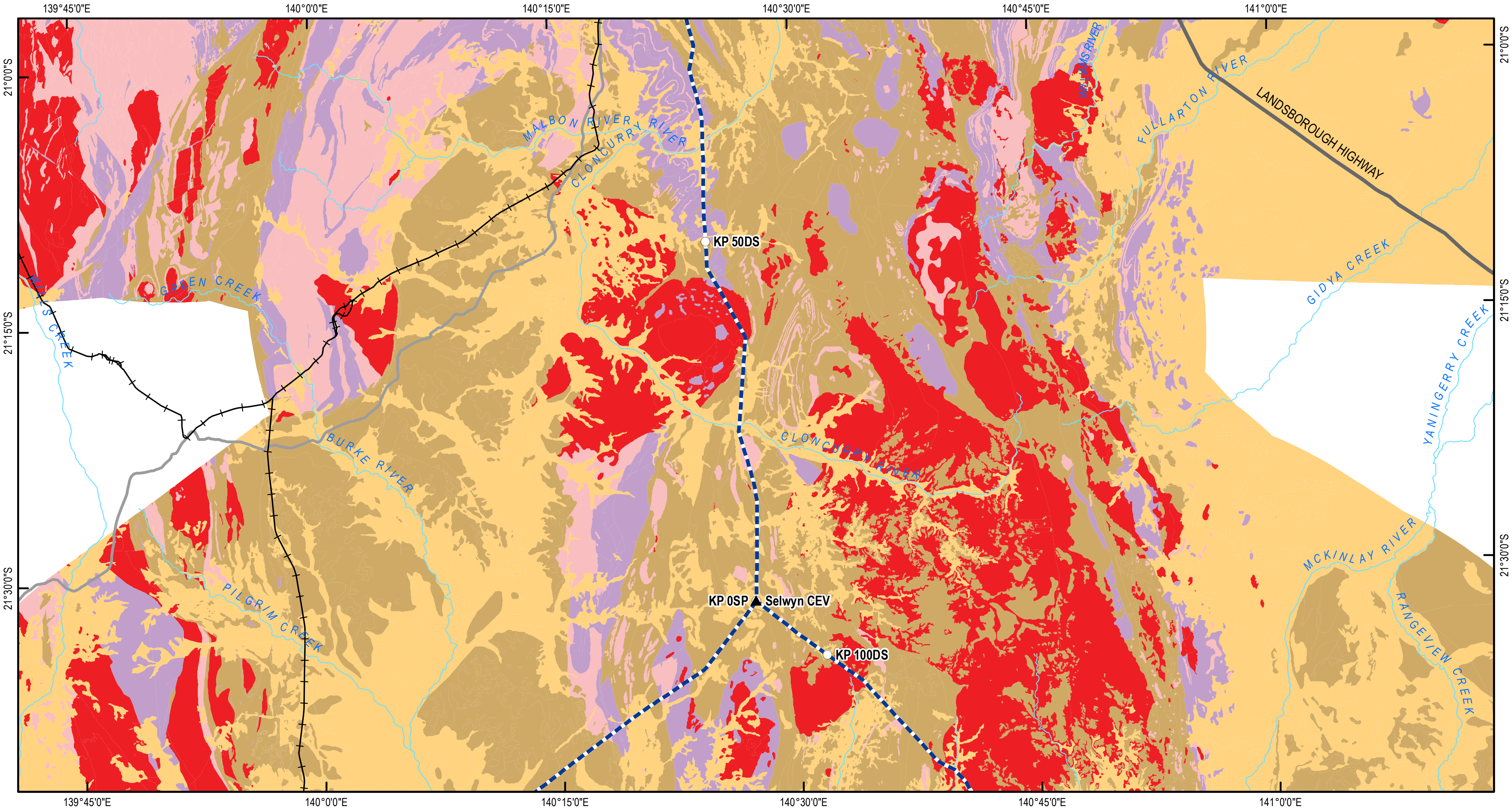
WKSP Geology_RevB

CopperString 2.0 EIS

Figure 6-3F - Geology

COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ



Legend

- ▲ CEV Hut Site
- ○ Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Major Watercourse

Simplified Geology

- Superficial Deposits
- Sedimentary Rocks
- Igneous and Volcanic Rocks
- Granitic Rocks
- Metamorphic Rocks

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
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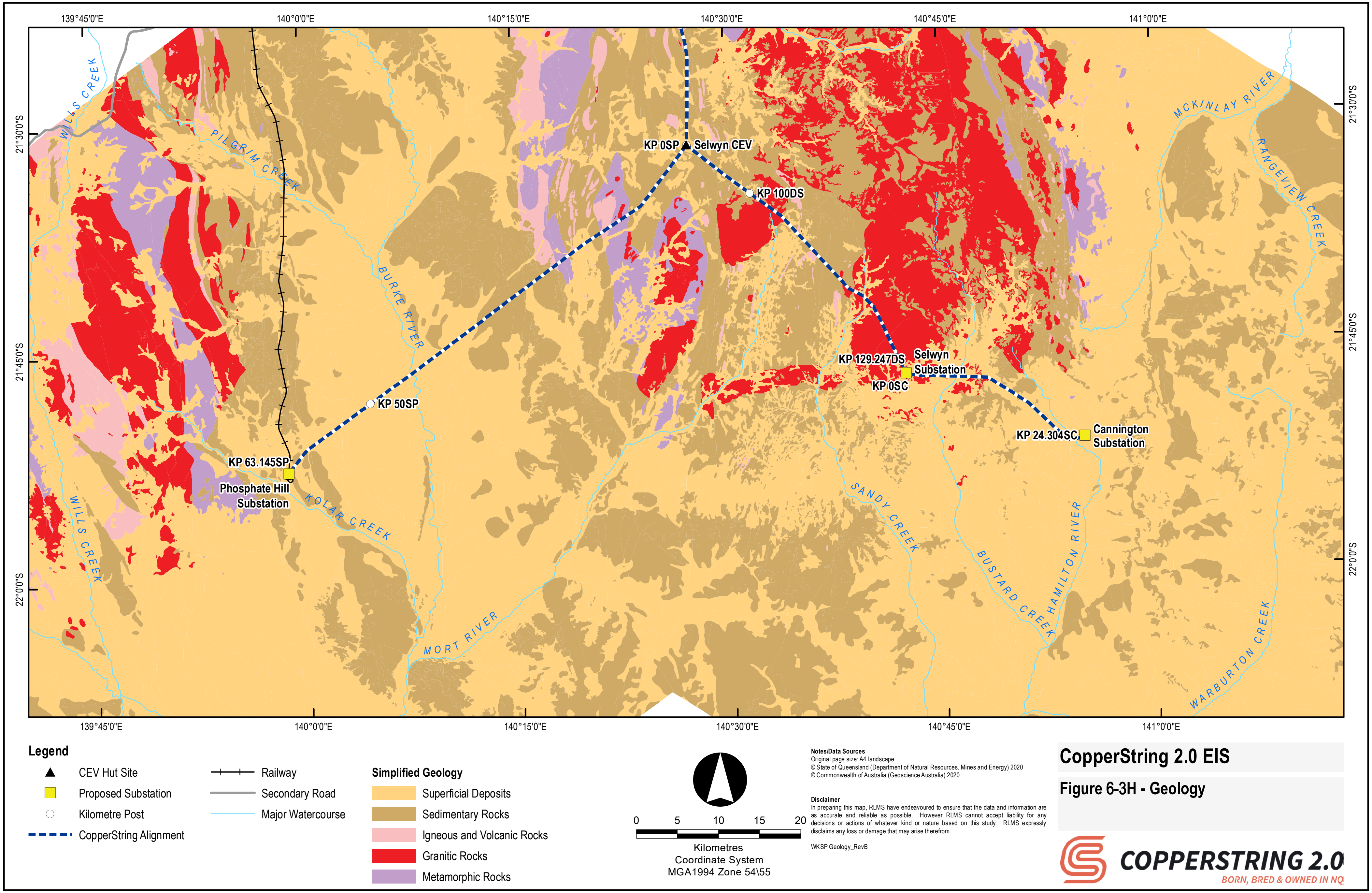
CopperString 2.0 EIS

Figure 6-3G - Geology

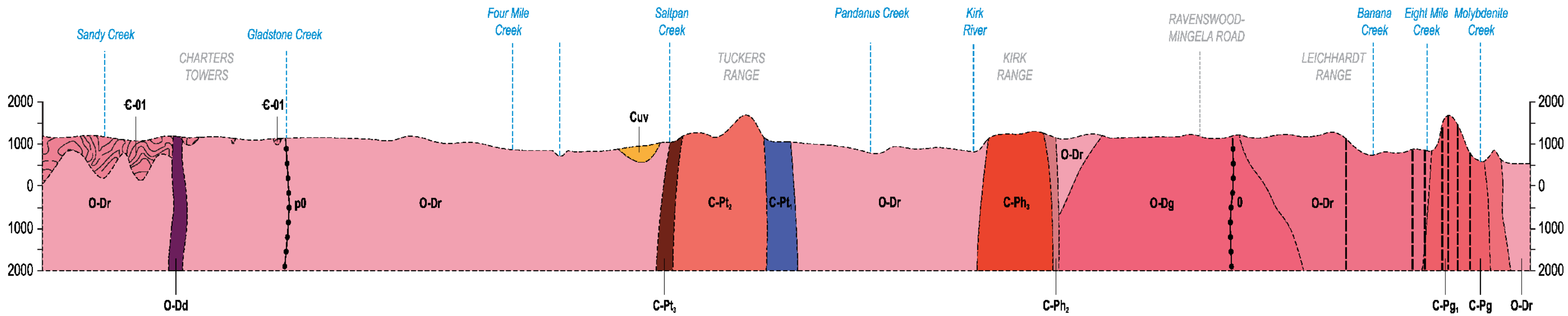
COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ



CopperString 2.0 EIS

Figure 6-3H - Geology

Geological Cross Section – Charters Towers



- C-Pg - Granodiorite, adamellite, leucograntie
- C-Ph$_3$ - Biolite-hornblende granodiorite, adamelite
- C-Ph$_2$ - Tonalite, minor diorite
- C-Pt$_3$ - Granodiorite, minor adamellite
- C-Pt$_2$ - Biolite-hornblende granodiorite, minor tonalite
- C-Pt$_1$ - Gabbro, diorite, mangerite, minor granodiorite
- Cuv - Rhyolite, agglomerate, andesite, tiff, volcanic breccia: minor
- 0-Dg - Porphyritic hornblende- biolite granodiorite
- 0-Dd - Porphyritic hornblende- biolite granodiorite
- 0-Dr - Hornblende-biolite granodiorite and tonalite; minor adamelite, gabbro and diorite southwest of Burdekin River. Foliated in places.
- Є-01 - Mica schist. Quartzite, quartz-feldspar-biotite schist, hornblende schist; cordierite, andalusite and staurolite hornfelses; chlorite schist, marble

The published Geological Survey of Queensland geological maps for the Charters Towers region, Sheet SF 55-2 provide a geological cross section interpretation through part of the study area.

Notes/Data Sources
Original page size: A4 landscape

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WKSP Geo_X_Section_Charters_Towers_RevA

CopperString 2.0 EIS

Figure 6-4A - Geological cross section - Charters Towers

COPPERSTRING 2.0
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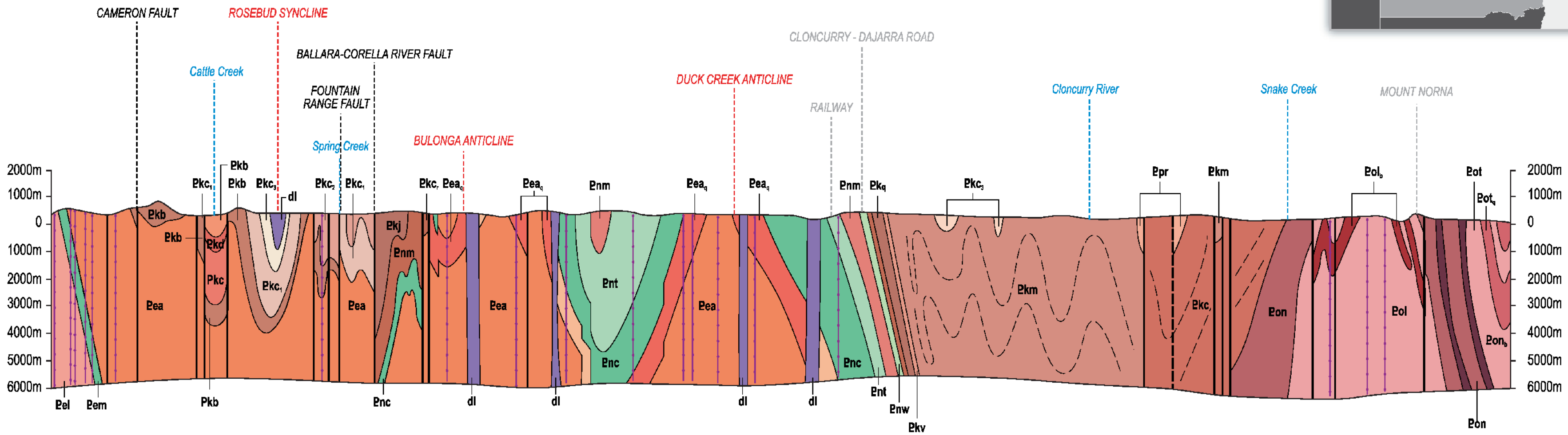
Geological Cross Section – Cloncurry



From a review of the Geological Survey of Queensland1:250000 scale map (Sheet SF 54-2, Cloncurry) the geological long section denoted 'C-0' provides an interpretation of the lithological profile that may be typical of that beneath the proposed alignment. It must be borne in mind that the interpretation is conjectured, and the position and persistence of faults, for example, may not be reliable. The vertical declination of faults and schematic assessment of folding that is shown is also conjectured, not accurate.

It is the case that the folded and faulted PreCambrian age (Proterozoic) rocks are all relatively resistant.

Notes/Data Sources
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WKSP Geo_X_Section_Cloncurry_RevA

CopperString 2.0 EIS

Figure 6-4B - Geological cross section - Cloncurry

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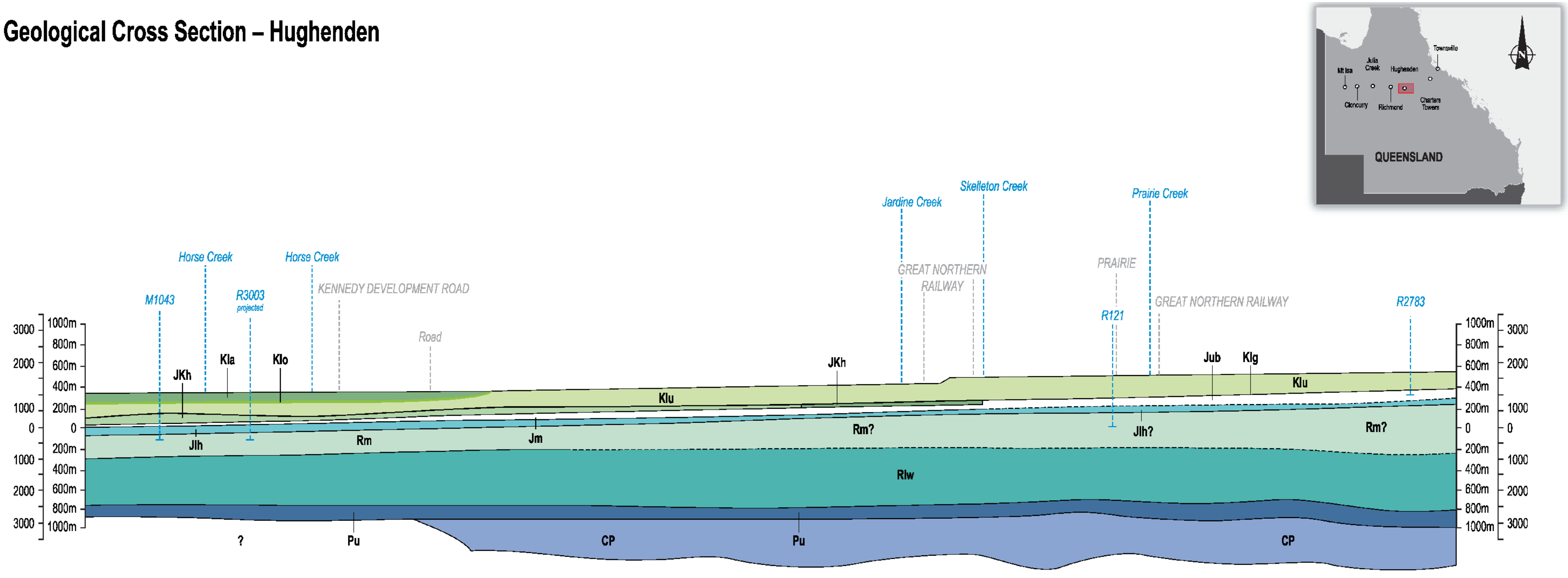
Geological Cross Section – Hughenden



	Kla	-	Mudstone, siltstone; minor labile sandstone, in part calcareous, cone-in-cone limestone
	Klo	-	Platy and concretionary limestone, calcareous shale, coquinite
	Klg	-	Quartzose to sublabile sandstone, pebbly sandstone, conglomerate
	JKh	-	Quartzose to sublabile sandstone,siltstone, mudstone. Section only
	Jub	-	Quartzose sandstone, fine micaceous sandstone, siltstone, mudstone, carbonaceous shale, coal; minor breccia
	Jlh	-	Quartose to sublabile sandstone; minor siltstone, mudstone
	Rm	-	Siltstone, mudstone, labile to quartzose sandstone
	Rlw	-	Quartzose to sublabile clayey sandstone, siltstone, mudstone
	Pu	-	Labile to quartzose sandstone, siltstone, mudstone, carbonaceous shale, coal; minor conglomerate. Section only
	CP	-	Labile to quartzose sandstone, mudstone, siltstone; minor coal, conglomerate. Section only

The published Geological Survey of Queensland geological maps for the Hughenden region, Sheet SF55-1 provide a geological cross section interpretations through much of the Carpentaria Plains.

Notes/Data Sources
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Figure 6-4C - Geological cross section - Hughenden

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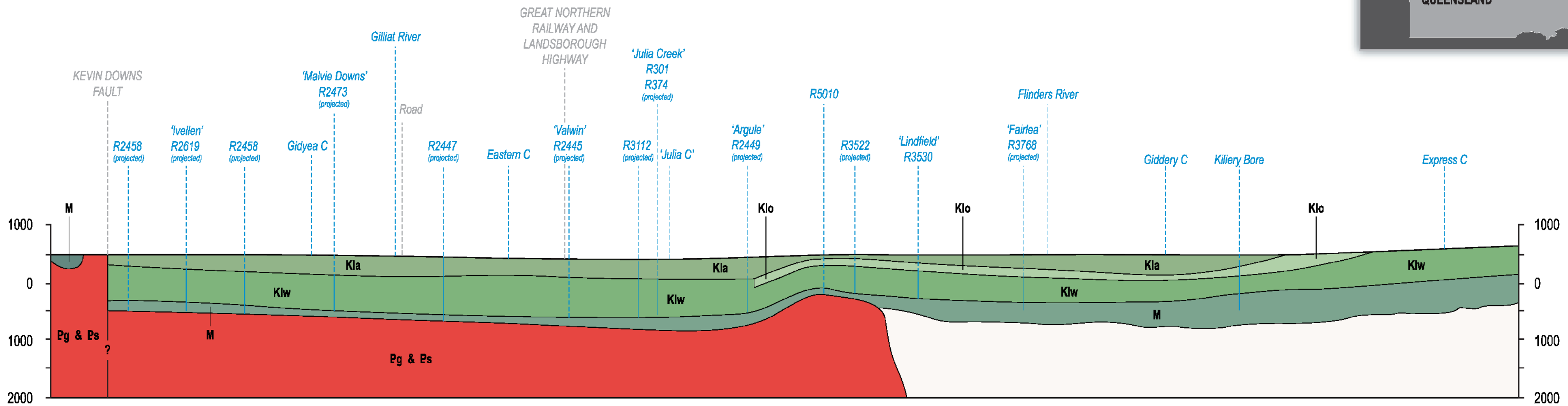
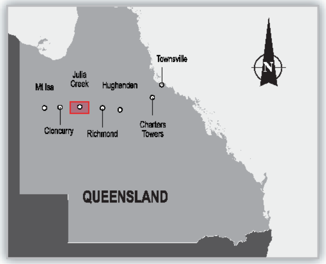
Geological Cross Section – Julia Creek





Kla	-	Claystone, siltstone, silty limestone
Klo	-	Limestone, calcareous shale
Klw	-	Claystone, glauconitic claystone, limestone, silty limestone
M	-	Sandstone, conglomerate, shale
Pg	-	Granite, pegmatite
Ps	-	Schist, amphibolite

The published Geological Survey of Queensland geological maps for the Julia Creek region, Sheet ST 54-4 provide a geological cross section interpretations through much of the Carpentaria Plains. Whilst the cross sections do not intersect the proposed alignment, both provide an indication of the geological distribution. Mesozoic age sedimentary rocks, principally the Cretaceous Allaru Member mudstone, siltstone and silty limestone dominates, perhaps typically extending to greater than 50m depth. Superficial alluvial gravel, sand and clay soils are associated with the broad river systems.

Notes/Data Sources
Original page size: A4 landscape

WKSP Geo_X_Section_Julia_Creek_RevA

CopperString 2.0 EIS

Figure 6-4D - Geological cross section - Julia Creek

COPPERSTRING 2.0
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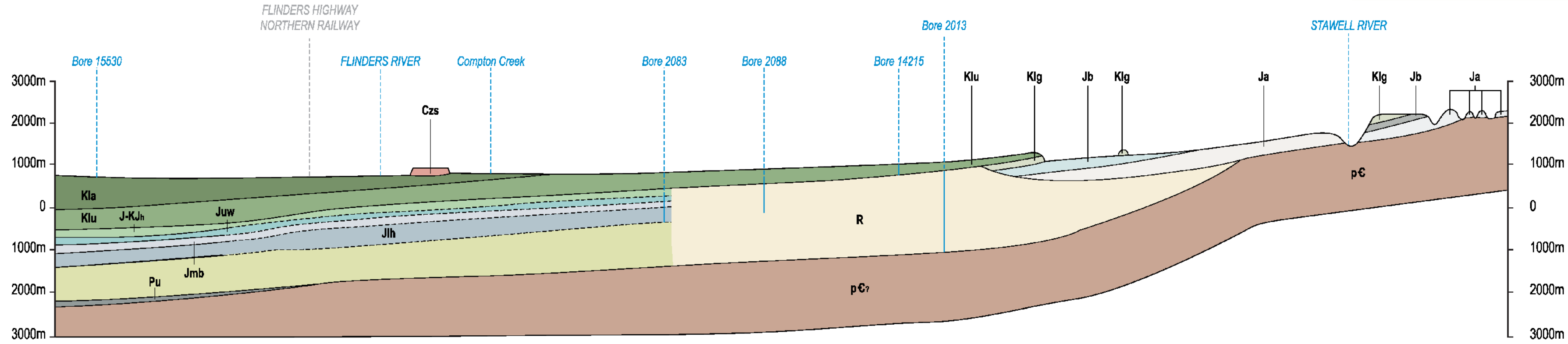
Geological Cross Section – Richmond



- Czs - Olivine basalt
- Kla - Mudstone, siltstone, minor labile sandstone; in part calcareous; cone-in-cone limestone
- Klu - undifferentiated
- Klg - Quarts sandstone, pebble conglomerate
- Jb - Quartz sandstone, siltstone
- Ja - Quartz sandstone; in part pebbly; siltstone and mudstone; minor breccia
- J-KJh - Quartzose to sublabile sandstone, siltstone, midstone
- Juw - Siltstone, mudstone, minor labile sandstone
- Jmb - Siltstone, mudstone, labile, minor coal
- R - Sandstone, mudstone, siltstone, conglomerate
- p€ - Schist, gneiss, pegmatite, amphibolite; rhyolite intrusives

The publsihed Geological Survey of Queensland geological maps for the Richmond region, Sheet ST 54-4 provide a geological crosssection interpretations through much of the Carpentaria Plains. Whilst the cross sections do not intersect the proposed alignment, both provide an indciation of the geological distribution. Mesozoic age sedimentary rocks, principally the Cretaceous Allaru Member mudstone, siltstone and silty limestone dominates, perhaps typically extending to greater than 50m depth. Superficial alluvial gravel, sand and clay soils are associated with the broadriver systems. Notably, the proposed alignment remains south of the Flinders River.

Notes/Data Sources
Original page size: A4 landscape

WKSP Geo_X_Section_Richmond_RevA

CopperString 2.0 EIS

Figure 6-4E - Geological cross section - Richmond

COPPERSTRING 2.0
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Geological structures and faulting

Aquifers

The corridor selection overlies a vast array of hydrogeology and groundwater reserves. The most significant groundwater reserve is the Great Artesian Basin, which is located beneath a part of the Renewable Energy Hub, most of the CopperString Core section, and a small section of the Cannington Connection.

Groundwater is used in the area for both stock use and domestic use, including as a water supply source for the following towns:

- Pentland
- Torrens Creek
- Prairie
- Hughenden
- Richmond
- Maxwelton
- Julia Creek.

Further detail regarding aquifers and other water resources is found in Volume 2 Chapter 9 Water resources and water quality.

Fossils

Mesozoic strata that make up the Gulf Plains are noted for the prevalence of vertebrate macrofossils. The region around Richmond has been the site of internationally important finds. However, most of the fossils found have been in the area north of the Flinders River, rather than in the Alluru Member, that dominates the corridor selection south of the Flinders River (Coffey Geotechnics, 2010).

There is a locally important fossil site near Mount Isa, known as Beetle Creek, which is renowned for a very large number of trilobite fossils (Coffey Geotechnics, 2010). This area is approximately 20 km north-west of Mount Isa, which is well outside the corridor selection.

It is not possible to suggest specific areas where further important finds might be made. It is entirely probable that there are further significant finds yet to be made and these could exist within the corridor selection.

Faulting

Faulting has been mapped as prevalent in areas of basement rock outcrop, most particularly in the Northwest Highlands and Einasleigh Upland areas. Whilst potential for seismic activity is documented as a rare event, any movement is likely to be concentrated around major, regional, faults.

The dominant orientation of faults is approximately north to south. The fault lines mapped in the vicinity of the Project are as follows:

- Line 07GA-GC1 is 492.92 km long and follows a mostly north-south orientation. It originates in the Jorgensen Range, approximately 43 km north-west of Mount Surprise and terminates approximately 86 km south of Charters Towers, east of the Campaspe River. The Gregory Developmental Road coincides with this fault line. The Renewable Energy Hub section of the corridor selection crosses this fault line between KP 100WD and KP 120WD.

- Line 14GA-CF1 is 669.28 km long and follows a mostly north-south orientation. It originates approximately 100 km north of Kajabbi and coincides with Burketown Road, Julia Creek Kynuna Road, and Landsborough Highway before terminating approximately 31 km north-west of Longreach. The CopperString Core section of the corridor selection crosses this fault line between KP 590WD and KP 600WD, south of Julia Creek..
- Line 06GA-M5 is 159.52 km long and follows a mostly north-south orientation. It originates approximately 14 km south of Gilliat and terminates approximately 19 km south of Cannington Mine, coinciding with McKinlay Gilliat Road and Toolebuc McKinlay Road. The corridor selection does not traverse this fault line. Its closest proximity is the CopperString Core section, approximately 2.4 km north of the northernmost point of the fault line and the termination of the Project at Cannington Mine, approximately 1.8 km west of the fault line.
- Line 06GA-M6 is 283.2 km long and follows a mostly east-west orientation. It originates approximately 25 km east-north-east of Cannington Mine and terminates approximately 60 km west-south-west of Dajarra, near Mussel Creek. The corridor selection does not traverse this fault line. The termination points at Phosphate Hill Mine and Cannington Mine are approximately 6.5 km and 3.9 km north of the line respectively.
- Line 06GA-M4 is 200 km long and follows a mostly north-south orientation. It originates near Round Mountain, approximately 50 km north-west of Cloncurry, and terminates approximately 23 km south-east of McKinlay. It is 200 km long and largely coincides with Landsborough Highway. The CopperString Core selection traverses this fault line between KP 720WD and KP 730WD..
- Line 94MTI-01 is 255.52 km long and follows a mostly east-west orientation. It originates 2 km east of the Fullarton River, approximately 26 km south of the Flinders Highway, between Gilliat and Cloncurry, and terminates near the Templeton River, approximately 70 km west of Mount Isa. The Southern Connection of the corridor selection crosses this fault line at KP 23DS.

Fault lines within the study area are shown in the geological cross-sections in Figure 6-4.

Geological constraints

Availability of construction material

The Project may require construction materials, including rock fill for erosion control and crushed rock for use as granular structural fill, and for use in temporary access tracks and camps. Transport of quarried resistant rock types may be required over large distances. Rock fill is unlikely to be present in the Desert Uplands, Mitchell Grass Downs and Gulf Plains area.

Rock outcrops in the Einasleigh Uplands may provide opportunity for quarrying.

Some sedimentary and metamorphic rock types (mudstone, sandstone, slate, schist and similar) might be suited to extraction by ripping, however given the unpredictable presence of minor intrusions and quartzitic content, it may require extraction by blasting. This may impact quarry and construction (cuttings at tower locations or access roads) activities (Coffey Geotechnics, 2010).

Sand and aggregate for the concrete batching process is likely to be suppled from the region however Hughenden, Richmond and Julia Creek (black soil areas) will likely need to source sand and aggregate from the Charters Towers/Pentland or Cloncurry areas. The final source of materials is subject to further engagement with key stakeholders, including local councils.

Faults and seismic hazard

Queensland Globe mapping shows numerous major faults in the study area, particularly in the Northwest Highlands and Einasleigh Uplands (refer to 6.3.2).

The risk of seismic activity is low, however any movement is likely to be concentrated around major, regional, faults.

Foundations

In upland areas, competent bedrock is likely to be present at a shallow depth. Given the complexity of the distribution of rock, sharp variation in the foundation characteristics may occur. Variable rock types frequently exhibit differential weathering. It is recommended that site-specific assessments are carried out for Project activities, particularly focused on areas of known complex geology and jointed rock types.

Deeper soil cover areas may be present throughout the Desert Uplands, Mitchell Grass Downs and Gulf Plains, particularly in the area associated with the Cape and Campaspe River (lateritic soils).

6.3.3 Landform features

Landform features and geomorphological processes

Catchments

The corridor selection traverses numerous watercourses, with significant river systems that drain to the following catchments:

- Haughton River
- Burdekin River
- Cooper Creek
- Flinders River
- Leichhardt River
- Georgina River.

Rivers and creeks within the study area are typically ephemeral, only flowing in response to rainfall events. The watercourses have adapted to the variability of flow and sediment inputs. The majority of watercourses within the study area have steep sides with bed-level lowering. Many show signs of bank erosion and bed scour. The rivers are typically tree-lined, with tree roots increasing bank stability.

River channels display continuous channel patterns (either anastomosing, meandering or braided) that depend largely on the bed slope and flow magnitudes.

A list of the most significant watercourses traversed by the corridor selection is included in Volume 2 Chapter 9 Water resources and water quality.

Runoff (sheetwash), rill and gully erosion

Areas of erosion have been observed throughout the study area, including sheetwash, rill and gully erosion.

Erosion is related to vegetation cover, rainfall intensity, soil type, and slope steepness and length. Runoff erosion, or sheetwash, occurs when unconfined flow over bare or sparsely vegetated ground strips the surface soil layers. In northern Queensland, intense, prolonged rainfall often occurs during the summer months, particularly when impacted by tropical cyclones.

Gullies are narrow deep trenches, forming either along incised watercourses or as a result of erosion into previously intact ground. Upstream erosion of gully headcuts can cause expanding incised networks to form. Piping can occur upstream of gully headcuts, accelerating the gullying process.

Rills are similar to gullying, but at a smaller scale (rills are defined as minor trenches that can be ploughed out). Landscape changes, which can lead to increased erosion and gully formation, are as follows:

- Destruction of protective surface vegetation, whether through storm/cyclone, bushfire or artificial clearance
- Flow concentration, increasing the energy available for erosion, e.g. along tracks.

These processes are exacerbated in dispersive, highly erodible sodic texture contrast soils. The structure and chemical composition of this type of soil makes them susceptible to subsurface piping/tunnelling; and surface rill and gully erosion, particularly once the vegetation cover is removed.

Refer to Section 6.4.2 for a more detailed discussion on the erosion potential of the study area.

Wind erosion

Hot, dry winds during early summer cause soils to lose moisture. Very strong winds are typical of tropical cyclones, but are generally associated with heavy rainfall. Water erosion is, therefore, more likely to occur during cyclones, than wind erosion.

Site and aerial photograph observations from the Coffey Geotechnics (2010) study indicate that wind transport of sediment occurs throughout the study area, where loose, fine-grained topsoils are present. Dune formations from wind erosion were identified in the Gulf Plains east of the Williams River. In some areas with no or sparse vegetation (e.g. cleared areas) aeolian deposits were observed to have formed a thin topsoil layer. Bulldust was common along tracks.

Tors

Tors are rounded or convex steep-sided hills with large blocks of bedrock outcropping at the peak. These landforms are formed by long periods of weathering, and generally comprise granitic or metamorphic rock (e.g. Quartzite). The ongoing rock weathering can cause the hillsides to be covered with boulders.

Tors are a characteristic landform feature of the Northwest Highlands and are also found in the Einasleigh Uplands bioregions.

Gilgai

Gilgai are patterns of irregular mounds and depressions caused by swelling and shrinking of cracking type clay soils during wetting and drying cycles. Gilgais can be up to 2 m high and 50 m wide. On flatter ground, gilgai are roughly circular, whereas on steeper slopes, they become elongated.

Landowners in the study area generically refer to small ground depressions as “melonholes”, however these are potentially subsurface erosion and ground collapse (shallow sinkholes) within sodic soils, rather than gilgai.

Gilgai are common in areas of clay plains in the Northwest Highlands and are a common landform feature in the Gulf Plains. Additionally, vegetation on the Gulf Plains can form “fairy rings”, which can appear gilgai-like in aerial photographs.

Physiography, topography and geomorphology

Einasleigh Uplands

The corridor selection originates adjacent to the Ayr Ravenswood Road, approximately 43 km south-east of Woodstock, and traverses a small area of the northern Brigalow Belt bioregion. The Brigalow Belt is associated with undulating to rugged ranges and alluvial plains.

The corridor selection commences at an elevation of approximately 80 m Australian Height Datum (AHD) and traverses the Brigalow Belt bioregion, in a south-westerly direction for approximately 10 km and then heads in a west-north-westerly direction, entering the Einasleigh Uplands bioregion around KP 11WD.

The Einasleigh Uplands represents the hilly territory of the Great Dividing Range. Within the study area, the Einasleigh Uplands rise to 420 m AHD, above broad plains, which have an elevation of approximately 250 m AHD. The corridor selection heads in a north-west direction for approximately 11 km before heading south-west between the Leichhardt Range and the Kirk River. At approximately KP 42WD, the corridor selection takes a southern trajectory and crosses Oaky Creek (a tributary of the Kirk River) before continuing west across Pandanus Creek and then heading south-west, crossing the Burdekin River around KP 71WD.

The corridor selection continues through the Einasleigh Uplands in a south-west direction, crossing several creeks. The Burdekin River and its tributaries dominate the fluvial environment of the Einasleigh Uplands. The characteristics of the rivers of the uplands are typically incised trenches, containing a channel adjusted to the extreme variability of flows experienced in the region.

Desert Uplands

From KP 124WD to KP 321WD, the corridor selection is situated within the Desert Uplands bioregion, which is characterised by upland landforms, dominated by sandstone ranges and sand plains. The corridor selection enters the Desert Uplands in a south-west direction at an elevation of around 300 m AHD. It traverses Balfe Creek, Campaspe River, Cape River and Warrigal Creek. It continues across the Uplands and crosses the Great Dividing Range at 480 m AHD between KP 229WD and KP 230WD, then continues west, parallel with the Flinders Highway, crossing Torrens Creek, Bullock Creek, Prairie Creek and Skeleton Creek.

Mitchell Grass Downs

West of Skeleton Creek, the corridor selection enters the Mitchell Grass Downs bioregion, a large bioregion that contains most of the corridor selection. Mitchell Grass Downs consists of largely treeless plains with some occasional ridges, rivers and gorges.

Around KP 379WD, the transmission line enters an area of braided channels of Walker Creek and Warianna Creek that form part of the eastern extent of the Flinders River catchment. The corridor selection continues west, generally parallel with the Flinders Highway, crossing the anastomosing channels of Alick Creek where it briefly enters the Gulf Plains bioregion at KP 525WD before re-entering the Mitchell Grass Downs at KP 547WD.

The corridor selection then continues west across relatively flat, treeless plains around 140 m AHD and the braided channels of Julia Creek, Eastern Creek and Sadowa Creek, which are all part of the Flinders River catchment.

Gulf Plains

At KP 625WD, the corridor selection again traverses the Gulf Plains bioregion. These plains comprise a broad expanse of flat to gently undulating alluvial clay deposits, which contain gilgais in places. The corridor selection traverses the Gulf Plains at an elevation of 130 m AHD to 170 m AHD.

The plains are characterised by intricate networks of channels, which form large anastomosing rivers. The corridor selection crosses the channels of the Gilliat River, McKinlay River, Gidya Creek, Holy Joe Creek, Fullarton River and Williams River (all part of the Flinders River catchment).

Northwest Highlands

At approximately KP 694WD, the corridor selection enters the Northwest Highlands bioregion. It rises to 220 m AHD as it crosses the Landsborough Highway and continues west across the Cloncurry River. The CopperString Core section terminates at the proposed Dajarra Road Substation, located approximately 3 km south of the Barkly Highway at an elevation of 220 m AHD.

From the Dajarra Road Substation, the Mount Isa Augmentation section of the Project continues west across the sharp topography of the Northwest Highlands, which reflects the faulted, folded nature of the ancient underlying geology. The area is characterised by sharp ridges, elongated plateaux, and steep-sided tors, separated by narrow river valleys and broad, alluvial clay plains.

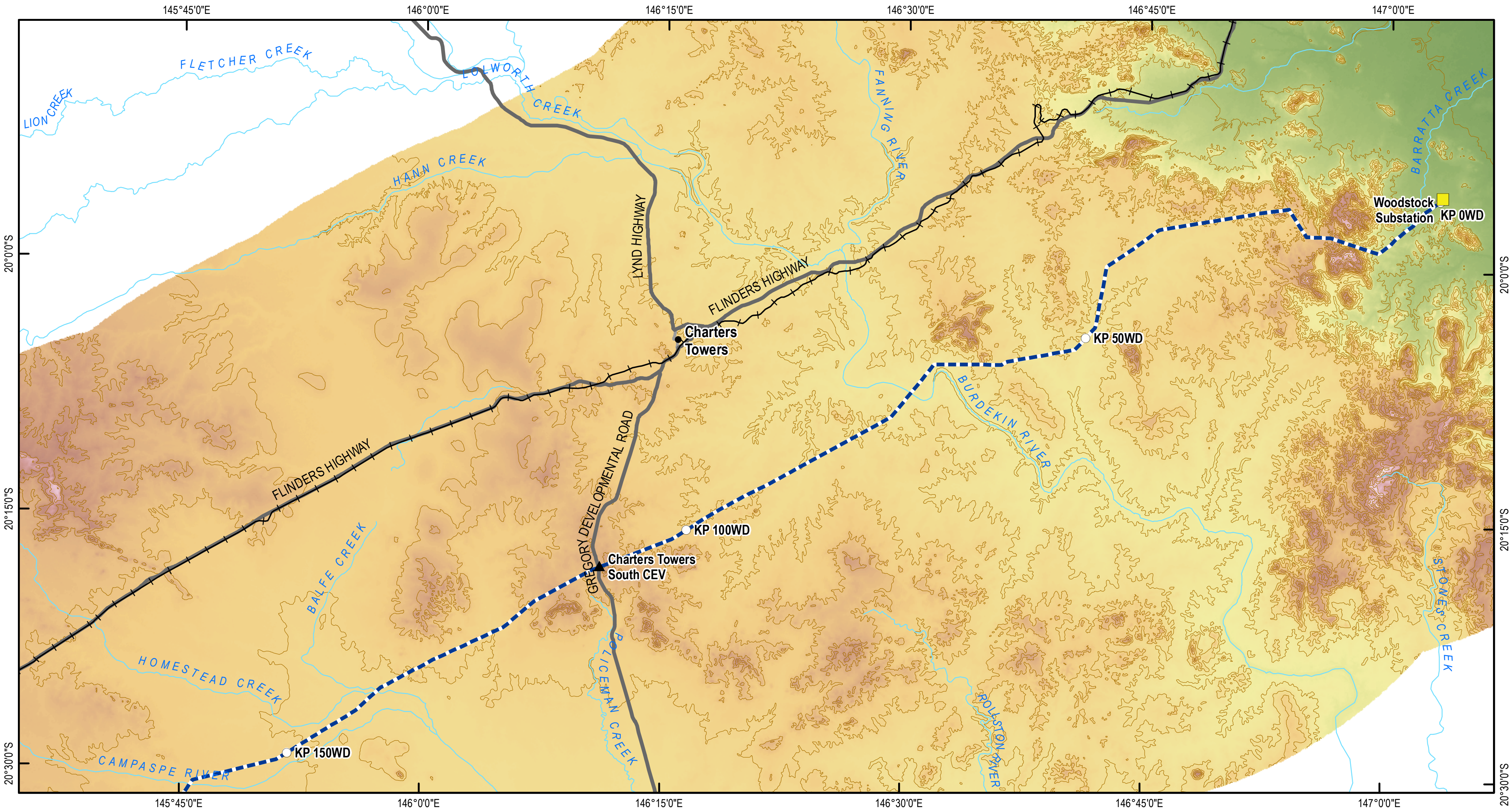
The corridor selection crosses the Corella River around KP 31DM. Just west of the Barkly Highway, the corridor selection enters an area of steep mountains, with elevations of up to 570 m AHD. It crosses Cameron Creek before crossing the Barkly Highway again and continuing west across the Leichhardt River East Branch, north of Lake Mary Kathleen. The corridor selection continues across more steep mountainous terrain, streams and tributaries, passing approximately 4 km north of Mount Macarthur before terminating just west of the Leichhardt River at the proposed Mount Isa Substation. The highlands rise to over 600 m AHD in the corridor selection area between Cloncurry and Mount Isa, above the high-elevation plain, which is between 250 m and 300 m AHD. Tors rise steeply up to 200 m above the plains. Gilgai cover large areas of the clay plains, indicating the presence of cracking clays, which are prone to ground movement.

From the Dajarra Road Substation, near Cloncurry, the Southern Connection of the corridor selection traverses the Northwest Highlands in a southerly direction. It crosses Cloncurry Duchess Road just after KP 13DS, then heads south-south-east through the valleys of the steep-sided tors of the highlands. It then continues south and crosses the Cloncurry River, at KP 39DS and again at KP 71DS, north of the Selwyn Range. Approximately 5 km west of the township of Selwyn, the Southern Connection heads south-east and continues for another approximately 39 km through the Selwyn Ranges before terminating at the Selwyn Substation.

The Cannington Connection originates at the Selwyn Substation and heads west for approximately 10 km, then south-west for another 12 km before terminating at the Cannington Substation. The Cannington Connection is located within the Mitchell Grass Downs bioregion.

The Phosphate Hill Connection originates at approximately KP90DS on the Southern Connection and extends south-west through a flatter section of the Northwest Highlands, then enters the Mitchell Grass Downs bioregion at KP 25SP before crossing the Burke River and terminating at the Phosphate Hill Mine.

The topography of the study area is illustrated in Figure 6-5.



Legend

- Town/City
- CEV Hut Site
- Proposed Substation
- Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)

1225

0

0 5 10 15 20

Kilometres

Coordinate System

MGA1994 Zone 54\55

Notes/Data Sources

Original page size: A4 landscape

Disclaimer

In preparing this map, RLMS have endeavoured to ensure that the data and information are as accurate and reliable as possible. However RLMS cannot accept liability for any decisions or actions of whatever kind or nature based on this study. RLMS expressly disclaims any loss or damage that may arise therefrom.

WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5A - Topography

COPPERSTRING 2.0

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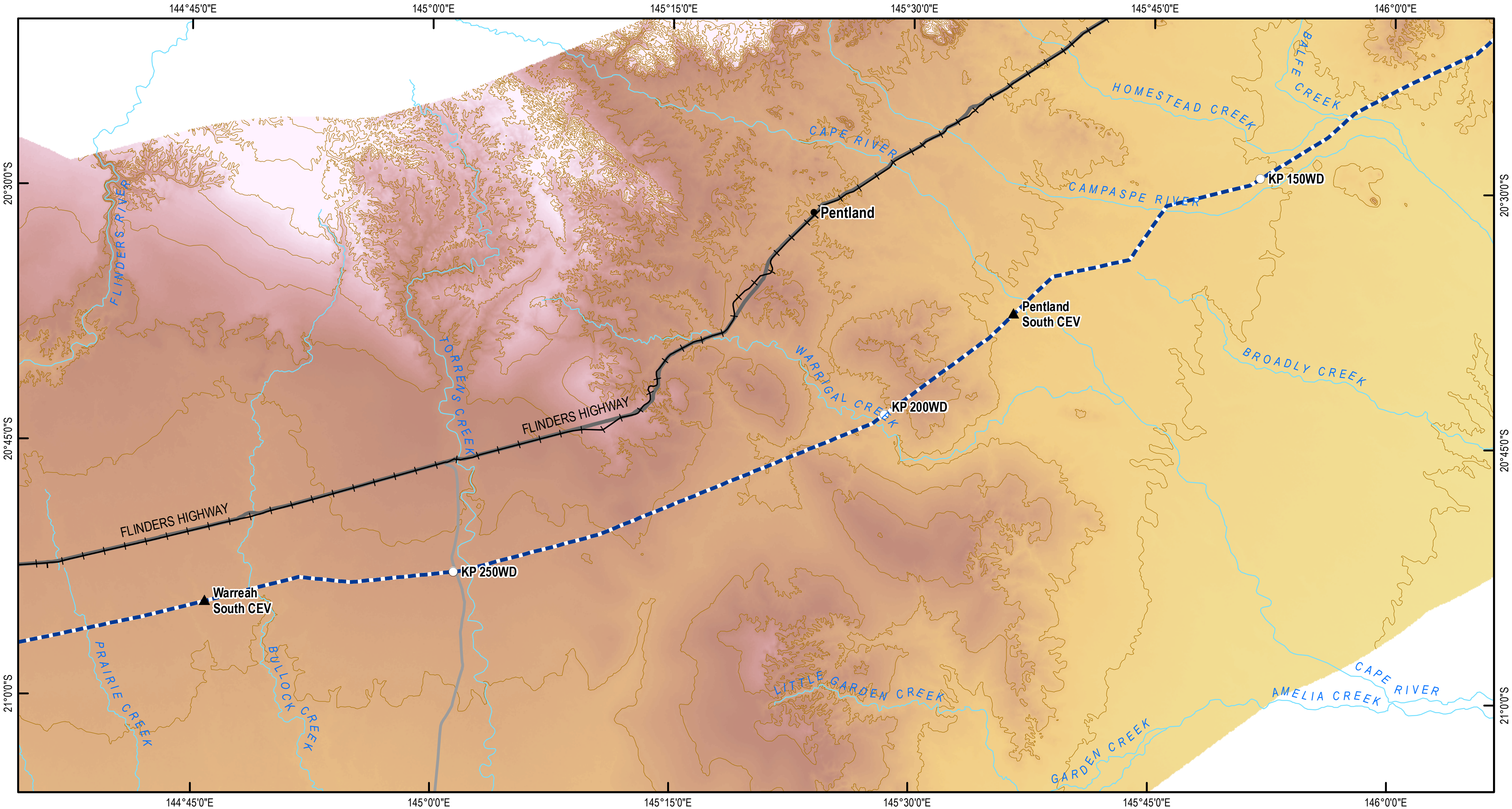

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- ● Town/City
- ▲ CEV Hut Site
- ○ Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)
1225
0

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
Original page size: A4 landscape

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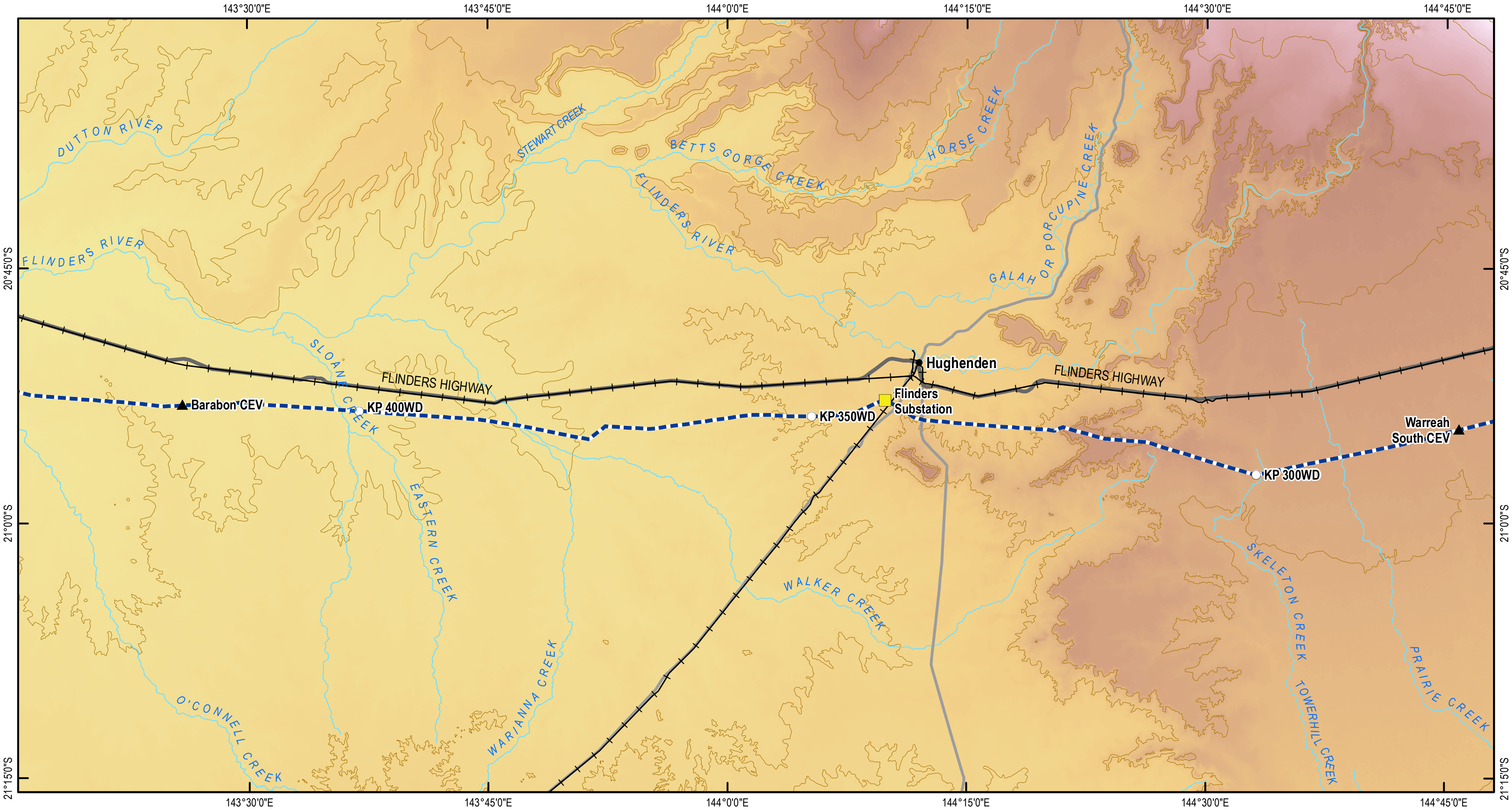
WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5B - Topography

COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ



Legend

- Town/City
- CEV Hut Site
- Proposed Substation
- Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)

1225

0

0 5 10 15 20

Kilometres

Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources

Original page size: A4 landscape

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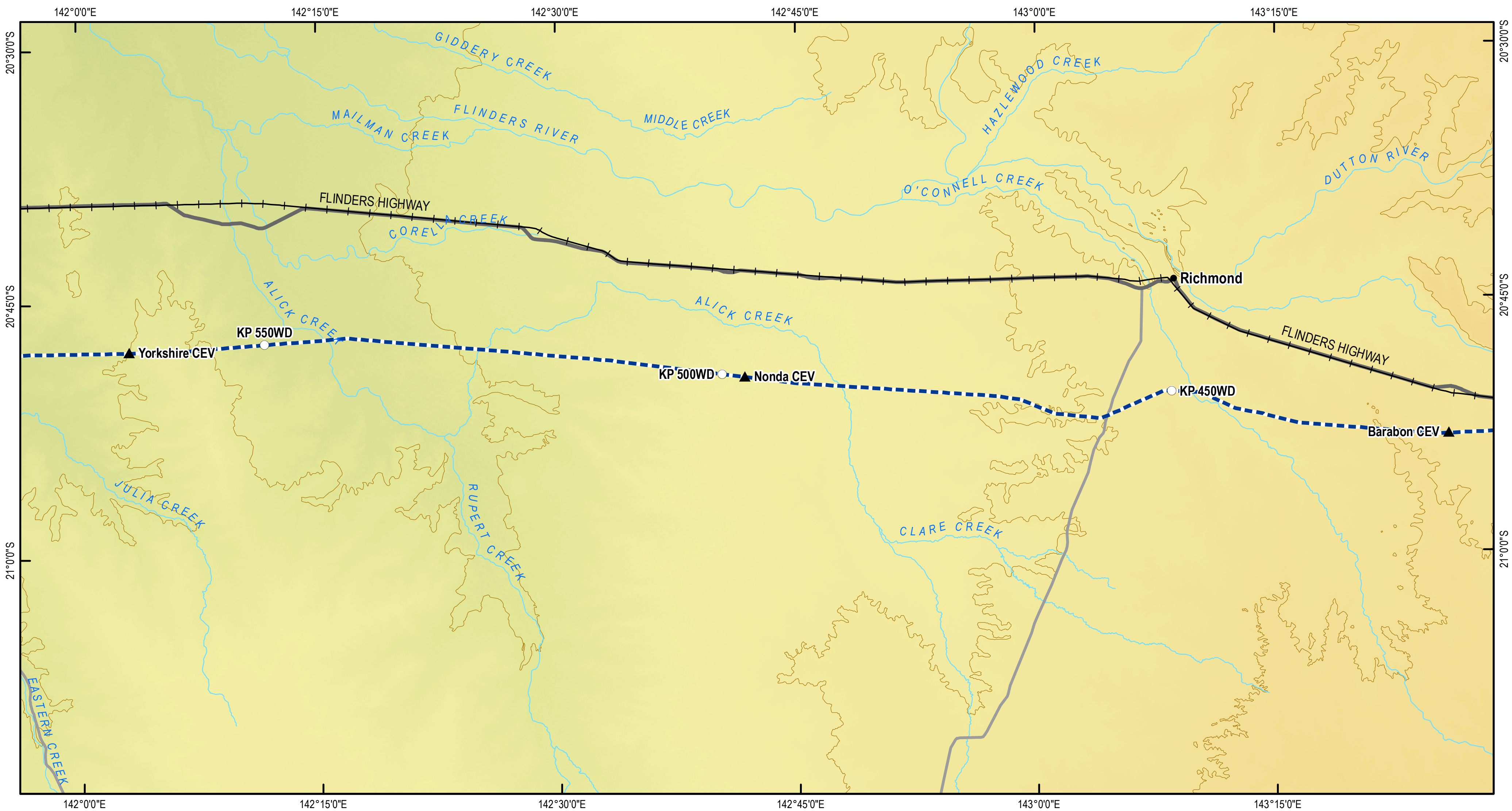
WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5C - Topography

COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ



Legend

- Town/City
- CEV Hut Site
- Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)
1225
0

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
Original page size: A4 landscape

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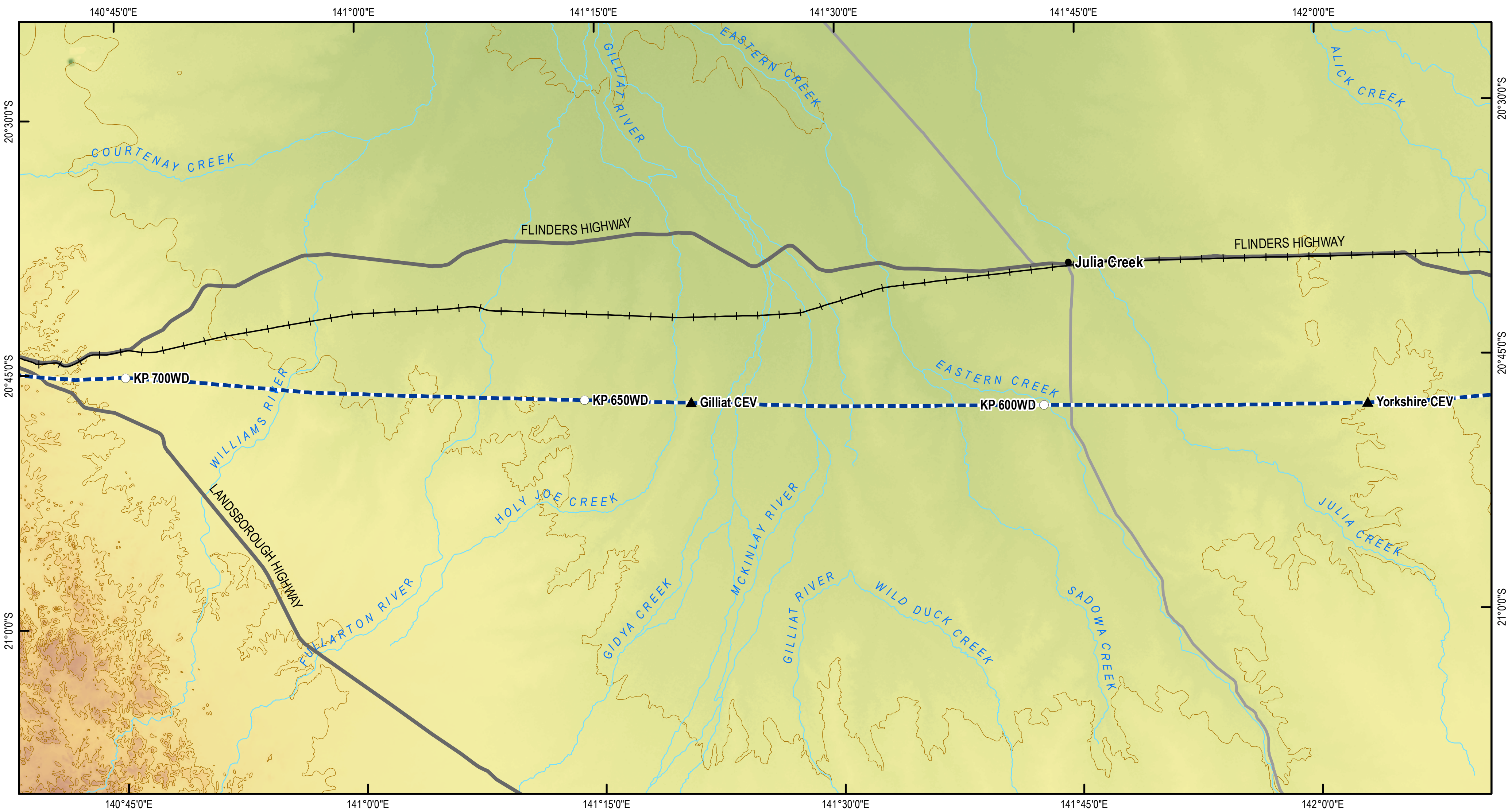
WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5D - Topography

COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ



Legend

- ● Town/City
- ▲ CEV Hut Site
- ○ Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)
1225
0

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
Original page size: A4 landscape

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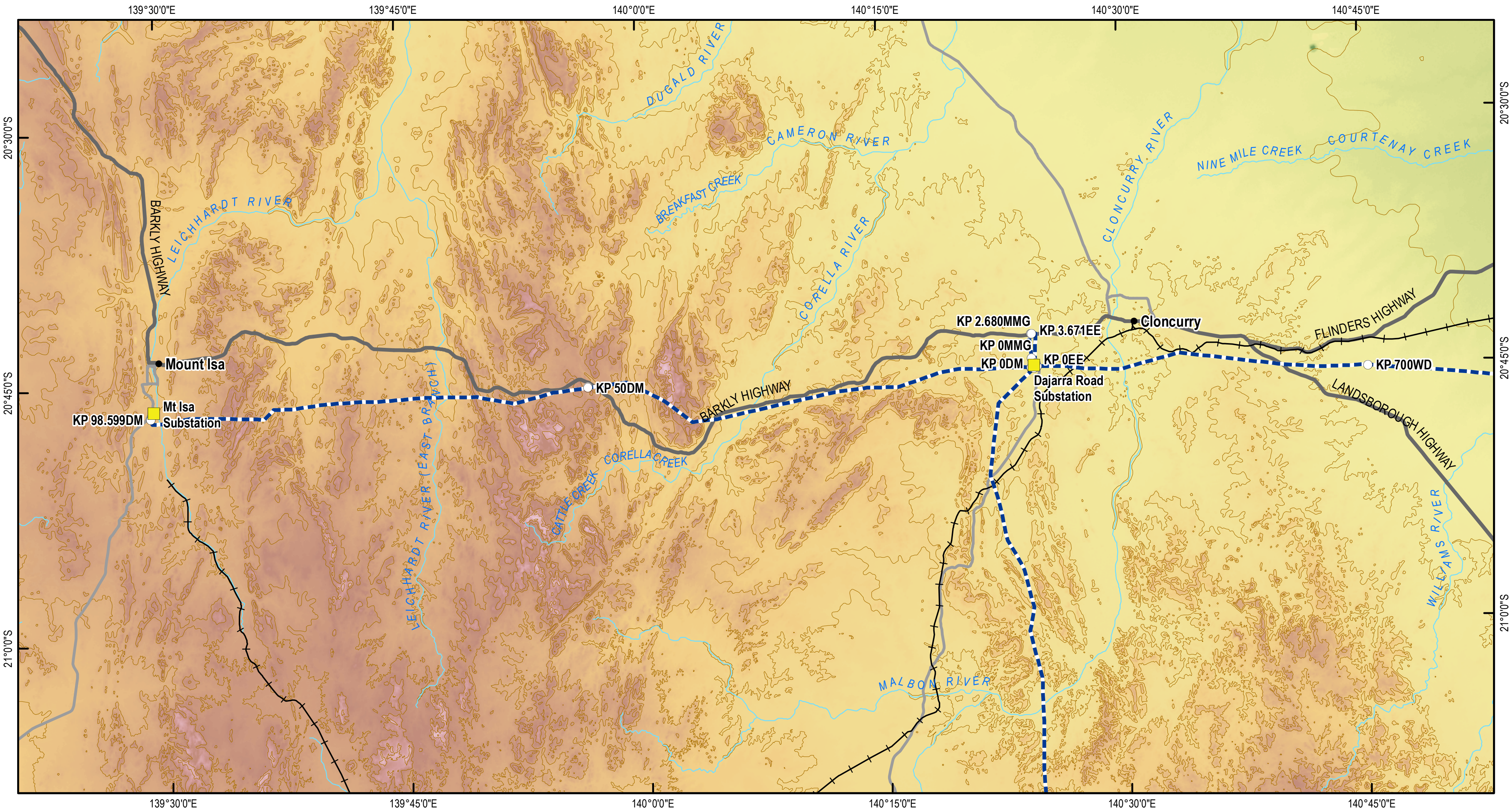
WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5E - Topography

COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ



Legend

- Town/City
- Proposed Substation
- Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)

1225

0

0 5 10 15 20

Kilometres

Coordinate System

MGA1994 Zone 54\55

Notes/Data Sources

Original page size: A4 landscape

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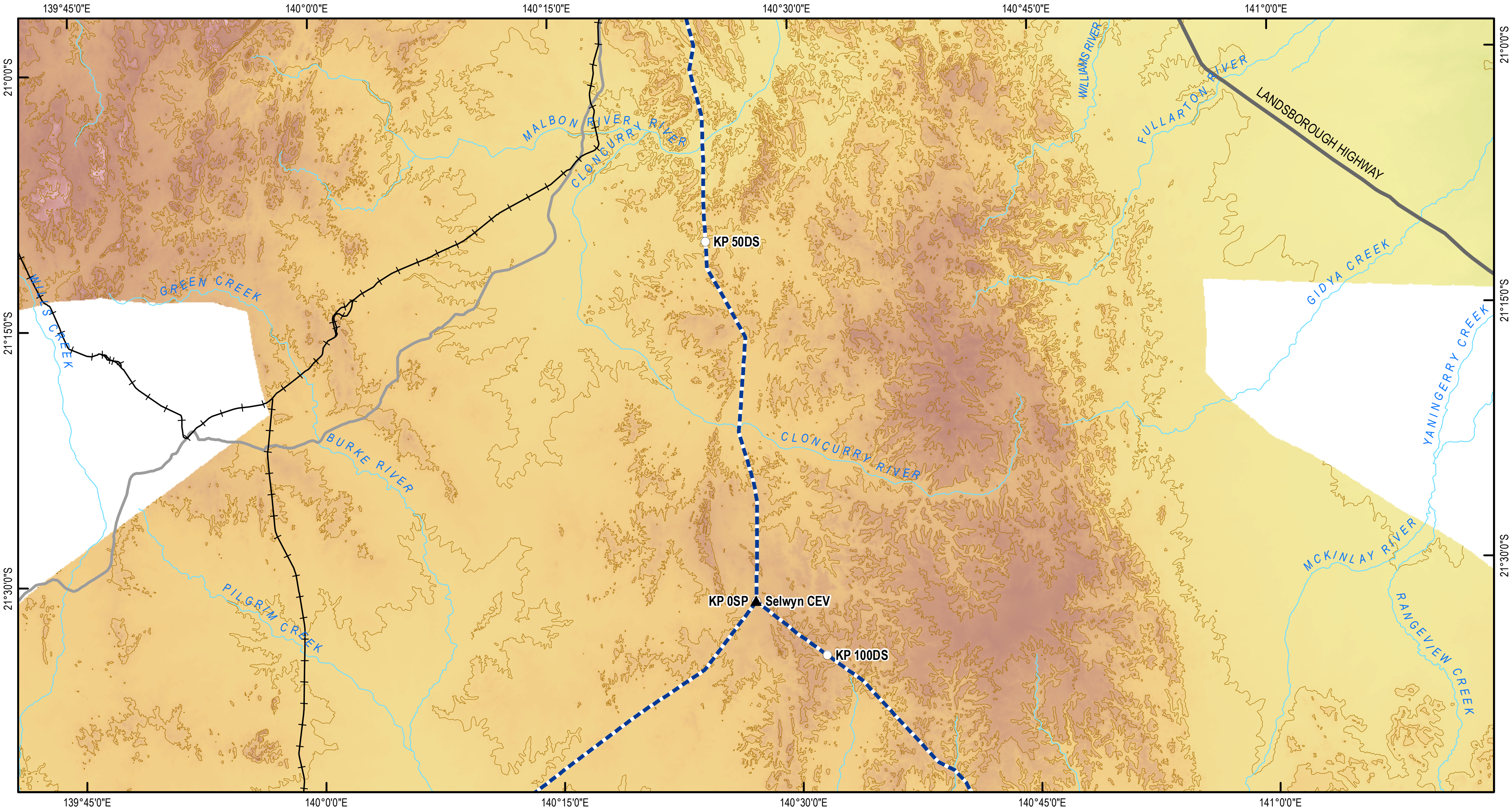
WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5F - Topography

COPPERSTRING 2.0

BORN, BRED & OWNED IN NQ



Legend

- ▲ CEV Hut Site
- ○ Kilometre Post
- CopperString Alignment
- Railway
- Highway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)
1225
0

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

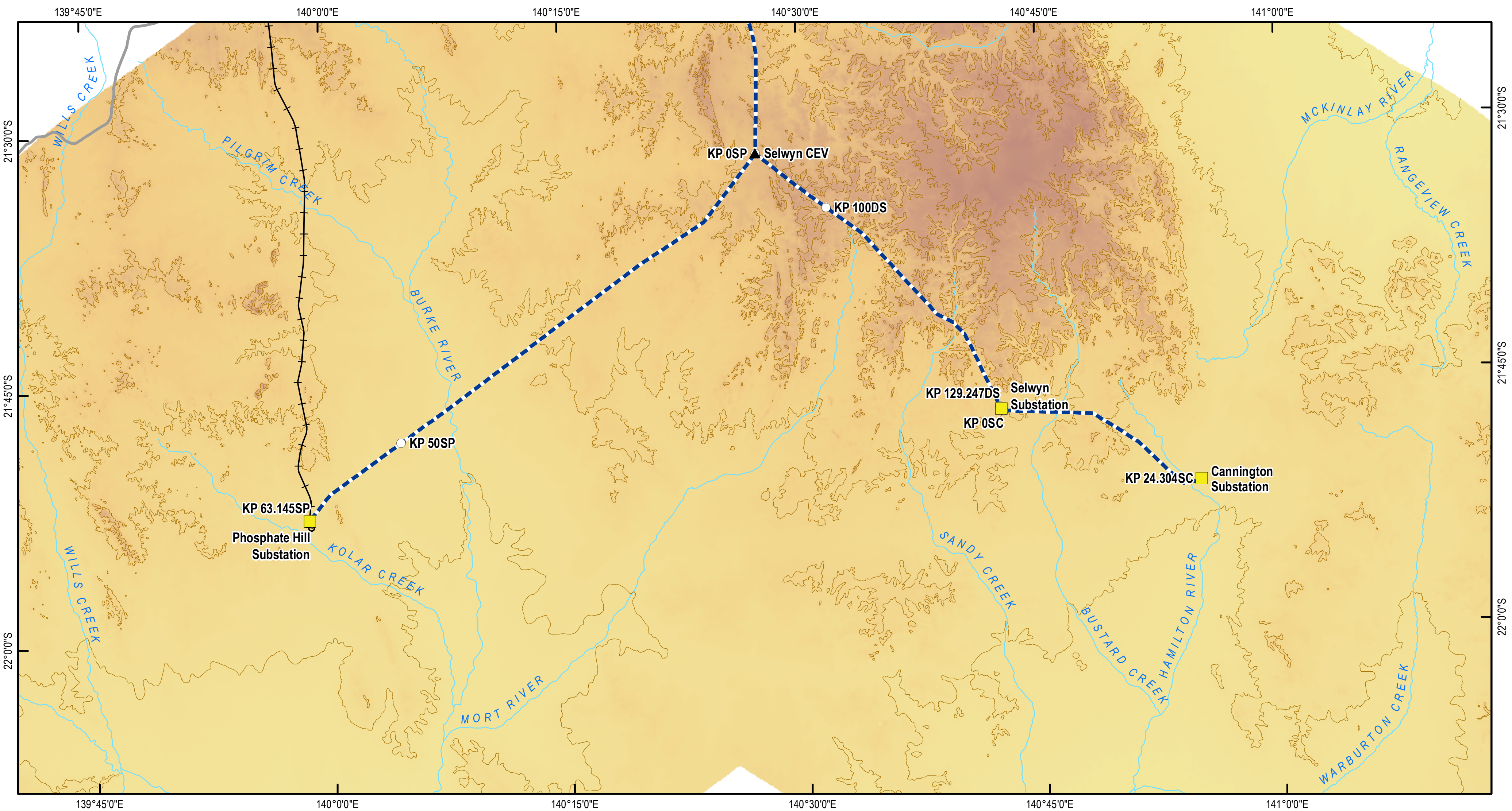
Notes/Data Sources
Original page size: A4 landscape

WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5G - Topography

COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ



Legend

- ▲ CEV Hut Site
- Proposed Substation
- Kilometre Post
- CopperString Alignment
- Railway
- Secondary Road
- Contour (50m interval)
- Major Watercourse

Elevation (m)
1225
0

0 5 10 15 20
Kilometres
Coordinate System
MGA1994 Zone 54\55

Notes/Data Sources
Original page size: A4 landscape

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WKSP Topography_RevB

CopperString 2.0 EIS

Figure 6-5H - Topography

COPPERSTRING 2.0
BORN, BRED & OWNED IN NQ

Landform constraints

Steep slopes and dissecting gullies

The Coffey Geotechnics (2010) study assessed topographic data with a contour interval of 50 m or greater. Smaller landforms, such as incised watercourses and gully networks (or even small hills, escarpments and tors) could be indistinct from the data. Field observations indicated some steeply undulating ground with a relief within 30 m variation in elevation. Construction in areas of steep slopes and gullies should be avoided as these areas could present erosion impacts.

In the Northwest Highlands, the landscape is typically high relief, with steep escarpments, isolated tors and plateau edges. Gully networks frequently dissect steep slopes, and are unlikely to provide good footing support (Coffey Geotechnics, 2010). Whilst this high relief landscape may present constraints to the design and construction of the Project, in particular the location of towers, the Northwest Highlands bioregion already includes the existing 100 km Ergon Energy transmission line between Cloncurry and Mount Isa. The Project will duplicate this plus another 200 km, within the Northwest Highlands, south to Cannington Mine and Phosphate Hill Mine.

The Einasleigh Uplands are also characterised by steeply undulating, rolling “granite country” relief. This should be taken into consideration when locating towers. Consideration should be given to potential future erosion over the lifespan of the project (e.g. construction should not be undertaken in designated buffer zones upstream or upslope of actively eroding gullies or clifflines).

The proposed locations of the majority of project activities (e.g. construction camps and laydown areas) are in low-relief valleys, avoiding potential topographic construction constraints.

Rivers

The corridor selection crosses many rivers of variable size and characteristics. Consideration should be given to design measures to reduce the likelihood of damage to project assets, particularly the transmission line.

The majority of single-thread and braided channels are contained within an incised trench (Coffey Geotechnics, 2010). Single-thread rivers are generally relatively narrow, typically between about 5 m and 200 m wide. Braided rivers (e.g. the Burdekin River and Cape River) may be significantly wider. This type of river is typical of the Northwest Highlands and Einasleigh Uplands. The rivers in these regions can be bedrock controlled and therefore are less likely to erode rapidly (Coffey Geotechnics, 2010). Given that the transmission towers are proposed to be constructed approximately 400-500 m apart, it is not anticipated that these rivers will significantly constrain the project design or functioning.

Braided and anastomosing rivers have similar planforms when viewed from above, with many interconnecting channels, however their characteristics and behaviour are markedly different. The anabranches of braided rivers are more likely to migrate, than those of anastomosing rivers however the Coffey Geotechnics (2010) study found that migration of braided river anabranches in the study area was constrained laterally by trench walls. Each channel of an anastomosing river tends to be incised, but not as deeply as the braided river trenches. Therefore, during flood events, anastomosing channels are more likely to be overtopped than entrenched braided rivers (Coffey Geotechnics, 2010).

Anastomosing channels (e.g. Gilliat River, Fullarton River and Alick Creek) are common in the Gulf Plains and consist of anabranches that behave as separate channels during low flows. During larger floods, flows overtop anabranch banks and broad expanses of floodplain are inundated. It is recommended in these areas that towers are constructed on higher elevation ground where practicable, so that the risk of flood and debris accumulation/damage is reduced.

Some anastomosing rivers are sufficiently broad to require location of towers within the channel belt. These rivers typically have semi-permanent islands. These islands may be subject to infrequent flood inundation, erosion, sediment and debris deposition, and possible dissection by new channels. Historical channel movement should be assessed to identify the location of islands that are likely to remain relatively stable over the lifespan of the project.

Boulders

The Coffey Geotechnics (2010) study identified boulder fields on higher and steeper areas. The boulders can become precarious. In steep terrain, and specifically where resistant rock types (including granite, volcanic rocks or quartzite sandstone) are mapped, and assessment of boulder fields is recommended. Boulders that could represent unacceptable hazards should be identified and removed or treated (broken or supported) to reduce the hazard from boulder rolling.

Landslides and slope instability

The Coffey Geotechnics (2010) study did not find evidence of large-scale slope instability within the study area. However, landslides or cliff falls may occur along the steeper slopes of the study area, particularly in the Northwest Highlands. Towers should be located away from steep slopes, where practicable, to avoid landslide constraints. If this is not possible, it is recommended that a site-specific slope stability assessment is carried out to evaluate the potential degree of constraint.

6.3.4 Soils

Soil types

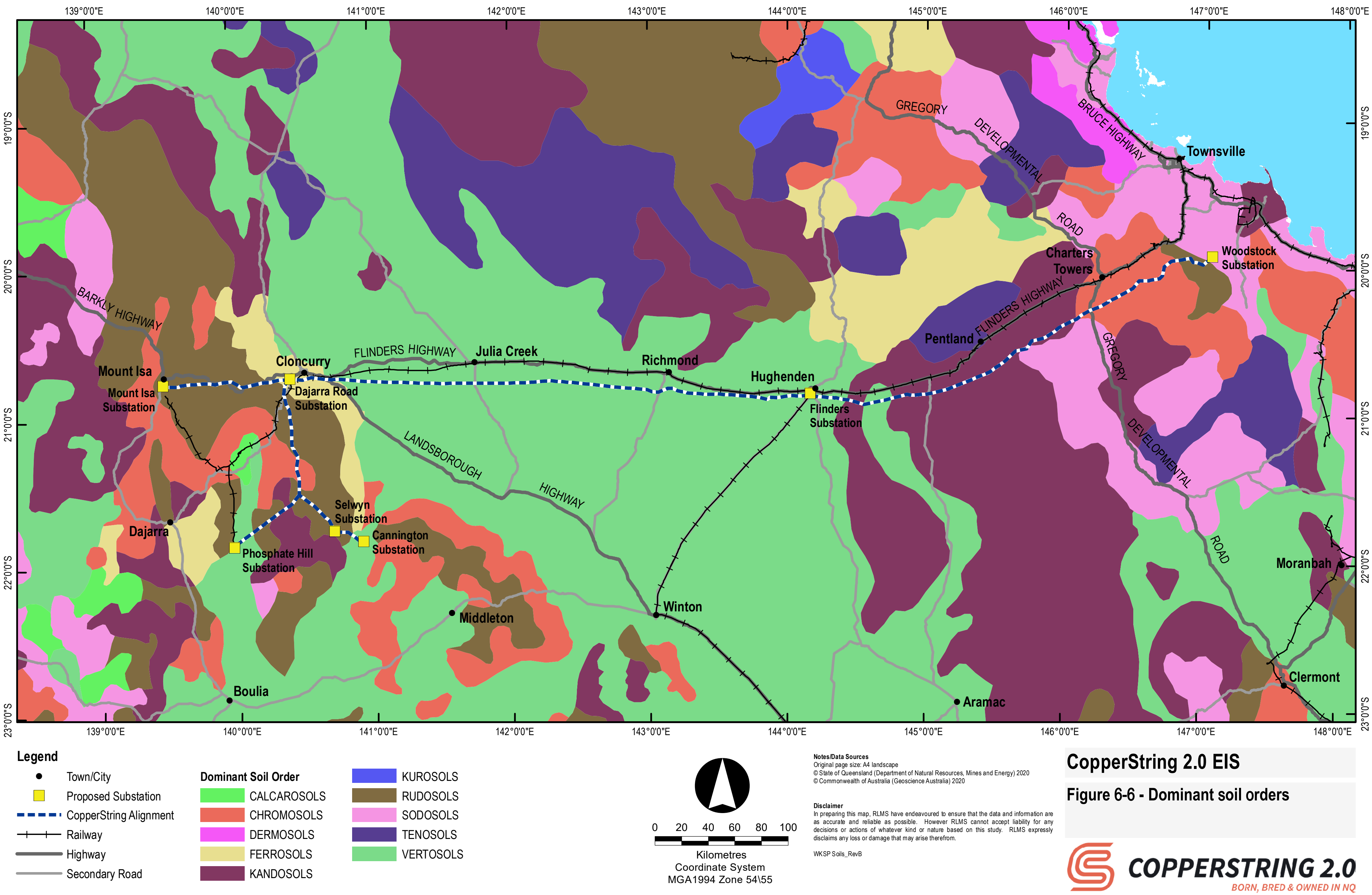
The dominant soil types found in the study area are described in Table 6-3 and are shown in Figure 6-6. While these are the dominant soils mapped by the Australian Soil Resource Information System, a range of soil types are found with varying physical and chemical properties.

Table 6-3 Dominant soil types in study area

ASC Soil type (Isbell, 2016)	Description	Chemical properties	Physical properties
Einasleigh Uplands			
Sodosols	Strong texture contrast (i.e. shows a clear boundary between the sandy to loamy surface soil and the clay subsoil)	Sodic and alkaline	Little to no expansive clays, subsoils are often dispersive with high erosion risk

ASC Soil type (Isbell, 2016)	Description	Chemical properties	Physical properties
Rudosols	Either deep layered alluvial soils (stratic) or shallow stony soils (leptic), associated with watercourses	Low salt levels	Little to no shrink swell clays, not generally dispersive
Chromosols	Strong texture contrast with surface loamy soil and clay subsoil. May be located on flat alluvial areas and on sloping land	Non-sodic, slightly acidic to slightly alkaline clay subsoils Can have high salt levels particularly on lower slopes	Little to no expansive clays, generally not dispersive but rill, sheet and stream bank erosion may occur
Desert Uplands			
Kandosols	Sandy loam in the surface which may increase in clay content with depth to sandy light clay in the subsoil	Neutral to acidic, very low salt levels	Porous and friable, no shrink swell clays, generally not dispersive however likely to produce dust
Sodosols	Strong texture contrast	Sodic and alkaline	Little to no expansive clays, subsoils are often dispersive with high erosion risk
Vertosols	Cracking clay soils of uniform texture	pH is neutral to strongly alkaline, high salt levels particularly on lower slopes	Contain shrink-swell clays, often dispersive subsoils with high erosion risk
Mitchell Grass Downs			
Vertosols	Cracking clay soils	pH is neutral to strongly alkaline, high salt levels particularly on lower slopes	Contain shrink-swell clays, often dispersive subsoils with high erosion risk
Gulf Plains			
Vertosols	Cracking clay soils	pH is neutral to strongly alkaline, high salt levels particularly on lower slopes	Contain shrink-swell clays, often dispersive subsoils with high erosion risk

ASC Soil type (Isbell, 2016)	Description	Chemical properties	Physical properties
Northwest Highlands			
Ferrosols	High in free iron oxide in the subsoil. Lacking texture contrast	High clay content	Stable with strong structure
Rudosols	Either deep layered alluvial soils (stratic) or shallow stony soils (leptic), associated with watercourses	Low salt levels	Little to no shrink swell clays, not generally dispersive
Chromosols	Texture contrast with surface loamy soil and clay subsoil. May be located on flat alluvial areas and on sloping land	Non-sodic, slightly acidic to slightly alkaline clay subsoils Can have high salt levels particularly on lower slopes	Little to no expansive clays, generally not dispersive but rill, sheet and stream bank erosion may occur
Kandosols	Sandy loam in the surface which may increase in clay content with depth to sandy light clay in the subsoil	Neutral to acidic, very low salt levels	Porous and friable, no shrink swell clays, generally not dispersive however likely to produce dust



Notes/Data Sources
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WKSP Soils_RevB

CopperString 2.0 EIS

Figure 6-6 - Dominant soil orders

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BORN, BRED & OWNED IN NQ

Einasleigh Uplands

The Coffey Geotechnics (2010) study identified that parent materials in the Einasleigh Uplands include igneous rocks, volcanic rocks and some metamorphosed sedimentary rocks. Soil types include:

- Weakly developed and skeletal soils on the hills and rises (i.e. Rudosols, Kandosols or Tenosols)
- Red and yellow texture contrast soils on slopes (i.e. Chromosols, Sodosols, or Kurosols)
- Pockets of deep clay soils in alluvial plains (Ferrosols, Vertosols or Dermosols).

Soils with a clayey sand texture commonly occur on decomposed granite in the hills and rises. The underlying decomposed granite was easily broken down, giving a coarse sand texture.

Texture contrast soils were commonly found on metamorphosed sedimentary rocks. Surface soils were generally greyish brown to yellowish brown in colour. Surface horizons had loamy sand textures, and were weakly pedal to massive. Hard setting surfaces and loose surface gravel were common.

Subsoils were described as clay in terms of their texture, with moderate blocky or columnar structure. These soils were highly dispersive and undercutting was seen in many eroded profiles. Subsoils were generally brown to grey in colour and exhibited a high percentage of mottling.

In some areas, subsoils were highly weathered and bleached with prominent concentrated iron compounds. These subsoils were found in eroded areas, where the underlying soil had been exposed. Overlying horizons of these soils had been eroded. However, it is possible that these soils would be classified as Podosols, if horizons remained intact.

Isolated patches of grey cracking clay soils, which have developed on alluvial deposits, are also found in the Einasleigh Uplands.

Soils are generally acidic and sodic. These soils are prone to gully erosion, which can propagate rapidly. Sodic soils typically have a hard-setting surface, which can reduce permeability and accelerate overland flows, thus increasing the likelihood of erosion.

Soils commonly supported eucalypt woodland with an understorey of native grasses.

Desert Uplands and Mitchell Grass Downs

The Desert Uplands and Mitchell Grass Downs bioregions consist of nearly flat to gently undulating plains typified by clay soils. Parent material consists of fine textured alluvium, and calcareous mudstone, siltstone and claystone. The exceptions are areas to the east of the Desert Uplands, which are underlain by basalt typically north of the corridor selection. The major group of these soils in this area are alkaline clays. Soil types in this area are classified as Vertosols.

Soils have a medium acidic surface soil with alkaline subsoils. Soils can have a thin crust of laminated brown fine sand or silt at the surface. In some areas, this silt layer can be relatively thick (greater than 100 mm), with a weak consistency, giving the soils an ashy surface appearance (locally, areas underlain with these soils are known as “ashy downs“).

These heavy textured soils have low permeability and are subject to periodic inundation. Soils have high salt content and are commonly sodic. Swelling clay minerals in the soil create areas of melonhole gilgai and gilgai microrelief. The saline and sodic nature of these soils makes them prone to erosion. Soils can have shallow compact and impermeable surface horizons. When dry, the ashy downs soil can develop a thick horizon of single grained soil. These are easily disturbed and are highly prone to wind erosion. These soils generate large amounts of dust.

Soils in the Desert Uplands that have developed on basalt parent material are mainly black, heavy clays (Vertosols) however, pockets of iron rich clay soils (Ferrosols) also exist. These soils are commonly acidic, and can be stony.

Northwest Highlands

Steep slopes and skeletal soils dominate the Northwest Highlands area. Patches of deeper soils are restricted however, soil depth changes rapidly with changes in lithology and topography.

Soils in the Northwest Highlands can be divided into two main categories based on the landforms on which they have developed. Shallow and skeletal soils occur on the rocky mountain and hill slopes and crests, and in the broken tablelands, while deeper loams and clays occur in small patches on the depositional alluvial plains.

Soils in rocky mountain and hill slopes are frequently stony and lack profile development. Soils is these areas are classified as Rudosols. In the less steep areas, where soil has been able to accumulate, surface soils are loose or massive with a soft consistency. Surface gravel is common.

Soils are moderately well drained with low salt content and low nutrient status. Agriculture on these soils is restricted due to the steep slopes and stony surfaces. Soils are also prone to surface crusting. Soils in the rocky mountains and hill slopes generally carry sparse low trees and spinifex. The tableland areas support some sparse grassland, with bare ground being common.

On the valley floors, patches of clay soils occur. In some areas, these are deep, ferric clay soils (ferrosols). These soils are commonly acidic throughout. On the broader alluvial plains, pockets of heavy textured brown to grey cracking clays prevail. The soils may be gilgaied. Smaller areas of sandy alluvial soils occur on narrow alluvial plains and levees.

Soil erodibility

Soil erodibility in the study area is variable based on the physical and chemical properties of soils. Sodic and dispersive soils found in the Einasleigh Uplands, Desert Uplands, Mitchell Grass Downs and Gulf Plains are highly prone to water erosion. Substantial areas of sheet, rill and gully erosion was identified during field surveys undertaken for the Coffey Geotechnics (2010) investigation.

Gullying is widespread throughout the Einasleigh Uplands. The gullies generally have a depth of one metre or less, due to shallow bedrock. The Coffey Geotechnics (2010) study also observed extensive rill and gully networks radiating from river anabranches in the Desert Uplands, Mitchell Grass Downs and Gulf Plains. Gully and incised creek networks can also be found along the steep sides of plateaux and ridge escarpments in the Northwest Highlands.

Waterlogging is a seasonal problem in the Gulf Plains, Mitchell Grass Downs and Desert Uplands regions, with the majority of rainfall falling in the summer months. The large networks of anastomosing rivers can flow overbank and inundate broad areas.

Soils with fine, loose surface material are prone to wind erosion, particularly if cleared of vegetation or mechanically disturbed. In general, soils of the Ashy Downs are susceptible to wind erosion, due to the prevalence of loamy soils.

Any Project activities that are likely to disturb the ground and/or require vegetation removal have the potential to trigger or exacerbate erosion.

Topsoil resources

Topsoil resources for use in rehabilitation are mainly confined to the surface horizon of soil profiles. Topsoil will be salvaged prior to stripping in areas where large-scale earthworks are planned. Indicative depths of topsoil suitable for use in rehabilitation are outlined below in Table 6-4.

Stripping depths will be variable depending on site-specific condition. Site-specific assessments of soil resources will be conducted prior to large scale soil stripping (such as at substation locations) to ascertain soil quality and quantity.

Table 6-4 Indicative soil resources

<table>
<tr><th colspan="2">Soils</th><th rowspan="2">Indicative stripping depth (m)</th><th rowspan="2">Notes</th></tr>
<tr><th>Factual Key (Northcote, 1979)</th><th>ASC (Isbell, 2016)</th></tr>
<tr><td>Skeletal soils and red and yellow earths</td><td>Rudosols and kandosols</td><td>0</td><td rowspan="2">Skeletal soils have limited available topsoil.</td></tr>
<tr><td>Skeletal soils on ferruginous, mottled pallid zones</td><td>Rudosols and kandosols</td><td>0-0.1</td></tr>
<tr><td>Red and yellow earths</td><td>Kandosols and texture contrast soils</td><td>0.1-0.3</td><td>Suitable for use in rehabilitation. Topsoil depth is variable across the profiles within this group.</td></tr>
<tr><td>Grey and brown soils of heavy texture</td><td>Vertosols and dermosols</td><td>0.1-0.3</td><td>Heavy clay texture makes these soils difficult to handle and difficult for germination of some seeds.</td></tr>
<tr><td>Yellow and red earths, brown soils of light texture</td><td>Tenosols and texture contrast soils</td><td>0.1-0.3</td><td>Suitable to use in rehabilitation. However stripping these soils would expose highly dispersive subsoil. Subsoil stabilisation may be required.</td></tr>
<tr><td>Grey and brown soils of heavy texture</td><td>Vertosols and dermosols</td><td>0.2</td><td rowspan="2">Heavy clay texture makes these soils difficult to handle and difficult for germination of some seeds. Suitable for use in rehabilitation, if</td></tr>
<tr><td>Grey and brown soils of heavy texture</td><td>Vertosols and dermosols</td><td>0.2</td></tr>
</table>

Soils		Indicative stripping depth (m)	Notes
Factual Key (Northcote, 1979)	ASC (Isbell, 2016)		
Mainly black earths	Vertosols and dermosols	0.2	to be reseeded with native grasses.
Skeletal soils, decomposed granites	Rudosols	0-0.1	Skeletal soils have limited available topsoil.
Red and yellow earths and brown soils of light texture	Kandosols and tenosols	0.1-0.3	Suitable to use in rehabilitation however stripping these soils would expose highly dispersive subsoil. Subsoil stabilisation may be required.
Skeletal soils and red and yellow earths	Rudosols and kandosols	0.1-0.3	Topsoils depths is variable across the profiles within this group. Skeletal soils have limited available topsoil.
Red and yellow earths and brown soils of light texture	Kandosols, dermosols and texture contrast soils	0.1-0.3	Suitable for use in rehabilitation. Topsoil depth is variable across the profile within this group.

Acid sulfate soils

Acid sulfate soils are commonly found at elevations below 5 m AHD and sometimes beneath newer soils below elevations of 20 m AHD. Acid sulfate soils are safe when undisturbed but if they are dug up or drained, the pyrite in the soil reacts with oxygen and oxidises. This process turns pyrite into sulfuric acid, which can damage the environment, buildings, roads and other structures (Department of Environment and Science, 2019).

Project activities will occur well above 20 m AHD and it is unlikely that pyrite-forming conditions exist in the corridor selection. In the event of acid sulfate soils or potential acid sulfate soils occurring in the corridor selection, management of the soils should be in accordance with the Acid Sulfate Soil Management Guideline, version 4.0.

Soil constraints

Gilgai and cracking clay soils

Cracking clays, in particular gilgai clays have particular constraints associated with them including uneven ground, differential soil clay composition, soil chemistry, and ground movements due to cracking, shrink/swell and heave.

Gilgai are prone to ground movement and heave, which can result in unstable foundations. Buried services and foundation structures must be buried at depths below the lower limit of ground movement and within a relatively stable subsoil moisture regime.

Sodic and dispersive soils

Within the corridor selection, soils can be sodic and therefore prone to erosion in response to minor disturbances. This is particularly the case in soils formed in the Einasleigh Uplands (Coffey Geotechnics, 2010). Low-lying land is this area is prone to gullying due to the sodic nature of the subsoils.

The sodic, dispersive soils of the study area are prone to subsurface erosion (piping/tunnelling). Dispersive soils become more prone to erosion if they are remoulded, such as landscape re-profiling to create dams or other earthworks. Dispersivity also increases if the ground salinity decreases, e.g. following a rise in the water table (Coffey Geotechnics, 2010).

Salinity

Salinity refers to the concentration of soluble salts in the soil water and can have the following effects on the Project:

- Impacts to rehabilitation attempts in saline soils
- Wind and water erosion in saline soils where vegetation cover has been reduced
- Risk of subsurface erosion where sodium chloride is dispersed in water
- Corrosion of footings and other susceptible subsurface infrastructure.

Erosion

Erosion processes within the study area can be classified into three different types:

- Surface (river, runoff/sheetwash, rainsplash, rilling and gullying)
- Subsurface (piping/tunnelling)
- Wind-blown (aeolian).

Any Project activity involving ground disturbance and/or vegetation removal has the potential to trigger or exacerbate erosion. Eroded material can be redeposited downslope, downstream or down-wind. Both erosion and sedimentation can have a negative impact on Project assets. The impact of an activity will be determined by a combination of the erodibility of the affected materials, as well as the actual process of erosion.

During flooding, flows can spread across these natural broad floodplains. If these flows are concentrated (e.g. through culverts or along access tracks) velocities and water volumes will increase, thereby increasing the likelihood of erosion.

It should be noted that erosional processes are common in the study area and may or may not be exacerbated by the construction of the Project. An understanding of the baseline conditions in terms of erosion should inform site selection and the design of towers, substations and access tracks. Similarly, identification of existing erosion control works and soil conservation plans should inform site selection and be considered in development of the erosion and sediment control plan (ESCP) (refer to Volume 3 Appendix S Concept erosion and sediment control plan). Assessment of baseline conditions of erosion and identification of any existing erosion control works and soil conservation plans will be undertaken by the Construction Contractor during the pre-construction phase of the Project.

Increased sedimentation

Once eroded, sediment is transported downslope/downstream and deposited when flow velocities decrease. In these areas, sedimentation may cause burial of vegetation, and reduce revegetation success.

Gullies, creeks and rivers

Land degradation can result from increased lateral erosion in gullies, creeks and rivers. This can lead to increased deposition of sediment on the floodplains. Erosion along gullies, creeks and rivers may lead to the uprooting of vegetation, resulting in organic debris being caught in infrastructure down gradient.

Soil compaction

Project activities that subject the ground to loading, such as access tracks, laydown areas and facilities, can cause soil compaction. Once compacted, it can be difficult to return the material to its original state. Clay soils on the Mitchell Grass Downs and Gulf Plains section of the Project and the texture contrast soils in the Einasleigh Uplands and Desert Uplands section are susceptible to compaction. Conversely, uncompacted material is prone to erosion (e.g. new spoil heaps which have not settled to an equilibrium consolidation state).

Introduction of preferential pathways for water flow

Project activities that create surface depressions could form preferential paths for runoff (e.g. wheel rutting of access tracks and foundation pads). This is particularly problematic on newly exposed slopes, which could allow acceleration of runoff. Uncontrolled concentration of flow can exacerbate erosion or divert flow from dams and water collection points.

Field observations within the study area (Coffey Geotechnics, 2010) indicated that access tracks do become preferential pathways for overland flow. Along many tracks, surface soils had been eroded, exposing hardpans. These hardpans can reduce subsoil erosion though they are likely to be discontinuous.

Dust

Dust can be generated when surface soils lose their cohesion, exacerbated by surface disturbance, in dry conditions. Project activities including topsoil and vegetation stripping and vehicle traffic are likely to cause dust generation. Once soil loses its structure and turns to dust it is difficult to manage and generally is unsuitable for use in rehabilitation.

6.3.5 Contaminated land

There are no properties within the corridor selection that are listed on the Contaminated Land Register.

17 properties are listed on the Environmental Management Register (a register of properties that have been or are being used for Notifiable Activities).

There are also seven properties that have been identified as having potential unexploded ordnance.

A detailed discussion is included in Volume 2 Chapter 5 Land, and Volume 3 Appendix K Land use and tenure.

6.3.6 Agricultural land

The Queensland Agricultural Land Audit (Department of Agriculture and Fisheries, 2017) identifies land that is important to current and future agricultural production in Queensland. The broad groupings of agricultural land-use categories used in the audit are:

- Broadacre cropping
- Sugarcane
- Annual and perennial horticulture and perennial horticulture
- Grazing (sown and native pastures)
- Forestry (plantation and native)
- Intensive livestock.

The main land use identified in the study area is cattle grazing on natural pastures. The majority of the corridor selection is within the North West agricultural land audit region and involves medium pasture production of 1500 to 3000 kg/ha. The economic importance of the agricultural industry in the study area is discussed in Volume 2 Chapter 16 Economics.

The SPP outlines policies about matters of state interest in land use planning and development, including development that may have an impact on important agricultural areas (Department of Infrastructure, Local Government and Planning, 2017).

The following SPP policies are relevant to the study area and must be integrated into planning and development outcomes:

- Agriculture and agricultural development opportunities are promoted and enhanced in important agricultural areas
- Agricultural Land Classification (ALC) Class A and Class B land is protected for sustainable agricultural use by:
  - Avoiding fragmentation of ALC Class A or Class B land into lot sizes inconsistent with the current or potential use of the land for agriculture
  - Avoiding development that will have an irreversible impact on, or adjacent to, ALC Class A or Class B land
  - Maintaining or enhancing land conditions and the biophysical resources underpinning ALC Class A or Class B land.
- Growth in agricultural production and a strong agriculture industry is facilitated by:
  - Ensuring development on, or adjacent to, the stock route network does not compromise the network's primary use for moving stock on foot, and other uses and values including grazing, environmental, recreational, cultural heritage, and tourism values.

The corridor selection does not traverse any important agricultural areas or priority agricultural areas. The closest important agricultural area is approximately 6.9 km north of the corridor selection near Richmond. This area is unlikely to be impacted by the Project.

The Woodstock Substation and the first approximately eight kilometres of the corridor selection passes through ALC Class A and B areas.

The Renewable Energy Hub section of the corridor selection passes through some areas of ALC Class B, around the flood plains of the Campaspe and Cape Rivers, Warrigal Creek and Moocha Creek, and southeast of Prairie.

The Phosphate Hill Connection also traverses an area of ALC Class B, where it crosses the Burke River.

ALC Class A is cropland suitable for a wide range of crops, whilst ALC Class B is land suitable for a limited range of crops.

The corridor selection crosses a number of stock routes that are discussed in Volume 2, Chapter 5 Land.

The Project will not affect any important agricultural areas or priority agricultural areas.

Grazing on natural pastures will continue as a predominant land use, as landholders will have access to the easement for grazing livestock. The loss of grazing land in areas where towers, substations and other facilities are constructed is minimal when considered in a regional context.

Similarly, the areas mapped as ALC Class A and B will continue to be used for their current agricultural purposes.

6.3.7 Mineral deposits

North Queensland is well known for its economic (and historic exploitation of) mineral reserves. The study area is rich in lead, zinc and copper (predominant in Mount Isa), copper and gold (Cloncurry) and gold (Charters Towers).

The North West Minerals Province is an area that extends from the Northern Territory border in the west to approximately midway between Julia Creek and Richmond in the east. It extends north to the Gulf of Carpentaria and beyond Boulia in the south. The North West Minerals Province contains some of the world's richest deposits of copper, silver and zinc.

The Mount Isa and Cloncurry areas currently support a number of mines including:

- Century Mine
- Capricorn Copper Mine
- Mount Isa Mines
- Ernest Henry Mine
- Eloise Copper Mine
- Mount Dore Mine
- Cannington Mine
- Phosphate Hill Mine
- Osborne Mine.

The economic importance of the mining industry in the study area is discussed in Volume 2 Chapter 16 Economics. Further information about mining and exploration activities can be found in Volume 3 Appendix K Land use and tenure.

6.3.8 Project infrastructure

The Project infrastructure and associated construction activities is discussed in the following sections.

Transmission line easement

The transmission line easement for various parts of the Project is as follows:

- 120 m wide for 342 km over the Renewable Energy Hub and 395 km over the CopperString Core sections, of which only 60 m will be cleared.
- 80 m wide for the 3 km Dajarra Road Connection for Dugald River (full width cleared)
- 60 m wide for all other sections of the corridor selection (full width cleared).

The transmission towers will be constructed on the easement, as will the majority of the access tracks and brake and winch sites.

Transmission towers

Transmission towers will be constructed approximately every 400 to 500 m, depending on the terrain. Each tower will have a temporary disturbance footprint between 600 and 1,100 m^2 and a permanent footprint of between 70 and 150 m^2.

Transmission tower sites will be cleared of vegetation and may require minor benching to prepare the site for foundation installation. On flat or gently sloping sites, preparation may only involve slashing the area or running a blade across the surface. The impacts to geology, landforms and soils are therefore expected to be minimal.

Drawings showing indicative placement of transmission towers are included in Volume 3 Appendix H Tower siting plans.

Access tracks

Access tracks will be 7 m wide, allowing for a 5 m wide road bed with 1 m wing ditches on either side. This is the minimum width to allow the safe movement, including turning, of vehicles and construction equipment. Access tracks will generally only be constructed using a grader to push a thin layer of soil and will not include any earthworks. Depending on terrain, a small proportion of earthworks may be required for access tracks that spur from the main track to access tower sites.

CEV huts

The transmission system includes a fibre optic communications network with the fibre incorporated in optical ground wires. Controlled environment vault (CEV) huts are the main component of optical ground wire repeater stations that are required to boost the optical signal of the transmission line. CEV huts will be constructed outside, but abutting, the easement at intervals of 80 to 120 km.

CEV huts are prefabricated and will be mounted on piers in a fenced area of approximately 15 x 16 m where the CEV hut does not have a solar PV power supply system, or 20 x 30 m if it does. However, the permanent disturbance footprint to maintain fire security will require an area of approximately 60 x 65 m.

Construction of the CEV huts is not expected to have an impact on geology, landforms and soils as the footprint is very small and earthworks are not required. Indicative plans and locations of the CEV huts are included in Volume 3 Appendix I Indicative infrastructure layout and cross-section drawings.

Brake and winch sites

Brake and winch sites are required for tensioning of the transmission line at tower locations. They will consist of a cleared area of 60 m x 250 m, located about 100-200 m from the transmission tower, in line with the direction of pull. Brake and winch sites will be required approximately every 5 km to 10 km and can be contained within the easement if the line is straight at that tower location, or out of the easement where the line bends.

Brake and winch sites are not expected to have an impact on geology, landforms and soils as they will not involve any earthworks.

Substations

Seven new substations will be constructed as part of the Project. The Woodstock Substation will have a total area of approximately 32 ha, while the remaining six substations will have a total area of approximately 25 ha.

These sites will be cleared of vegetation and benched for construction. Foundations for the substation equipment will be excavated and an earth grid will be installed under the entire substation site. Foundations will be one of two main types as follows:

- Bored concrete foundations – will be used where site conditions are favourable for drilling
- Excavated or rock anchor foundations – will be used when ground conditions are not suitable for drilling (e.g. in hard rock).

Indicative plans and locations of the substations are included in Volume 3 Appendix I Indicative infrastructure layout and cross-section drawings.

Laydown areas, construction camps and concrete batch plants

Laydown areas of approximately 250 x 250 m (6.25 ha) are required in each construction zone along the transmission line, and 500 x 500 m (25 ha) for each substation. Each site will have a construction site office, crib rooms, ablutions and workshops. These buildings are likely to be in the form of demountable huts. Laydown areas will generally be located on high ground, near existing roads or tracks, or near rail sidings.

Although a number of work zones will have facilities to accommodate all or some of the construction workforce (e.g. Townsville and Mount Isa), the assembly of temporary construction camps will be required at most construction zones. A 350 person construction camp with full facilities will require approximately 8 ha.

Where existing concrete batch plants are not available or have the capacity to support the Project, new concrete batch plants will be established for the duration of the Project. A concrete batch plant will require an area of approximately 2 ha and comprise the following key components:

- Raw materials receivable and storage areas for sand, aggregate, cement powder, setting retardants and additives
- Plant and equipment for the processing, production and delivery of wet concrete
- Cleaning and waste collection facilities
- Administration and management offices
- Small workshops.

Impacts to geology, landforms and soils is likely to be minimal. For sites that were previously undeveloped, the topsoil will be stripped and stored. The area will be topped with a gravel layer of approximately 150 mm thickness. Following construction, these areas will be returned to their previous land uses as agreed with landholders.

Fly yard (helicopter landing area)

Fly yards may potentially be required along the transmission line route during construction. Each fly yard will have a footprint of 100 x 100 m to allow the safe landing and take-off of helicopters. If helicopters are required for tower transport and assembly the fly yards will be approximately 4 to 6 ha in area and will be sited at locations to optimise the flying time required to reach transmission tower sites.

Fly yards are not anticipated to have an impact on geology, landforms and soils as no earthworks are required.

Helicopter landing areas will be located at each main substation along the transmission line route to allow for maintenance activities carried out with helicopters.

6.3.9 Recommendations

The corridor selection traverses a range of geology, topography and soils. The potential for Project activities to impact adversely on these features stems from the need to excavate and store volumes of rock and soils and from the movement of vehicles and equipment across the site during construction and operations.

The following recommendations are made based on the assessment of the existing environment:

- Design of the Project should minimise river crossings
- Design of the Project should consider placement of transmission towers in relation to watercourses
- Existing access tracks should be used where possible and new tracks kept to a minimum
- Design of the Project should consider placement of transmission towers, substations, construction camps, and laydown areas to suit the geology and topography of the area.

6.4 Impact assessment and mitigation measures

6.4.1 Design response

Design parameters to avoid/minimise impacts to the environmental values of land including soils, subsoils, landforms and associated rural activities and ecological habitats will be focused on:

- Avoiding soil disturbance in high constraint areas
- Design and installation of erosion control measures
- Sampling, selection and design of borrow pits where required
- Avoiding existing erosion control works and soil conservation plans
- Minimising the construction of new access tracks as far as practicable.
- Minimising vegetation clearing

- Locating temporary Project infrastructure, such as construction camps, laydown areas and concrete batch plants near existing towns on existing cleared areas where possible to avoid/minimise area disturbance.
- Design and placement of transmission towers to suit the natural ground profile, minimise earthworks, and minimise interfacing with riparian zones where practicable.
- Design and placement of substations and CEV huts.

High-constraint areas

Watercourse crossings may present a high-constraint particularly during high rainfall periods. Design recommendations included in relation to river constraint during the detailed design of the Project includes:

- Where access tracks are proposed to cross waterways, they will do so perpendicular to the channels to reduce the crossing width
- The corridor selection will avoid running parallel to rivers, creeks or gullies, particularly along outer banks of meander bends. This will reduce the likelihood of damage from lateral erosion
- Final tower placement will avoid siting adjacent to eroding gullies or eroding river systems.

If these design recommendations are implemented, then a negligible impact is likely to occur to waterways.

Steep slopes (>20°) should be considered as high constraint areas. These locations are anticipated to present particular management issues, in particular associated with surface water runoff and resultant soil erosion, if the ground is disturbed (e.g. during earthworks construction). Avoidance of these landforms is to be achieved where detailed design allows. Where avoidance is not practicable, the design will incorporate measures to reduce land degradation through erosion. These are detailed in the following sections.

General erosion control measures

Roads, tracks, fencing and buildings will be placed to avoid disrupting overbank flood paths, where practicable, noting that the Project traverses 185 km of flood plain.

Erodible soils and sensitive reaches of watercourses will be avoided where practicable. A buffer zone will be left around these sensitive areas. The distance required for buffer zones will range between 5-100 m, depending on site-specific conditions such as soil types, slope, erosion rates, and water pathways. A site-specific assessment may be required to determine suitable buffer zone distances.

Hardstand surfaces (e.g. crushed rock) will be placed at laydown/delivery sites, workshop areas and construction camps to manage runoff and to reduce sediment loads.

Erosion control measures will be designed to reduce the sediment load of runoff from substation sites, particularly in areas of sodic soils. Substation sites will include provision for secondary containment ponds to limit the potential for sediment runoff

The construction program is structured so that where possible peak construction activities in areas susceptible to flooding are programmed to occur outside of the wet weather period. In addition, Volume 3 Appendix X Transport impact assessment addresses wet weather aspects associated with the use of unsealed access tracks.

Borrow pits can be used as a source of construction materials during the Project. Where utilised, these pits will be managed as follow:

- Borrow pits will be located away from problem soil areas (e.g. steep slopes, sodic soils)
- If significant quantities of material are required, a management plan will be developed that should include the excavation's design and directing surface water runoff to managed control points; where 5000 t of material (or more) is proposed to be extracted from one location, an application for ERA 16 will be submitted to the Department of Environment and Science
- Pits that expose sodic or saline subsoils will be bunded

Stripping depths will vary depending on site-specific conditions. Site-specific assessment of soil resources at each major site (substation, laydown areas, construction camps, borrow pits etc.) will be conducted prior to large-scale soil stripping, to ascertain soil quality and quantity. For sites of small-scale disturbance, such as tower sites, indicative depths of topsoil suitable for use in rehabilitation are outlined in Table 6-4.

Project-specific stripping and stockpiling guidelines will be formulated, including the nomination of appropriate depths, scheduling, and location of areas to be stripped and stockpile locations

Transmission towers

Site selection for the transmission towers is critical to avoid/minimise potential environmental impacts. The identified design constraints will be considered when locating towers, particularly in high energy river and gully environments.

Substations, laydown/delivery areas and construction camp sites

During the selection process for large work sites and construction camp areas, there will be a preference to utilise already cleared areas. Limited levelling and clearing of sites is preferred to minimise the impact to soils and geology.

6.4.2 Pre-construction

Significant earthworks are not proposed for the Project; however, careful management and handling of soil resources within the study area can greatly reduce the environmental impact of the Project. Effective soil management can reduce erosion, protect watercourses from sediment-laden runoff and improve chances of successful rehabilitation.

Prior to construction, an assessment of impacts to topography, geology and soils will be undertaken by the Construction Contractor in accordance with the Soil Science Guidelines of Australia, Queensland Branch (2015).

An ESCP will be prepared for the construction phase of the Project. The ESCP will include control principles and management techniques to be used as a guide by construction contractors, in accordance with the IECA Best Practice Erosion and Sediment Control (2008) guideline. The ESCP will include onsite drainage, stormwater runoff and treatment (if required), vegetation works (clearing and rehabilitation), site exit and egress points and stockpile management.

Successful implementation of the ESCP will decrease the likelihood of sediment being transported downslope/downstream, thus lowering risk of impact on creeks and rivers downstream. It will also reduce the likelihood of impacts to sensitive receptors through dust generation.

Rehabilitation plans will also be prepared during the design phase of the Project and will be implemented immediately during and following construction to re-establish ground cover.

The following erosion control measures are recommended during all phases of construction, rehabilitation and maintenance phases of the Project.

General erosion control measures

The following mitigation measures, in accordance with the IECA Best Practice Erosion and Sediment Control (2008), will be implemented across the Project to ensure the potential for erosion is limited:

- Disturbance (including clearance of any vegetation) will be restricted to only areas required to construct the required infrastructure and ongoing maintenance requirements in accordance with the relevant standards and legislation. Construction areas for substations and towers will be cleared progressively, with construction activities commencing as soon as is practicable following clearance.
- Roads will be maintained and traffic controlled to the maintained surface as travelling alongside the road to avoid rutted and uneven surfaces results in widening of the roadway.
- Grasses and other ground-cover vegetation will be re-established on bare areas as soon as possible following construction, especially during wetter summer months. This would reduce overland flow velocities, act as silt traps and stabilise the soil surface.

Erosion control measures in highly erodible areas

Specific control measures for areas identified as highly erodible include:

- Erosion control measures, such as the use of erosion matting (e.g. Jute Mesh) or sediment socks (e.g. sand-filled UV-resistant fabric tubes), will be used for earthwork activities.
- Large scale clearing on sodic and dispersive soils will be avoided where possible, especially if reworking is necessary (e.g. for earthworks and backfill).
- Application of soil ameliorants such as gypsum will be considered for sodic soils as these can reduce dispersivity, waterlogging and crusting (IECA, 2008).
- Gullies, once initiated in erodible areas, are difficult to control or ameliorate. Management of aggressively eroding gully networks may require significant engineering structures.

Timing of disturbance

Rainfall and, therefore, soil erosion in the study area is highly seasonal, with a defined and predominant wet season. More than 90% of soil loss occurs during the wetter months between November and April, with 66% occurring during December to February (Prosser et al., 2002, cited in RLMS, 2010).

Many of the soils within the study area are subject to a loss in shear strength with increases in their moisture content. After prolonged or intense rainfall and especially under traffic loads the soil is likely to become weak and possibly slippery for tyred vehicles.

6.4.3 Construction

Impacts will generally be related to construction of access tracks, substations, CEV huts and transmission towers. There is also the potential to uncover fossils during excavations. These impacts are discussed in the following sections.

Access tracks

Access tracks will typically be constructed parallel with the transmission line and within the easement. Vegetation clearing under the transmission line will possibly be necessary to enable construction and maintenance access. Dust generation is likely to be a significant issue in easement management. The following general measures will be implemented to reduce dust levels on the easement and access tracks:

- Revegetation or rehabilitation will be undertaken as soon as possible to reduce the exposure time of bare soil.
- Dust suppression (water spray) will be carried out on exposed soils. As water resources are limited in the study area, dust suppression via dampening will be limited to areas near homesteads and other sensitive receptors.
- Integrity of access tracks will be maintained, with regular grading and possibly dampening with water trucks during intensive construction operations and ongoing maintenance activities.
- Appropriate site vehicle weight and speed restrictions will be implemented, to minimise the adverse impacts that speeding traffic can have on subgrade (soil) performance under vehicle load.

Substations, laydown/delivery areas and construction camp sites

Where large-scale levelling of work sites and temporary camps is required, the sites may be subject to increased erosion. Where areas require stripping and stockpiling of soils (e.g. construction of substations), the management strategies outlined in Table 6-5 should be implemented.

Table 6-5 Strategies for managing soil resources

Prior to soil stripping	During soil stripping and stockpiling	Stockpiled soil awaiting use in rehabilitation works
Carry out a site-specific assessment of topsoil resources in areas of large disturbance to: • Quantify soil resources • Establish best-practice handling techniques • Characterise the suitability of soil resources for rehabilitation works • Formulate project-specific stripping and stockpiling guidelines, including the nomination of appropriate depths, scheduling, and location of areas to be stripped and stockpile locations.	• Exclude vehicular traffic from areas where soils are to be stripped, where practicable • Exclude traffic from soils that are sensitive to structural degradation, where appropriate • Limit vegetation clearance to only the area needed to safely construct the facilities • Use loaders and trucks, rather than scrapers, to reduce soil structure degradation • Selective stockpiling of soils according to soil type (i.e. Topsoil and subsoil to be stored separately) and according to salinity levels • Stockpiling of soils in a manner that does not compromise the long-term viability of the soil resource	• Implement measures to ensure long-term viability of soil resources • Locate stockpiles outside of work areas and ensure stockpiles are clearly marked • Located stockpiles away from watercourses and drainage lines • Stockpile topsoil in thin layers (no more than 3 m high to prevent problems associated with anaerobic conditions) with a layer of mulch • Implement sediment control measures, such as the installation of silt fences on the lower sides of stockpiles to control potential loss of stockpiled soil through erosion prior to vegetative stabilisation.

Transmission towers

The greatest impact in relation to transmission towers is likely to occur during the construction phase. During construction, tower sites may be heavily trafficked, with ground disturbance in construction material laydown areas, footing drill pads, and truck turning areas. The following management practices will be implemented to reduce these impacts:

- Tower sites will be ripped following construction to break up any compacted soil
- As with the temporary construction sites and camps, rehabilitation of tower sites will commence as soon as is practicable following construction.

Fossil disturbance

There is the potential to uncover fossils during excavation or drilling works in the limestone around the Richmond area. The identification of fossils can be challenging in the field, however, construction teams should be made aware of the potential for fossils to exist through the Construction Environmental Management Plan and site inductions.

Should the discovery of fossilised materials be suspected, the following management strategies will be implemented:

- Ground breaking works in the immediate vicinity should be stopped
- A suitability-qualified individual (i.e. palaeontologist) should be engaged to complete an assessment of the significance of the site.

Rehabilitation of associated infrastructure

Following construction and decommissioning of the associated infrastructure components required for the Project's construction, including borrow pits, rehabilitation will be carried out in accordance with the Concept Rehabilitation Plan (refer to Volume 3 Appendix T Concept rehabilitation plan).

Monitoring and maintenance program

As erosion is a natural process, it is likely to occur throughout the life of the Project. A baseline erosion monitoring program will be undertaken in the study area to establish contemporary erosion rates. An erosion monitoring program will be implemented as part of the ESCP and will include:

- Monitoring location and type of erosion
- Determining erosion rates
- Monitoring the effectiveness and integrity of erosion control measures
- Monitoring the quality of runoff water.

Maintenance of defects observed during the monitoring will be routinely carried out by:

- Repair of erosion control structures
- Removal of sediment build-up behind erosion control measures involving damming of water, to maintain their retention capacity
- Reinstatement of eroded soil or landforms
- Relevelling within areas of differential settlement over buried services
- Revegetation of areas where ground coverage is inadequate.

6.4.4 Operation

The impacts to geology, landforms and soils during the operation phase of the Project are minimal and only associated with used of access tracks. Soil compaction and dust generation may be experienced from use of access tracks however access to tracks will be limited to relevant personnel and speed restrictions will be enforced on access tracks.

6.4.5 Summary of potential mitigation and management measures

The primary mitigation and management measures that are proposed to minimise the impacts identified above include:

- Site selection for activities that require earthworks (i.e. Construction of transmission towers, substations, construction camps)

- Development and implementation of a Vegetation Management Plan
- Development and implementation of an ESCP
- Development and implementation of a Rehabilitation Plan.

Table 6-6 provides a summary of mitigation and management measures for potential impacts during all stages of the Project

Table 6-6 Summary of mitigation and management measures

Project activity/impact	Mitigation and Management Measures
Design	
Selection and design of sites that involve ground disturbance – steep slopes	• Steep slopes (>20°) should be avoided where detailed design allows. Where avoidance is not practicable, the design will incorporate measures to reduce erosion impacts
Selection and design of sites that involve ground disturbance – watercourses	• The corridor selection will avoid running parallel to rivers, creeks or gullies, particularly along outer banks of meander bends. • Where access tracks are proposed to cross waterways, they will do so perpendicular to the channels to reduce the crossing width • Final tower placement will avoid siting adjacent to eroding gullies or eroding river systems • Roads, tracks, fencing and buildings will be placed to avoid disrupting overbank flood paths
Selection and design of sites that involve ground disturbance – substation, laydown areas and construction camps	• During the selection process for large work sites and construction camp areas, there will be a preference to utilise already cleared areas • Hardstand surfaces (e.g. crushed rock) will be placed at laydown/delivery sites, workshop areas and construction camps to manage runoff and to reduce sediment loads • Limited levelling and clearing of sites is preferred to minimise the impact to soils and geology • Erosion control measures will be designed to reduce the sediment load of runoff from substation sites, particularly in areas of sodic soils. • Substation sites will include provision for secondary containment ponds to limit the potential for sediment runoff
Selection and design of sites that involve ground disturbance – transmission towers	• Site selection for the towers is critical to avoid/minimise potential environmental impacts. The identified design constraints will be considered when locating towers, particularly in high energy river and gully environments

Project activity/impact	Mitigation and Management Measures
Selection and design of sites that involve ground disturbance - Erodible soils and sensitive reaches of watercourses	• Erodible soils and sensitive reaches of watercourses will be avoided where practicable. A buffer zone will be left around these sensitive areas. • Management of aggressively eroding gully networks may require significant engineering structures.
Selection of borrow pit sites	• Borrow pits will be located away from problem soil areas (e.g. steep slopes, sodic soils) • Pits that expose sodic or saline subsoils will be bunded
Pre-construction	
Planning of all construction activities	• Develop ESCP in accordance with IECA Best Practice Erosion and Sediment Control (2008) guideline • Develop a Vegetation Management Plan, which will include vegetation clearing requirements and/or restrictions • Develop a Rehabilitation Plan relevant to various land uses as well as establishing key rehabilitation actions including topsoil management, sodic soil(s) management, soil compaction, contaminated land management, watercourse crossings, landform management and revegetation and associated monitoring and maintenance actions • Peak construction activities will be scheduled outside of the wet season • The Road Use and Traffic Management Plans will address wet weather aspects associated with the use of unsealed access tracks. • Management plans will be developed for borrow pits if significant quantities of material are required
Construction	
Ground disturbance - general	• Disturbance will be restricted to areas required to construct infrastructure and for ongoing maintenance • Minimise the area of open disturbed ground. The majority of clearing will be to construct access tracks, which will be established as soon as possible to enable access from construction camps to work areas. All other areas requiring clearing (e.g. Substation and tower sites) will be cleared progressively, with construction activities commencing as soon as is practicable following clearance • Areas requiring stripping and stockpiling of soils should follow management strategies outlined in Table 6-5.

Project activity/impact	Mitigation and Management Measures
Ground disturbance - highly erodible areas	• Erosion control measures, such as the use of erosion matting (e.g. Jute Mesh) or sediment socks (e.g. sand-filled UV-resistant fabric tubes), will be used for earthwork activities • Large scale clearing on sodic and dispersive soils will be avoided where possible • Application of soil ameliorants such as gypsum will be considered for sodic soils
Rehabilitation	• Rehabilitation will be carried out in accordance with the Concept Rehabilitation Plan (refer to Volume 3 Appendix T Concept rehabilitation plan) • Construction access tracks that are not required for future maintenance will be rehabilitated to minimise erosion and alteration to the natural ground contours • Tower sites will be ripped following construction to break up any compacted soil • Partial rehabilitation of tower sites will commence as soon as practicable following construction • Grasses and other ground-cover vegetation will be re-established on bare areas (other than access tracks) as soon as possible following construction • Rehabilitation of pits will be carried out as soon as is practicable
Ground disturbance - fossils	• Unexpected finds protocol • Construction teams should be made aware of the potential for fossils to exist • In the event of a fossil find, ground-breaking works in the immediate vicinity should be stopped and a suitability qualified individual (i.e. palaeontologist) should be engaged to assess the site
Construction and use of access tracks	• Watering of access roads near homesteads and sensitive receptors to minimise dust and nuisance air emissions • Access to tracks will be limited to relevant personnel and speed restrictions will be enforced on access tracks • Roads will be maintained and traffic controlled to the maintained surface to avoid rutted and uneven surfaces results in widening of the roadway

Project activity/impact	Mitigation and Management Measures
Operation	
Use of access tracks	• Access to tracks will be limited to relevant personnel and speed restrictions will be enforced on access tracks

Table 6-7 provides a risk rating for all potential impacts both before and after mitigation strategies are implemented.

Table 6-7 Risk rating of potential impacts to topography, geology and soils

Associated Potential Impacts	Unmitigated Risk rating	Mitigated Risk rating
Construction activities		
Sediment run-off	Moderate	Low
Earthworks- excess soil is generated from cut activities	Low	Low
Barriers to rehabilitation (due to loss, degradation or contamination of soil resources)	Moderate	Low
Reduction in the integrity of soil structure and landscapes, and reduced soil quality	Moderate	Low
Loss of topsoil and subsoil resources through erosion	Moderate	Low
Soil compaction from access tracks, laydown areas and facilities	Moderate	Low
Dust impact to sensitive receptors	Low	Low
Fossil disturbance	Low	Low
Gullying and rill erosion could develop overtime	Moderate	Low
Operation activities		
Soil compaction from access tracks	Moderate	Low
Dust impact to sensitive receptors	Low	Low

Residual impacts

Residual impacts that are likely to be caused by the Project and cannot be controlled or avoided include the following short-term impacts during construction:

- Increased dust generation
- Compaction in areas of soft soil – particularly in the Gulf Plains bioregion
- Increased erosion – particularly in the Gulf Plains and Einasleigh Uplands
- Potential disturbance of fossils – particularly in the eastern section of the Gulf Plains within limestone deposits.

The only potential long-term impact likely to occur over the Project life is compaction and erosion of soils along access tracks and easements from ongoing maintenance activities. This is considered minor due to the limited intensity and frequency of maintenance activities.

Despite the variability of ground conditions and impacts, provided the recommended management and mitigation measures are successfully implemented, the residual impacts can be limited to tolerable levels.

6.5 Conclusion

The Project traverses a large linear area with a diverse range of geology, soils and landforms. The corridor selection is divided into five bioregions (with the small section of Brigalow Belt being incorporated into the Einasleigh Uplands) that relate to the underlying geological structure. Higher topography is present in the Northwest Highlands (the Mount Isa Augmentation and Southern Connection sections as well as large parts of the CopperString Core, Cannington Connection and Phosphate Hill Connection sections). Vast tracts of generally flat grasslands characterise the Gulf Plains, Mitchell Grass Downs and Desert Uplands areas that make up the CopperString Core section and the western extent of the Renewable Hub. At the eastern extent of the Renewable Hub section (Einasleigh Uplands), the topography is higher again, where it represents the hills and mountains of the Great Dividing Range.

The geology, soils and landforms in the corridor selection may present constraints to activities such as:

- Sourcing quarry materials
- Providing suitable foundations
- Steep slopes and dissecting gullies
- 62 watercourse crossings (named watercourses identified on Geoscience Australia (2006) 1:250,000 Topographic data)
- 94 major or high risk waterway crossings for waterway barrier works, as defined by the *Fisheries Act 1994*
- Approximately 185 km of floodplain.

Geotechnical investigations and detailed design will be undertaken to address these constraints.

Many soils in the study area are susceptible to varying types of erosion. Impacts to soils can be mitigated through the preparation and implementation of an Erosion and Sediment Control Plan.

The Project is expected to have a negligible impact on the geology and low physical impact on landforms and soils where appropriate mitigation measures are implemented. Commitments identified to manage potential impacts to soils include:

- Develop and implement an erosion and sediment control plan
- Develop and implement a vegetation management plan
- Develop and implement a rehabilitation plan
- Develop and implement an unexpected finds protocol as part of the environmental management plan
- Develop and implement a Road Use and Traffic Management Plans

No cumulative impacts to geology and soils are anticipated as a result of the Project.