APPENDIX Q

DUNGOWAN DAM AND PIPELINE EIS

Lands, Soils and Erosion Assessment

Dungowan Dam and pipeline project

Land, Soils and Erosion Assessment

Prepared for Water Infrastructure NSW

September 2022

Dungowan Dam and pipeline project

Land, Soils and Erosion Assessment

Water Infrastructure NSW

J200042 DUN-EMM-EN-RPT-0014

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Executive Summary

This Land, Soils and Erosion Assessment documents the assessment methods, results and the mitigation and management measures proposed to address impacts of the Dungowan Dam and pipeline project on land and soils. The assessment has considered available mapping and a limited soil sampling program, to characterise the existing environment and identify constraints within, and impacts arising from, the Dungowan Dam and pipeline project. The assessment recommends mitigation measures to reduce the impacts from the project where possible.

ES1 Soil assessment

The soils within the operational footprint were sampled and mapped into two soil mapping units (SMUs), Dermosols (DE) and Dermosols/Rudosols (DE/RU), with little physical difference between the two units. Physically the soils are consistently shallow, particularly on the hillslopes, and coarse fragments are consistent throughout all soil profiles. Chemically the SMUs are benign, with no salinity or dispersion limitations and subsequently are expected to pose minimal erosion hazard. No assessment of fertility was made, though the cations within the soil are generally within recommended limits for plant suitability.

Construction of the project will result in up to 315 ha of soil disturbance in stages for a period of up to six years. The soil disturbance during construction has the potential to result in the following impacts:

- reduce soil stability and increase susceptibility to erosion due to vegetation removal or soil exposure, especially if the subsoil is sodic and dispersive;
- loss or degradation of topsoil material viable for use in rehabilitation;
- introduce constraints into the topsoil material if soil is inadequately managed;
- risk of exposing buried contaminants (pesticides and hydrocarbons); and
- introduction of contaminants into soil material (eg hydrocarbons from construction plant).

Impacts to soils during construction and operation are associated with:

- land disturbance and concentration of flows during the construction phase of the project;
- erosion of the shoreline due to fluctuating water level during the construction and operational phases; and
- erosion downstream of the spillway channel and emergency drawdown pipeline during major flow events.

ES2 Land and soil capability (LSC)

The *Land and Soil Capability Assessment Scheme* (OEH 2012) ('LSC Scheme') assesses the capacity of subject land to support a range of land uses. The LSC Scheme considers the inherent biophysical features of the land and soil, and their associated hazards and limitations, to these land uses. Each hazard is given a rating between 1 (best, highest capability land) and 8 (worst, lowest capability land). The overall LSC class of the land is based on the most limiting feature/hazard.

A field soil survey was completed from 8–9 September 2020 and mapped the project inundation extent into two soil mapping units. These are very similar in nature, being Dermosols, with the only difference being the presence of large coarse fragments resulting in shallow refusal depths and subsequent classification of Rudosols in the DE/RU SMU unit. The physical and chemical characteristics of both SMUs are consistent outside of these factors. The soil chemistry of both SMUs is benign, with no limitations from soil pH, sodicity, salinity or cations.

The SMUs within the inundation extent are consistently LSC class 6–8, due to limitation to the LSC classes of shallow soils and rockiness and water erosion. Of the 20 soil investigation sites, 10 are constrained by water erosion hazard (Class 6 or 7) due to steep slopes and five of the remaining 10 sites are limited by prohibitively shallow and rocky soils (Class 7–8). Generally this means the land and soil capability of the inundation extent is low to extremely low capability land, generally; *very high* (Class 6) *to severe limitations* (Class 8) *for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation* (Class 6) or *incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation* (Class 8). The remaining five sites, all within the DE SMU, are LSC class 4 due to shallow soils and rockiness hazard.

Land capability of areas upstream of the new Dungowan Dam embankment along Dungowan Creek will be impacted during construction and then ultimately inundated when the dam fills and will not be available for agricultural production. However, it is noted that no agricultural enterprises currently exist upstream of the new dam embankment.

While decommissioning of the existing dam will reduce the existing area of inundation, the resulting exposed lands will be too steep and isolated for viable agricultural production.

The land and soil capability of agricultural lands along the pipeline easement are unlikely to change from their current capability, provided appropriate management and mitigation measures are implemented, as recommended in Chapter 7 of this report.

ES3 Erosion risk

Due to the variability of slopes and soil types within the project footprint, the project has been assessed as having a wide-ranging erosion hazard, categorised as very low to very high. Potential on site erosion and sedimentation impacts include but are not limited to:

- erosion of constructed landform such as embankments, roads, power line pads, and stockpiles requiring rework to repair and increased maintenance costs during the construction and operational phases;
- erosion along the pipe trench resulting in costly rework and repair during the construction and operations phases;
- unsafe work conditions due to the presence of gullies, tunnels, mud, uncontrolled water and dust;
- construction downtime and delays due to access restrictions and the time taken to repair and desilt the site;
- decrease in dam capacity and water quality due to deposition of eroded sediment; and
- reputational damage and litigation costs associated with non-compliance and pollution events.

ES4 Management measures

Potential impacts during both construction and operation can be mitigated and managed through appropriate engineering design such as spillway and outlet pipe energy dissipators, and the development and implementation of relevant management plans and sub plans. Recommendations for inclusions within these management plans are provided in Chapter 7 of this report.

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1 Introduction

1.1 The project

The Peel River, part of the Namoi River catchment, provides water for irrigation as well as being the primary water supply for the city of Tamworth. Prompted by the millennium drought, investigations into the future water supply and demand for bulk water were undertaken for the regional city of Tamworth and the Peel Valley water users. The Dungowan Dam and pipeline project (the project) is a critical project to improving long-term water security for the region. The project includes a new dam at Dungowan (new Dungowan Dam) approximately 3.5 km downstream of the existing Dungowan Dam and a new section of pipeline about 32km long between the proposed Dam outlet and the tie in point to an existing pipeline from Dungowan Showground to the Calala Water Treatment Plant (WTP).

In September 2022, the Minister for Planning and Homes declared the project to be Critical State Significant Infrastructure (CSSI) as it is a development that is essential for the State for economic and social reasons. This requires Schedule 5 of the *State Environmental Planning Policy (Planning Systems) 2021* to be updated to reflect the CSSI status of the project. As CSSI, the project is subject to Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), which requires the preparation of an environmental impact statement (EIS) and the approval of the NSW Minister for Planning and Homes.

The EIS has been prepared for the planning approval application for the project. This Land, Soils and Erosion (LSE) assessment has been prepared to support the EIS.

In addition to requiring approval from the NSW Minister for Planning and Homes, the project has been deemed a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and requires approval from the Commonwealth Minister for the Environment. The Minister for the Environment has accredited the NSW planning process for the assessment of the project. Therefore, a single EIS has been prepared to address the requirements set out by the NSW Department of Planning and Environment (DPE) and the Commonwealth Department of Agriculture, Water and Environment.

1.2 Project location

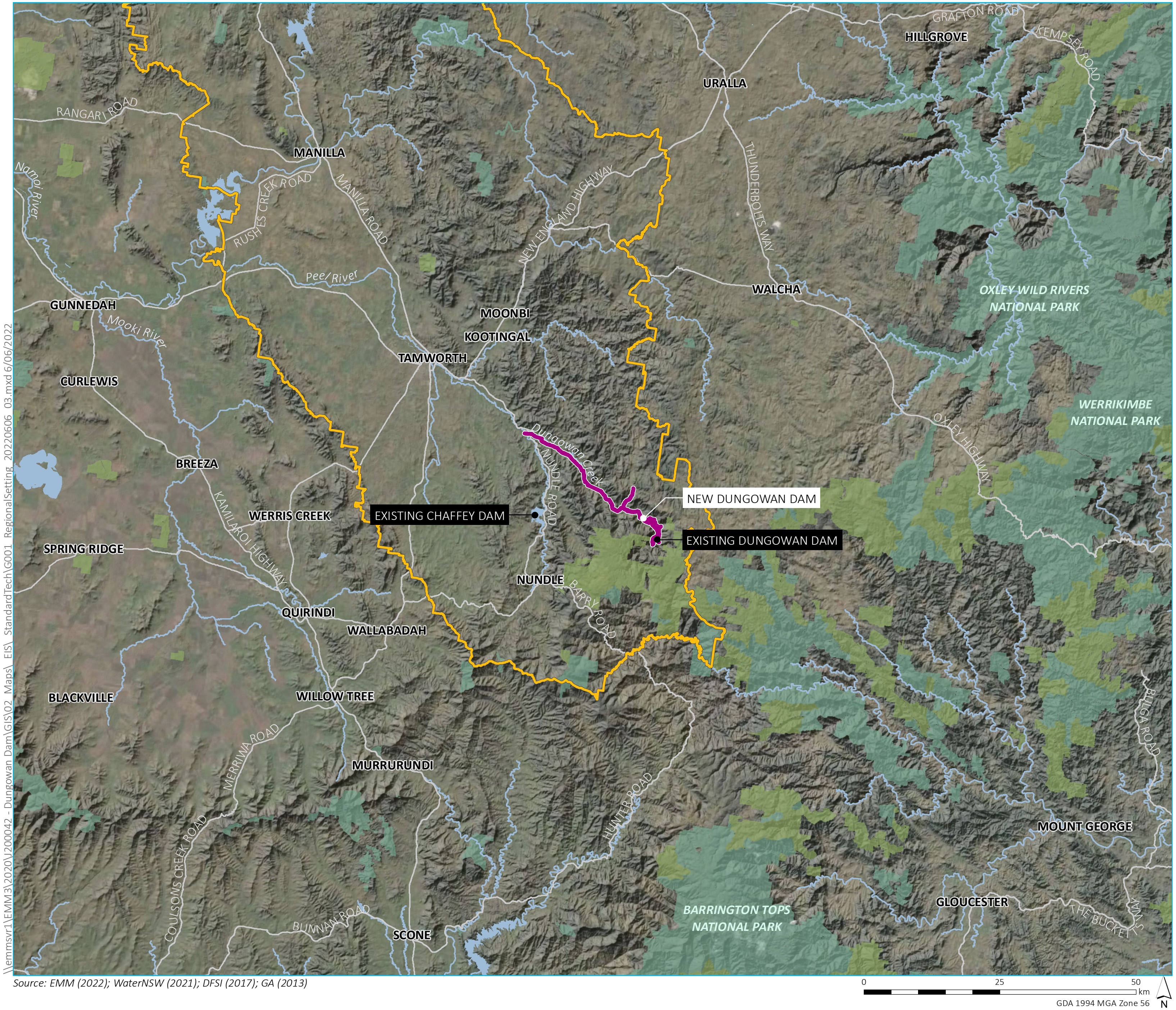
The project is located in the Tamworth Regional local government area (LGA), the New England Tablelands bioregion and part of the New England and North West region of NSW, west of the Great Dividing Range (DPE 2017). The New England and North West region is home to approximately 186,900 people and has a total area of around 99,100 km^2 (ABS 2018).

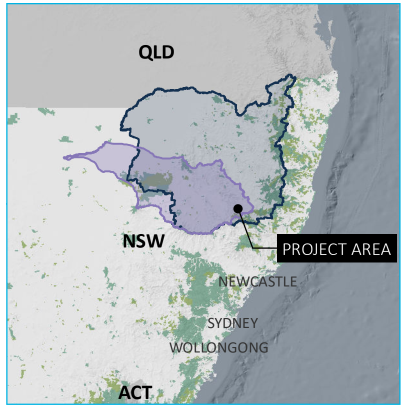
The city of Tamworth is the nearest (and largest) town to the project with over 40,000 residents. Other nearby regional towns include Quirindi (70 km west), Manilla (90 km north-west), Gloucester (90 km south-east), Armidale (100 km north) and Gunnedah (110 km west of the project).

The existing Dungowan Dam is in the Namoi River catchment approximately 50 km south-east of Tamworth in NSW. The Namoi catchment covers 4,700 km^2 and borders the Gwydir and Castlereagh catchments and is bounded by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mount Kaputar to the north.

The existing Dungowan Dam is on Dungowan Creek, which is a tributary of the Peel River. Dungowan Creek is confined by the existing Dungowan Dam, while the Peel River system is regulated by Chaffey Dam, located in the upper catchment near the town of Woolomin, approximately 45 km from Tamworth.

The project's regional setting is shown in Figure 1.1.





KEY
- Project footprint
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest
- Tamworth Regional local government area

INSET KEY
- Namoi River catchment
- New England North West region

Source: EMM (2022); WaterNSW (2021); DFSI (2017); GA (2013)

Regional setting

Dungowan Dam and pipeline project
Figure 1.1

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1.2.1 Project impact areas

In outlining the project, a project footprint has been defined to facilitate the assessment of direct impacts from the project:

- Project footprint: all areas where direct impacts may be experienced during construction and/or operation.

The project footprint has an area of 315 ha and is comprised of the construction and operational footprints, of which there is some overlap:

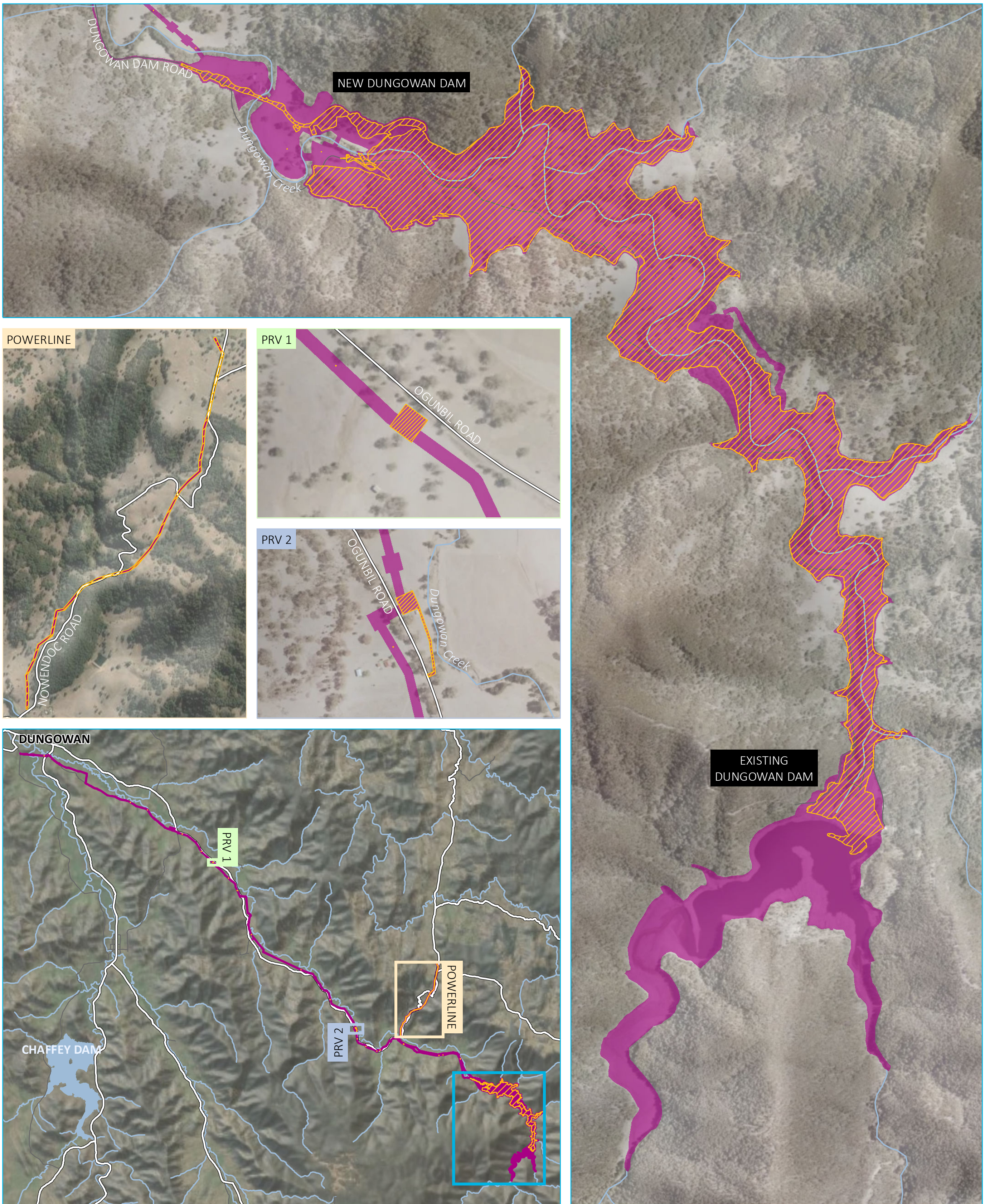
- Construction footprint: areas where vegetation clearing and/or ground disturbance is required for construction of the dam, pipeline, power line and ancillary facilities, including the area needed to decommission and rehabilitate the existing dam.
- Operational footprint: areas where there will be permanent operational elements or easements, including infrastructure needed to operate the new Dungowan Dam and pipeline. The operation footprint includes the inundation area, being the area defined by the proposed full supply level (FSL) for the project.

Additional areas outside the project footprint have also been considered where relevant to the assessment of project impacts and include:

- Upstream flood extent: An area above the FSL to the level of a probable maximum flood (PMF) event that would be inundated for relatively short periods during operation associated with extreme rainfall events.
- Project area: A 10 km buffer around the project footprint defined to allow for assessment of potential indirect impacts.
- Downstream impact area: the area where hydrological changes may occur due to the project. This area is discussed in detail in the Surface Water Assessment (EMM 2022) as well as other technical reports subject to changed flow regimes as a result of the new Dungowan Dam operation. The downstream impact area includes Dungowan Creek and also the Peel River downstream of Chaffey Dam.

1.2.2 Land, Soils and Erosion (LSE) assessment study area

The study area for the LSE assessment is the project construction and operational footprints, which are shown in Figure 1.2.



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Source: EMM (2022); WaterNSW (2021); Metromap (2019); Esri (2019); DFSI (2017); GA (2013)

0 0.5 1 km
GDA 1994 MGA Zone 56
N

KEY

Construction footprint

Operational footprint

Existing environment

Major road

Minor road

Named watercourse

Named waterbody

Project footprint

Dungowan Dam and pipeline project
Figure 1.2

EMM
creating opportunities

1.3 Purpose of this report

This LSE assessment supports the EIS for the project. It documents the assessment methods, results and the mitigation and management measures proposed to address any unavoidable residual impacts to the project land or soils.

The specific objectives of this assessment are to:

- describe the existing environment of land and soils;
- identify land, soil and erosion constraints within, and impacts arising from the project; and
- provide mitigation measures to reduce the impacts from the project wherever possible.

1.3.1 Assessment guidelines and requirements

This LSE assessment has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for the Dungowan Dam and pipeline project, as well as relevant government assessment requirements, guidelines and policies, and in consultation with the responsible government agencies.

The SEARs must be addressed in the EIS. This LSE assessment was undertaken to satisfy the requirements of the project issued SEARs for Land, specifically relating to soils. Table 1.1. lists the matters relevant to this assessment and where they are addressed in this report.

Table 1.1 Relevant SEARs for this assessment

SEARs condition	Requirement	Chapter/Section addressed
27	An assessment of the impact of the project on soils and land capability of the site and surrounds, including: a) stability; b) acid sulphate soils; c) salinity; d) soil erosion and sediment transport; and e) acid drainage from waste rock, overburden, spoil and excavated areas.	a) Chapter 5 of this report b) Section 4.1.6 and Contamination Preliminary Site Investigation (PSI) (Appended to the EIS) c) Section 4.4.2 and Chapter 6 of this report d) Chapters 5 and 6 of this report; Geomorphology assessment contained in the Surface Water Assessment (Appended to the EIS). e) Contamination PSI and Waste Management Assessment (Appended to the EIS)
35	The Proponent must assess the impacts on soil and land resources (including erosion risk or hazard). Particular attention must be given to soil erosion and sediment transport consistent with the practices and principles in the current guidelines.	Chapter 5 and Section 6.2 of this report.

To inform preparation of the SEARs, the DPE invited relevant government agencies to advise on matters to be addressed in the EIS. These matters were considered by the Secretary for DPE when preparing the SEARs.

1.3.2 Other relevant reports

This LSE assessment has been prepared with reference to other technical reports that were compiled as part of the EIS. The other relevant reports referenced in this assessment are listed below:

- Groundwater Assessment (EMM 2022) – Appended to the EIS;
- Land Use and Property Assessment (Tremain Ivey Advisory 2022) – Appended to the EIS;
- Contamination Preliminary Site Investigation (EMM 2022) – Appended to the EIS;
- Waste Management Assessment (EMM 2022) – Appended to the EIS; and
- Surface Water Assessment (EMM 2022) – Appended to the EIS.

2 Description of the project

This chapter provides a summary of the Dungowan Dam and pipeline project. It outlines the permanent infrastructure required to operate the project, as well as the key construction elements and activities required to construct the project. A comprehensive and detailed description of the project is provided as Appendix B1 of the EIS, which has been relied upon for the basis of this technical assessment.

2.1 Project overview

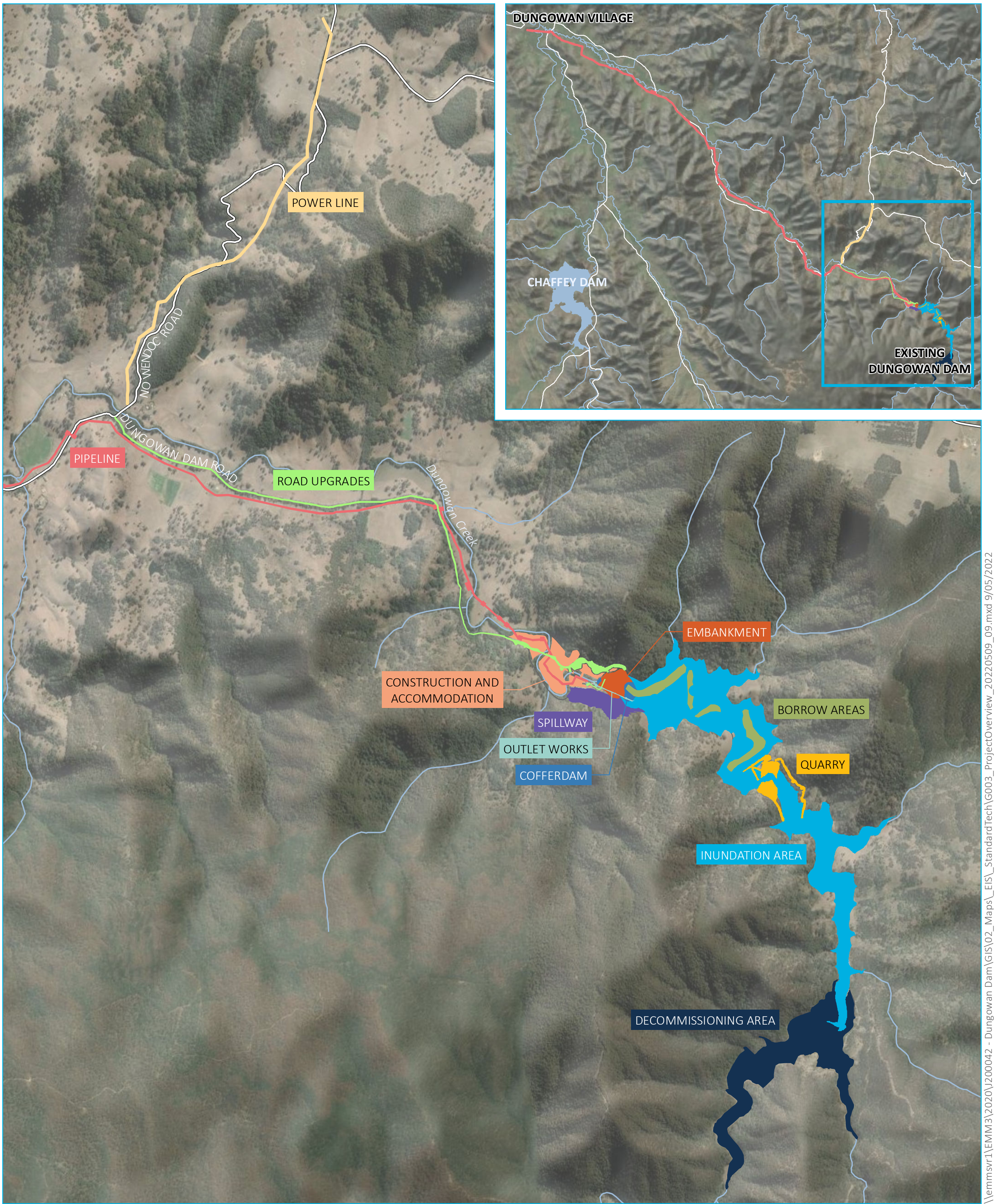
Water Infrastructure NSW proposes to build a new dam at Dungowan (new Dungowan Dam) about 3.5 km downstream of the existing Dungowan Dam and an enlarged delivery pipeline from the new Dungowan Dam outlet to the tie in point to the existing pipeline from Dungowan Showground to the Calala WTP. The existing pipeline from Dungowan Showground to the Calala WTP is not part of the Dungowan Dam and pipeline project. A summary of project elements is provided in Table 2.1. An overview of the project is provided in Figure 2.1.

Table 2.1 Overview of the project

Project element	Summary of the project
New Dungowan Dam infrastructure	Earth and rockfill embankment dam with height of ~58 m and a dam crest length of ~270 m.
	Storage capacity of 22.5 GL at full supply level (FSL) of RL 660.2 m AHD.
	The new Dungowan Dam on Dungowan Creek has a catchment size of 175 km^2 and is part of the Peel Valley and Namoi River catchment.
	Inundation extent (to FSL) of 130 ha (1.3 km^2)
	Spillway to the south of the dam wall including an approach channel, uncontrolled concrete ogee crest, chute and stilling basin. Free standing multiple-level intake tower connected with a bridge to the embankment, diversion tunnel with outlet conduit, valve house and associated pipework and valves.
	A permanent access road over the Dam crest to the valve house for operation and maintenance.
	Water diversion works including a diversion tunnel and temporary pipeline and upstream and downstream cofferdams to facilitate construction of the dam wall embankment.
Pipeline infrastructure	31.6 km of buried high density polyethylene (HDPE) pipe between 710 mm to 900 mm nominal diameter.
	Maximum 71 ML/day from the proposed dam to the junction with the pipeline from Chaffey Dam to the Calala Water Treatment Plant, to replace the existing 22 ML/day pipeline. The pipeline would connect to the valve house on the left abutment of the embankment. Valve infrastructure would include control valves installed in two above ground buildings along the pipeline.
	10 m wide easement for the 31.6 km length of the pipeline. The replacement pipeline extends from the new Dungowan Dam to a connection point with the existing pipeline between Dungowan Showground and Calala WTP.
Ancillary infrastructure and works	Road works to improve existing roads to provide construction access, temporary establishment and use of a construction compound, an accommodation camp, two upstream quarries and four borrow areas within the inundation area.
	A new 4.2 km long 11 kV overhead powerline (including a new easement and access track) connecting to an existing overhead line approximately 6 km north west of the dam. The existing overhead line that extends approximately 13.2 km to the Niangala area would also require minor upgrades, including re-stringing of new overhead wiring and replacement of some poles.
Decommissioning of existing Dungowan Dam	Dewatering of existing dam, removal of existing Dungowan Dam infrastructure and full height breach of the existing Dungowan Dam wall. Rehabilitation of inundation area of existing Dungowan Dam.

Table 2.1 Overview of the project

Project element	Summary of the project
Disturbance	Areas of disturbance have been identified based on the direct impacts of the project. There is some overlap in the areas disturbed during construction and operation, with a resulting total disturbance area proposed for the project of 315 ha (project footprint). Disturbance would occur in a staged manner, with construction requiring disturbance of approximately 315 ha (construction footprint). Following construction and once rehabilitation is completed, there would be a permanent disturbance of approximately 158 ha comprising the inundation area and permanent infrastructure (operational footprint).
Construction	Construction duration of approximately 6 years.
	Construction workforce of approximately 125 workers at construction peak.
Operation	WaterNSW will be responsible for management, operation and general maintenance of the new dam. Tamworth Regional Council will be responsible for the management, operation and general maintenance of the pipeline. Public use and access to the dam would not be permitted and there would be no public facilities available during operation.
	One to two new full time workers plus part time work for existing WaterNSW operations team. Due to the new Dungowan Dam being prioritised over Chaffey Dam for Tamworth's future water supply, the water reserved for town water in Chaffey Dam would increase from 14.3 GL to 30 GL to ensure that water is set aside to meet Tamworth's town water supply water demand in years when rainfall is low.
Design life	100 years for zoned earthen embankment, structural concrete elements of the dam and the pipeline. 15 to 50 years for other non-structural project elements and pavements.
Assessment period (operational)	The assessment end point is when the water system performance reaches a level when an additional water supply option or change to the Water Sharing Plan is required. This has been estimated to be when the mean average annual water demand from Tamworth increases to 11 GL/year.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

0 0.5 1 km
GDA 1994 MGA Zone 56
N

KEY

- Inundation area
- Borrow areas
- Construction and accommodation camp
- Outlet works
- Cofferdams
- Embankment
- Quarries
- Spillway
- Road upgrade
- Decommissioning area
- Power line footprint
- Pipeline construction footprint

Existing environment

- Major road
- Minor road
- Named watercourse
- Named waterbody

Project overview

Dungowan Dam and pipeline project
Figure 2.1

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3 Description of the environment

3.1 Climate

Climate data has been obtained from the Bureau of Meteorology (BoM) Nemingah station, located 20 km northwest of Dungowan, where monitoring commenced in 1959. The project area has a mild temperate climate and is characterised by hot summers and cooler winter months. An overview of the climate statistics is provided in Table 3.1.

Table 3.1 Temperature overview (BoM 55160, Nemingah Station)

Parameter	Range	Month	Unit (°C)
Mean maximum temperature	Highest	January	33.1
	Lowest	July	16.4
Mean minimum temperature	Highest	January	17.8
	Lowest	July	2.2

Rainfall data has been obtained from the Dungowan Ravencroft station (BoM 55181), where monitoring commenced in late 1958. Monthly rainfall is highest in November, December and January, where the mean monthly rainfall is 89 mm. Monthly rainfall is lower between March and September, where the mean monthly rainfall is 51 mm. The annual rainfall average is 763 mm, however droughts are recorded and it is not uncommon to experience less than 10 mm of rainfall in a month, or consecutive months.

3.2 Geology

Surficial geology and its contribution as the parent material is one of the dominant factors on soil formation. The consideration of surficial geology therefore provides an indication of the soil landscapes and soil types present in the area of investigation. The geological units relevant to the project are listed in Table 3.2.

Table 3.2 Geological units

Unit	Code	Age	Description
Quaternary Alluvium	Qa	Quaternary	Quaternary Alluvium, comprising undifferentiated alluvial deposits of sand, silt, clay and gravel
Liverpool Range Beds	Ti	Tertiary	Basalt, dolerite, polymictic conglomerate quartzose sandstone and shale
Walcha Road Adamellite	Paw	Permian	Adamellite
Kilburnie Adamellite	Pak		Adamellite
Mt Ephraime Granite	Pge		Granite
Unnamed serpentinite	Pe		Serpentinite
Tangaratta Formation	C-Dt	Carboniferous – Devonian	Mudstone, feldsoathic argenite
Sandon Association	Csa	Carboniferous - Devonian	Lithic (meta)wake, slate, phyllite, chert, jasper, amphibolite, metabasalt, greywacke, sandstone, siltstone, mudstone and para-conglomerate

Table 3.2 Geological units

Unit	Code	Age	Description
Tamworth Group, Moore Creek Limestone	Dty	Middle to Lower Devonian	Cherty argillite, limestone, greywacke, mudstone
Tamworth Group, Silver Gully Formation	Dts		Rudite, polymictic breccia, arenite, limestone
Tamworth Group, Wogarda Argillite	Dtw		Cherty argillite, greywacke

Notes: Source: *Tamworth 1:250,000 Geology Map*

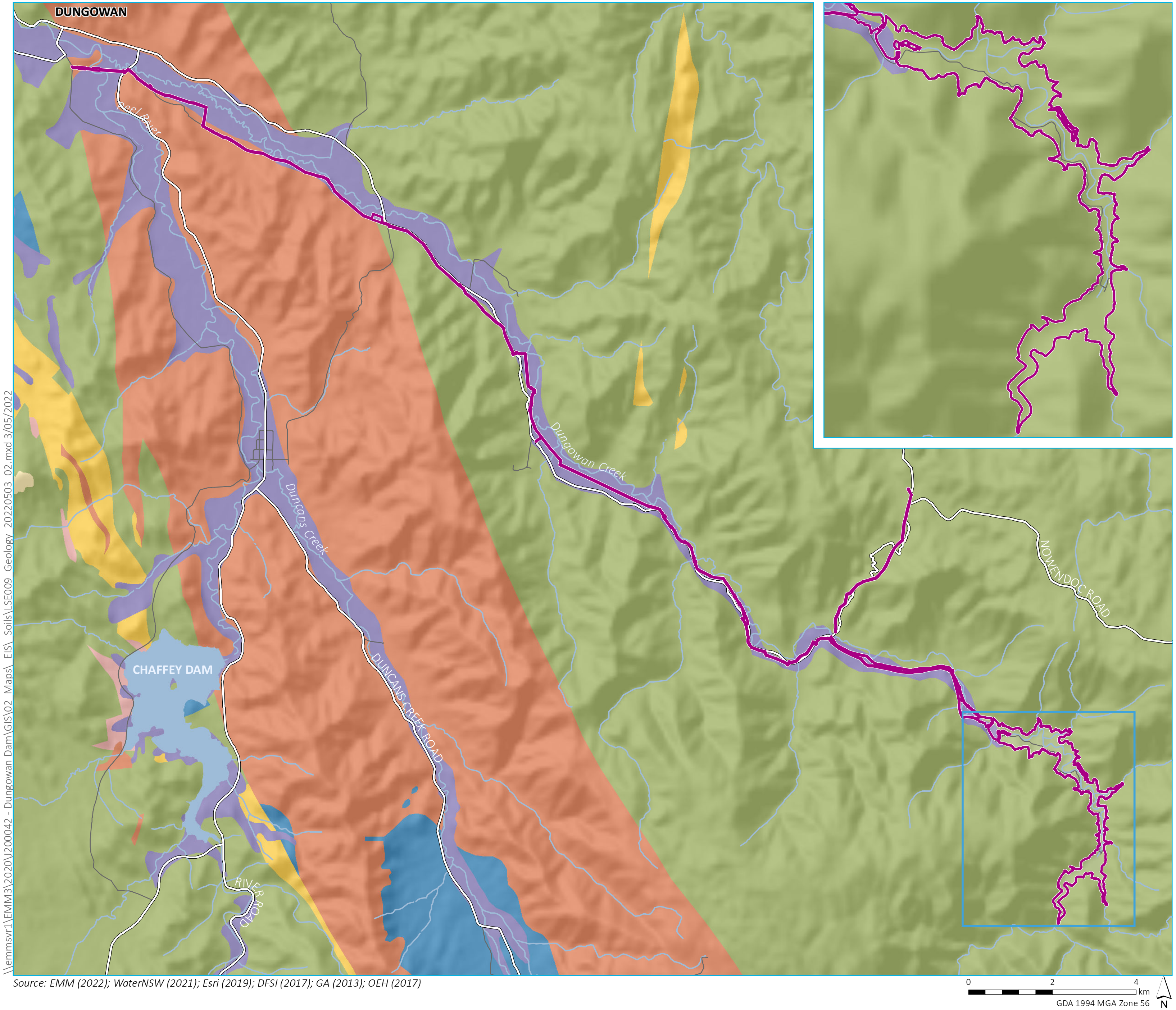
Reference to the *1:250,000 Geological Sheet for Tamworth* (Offenberg 1971) shows at the project area there is Quaternary Alluvium overlying Devonian to Ordovician Age Woolomin Group (previously Woolomin Beds). The Woolomin Group are part of the Woolomin Texas Block, which occurs between the Peel Manning Fault in the west and the Demon Fault in the east (Robinson and Phillips 2015). The Woolomin Texas Block is an anticlinal subdivision of the New England Fold Belt (GHD 2020). The NSW Geological Survey released an updated seamless compilation of the area's geology in May 2020 (Colquhoun et al 2020). This included some nomenclature changes and boundary refinements. The more recent seamless digital data shows the geological unit underlying the new Dungowan Dam site is referred to as the Sandon Association, comprising lithic (meta)wake, slate, phyllite, chert, jasper, amphibolite, metabasalt, greywacke, sandstone, siltstone, mudstone and para-conglomerate of Devonian to Carboniferous age. Herein the more recent terminology will be adopted, with use of the Sandon Association geological unit.

The geological outcrop is mapped in Figure 3.1. The Sandon Association has a large extent while alluvium deposits are restricted to valley floors. The Quaternary Alluvium, in an undifferentiated unit, comprises clay, silt, sand and gravel and can be up to 5 m in thickness (EMM 2022, SMEC 2020).

SMEC (2020) undertook a geotechnical investigation program and observed predominately silicified mudstone, chert, metamudstone and phyllite in boreholes drilled through the Sandon Association within the project footprint. In other parts of the Woolomin Texas Block carboniferous marine sediments and volcanics are noted (Osborne et at 1998). GHD (2017) ground truthed the geology and observed metasedimentary sequences of phyllite and metasiltstone with minor slate, chert and quartz in the Sandon Association.

To the north and west there are intrusions of Permian aged Kilburnie Adamellite, Walcha Road Adamellite and Mt Ephraime Granite and unnamed serpentinite. To the south are the Tertiary Liverpool Range Beds, comprising extrusive igneous flows of basalt as well as intrusive igneous dolerite, and polymictic conglomerate quartzose sandstone and shale. To the east is the Carboniferous-Devonian Tangaratta Formation and the Middle to Lower Devonian Tamworth Group, which has undergone significant folding and fracturing in a north-south orientation. This is part of the Tamworth Synclinorial Zone and comprises a series of mapped faults (including the Peel Fault, Spring Creek Fault, Baldwin Fault) that separates the folded sequences of the Tamworth Group from the older Woolomin Texas Block.

GHD (2017) undertook a literature review of the Dungowan Creek area, focusing on geotechnical reports commissioned for the existing dam. A review of all data indicates the thickness of the weathered rock ranges from 0–5 m, with an average thickness of 2.4 m. SMEC (2020a) report the thickness of the weathered rock in the valley floor is between 3.1–6.3 m. The alluvium, present only in valley floors, ranged in thickness from 1.2–4.6 m, with an average thickness of 2.6 m. Alluvium was not continuous and was only observed in 'pockets'. The thicker sections of weathered rock were also encountered in valley floors, with fresh rock often outcropping on steep slopes. There were also observations of fill from the original dam foundation excavations.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); OEH (2017)

KEY

Project footprint

Existing environment

Major road

Minor road

Named watercourse

Named waterbody

Geology 250k

Cambrian

Devonian

Permian

Quaternary

Ordovician

Silurian

Tertiary

Project area geology and structure

Dungowan Dam and pipeline project
Land, soils and erosion assessment
Figure 3.1

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3.3 Topography

The study area topography is defined by Dungowan Creek and associated narrow alluvial terraces and alluvial plains confined between relatively narrow sloping hills (SMEC 2020). The alluvial terraces extent approximately 4.6 km upstream and two (2) km downstream of the new Dungowan Dam embankment. The width of the terraces is variable, typically between 20 m to 100 m, with a width of 50 m at the new Dungowan Dam site.

Elevation at the site ranges between 430 and 480 m Australian Height Datum (AHD) at the western end of the pipeline, to 560 to 700 m AHD at the eastern end in proximity to the existing dam, where the site exhibits significant valley confinement with peaks up to 1,050 m AHD within 1 km of the site. The new Dungowan Dam crest is situated at 672 m AHD with a toe level of 610 m AHD. The existing Dungowan Dam has a crest level of 689 m AHD and a toe level of 655 m AHD. All elevations are approximate. The local project topography is shown in Figure 3.2.

3.4 Surface water

The project footprint is located within the Namoi catchment and the Upper Peel River sub-catchment. Dungowan Creek is a tributary of the Peel River. Dungowan Creek is regulated by the existing Dungowan Dam and pipeline, while the Peel River system is regulated by Chaffey Dam, which is in the upper catchment near the town of Woolomin, approximately 45 km from Tamworth.

The Peel River supplies water for irrigation, stock and domestic, as well as Tamworth's town water supply and industrial water needs. Chaffey Dam, which was completed in 1979 and augmented in 2016, has a total storage capacity of approximately 100 GL. The Chaffey Dam storage is a shared resource servicing both the water supply needs of Tamworth and agricultural production in the area. Tamworth water supply is supplemented by Dungowan Dam, which is owned and operated by Tamworth Regional Council. The existing Dungowan Dam has a capacity of approximately 6 GL.

From a water management perspective, the Peel Valley catchment is managed and operated independently of the regulated Namoi River catchment water sources. However, water allocations within the catchment are still subject to the provisions of the Murray-Darling Basin Plan (MDBP), including the Sustainable Diversion Limits (SDLs). Water allocations within the Peel Valley are controlled in accordance with the requirements of the *Water Sharing Plan for the Namoi and Peel Unregulated Rivers Water Sources 2012*) and the *Peel Regulated River Water Source* 2010 (which is extended to 2022).

3.5 Groundwater

There are two groundwater systems in the project footprint, one associated with the Quaternary alluvium and the other associated with the Ordovician fractured rock (NOW 2010). The local alluvial system overlies the fractured rock and is limited to unconsolidated deposits associated with the rivers and floodplains. The regional fractured rock systems form the valley slopes, the hills and ranges and cover most of the catchment. There is the potential for perched groundwater in the weathered rock where present.

These groundwater systems are managed under the *Water Sharing Plan (WSP) for the NSW Murray Darling Basin Fracture Rock Groundwater Sources* 2020, New England Fold Belt Murray Darling Basin Groundwater Source and the *WSP for the Namoi and Peel Unregulated River Water Sources* 2012, Upper Peel River Tributaries Water Sources, Dungowan River Management Zone.

The Peel Alluvium comprises the alluvial groundwater adjacent to the regulated and unregulated rivers in the Peel Valley, including Dungowan River (NOW 2010). The alluvial groundwater system is a shallow unconfined system comprising unconsolidated cobble, gravel, sand, silt and clayey sediments. Further upgradient in the Peel Valley the alluvium comprises coarser sediments in thick deposits (ie greater than 15 m) which form productive aquifers. However, the extent of the mapped alluvium within the project footprint is relatively thinner compared to the Lower Peel River catchment. Alluvial groundwater is assumed to be hydraulically connected to surface water in Dungowan Creek (NOW 2010) (Water Resources 1992).

The fractured rock is likely to have very low primary porosity with groundwater flow occurring within secondary porosity features such as fractures or along contact boundaries between different rock lithologies. The hydraulic conductivity and groundwater storage within these secondary porosity features is typically very low, making it an ideal surrounding rock for water impoundment.

Recharge to the fractured rock and upper reaches of the valley alluvial aquifers is generally considered to be via rainfall on the upper slopes, ridgelines and hilltops of the landscapes where the rock sub-crops or outcrops. Infiltration at rock outcrop is reported to be 4% of annual rainfall (NOW 2010). Discharge points are likely to comprise of natural locations such as springs, spring fed dams, lower slopes and the relatively lower lying areas.

3.6 Soils

A detailed assessment of the soil landscapes and soil types present on the site, based on available desktop information and field soil survey and mapping, is presented in Chapter 4.

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); OEH (2017); Esri (2019)

Project local topography

Dungowan Dam and pipeline project
Land, soils and erosion assessment
Figure 3.2

4 Soil assessment

The soil assessment comprised the following:

- a desktop review of existing information and the current state of the environment within the project footprint (Section 4.1);
- a field soil survey to validate and inform the soil types present within the project footprint (Section 4.2); and
- determination of the soil mapping units (SMUs) present in the operational footprint of the project and their key physical and chemical characteristics (Section 4.3 and 4.4).

The soil assessment provides key information used in the erosion hazard assessment (Chapter 5).

4.1 Desktop review

Existing information on soils and soil environments was sourced from the following regional mapping published by government departments:

- Australian soil classification (ASC) soil type map of NSW (OEH 2017a).
- Great soil group soil type mapping of NSW (OEH 2017b).
- Hydrological soil group mapping (OEH 2017c).
- Inherent soil fertility mapping (OEH 2017d).
- Land and soil capability classes mapping (OEH 2017e).
- NSW soil and land information system (SALIS) (DPIE 2020) accessed through eSPADE (DPIE 2020).

The relevant information from the above documentation for the project has been summarised and presented in sections 4.1.1–4.1.6 below.

4.1.1 Australian Soil Classification

The ASC scheme (Isbell 2016) is a multi-category scheme with soil classes defined based on diagnostic horizons and their arrangement in vertical sequence as seen in an exposed soil profile.

With reference to the NSW Soil and Land Information (SALIS) System (DPIE 2015–2020) through the 'eSPADE' Soil Profile Database (Version 2.1, DPIE 2020), the soil types shown in regional soil mapping are presented in Table 4.1.

The soils of the operational footprint are Dermosols, Chromosols, Rudosols and Tenosols. The soil types along the pipeline include Dermosols, Chromosols, Rudosols and Tenosols and some minor instances of Ferrosols. Sodosols are in proximity to the western end of the pipeline project footprint, though are not intersected by the project footprint, and are included due to their potential erosion risk.

The ASC soil map for the project footprint (from OEH 2017a) is presented in Figure 4.1.

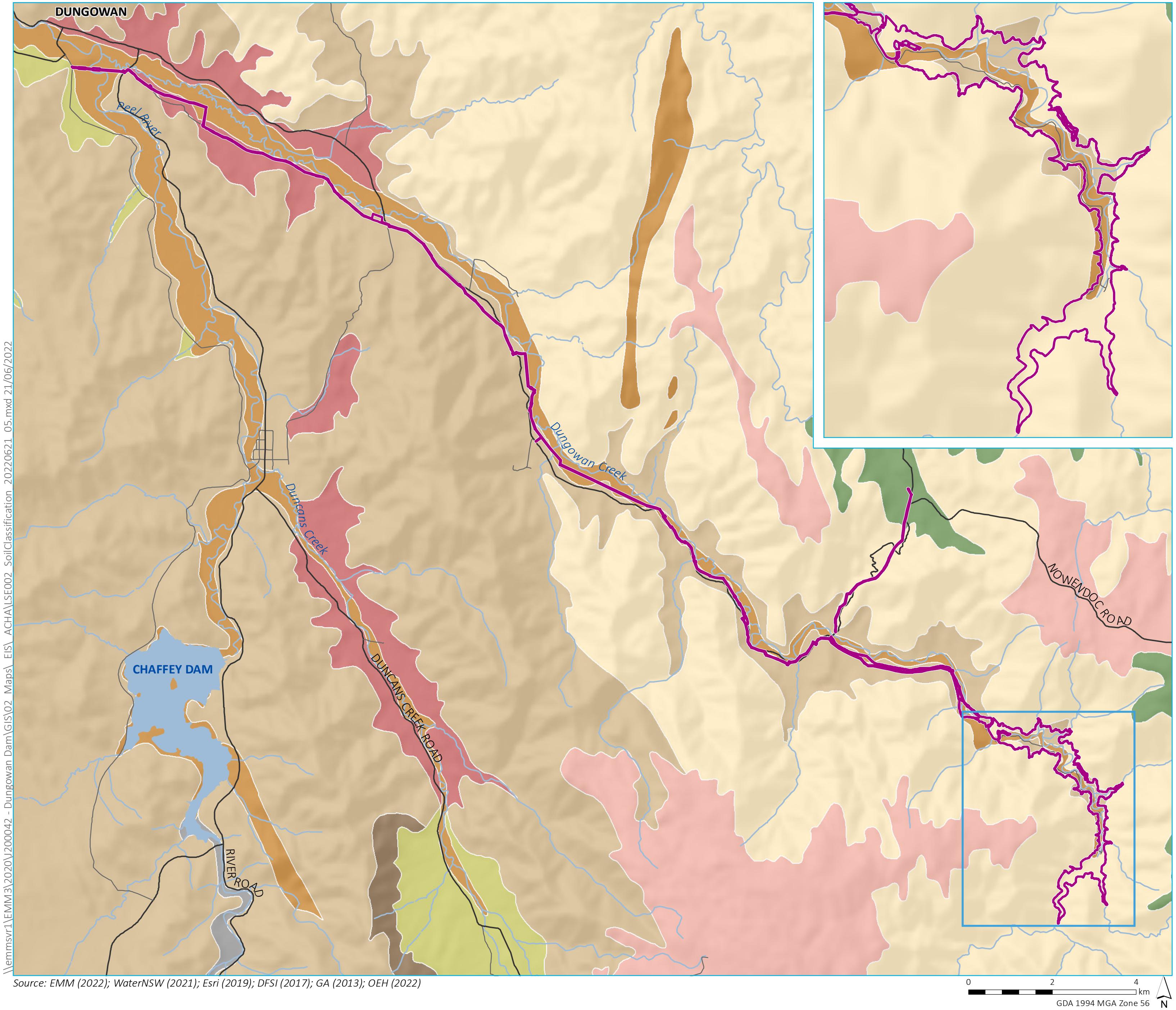
Table 4.1 Summary of regional ASC soil mapping

Soil Type	ASC description[1]	Agricultural potential [2]
Dermosols	• Soils with structured B2 horizons and lacking strong texture contrast between A and B horizons. • Soils other than Vertosols, Hydrosols, Calcarosols and Ferrosols which: – have B2 horizons with structure more developed than weak[3] throughout the major part of the horizon; and – do not have *clear or abrupt textural B horizons*. • This is a soil order known for its diversity but does bring together a range of soil with important properties in common.	• Generally high agricultural potential, subject to the variability of the soil order. • Good structure, moderate to high chemical fertility and water-holding capacity. • Can be susceptible to soil acidification and soil structural decline.
Chromosols	• Soils with strong texture contrast between A horizons and B horizons where the latter are not strongly acid and are not sodic. • Upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) is not strongly acid and is not sodic.	• Generally moderate agricultural potential with moderate chemical fertility and water holding capacity. • Can be susceptible to soil acidification and soil structural decline. • These soils are among the most widespread soils used for agriculture in Australia, particularly those with red subsoils.
Rudosols	• Soils with negligible pedological development apart from minimal development of an A horizon or presence of less than 10% of a B horizon in fissures of the parent material or saprolite. • Typically, young soils where soil forming factors have had little time to pedologically modify parent rock or sediments.	• Most have low or very low agricultural potential. • Typically, thin, rocky and/or sandy with low chemical fertility. • Alluvial soils can often have high agricultural potential.
Tenosols	• Soils with generally only weak pedologic organisation apart from A horizons. • Typically, very sandy with the surface soils often naturally acidic.	• Generally low or very low agricultural potential. • Typically, very sandy with low chemical fertility, water holding capacity and structure. • Alluvial soils are often deep, fertile and have high agricultural potential.
Kurosols	• Soils with strong texture contrast between A and *strongly acid B horizons*. • Soils other than Hydrosols with: • with a *clear or abrupt textural B horizon* and in which the major part of the upper 0.2 m of the B2t horizon (or the major part of the entire B2t horizon if it is less than 0.2 m thick) is *strongly acid.*	• Generally low agricultural potential. • High acidity, low chemical fertility, generally low water holding capacity. • Frequent sodic conditions.
Ferrosols	• Soils with B2 horizons which are high in free iron oxide, and which lack strong texture contrast between A and B horizons. • Soils other than Vertosols, Hydrosols and Calcarosols which: – Have B2 horizons in which the major part has a free iron oxide content greater than 5% Fe in the fine earth fraction (<2 mm); and – do not have *clear or abrupt textural B horizons* or a B2 horizon in which at least 0.3 m has *vertic properties.*	• Generally high agricultural potential. • Good structure, moderate to high chemical fertility and water-holding capacity. • High rainfall equivalents may suffer from soil acidification and nutrient leaching. • May be subject to structural decline after repeated cultivation.

Table 4.1 Summary of regional ASC soil mapping

Soil Type	ASC description[1]	Agricultural potential [2]
Sodosols	• Soils with strong texture contrast between A horizons and sodic B horizons which are not strongly acid. • Upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) is sodic and not strongly acid.	• Typically have very low agricultural potential with high sodicity leading to high erodibility, poor structure and low permeability. • Subsoils are often dispersive and prone to gully and tunnel erosion. • Often hard- setting when dry and prone to crust formation. • Low to moderate chemical fertility and can be associated with soil salinity.

1 per Isbell (2016)
2 per Gray and Murphy (2002)
3 It is common experience that pedologists are inclined to use the phrase 'weak to moderate' when they are in doubt as to the grade of structure. If such a designation is used it will result in the soil being classed as a Dermosol.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); OEH (2022)

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KEY
Project footprint
Major road
Minor road
Named watercourse
Named waterbody
Australian soil classification - order level
Chromosols
Dermosols
Ferrosols
Kurosols
Kurosols (natric)
Rudosols
Sodosols
Tenosols
Vertosols

Australian soil classification

Dungowan Dam and pipeline project
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Figure 4.1

EMM
creating opportunities

4.1.2 Great Soil Groups

Great soil groups (GSG) is a soil classification system developed by Stace et al. (1968) based on the description of soil properties such as colour, texture, structure, drainage, lime, iron, organic matter and salt accumulation, as well as on theories of soil formation. The GSG classification has since been superseded by the ASC and commonly GSG soils have been converted to their ASC equivalent in many mapping systems.

Historic soil mapping identified from NSW government mapping (OEH 2017b) for the project footprint are displayed in Table 4.2 with their corresponding ASC equivalents and associated component of the project footprint.

Table 4.2 Regional soil mapping - GSG mapping

GSG	ASC equivalent	Project area
Red brown earths (RBE)	Chromosols	Dam
Chernozems (CH)	Dermosols	Dam
Lithosols (L)	Rudosols and Tenosols	Dam and powerline
Non-calcic brown soils (NKB)	Chromosols	Pipeline
Euchrozems (E)	Ferrosols	Pipeline
Solodic soils (SC)	Sodosols	Pipeline
Soloths (SH)	Kurosols (natric)	Powerline

4.1.3 Hydrologic soil group

The hydrologic soil groups (OEH 2017c) present in the project footprint are Groups B, C and D, defined as:

- **Group B**: soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission. In the project footprint the Group B hydrologic soil groups correspond to the Dermosols, Ferrosols, Rudosols and Tenosol soil types.

- **Group C**: soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission. In the project footprint the Group C hydrologic soil groups correspond to the Chromosol soil types.

- **Group D:** soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission. In the project footprint the Group D hydrologic soil groups correspond to the Sodosol soil types.

4.1.4 Inherent soil fertility

Inherent soil fertility is used as a general indication of a soil's capacity to retain and release nutrients and soil water for use by vegetation and is a function of the interrelationship between physical, chemical and biological components in the soil. The inherent fertility is derived using a relative classification based on the great soil group (GSG) classes.

Per the eSPADE database (DPIE 2020) the soils of the project footprint are mapped with variable inherent soil fertility, ranging from 'low' to 'high' (Table 4.3).

Table 4.3 Inherent soil fertility

Inherent soil fertility	ASC	Description[1]
High	Dermosols	Soils with high fertility that generally only require treatment with chemical fertilisers after several years of cultivation.
Moderately high	Ferrosols	Soils with a high level of fertility in their virgin state, but this fertility is significantly reduced after only a few years of cultivation.
Moderate	Chromosols	Soils with low to moderate fertilities that usually require fertiliser and/or have some physical restrictions for arable use.
Moderately low	Sodosols and Vertosols	Soils with low fertilities that, generally, will only support vegetation suited to grazing with large inputs of fertiliser required to improve the soils and make them suitable for arable purposes.
Low	Rudosols and Tenosols	Soils which, due to their poor physical and/or chemical status, only support limited plant growth. The maximum agricultural use of these soils is sparse grazing.

1 per Charman (1978)

4.1.5 Land and soil capability classes (agricultural potential)

The land and soil capability assessment scheme (OEH 2012) ('LSC scheme') uses 'LSC classes' that distinguish between the inherent physical capacity of the land to sustain a range of land uses (and management practices) in the long term without leading to degradation of soil, land, air and water resources.

With reference to the eSPADE database (DPIE 2020) and OEH (2017e) the project footprint is mapped at the state scale as LSC Classes 2, 3, 5 and 7, which represents land with a range of capability, from land with 'slight limitations', capable of a wide variety of land uses (LSC class 2 and 3), to 'high to severe limitations' to cropping (LSC class 5 and 7) (Table 4.4).

Modelled regional LSC mapping from eSPADE (DPIE 2020) is presented in Figure 4.2.

Table 4.4 Land and soil classifications mapped for the project area

LSC Class [1]	Description
Class 2 – Very high capability land	• Land has slight limitations. • Land is capable of most land uses and land management practices, including intensive cropping with cultivation. • Limitations can be managed by readily available, easily implemented management practices.
Class 3 – High capability land	• Land has moderate limitations for high-impact land uses. • Land is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. • Careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.

Table 4.4 Land and soil classifications mapped for the project area

LSC Class [1]	Description
Class 5 – Moderate-low capability land	• Land has high limitations for high-impact land uses. • Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. • The limitations need to be carefully managed to prevent long-term degradation.
Class 7 – Very low capability land	• Land has severe limitations that restrict most land uses and generally cannot be overcome. • On-site and off-site impacts of land management practices can be extremely severe if limitations are not managed. • There should be minimal disturbance of native vegetation.

1. As per OEH (2012)

4.1.6 Acid sulfate soils

There are no acid sulfate soils (ASS) mapped in the project footprint, as per the Guidelines for the *Use of Acid Sulfate Soil Risk Maps* (DLWC 1998) and based on ASS mapping in the eSPADE system (DPIE 2020). Acid sulfate soils are typically found in coastal areas, which does not apply to the project footprint, though they can occur in conducive alluvial environments and such can be present in inland waterways, and thus may be present in the project footprint.

A detailed assessment of ASS is presented in the Contamination Preliminary Site Investigation (PSI) report (EMM 2022). The Contamination PSI details that there is a provisional classification of low and extremely low probability of occurrence of Potential ASS (PASS), generally within the upper 1 m in wet/riparian areas of the site and notes that the existing Dungowan Dam area has been mapped as a high probability of occurrence of ASS. The report recommends further investigations be undertaken as part of the detailed design to further evaluate identified low-medium risks associated with the presence of PASS to ensure appropriate controls can be implemented if disturbed by project construction activities.

4.1.7 Desktop review summary

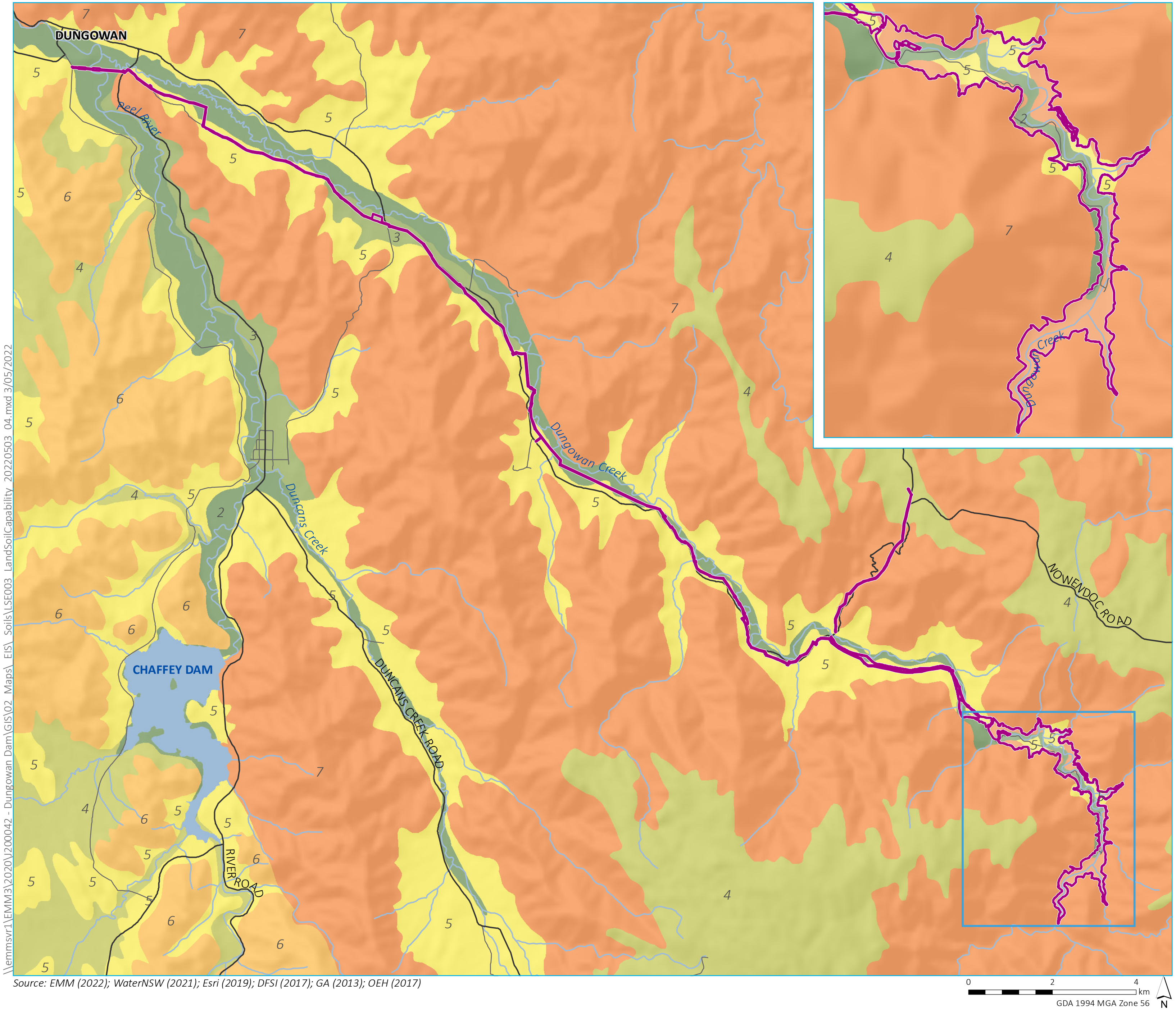
A summary of the available land and soil mapping available from eSPADE (DPIE 2020) characteristics and their associations is displayed in Table 4.5.

Table 4.5 Regional soil mapping summary

GSG	ASC	Hydrological soil group	Inherent soil fertility	Land and soil capability class	Project area
Red brown earths (RBE)	Chromosols	C	Moderate	5	Dam, pipeline
Chernozems (CH)	Dermosols	B	High	2	Dam, pipeline
Lithosols (L)	Rudosols and Tenosols	B	Low	7	Dam, pipeline, powerline
Non-calcic brown soils (NKB)	Chromosols	C	Moderate	7	Pipeline
Euchrozems (E)	Ferrosols	B	Moderately high	5	Pipeline
Solodic soils (SC)	Sodosols	D	Moderately low	5	Pipeline

Table 4.5 Regional soil mapping summary

GSG	ASC	Hydrological soil group	Inherent soil fertility	Land and soil capability class	Project area
Soloths (SH)	Kurosols	D	Moderately low	4	Powerline



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); OEH (2017)

KEY

- Project footprint
- Major road
- Minor road
- Named watercourse
- Named waterbody
- Waterbody

Land and soil capability

- 2
- 3
- 4
- 5
- 6
- 7

Modelled land and soil capability

Dungowan Dam and pipeline project
Land, soils and erosion assessment
Figure 4.2

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\\emmsvr1\EMM3\2020\200042 - Dungowan Dam\GIS\02_Maps_EIS_Soils\LSE003_LandSoilCapability_20220503_04.mxd 3/05/2022

4.2 Soils field survey

A field soil survey was completed from 8–9 September 2020 to examine the soil and landform properties of the operational footprint, with samples obtained for laboratory analysis. The survey was conducted with due regard for the following guidelines:

- Australian Soil and Land Survey Field Handbook (NCST 2009).
- Australian Soil and Land Survey: Guidelines for surveying soil and land resource (McKenzie et al. 2008).
- The Australian Soil Classification (Isbell 2016).

The sampling program (site selection and intensity) and field and laboratory analyses undertaken are described in Section 4.2.1.

4.2.1 Sample site selection and density

Site investigations focused on surveying the proposed infrastructure areas with the required intensity according to McKenzie et al. (2008).

The surveyed area encompasses approximately 130 ha. A total of 20 soil sites were investigated within the project inundation extent, achieving a site intensity of 1 site per 7 ha, satisfying a survey scale of 1:25,000, which per McKenzie et al. (2008) is considered a 'moderately high (detailed)' survey intensity with an objective of moderately intensive uses at 'field' level and detailed project planning.

The rationale for the location of the soil investigation sites was based on the desktop assessment detailed in Section 4.1. The investigation sites were distributed according to variations in the available desktop ASC mapping (OEH 2017a), elevation, landform and geology. The aim was to provide at least one detailed site description for each combination of these factors to assess their influence on soil distribution across the site area.

The soil investigation site locations are detailed below in Table 4.6 and shown alongside the soil mapping units in Figure 4.3.

Table 4.6 Soil investigation sites

Site ID	Coordinates [1]	
	X (Easting)	Y (Northing)
EMM01	344158	6526122
TP100	342378	6528381
TP18	343763	6527035
TP28	343618	6527371
TP37	343368	6527702
TP38	343426	6527705
TP52	343211	6528119
TP91	342535	6528756
TP94	343770	6527557
TP23	343832	6527285

Table 4.6 Soil investigation sites

Site ID	Coordinates [1]	
	X (Easting)	Y (Northing)
TP31	343390	6527736
TP56	342881	6528298
TP72	342754	6528541
TP78	342462	6528567
TP84	343024	6528707
TP88	341884	6528547
TP89	341831	6528546
TP90	342177	6528457
TP95	343403	6527390
TP97	342909	6527927

[1] Based on GDA94 MGA Zone 56

4.2.2 Field methodology

i Profile description

Soil site descriptions were undertaken in accordance with the *Australian Soil Survey and Land Survey Field Handbook, 3rd Edition* (NCST 2009) and classified using *The Australian Soil Classification* (Isbell 2016). Soil site descriptions include a soil profile description, site observation and photographs taken of the soil profile and landscape at each location. These profile descriptions are included in Annexure A.

Site observations include descriptions of:

- landform (including slope and morphology);
- geology;
- surface characteristics (eg gilgai and rockiness); and
- vegetation.

Soil profile descriptions include (where applicable) details of:

- horizon depths and designation;
- soil surface condition (crusting, cracking, self-mulching);
- boundary distinctness;
- field texture (ribboning technique as per NCST 2009);
- colour (hue and chroma using the Munsell colour chart);

- mottles;
- coarse fragments (visual assessment of shape, size and distribution);
- structure and pedality;
- segregations;
- hydrology (profile drainage and permeability); and
- field tests (eg pH, electrical conductivity).

ii Photographs

Photographs of the excavated soil profiles were taken, along with photos of the surrounding landscape of the site. These photographs are included in Annexure A.

4.2.3 Soil samples

Table 4.7 summarised the soil sampling activities undertaken.

Table 4.7 Soil sampling activities

Activity	Description
Soil core locations (sites)	Sampling locations were recorded with either: • a Garmin etrex 20 handheld Global Positioning System (GPS) unit with an accuracy of generally +/-4 m; or • ArcCollector GPS location software used on a mobile phone. Where neither of the above are possible the estimated position coordinates are retrieved from online mapping georeferencing.
Soil coring	The observation method in this survey utilised the existing test pits excavated for the cultural heritage assessment within the project area. Where pre-excavated pits or exposures were not available, hand auguring was undertaken with the use of a 75 millimetres (mm) Jarret auger or a shovel and crowbar where required. Soil cores were extended to a maximum of 1.2 m below ground level (BGL).
Abandonment	Where hand augured, soil cores were backfilled to the existing natural ground level using soil retrieved during soil coring.
Decontamination	Prior to commencing each soil core, bulk soil material was removed from the auger head.
Soil logging	Soil characteristics were described and profiles classified in accordance with the *Australian Soil and Land Survey Field Handbook* (NCST 2009) and the *Australian Soil Classification* (Isbell 2002) respectively. In addition to soil descriptions, the associated landscape features, including terrain, land use, areas of degradation, slopes and vegetation were recorded and photographed.
Soil sampling	Soil samples, approximately 500 g in volume, were obtained directly from the auger at nominal depths of 0–0.1 m, 0.2–0.3 m, 0.5–0.6 m, 0.8–0.9 m and 1.1–1.2 m, depending on sample site depth. These depths sometimes varied to accommodate horizon boundaries. Discrete soil samples were collected and placed into resealable plastic bags for dispatch to the laboratory.
Labelling	Sample bags were labelled with the sample site number and depth. For instance, a sample collected at site TWD 01 at a depth of 0–10 cm BGL was labelled as follows: TWD 01, 0-10 cm.
Dispatch	Samples were stored out of direct sunlight and transported by road for analysis at East West EnviroAg Pty Ltd (Tamworth, NSW).

4.2.4 Laboratory analysis

A National Association of Testing Authorities (NATA) accredited laboratory, East West Enviro Ag Pty Ltd (NATA accreditation 12360 and 15708), was used to ensure that laboratory testing was undertaken using scientifically correct methods. The following chemical analysis was performed on the submitted soil samples:

- pH (water & $CaCl_2$);
- electrical conductivity (EC);
- saturated electrical conductivity (ECe);
- chloride (Cl-) (1:5);
- exchangeable cations: calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K);
- effective cation exchange capacity (CEC); and
- particle size analysis (PSA) (sand/silt/clay calculated from texture).

Detailed laboratory results are provided in Erosion and sedimentation. Interpretation of the laboratory analysis results is based predominantly on guidelines provided in *Soil Chemical Methods* (Rayment and Lyons 2011), and *Interpreting soil test results – what do all the numbers mean?* (Hazelton & Murphy 2016). Interpretation of chemical analysis results is primarily limited to assessment of the salinity and sodicity of the soils (Section 4.4).

4.3 Soil mapping units

The soils were mapped into two SMUs across the operational footprint of the project, reflecting variations in soil type, geology and landform. These SMUs and the corresponding ASCs (after Isbell 2016) are summarised in Table 4.8 and presented in Figure 4.3. Descriptions of the physical and chemical characteristics of the SMUs is provided in sections 4.3.1, 4.3.2 and 4.4. Of the two SMUs, one is a *simple* SMU, with one predominant soil type present, whilst the other SMU is *complex* due to there being two or more soil types present within this unit that cannot be separated at the surveyed mapping scale.

Soil mapping across the operational footprint of the project was extrapolated according to the results of the surveyed areas. It is important to note that boundaries between soil units are based on field observations at an intensity of one site per seven hectares, and desktop digital aerial photographs / LiDAR DEM interpretation. Boundaries between soil units can be abrupt (within 10 m) or diffuse (>50 m) or somewhere in between. Owing to the natural variability between soil types, boundaries and landforms, the confidence levels of the mapped soil units decreases with distance from the originally proposed and surveyed sites. Any conclusions or interpretations of the data collected from this survey can only serve as an indication of the environmental condition of the site at the time of the investigation.

Table 4.8 Soil mapping units

Soil mapping unit	ASC	SMU Class	Sites
DE	Dermosol	Simple	EMM01, TP18, TP28, TP37, TP38, TP52, TP91, TP94, TP97, TP100
DE/RU	Dermosol/ Rudosol	Complex	TP23, TP31, TP56, TP72, TP78, TP84, TP88, TP89, TP90, TP95

The two soil mapping units are very similar in nature, being Dermosols, with the only difference being the presence of large coarse fragments resulting in shallow refusal depths and subsequent classification of Rudosols in the DE/RU SMU unit. The physical and characteristics of both SMUs are consistent outside of these factors.

4.3.1 Dermosols

The DE unit was found on the Quaternary alluvium (Qa) geological unit, associated with the flat alluvial terraces and moderately inclined lower hillslopes found in proximity to Dungowan Creek in the project footprint. This unit is common in areas extensively to completely cleared for grazing and pasture. Where remnant (un-cleared) vegetation is present this unit is associated with Belah (*Casuarina* cristata), Capertee Stringybark (*Eucalyptus cannonii*), and other Eucalypts (*Eucalyptus spp.*).

i Physical characteristics

The DE unit consists of soft to hardsetting surface, with black to dark brown, weakly to moderately structured topsoils with textures of sandy loams to clay loams, predominantly silty clay loams. The topsoil depths range from 5–30 cm deep, predominantly 20 cm deep. Many coarse fragments of angular platy shale and gravel are present on the soil surface and through the topsoil. The soils have predominantly gradational boundaries to subsoils of brown to dark brown, moderately to strongly structured clay loams to light clays with occasional silty or sandy textures. Many to abundant coarse fragments of angular platy shale, gravel and cobble are common through the subsoil, generally increasing in abundance with depth. The soil profiles are shallow, usually around 60 cm deep, with parent material being encountered as shallow as 40 cm BGL.

Table 4.9 SMU typical physical characteristics - DE

Depths (BGL)	Horizon	Colour	Mottles	Field texture	Coarse fragments	Structure	Boundary
0 – 20 cm	A1 - topsoil	Black to dark brown	None	Silty clay loam	Many angular platy medium to large pebbles of shale	Weak to strong polyhedral	Gradual
20 – 60 cm	B2 – subsoil	Brown to dark brown	None	Clay loam to light clay	Many to abundant angular platy medium pebbles to cobble of shale	Moderate to strong polyhedral	Gradual
60 cm +	B/C – parent material						

4.3.2 Dermosols/Rudosols

The DE/RU unit was associated with the moderately to steeply sloping hillslopes and crests of low hills of the Sandon Association (Csa) geological unit, in the project footprint. This unit is predominantly in a natural, uncleared state with occasional limited clearing of the Eucalypt (*Eucalyptus spp.*) vegetation.

i Physical characteristics

The DE/RU unit consists of soft to hardsetting surface with, weakly to moderately structured topsoils with textures of sandy loams to clay loams, with occasional silty textures. The topsoil depths are extremely shallow, predominantly 10 cm deep. Many to abundant coarse fragments of angular platy, medium cobble to stones of shale are present on the soil surface and through the topsoil.

Table 4.10 SMU typical physical characteristics – DE/RU

Depths (BGL)	Horizon	Colour	Mottles	Field texture	Coarse fragments	Structure	Boundary
0 – 10 cm	A1 - topsoil	Black to dark brown	None	Silty clay loam	Many to abundant angular platy medium pebbles to cobbles of shale	Weak to moderate polyhedral	Gradual
10 cm +	Refusal on cobbles						

4.4 Chemical characteristics

The similar nature of the soil material between the two soil mapping units is reflected in the chemical characteristics of both SMUs. There is no discernible difference between the chemical characteristics of the two SMUs. Detailed chemical characteristics are provided in the following sections.

4.4.1 Soil pH

Soil pH is a measure of soil acidity and alkalinity that gives an indication of the activity of hydrogen ions and hydroxyl ions in a water solution. Soil pH characterises the chemical environment of the soil and can indicate the suitability of soils for certain uses and possible limitations that may be present.

Soil pH is consistent through the soil profiles and across the project footprint. All but one pH (pH of 5.95) is between 6 and 7, which would be classified as slightly acidic (pH of 6.1–6.5) or neutral (pH of 6.5–7.3). Of the 17 samples subject to chemical analysis one soil sample is moderately acidic, 9 are slightly acidic and 8 are neutral according to the ratings for soil pH from Bruce & Rayment (1982). The pH results are within the range most suitable for plant growth (Hazelton & Murphy 2016).

4.4.2 Salinity

Soil salinity refers to the levels of accumulated water-soluble salts, predominantly of sodium, calcium and magnesium in the form of chlorides, sulfates or carbonates. These can severely affect plant growth and soil erosion potential.

i Electrical conductivity results

The electrical conductivity (EC) has been rated according to the values of Rayment & Lyons (2011) which considers the influence of soil texture (primarily clay percentage) on salinity and subsequent plant sensitivities to refine the ratings of electrical conductivity. The EC ratings are displayed by soil sites and SMUs in Table 4.11.

Table 4.11 EC ratings[1]

SMU	DE							DE/RU	
Depth (m)	**EMM01**	**TP18**	**TP37**	**TP52**	**TP91**	**TP97**	**TP100**	**TP31**	**TP90**
0–0.1	L	VL	VL		VL	L	VL	VL	VL
0.2–0.3		VL	VL			VL	VL		
0.3–0.4	VL								

Table 4.11 EC ratings[1]

SMU	DE							DE/RU	
Depth (m)	EMM01	TP18	TP37	TP52	TP91	TP97	TP100	TP31	TP90
0.4–0.5		VL	VL						
0.5–0.6				VL	VL		VL		

1. As per Shaw (1999) detailed in Rayment & Lyons (2011) and Hazelton & Murphy (2016).

As shown in Table 4.11, the EC ratings across both SMUs are predominantly very low (VL) with two low (L) instances in the topsoils of EMM01 and TP97. Very low ratings are suitable for plants sensitive to salinity, with no plant response to this salinity level. Low levels are suitable for plants which are moderately sensitive to salinity (Shaw 1999).

ii Saturated electrical conductivity results

Conventionally, a soil is classed as saline when it has an ECe value of greater than 4 dS/m (Hazelton & Murphy 2016). The ECe results for the analysed soils are displayed in Table 4.12.

Table 4.12 ECe ratings[1]

SMU	DE							DE/RU	
Depth (m)	EMM01	TP18	TP37	TP52	TP91	TP97	TP100	TP31	TP90
0–0.1	NS	NS	NS		NS	NS	NS	NS	NS
0.2–0.3		NS	NS			NS	NS		
0.3–0.4	NS								
0.4–0.5		NS	NS						
0.5–0.6				NS	NS		NS		

2. As per Hazelton & Murphy (2016).

The soils across the project footprint, in both SMUs were classed on non-saline (NS), where salinity influence on plants is noted to be mostly negligible (Hazelton & Murphy 2016).

iii Chlorine results

Chlorine is the most commonly occurring water-soluble anion in Australian soils and is essential for plant growth, however at excessive levels it can become detrimental to plant growth. Dryland salinity in Australia currently affects more than 5 million hectares of soil. General values of water-soluble chlorine are given in Rayment and Bruce (1984) and the analysed project soil chlorine levels are all rated as ‘very low’ (<100 mg/kg Cl), with a maximum chlorine level of 15.4 mg/kg.

4.4.3 Sodicity

- Soil sodicity is the amount of exchangeable sodium cations in a soil and is an indicator of potential hazards associated with soil structural decline and subsequent erosion. Sodic soils can have limitations including:
- severe surface crusting;

- low infiltration and hydraulic conductivity;
- hard and dense subsoils;
- high susceptibility to severe gully erosion; and
- high susceptibility to tunnel erosion.

Soil sodicity is typically indicated by the exchangeable sodium percentage (ESP), the amount of exchangeable sodium as a percentage of a soil cation exchange capacity. General ratings for soil sodicity are detailed in Table 4.13 adapted from Hazelton and Murphy (2016).

Table 4.13 Soil sodicity ratings

Exchangeable sodium percentage	Rating
0–6	Non-sodic
3–6	Slightly sodic and dispersion can occur under raindrop impact in surface soils
6–14	Sodic
>14	Strongly sodic

The critical ESP level for a soil to be dispersive is influenced by salinity and the amount of energy applied to the soil. The higher the soil or water salinity (EC) the higher the critical ESP level and the more energy applied to the soil the lower the critical ESP level becomes for dispersion to occur.

The soils across the project footprint are consistently non-sodic (ESP <6%), with a maximum ESP of 2.8%. The soil sodicity levels, despite having very low salinity, are indicative of soils that will not be dispersive and pose little risk of erosion relating to sodicity.

4.4.4 Cations

The five most abundant cations in soils are:

- calcium (Ca);
- magnesium (Mg);
- potassium (K);
- sodium (Na); and
- aluminium (Al) in strongly acid (pH <5.5) soils.

It is common practice to measure the concentrations of these five most abundant cations as other cations (such as zinc, manganese, iron and copper) are usually present in amounts insignificant to the cation balance. The sum of these five major cations is utilised as an approximation of the cation exchange capacity (CEC), known as effective CEC (ECEC). The individual cations are often expressed as a percentage of the ECEC, which is considered to be a more relevant indicator of cation influence on plant behaviour than actual cation levels (Hazelton & Murphy 2016).

i Desirable cation proportions

Table 4.14 Desirable proportions of CEC for plant growth

Cations	Desirable ranges of cations (% of CEC)
Ca	65–80
Mg	10–20
K	3–8
Na	<1
Al	<1

The cation results for the soils in the project footprint show that 11 of the 18 samples analysed had ideal levels of potassium, with 5 samples exceeding the recommended 8% of CEC. For magnesium cations 5 samples had the desired magnesium levels, with the other 13 samples exceeding 20% of CEC, up to a maximum of 34%. Of the 18 samples analysed 12 had ideal cation levels, with the other 5 samples all having at least 55% calcium. 7 samples had sodium levels below 1%, with 11 samples having at least 1% sodium but less than 2.85%, the maximum sodium percentage recorded.

Aluminium was not analysed within the laboratory analysis and the pH levels indicate it would not be available within the soil solution.

These results indicate that generally there will be no limitations to plants due to cations present in the soils, apart from slightly elevated levels of magnesium.

ii Calcium/Magnesium ratio

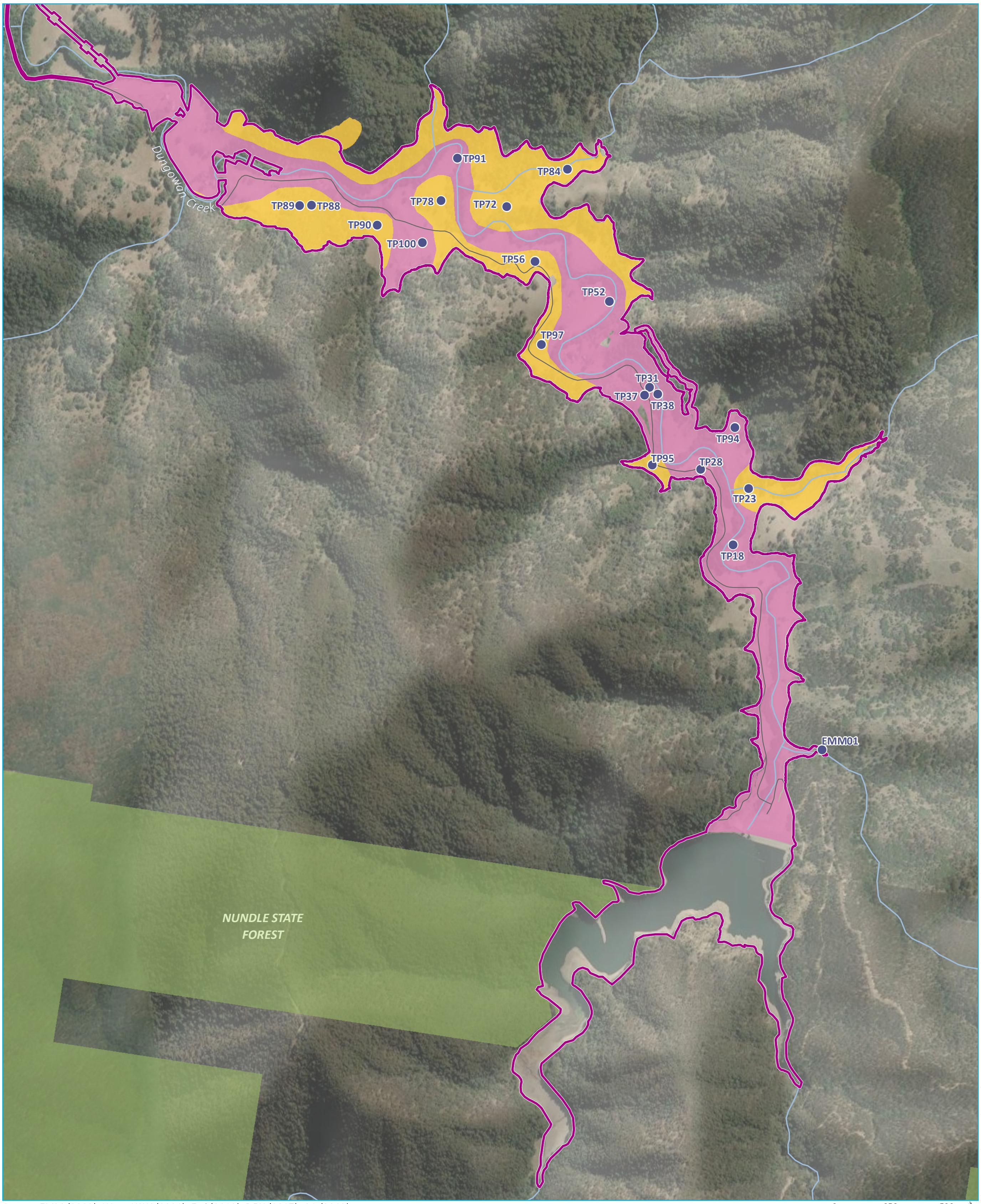
The ratio of calcium cations to magnesium cations in a soil CEC can be an indicator of possible erosion hazard, as in sufficient amounts magnesium can behave similarly to elevated sodium (sodicity) and cause dispersion and subsequent erosion. A Ca:Mg ratio of below 1 are thought to indicate this potential risk, and soils with a Ca:Mg ratio of <0.1 are referred to as *magnesic* by Isbell (2002). The effect of magnesium on dispersion is thought to only occur where ESP >4% (Hazelton & Murphy 2016).

Of the 18 soil samples analysed, 13 were classed as Ca (low) and the remaining 5 samples were classed as balanced.

Table 4.15 Ca:Mg ratio[1]

Ca:Mg ratio	Description
<1	Ca deficient
1–4	Ca (low)
4–6	Balanced
6–10	Mg (low)
>10	Mg deficient

3. (Hazelton & Murphy 2016).



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

KEY

Project footprint

Soil survey sites

Soil mapping units

DE

DE/RU

Existing environment

Minor road

Named watercourse

State forest

Project soil mapping units

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Land, soils and erosion assessment
Figure 4.3

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4.5 Land and Soil Capability Assessment Scheme

The *Land and Soil Capability Assessment Scheme* (OEH 2012) ('LSC Scheme') assesses the capacity of subject land to support a range of land uses. The LSC Scheme considers the inherent biophysical features of the land and soil, and their associated hazards and limitations, to these land uses (Table 4.16). Each hazard is given a rating between 1 (best, highest capability land) and 8 (worst, lowest capability land).

Table 4.16 LSC assessment considerations

Biophysical features	Assessed hazards and limitations
Soil type	Soil structure decline
Slope	Water erosion; including sheet, rill and gully erosion
Landform position	Wind erosion
Soil acidity	Soil acidification
Soil salinity	Soil and landscape salinity and drainage
Drainage	Waterlogging
Rockiness	Shallow soils and rockiness
Climate	Mass movement

The overall LSC class of the land (Table 4.17) is based on the most limiting feature/hazard. The LSC classes present at a site can be determined at various scales, ranging from state or regional to farm scale, varying in accuracy according to the information and resolution associated with them. State scale mapping has been completed for NSW and for the project, which is detailed in Section 4.1.5.

Table 4.17 Land and soil capability classes

LSC class	General definition
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)	
1	Extremely high capability land: Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices.
2	Very high capability land: Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.
3	High capability land: Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)	
4	Moderate capability land: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.

Table 4.17 Land and soil capability classes

LSC class	General definition
5	Moderate–low capability land: Land has high limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.
Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture)	
6	Low capability land: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation.
Land generally incapable of agricultural land use (selective forestry and nature conservation)	
7	Very low capability land: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.
8	Extremely low capability land: Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.

A LSC assessment, conducted as per the LSC Scheme, has been completed considering each soil mapping unit (SMU) that has been identified, to characterise the soils encountered and their consistency with the regional LSC mapping.

As noted previously, the overall LSC class of the land is based on the most limiting feature/hazard. Assessment of the soils encountered within the site indicate that the most limiting factor in these soils will be their shallow and rocky nature.

4.5.1 Preliminary LSC assessment

The below details the brief preliminary assessment of the project footprint investigated during the EMM soil programme against the LSC assessment scheme for the hazards deemed to be unlikely to be limiting for the final LSC classification.

i Water erosion hazard

The LSC water erosion hazard considers the project location within NSW in conjunction with the slope percentage of the soil investigation sites. According to the preliminary assessment of the LSC scheme the 10 sites of the DE/RU SMU has two sites of LSC class 1 where slopes are <1% and 8 sites of LSC class 6–7 where slopes are >20%. The DE SMU has 6 sites of LSC class 1–2 where slopes are <3% and 4 sites of LSC class 6–7 where slopes >20%.

ii Wind erosion hazard

The wind erosion LSC class requires the assessment of four hazards:

- wind erodibility class of surface soil;
- wind erosion power;
- exposure to wind; and
- average yearly rainfall.

The soils of the project footprint, across both SMUs have low wind erodibility class of surface soil, due to the consistent loam to clay loam surface textures, and the project footprint, nestled within the hills, has low wind exposure. The project site location is classed as high wind erosive power according to the LSC scheme and average annual rainfall of >500 mm. These factors result in consistent LSC classes of 2–3 for wind erosion hazard.

iii Soil structural decline

The soil structure decline hazard LSC class requires the assessment of surface soils using three key characteristics:

- surface soil texture;
- degree of sodicity; and
- degree of self-mulching.

The consistent surface soil textures (sandy loams, loams and clay loams) and minimal sodicity or self-mulching result in LSC class 3 for soils structural decline hazard.

iv Soil acidification hazard

The soil acidification hazard LSC class requires the assessment of three key characteristics:

- surface soil buffering capacity;
- mean annual rainfall; and
- soil surface pH.

The soils of the project footprint have consistent 'Moderate' buffering capacity for the purposes of the LSC acidification hazard assessment due to their consistent soil textures across both SMUs. This buffering capacity in correlation with the surface soil pHs and mean annual rainfall results in LSC class 3 for soil acidification hazard.

v Soil salinity hazard

The soil salinity hazard LSC class requires the assessment of three key characteristics:

- recharge potential;
- discharge potential; and
- salt store.

The area is mapped as a low salt store area, whilst recharge potential is estimated to be high and discharge potential to be moderate, resulting LSC class of 2 for soil salinity hazard.

vi Waterlogging hazard assessment

The waterlogging LSC class requires the assessment of two key characteristics:

- soil profile drainage; and
- waterlogging duration.

Waterlogging duration can be difficult to know without monitoring or local knowledge and in the case of the project is complicated by the proximity of the dam altering the natural flooding regime. It has been assumed that the typical waterlogging durations for the site is 0–0.25 months a year, and the predominantly well drained soils of the project site result in a LSC class of 2 for waterlogging hazard.

vii Mass movement hazard

The mass movement LSC class requires the assessment of three key characteristics:

- existing evidence of mass movement;
- slope class; and
- average annual rainfall.

With no recorded observations of mass movement and mean annual rainfall of >500 mm the LSC hazard class for mass movement is Class 1.

4.5.2 Shallow soils and rockiness LSC hazard

LSC classification of shallow soils and rockiness hazard considers the estimated percentage exposure of rocky outcrops and average soil depth. This is observed to be the primary limitation to the LSC class of the project soils.

i DE SMU

Of the 10 sites classified as the DE SMU, six sites had surface rock outcrops of <30% and soil profiles of greater than 50 cm, resulting in LSC classes of 4. All the four sites with surface rock outcrops >40% had soils depths between 25–75 cm, resulting in LSC classes of 6.

ii DE/RU SMU

Of the 10 sites classified as the DE/RU SMU, four sites had surface rock outcrops of <30%, five had rock outcrops of 30% to 50% and two sites had rock outcrops of 60% and 90%. All DE/RU sites had refusal at depths of 10 cm BGL, resulting in an LSC class of 7, with the exception of the site (TP95) with rock outcrop of 90%, which is LSC class 8 due to rock outcrop of >75%.

4.5.3 LSC Summary

The SMUs within the inundation extent are consistently LSC class 6–8, due to limitation to the LSC classes of shallow soils and rockiness and water erosion. Of the 20 soil investigation sites, 10 are constrained by water erosion hazard (Class 6 or 7) due to steep slopes and five of the remaining 10 sites are limited by prohibitively shallow and rocky soils (Class 7–8). Generally this means the land and soil capability of the inundation extent is low to extremely low capability land, generally; *very high* (Class 6) *to severe limitations* (Class 8) *for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation* (Class 6) or *incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation* (Class 8). The remaining five sites, all within the DE SMU, are LSC class 4 due to shallow soils and rockiness hazard.

4.6 Soil assessment summary

A soil survey for the operational footprint was conducted from 8–9 September 2020 inclusive and involved the excavation and/or description of 20 soil investigation sites. The project footprint soils were mapped into two soil mapping units (SMUs), Dermosols (DE) and Dermosols/Rudosols (DE/RU), with little physical difference between the two units with the exception of shallower refusal depths (around 0.1 m BGL, consequent Rudosol classification) due to consistent presence of large coarse fragments in the DE/RU SMU. Physically the soils were consistently shallow (generally 0.6 m), particularly on the hillslopes, and coarse fragments were consistent throughout all soil profiles. Chemically the SMUs are benign, with no salinity or sodicity limitations and subsequently are expected to pose minimal erosion hazard. No assessment of fertility was made, though the cations within the soil are generally within recommended limits for plant suitability.

It is also noteworthy that severe bush fires occurred in the catchment area over the 2019/2020 summer period, followed by a period of intense storms resulting in significant erosion of the catchment and subsequent sedimentation. The resulting debris flow has and continues to discharge into Dungowan Creek, which has caused a diversion of flow and bank erosion in some instances, and in-filling and modification to the low flow channel downstream of the entry points. Assessment of the project impacts on the soils encountered is described in Chapter 6.

Photograph 4.1 Eroded debris flow entering Dungowan Creek downstream of the new Dungowan Dam wall

Photograph 4.2 Eroded sediments in a lateral gully that feeds Dungowan Creek

5 Erosion Hazard Assessment

The process for the assessment of erosion hazard in NSW is detailed in Section 4.4.1 of Landcom (2004). It is a two-part process that considers overall project erosion hazard in considering slope and rainfall erosivity (R-factor) and then a more detailed assessment where land soil loss classes (SLC) are determined by calculating annual soil loss using the revised universal soil loss equation (RUSLE) employing site specific gradients and a nominal slope length of 80 m. The SLC dictates specific erosion management and mitigation measures as detailed in Landcom (2004).

An assessment of the erodibility of the soil itself is important as the presence or absence of a highly erodible dispersive soil will significantly influence the project drainage, erosion and sediment control requirements. In the case of the Dungowan Dam and pipeline project, no dispersive soil was identified.

5.1 Soil erosion hazard analysis

The erosion potential of a soil is determined by its physical and chemical properties and it expressed as its K-Factor (t.ha.h)/(ha.MJ.mm). Table 5.1 provides a soil erodibility ranking for K-Factor from Rosewell (1993).

Table 5.1 Rosewell (1993) soil erosion ranking

K-Factor (t ha h $ha^{-1}MJ^{-1}mm^{-1}$)	Erosion potential
<0.02	Low
>0.02 to <0.04	Moderate
>0.04	High

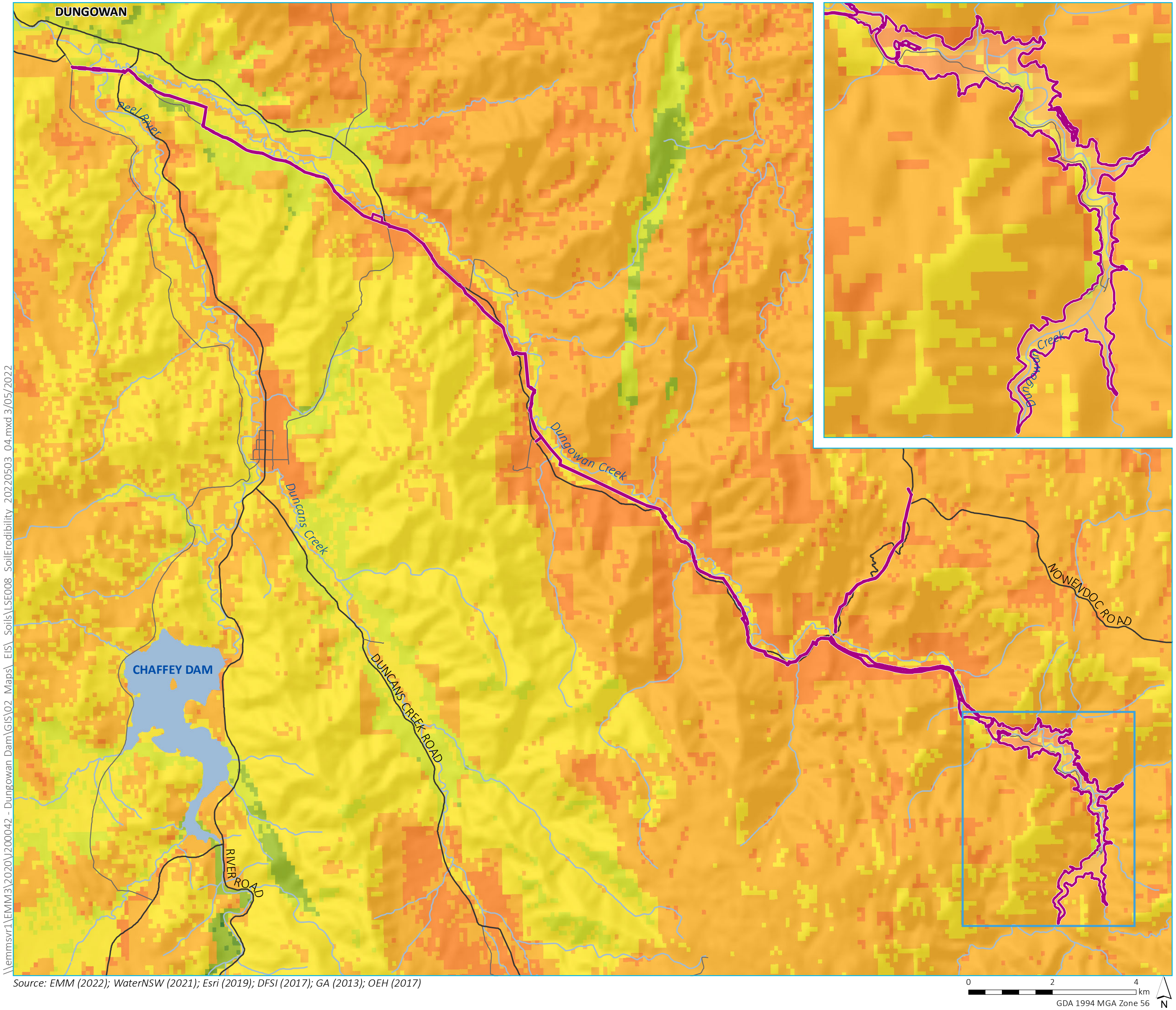
The modelled K-Factors for the project area were determined from the eSpade 2.1 database (DPIE 2020) (Figure 5.1). While the site soil assessment did not identify any sodic or magnesic soils, modelled K-Factors range from 0.04–0.07 t ha h $ha^{-1}MJ^{-1}mm^{-1}$, which indicate that the project soils have a high erosion potential.

To be expected, the least erodible soils are within the depositional alluvial flood plain areas where soil organic matter is higher and topsoil depth is greatest, and the most erodible soils are on the steeper erosional slopes.

5.1.1 Slope and rainfall erosivity erosion hazard analysis

The overall project water erosion hazard is determined using the process described in Section 4.4.1 of Landcom (2004); however, as it does not consider the K-factor, the erosion hazard can be considerably underestimated. If a low erosion hazard is determined, no further delineation of erosion hazard is required. If a high erosion hazard is determined, then further assessment to determine the SLC is required.

SLCs are determined by calculating the annual average soil loss using the RUSLE with a nominal 80 m slope length and soil surface cover factor (C-Factor); RUSLE calculates the annual average erosion in tonnes per hectare (t/ha) from rill and inter-rill (sheet) erosion. It does not consider gully or tunnel erosion and does not calculate peak erosion.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); OEH (2017)

Soil erodibility (K-factor)

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Figure 5.1

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Landcom (2004)[1] nominates additional requirements for land of SLC 4 and higher. The first step in the hazard assessment uses a nomograph from Figure 4.6 of Landcom (2004) (reproduced as Figure 5.2) that considers slope of the land and the Rainfall Erosivity (R-factor) to provide a low or high erosion hazard.

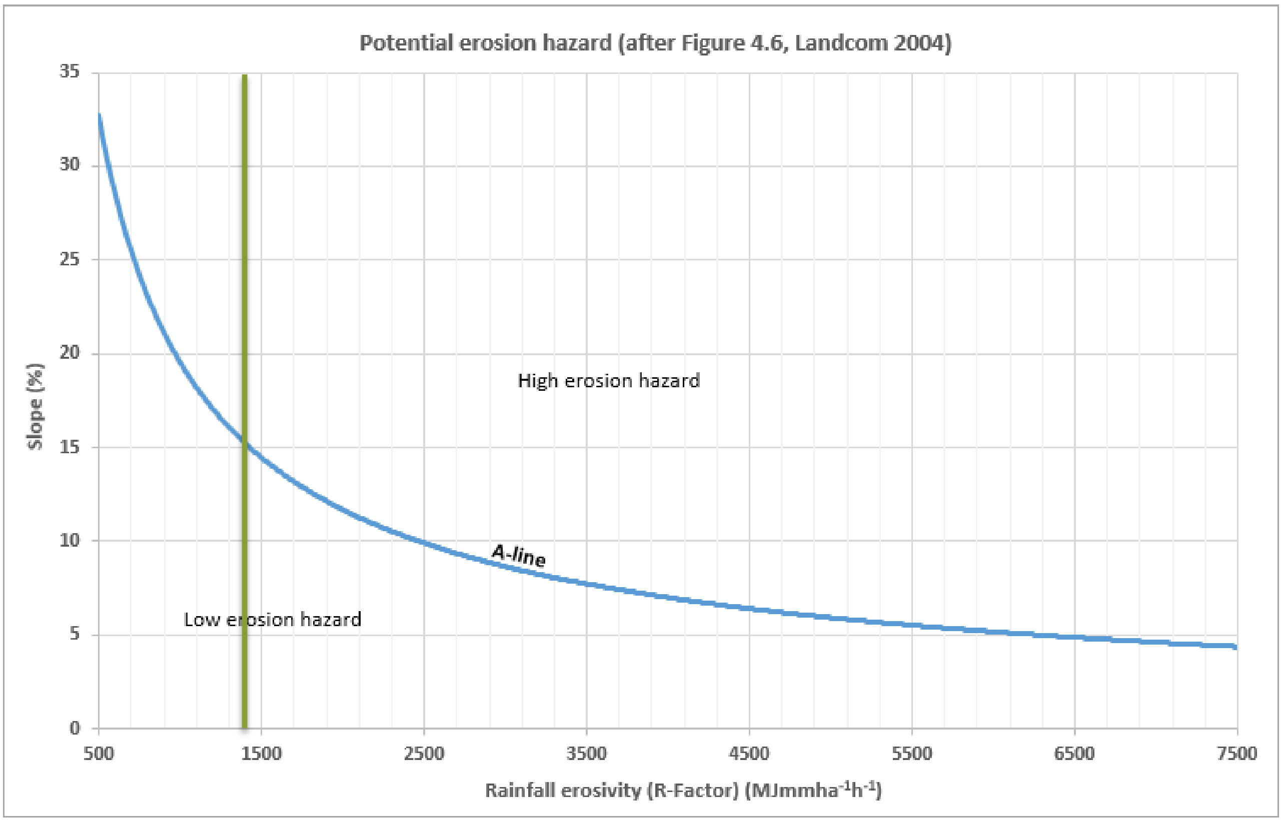


Figure 5.2 Assessment of potential erosion hazard (Landcom 2004)

The rainfall erosivity (R-factor) is calculated using the formula:

$$S= 164.74\ (1.1177)^{S}\ S^{0.6444}$$

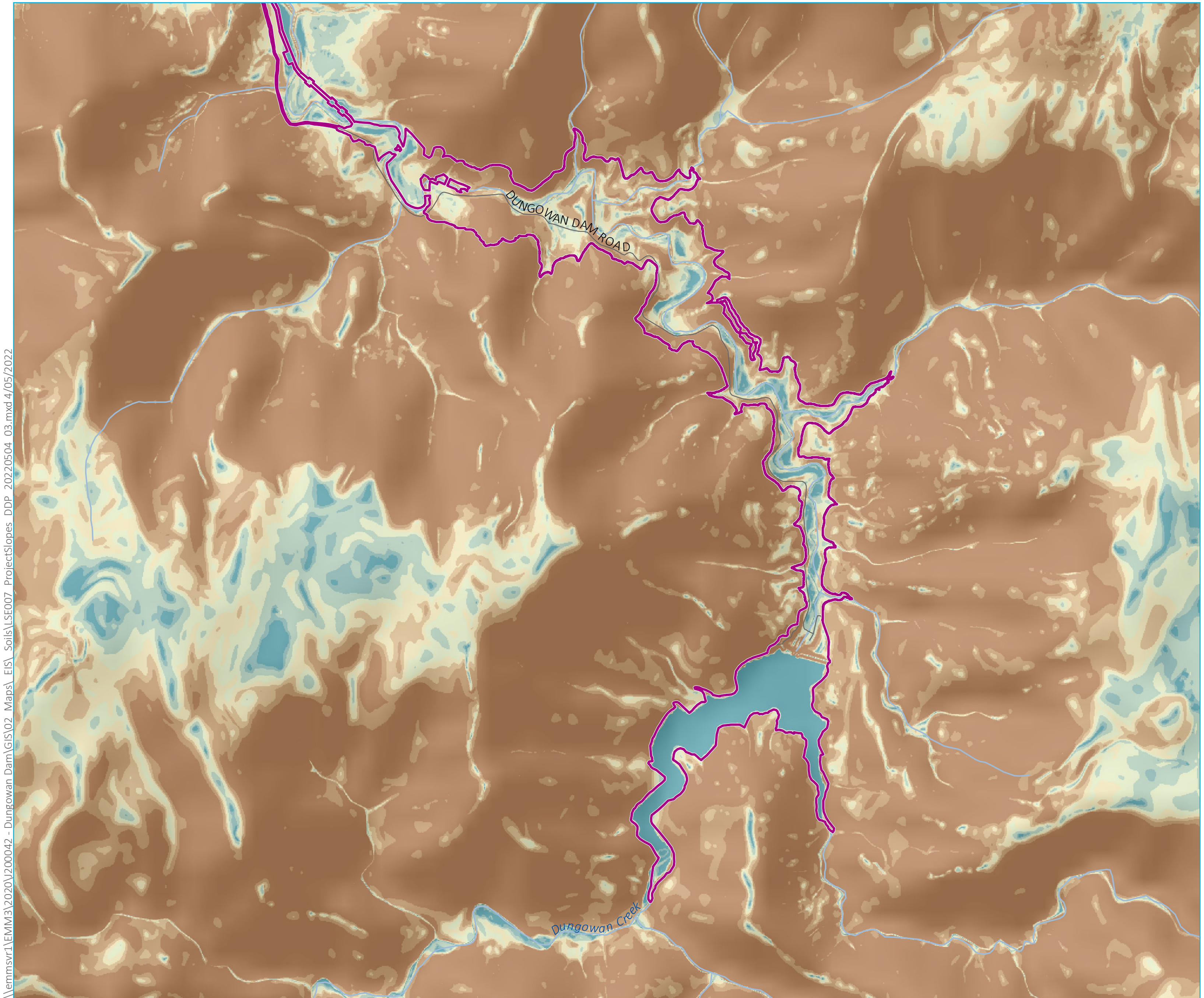
where, S is the 2-year ARI, 6-hour rainfall event in mm/h (0.5EY, 6-hour event) (Rosewell & Turner 1992).

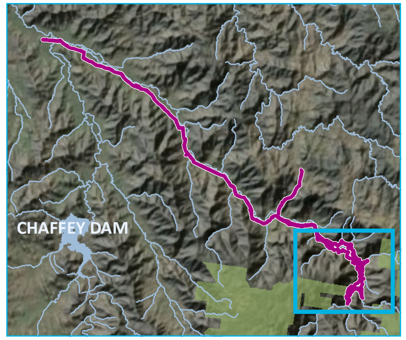
S equals 7.55 mm/h. The calculated R-Factor for the project is 1,404 MJmmha^{-1}h^{-1}. Slopes in the project footprint generally range from 0–87% (Figure 5.3). Applying these parameters to the erosion hazard nomograph results in a low to high erosion due to slope and rainfall. On this basis, further analysis of SLCs is required. A high erosion hazard requires further detailed assessment in accordance with Section 4.4.2 of Landcom (2004) to determine soil loss classes (Table 5.2).

[1] Landcom (2004), section 4.4.2(c)

Table 5.2 *Soil Loss Classes* (adapted from Table 4.2 Landcom 2004)

Soil Loss Class (SLC)	Calculated soil loss (t/ha/yr)	Erosion hazard
1	0–150	Very low
2	151–225	Low
3	226–350	Low-moderate
4	351–500	Moderate
5	501–750	High
6	751–1,500	Very high
7	>1,500	Extremely high





KEY
- Project footprint
- Minor road
- Named watercourse
- Named waterbody
- State forest

Slope
- < 3%
- 3 - 5%
- 5 - 10%
- 10 - 15%
- 15 - 20%
- 20 - 25%
- 25 - 35%
- > 35%

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); ELVIS (2019)

0 1 2 km
GDA 1994 MGA Zone 56
N

Project slopes

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Figure 5.3a

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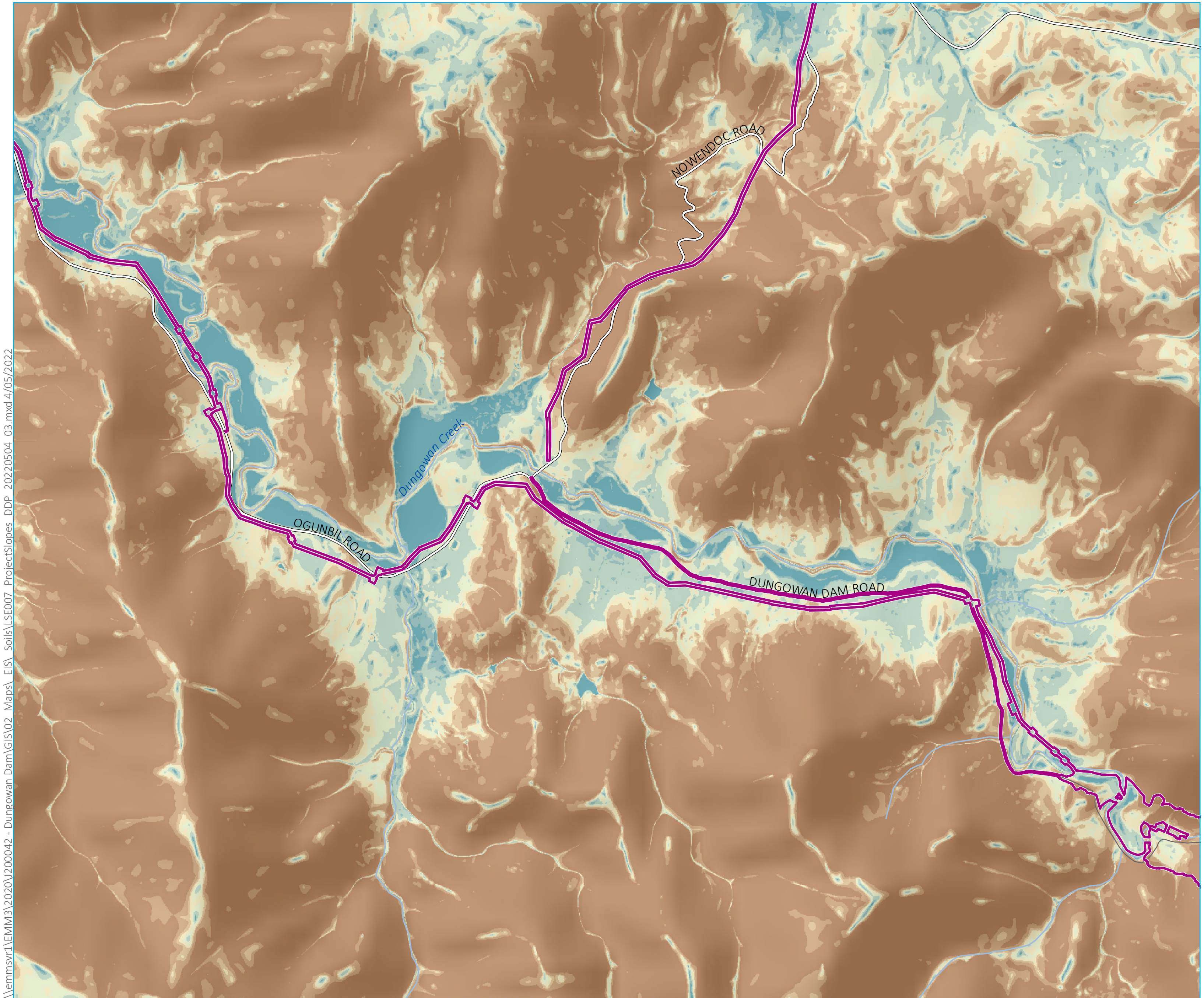

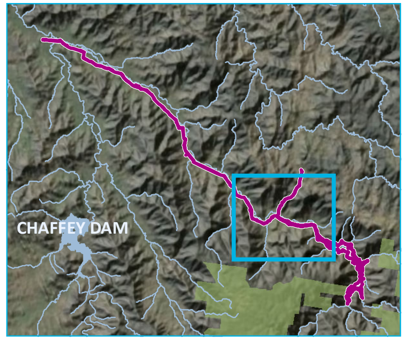

KEY
- Project footprint
- Major road
- Minor road
- Named watercourse
- Named waterbody
- State forest

Slope
- < 3%
- 3 - 5%
- 5 - 10%
- 10 - 15%
- 15 - 20%
- 20 - 25%
- 25 - 35%
- > 35%

Project slopes

Dungowan Dam and pipeline project
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Figure 5.3b

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); ELVIS (2019)

0 1 2 km
GDA 1994 MGA Zone 56
N

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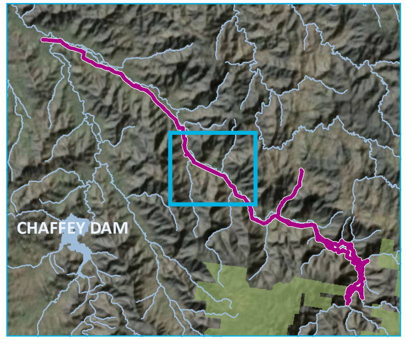


KEY

- Project footprint
- Major road
- Minor road
- Named watercourse
- Named waterbody
- State forest

Slope

- < 3%
- 3 - 5%
- 5 - 10%
- 10 - 15%
- 15 - 20%
- 20 - 25%
- 25 - 35%
- > 35%

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); ELVIS (2019)

0 1 km

GDA 1994 MGA Zone 56

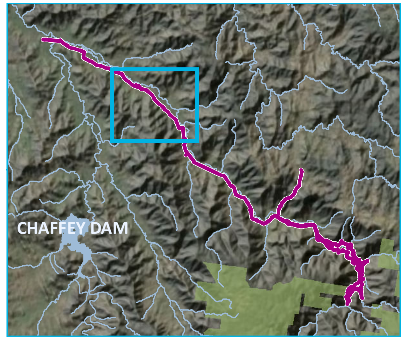
N

\\emmsvr1\EMM3\2020\200042 - Dungowan Dam\GIS\02_Maps_EIS_Soils\LSE007_ProjectSlopes_DDP_20220504_03.mxd 4/05/2022

Project slopes

Dungowan Dam and pipeline project
Land, soils and erosion assessment
Figure 5.3c

creating opportunities



KEY

- Project footprint
- Major road
- Minor road
- Named watercourse
- Named waterbody
- State forest

Slope

- < 3%
- 3 - 5%
- 5 - 10%
- 10 - 15%
- 15 - 20%
- 20 - 25%
- 25 - 35%
- > 35%

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); ELVIS (2019)

0 1 km

GDA 1994 MGA Zone 56

N

Project slopes

Dungowan Dam and pipeline project
Land, soils and erosion assessment
Figure 5.3d

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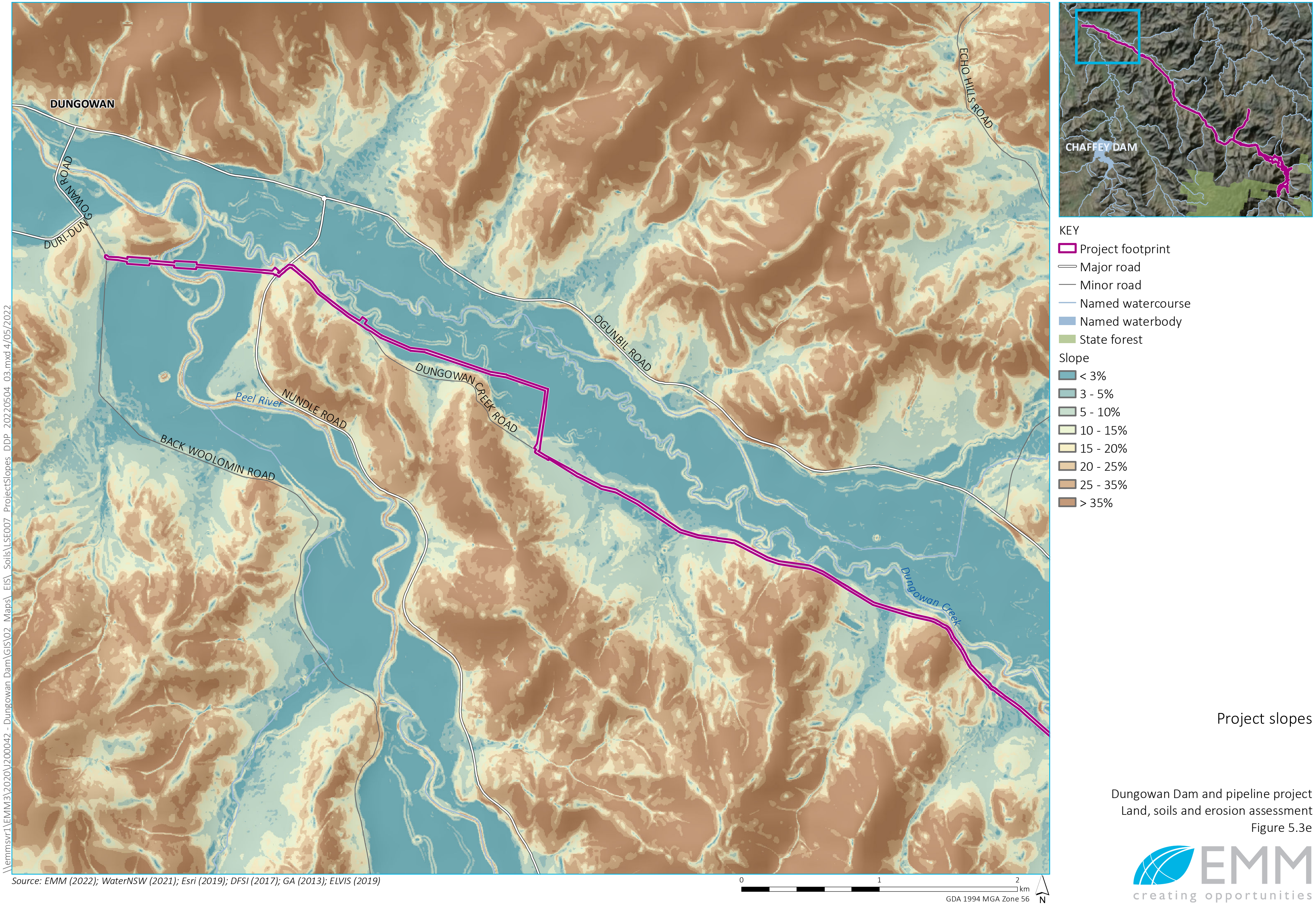
\\emmsvr1\EMM3\2020\200042 - Dungowan Dam\GIS\02_Maps_EIS_Soils\LSE007_ProjectSlopes_DDP_20220504_03.mxd 4/05/2022



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); ELVIS (2019)

Project slopes

Dungowan Dam and pipeline project
Land, soils and erosion assessment
Figure 5.3e

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Soil loss classes are determined calculating the annual average soil loss using the RUSLE with a nominal 80 m slope length, soil surface cover factor (C-Factor) of 1 (100% bare soil) and a soil conservation factor (P-Factor) of 1.3 (compacted and smooth soil). Calculated indicative soil loss in t/ha/yr for slopes ranges from 1–30% for the project are provided in Table 5.3.

Table 5.3 Annual average soil loss t/ha/yr

Slope	1%	10%	14%	20%	25%	30%	40%
R-Factor (calculated)	2149	2149	2149	2149	2149	2149	2149
K-Factor (OEH 2016)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
LS (Table A1 Landcom 2004 and USDA 1997)	0.19	2.81	4.61	7.32	9.51	11.6	15.67
P (Table A2 Landcom 2004)	1.3	1.3	1.3	1.3	1.3	1.3	1.3
C (Figure A5 Landcom 2004)	1	1	1	1	1	1	1
Soil loss t/ha/y	**31.85**	**471.02**	**772.74**	**1226.99**	**1594.09**	**1944.42**	**2626.64**
SLC	**1**	**4**	**6**	**7**	**7**	**7**	**7**

Applying the calculated annual average soil loss to Table 5.2 results in a SLC ranging from 1 (very low) to 7 (extremely high). Lands with SLCs ≥4 trigger increased erosion and sediment control management requirements as stipulated in Section 4.4.2 of Landcom 2004. The project footprint is in rainfall Zone 6 (Landcom 2004).

Land disturbing works in highly sensitive lands should be scheduled for periods when rainfall erosivity is low. Landcom 2004 defines highly sensitive lands as:

1. always on SLC 7 lands; and
2. at certain times of the year:
   a) on SLC 5 or 6 lands in all rainfall zones; and
   b) on SLC 4 lands in rainfall Zones 5 and 11.

Low and high rainfall erosivity periods for Zone 6 are provided in Table 5.4.

Table 5.4 Zone 6 high and low rainfall erosivity periods

SLC	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
1-4	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
5	H	H	H	H	H	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	H	H
6	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	L	L	L	L	H	H	H	H
7	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H

Source: Landcom (2004)

Where scheduling activities on highly sensitive land to periods when rainfall erosivity is low is not possible or is impractical, ideally ensure that any disturbed lands have C-Factors lower than 0.1 when the 3-day rainfall forecast suggests that rain is likely. Further project specific mitigation measures are provided in Chapter 7.

6 Impacts

6.1 Land and soil capability

6.1.1 Construction soil impacts

The proposed construction works will disturb soils through the following activities:

- clearing, topsoil stripping and earthworks across the construction footprint;
- decommissioning of the existing Dungowan Dam and rehabilitation of the former reservoir area; and
- excavation of borrow areas.

The soil disturbance during construction has the potential to result in the following impacts:

- reduce soil stability and increase susceptibility to erosion due to vegetation removal or soil exposure, especially if the subsoil is dispersive;
- loss or degradation of topsoil material viable for use in rehabilitation;
- introduce constraints into the topsoil material if soil is inadequately managed;
- risk of exposing buried contaminants (pesticides and hydrocarbons); and
- introduction of contaminants into soil material (eg hydrocarbons from plant).

Irrespective of their LSC classes, there will be four borrow areas upstream of the new Dungowan Dam wall along Dungowan Creek and the majority of the soils will be excavated for construction purposes and then ultimately inundated when the dam fills and not be available for agricultural production. There are currently no agricultural enterprises upstream of the new Dungowan Dam embankment. Topsoil stripped from the borrow areas should be retained for rehabilitation of the proposed quarries and the decommissioned existing dam and basin.

While decommissioning of the existing Dungowan Dam will reduce the existing area of inundation, the resulting exposed lands will be too steep and isolated for viable agricultural production and WaterNSW will exclude stock from these areas during operation to protect the new dam catchment from degradation to protect water quality.

i Soil mixing

Impacts on soils and LSC are typically a function of topsoil loss or degradation during construction and/or soil inversion due to ineffective soil management. Topsoil has the highest biological activity, organic matter, and plant nutrients, which are all key components of a productive soil. The potential loss of this upper layer of soil impacts vegetation by limiting the ability of the soil to provide nutrients, regulate water flow and resist pests and disease.

Inappropriate separation of topsoil and subsoils during stripping and stockpiling can result in less fertile topsoils due to introduced constraints or potentially toxic subsoils forming the upper portion of the soil profile. Mixing of the soil profile can also result in increased stoniness of surface soils impacting the ability to cultivate the soil and plant development.

Loss of nutrients and nutrient holding capacity results in a less fertile environment for crop and pasture production. The organic matter and finer soil particles (primarily clays) responsible for soil fertility can be easily eroded when exposed, leaving larger particles such as sand and gravel, which typically offer lower nutrient content.

ii Compaction

Topsoil degradation can result in organic matter reduction, which can lead to soil density increases and subsequent compaction. Compaction lowers the infiltration rate of water into the soil profile and reduces the available water holding capacity. Lower organic matter levels are also associated with weaker soil aggregates and therefore greater risk of further erosion and soil crusting. Construction equipment can also compact the soil outside of the construction footprint resulting in reduced water holding capacity, increased runoff and therefore erosion potential and lower the potential of plant root and shoot penetration.

iii Gully erosion

Subsidence and tunnel erosion within the pipeline trench as well as concentration of flow on access tracks and roads also have the potential to impact on LSC. Any tunnels that form within the trench due to poor compaction and/or the presence of non-cohesive or dispersive soils may generate outlet points at the bottom of slopes or drainage line crossings, potentially forming gullies that can erode soil resources.

6.1.2 Commissioning soil impacts

Trees will be cleared from the inundation footprint via the cut stump method to minimise disturbance and erosion by leaving stumps and the associated root balls. Construction related disturbances such as borrow pits, tracks and hard stands within the inundation footprint will not be rehabilitated.

Water will be released during the decommission of the existing Dungowan Dam via existing pipes and gates. Water will generally flow down the existing creek line until it is impounded by the new dam wall. As the dam fills, any areas that remain exposed following the construction phase will ultimately be inundated by water however, due to the low flow velocity outside of the existing creek line, erosion of these exposed areas is not expected to be significant and any eroded sediment and turbid runoff contained behind the new Dungowan Dam wall. Further discussion of water quality impacts associated with the commissioning of the new Dungowan Dam is included in the Surface Water Assessment appended to the EIS.

6.1.3 Operation soils impacts

i Dam operation

Impacts to soils during operation and maintenance of the new Dungowan Dam are expected to include:

- localised soil erosion associated with fluctuating water levels within the reservoir area resulting in overland and concentrated flow over exposed soils;
- erosion and subsequent sedimentation potential from disturbed areas such as unsealed tracks and drainage structures; and
- soil disturbance from maintenance activities such as machinery and vehicle traffic and excavation.

Soil structural decline associated with the wetting and drying of the insitu soils in the dam reservoir area due to fluctuations in water level, drowning of vegetation and wave action can lead to the formation of erosion scarps in the landform. Concentrated flow associated with lateral gullies may result in upward migration of gully heads from these scarps. Project soils are relatively resistant to erosion due to their electrochemical stability and rockiness. Many of the lateral gullies were observed to have eroded to bed rock in some locations and generally have a high rock bed load and significant head cut migration is not anticipated.

ii Pipeline operation

Impacts to soil during the operation and maintenance of the pipeline are anticipated to include:

- erosion from high velocity flows from discharge of water from the scour valves during an emergency or routine maintenance activities;
- erosion from high velocity flow due to pipe failure;
- compaction from vehicles and machinery during inspections and maintenance activities; and
- potential subsidence from tunnel erosion if compaction and/or soil amelioration is inadequate during the construction phase.

Further discussion of water quality and geomorphology impacts associated with the operation of the new Dungowan Dam and pipeline is included in the Surface Water Assessment appended to the EIS.

iii Powerline

Impacts to soil during the operation and maintenance of the powerline are anticipated to include:

- compaction from vehicles and machinery during inspections and maintenance activities; and
- potential subsidence from tunnel erosion if compaction and/or soil amelioration is inadequate during the construction phase

Further discussion of water quality and geomorphology impacts associated with the operation of the new Dungowan Dam and pipeline is included in the Surface Water Assessment appended to the EIS.

6.1.4 Changes to land and soil capability

As described in Section 4.1.5, the eSPADE database (DPIE 2020) and OEH (2017e) (Figure 4.2) has mapped the project footprint as LSC Classes 2, 3, 5 and 7, which represents land with a range of capability, from land with ‘slight limitations’, capable of a wide variety of land uses (LSC class 2 and 3), to ‘high to severe limitations’ to cropping (LSC class 5 and 7).

Site specific soil sampling in the operational footprint has identified that due to limited soil depth and the rockiness of soils, the areas mapped as LSC class 2 and 3 are more likely to be LSC class 4, 5 and 6.
With appropriate management and mitigation measures, as recommended in Chapter 7, the LSC of agricultural lands along the pipeline easement are unlikely to change from their current LSC.

6.2 Erosion and sedimentation

Construction of the project will result in 315 ha of soil disturbance of a period of approximately six years. As discussed in Chapter 5, the project has a very low to very high erosion hazard. The high erosion hazard is a function of slope steepness, erodibility of site soils and the rainfall erosivity during the summer storm season.

Due to the steep gradients, sheet flow velocities are likely to exceed the maximum permissible velocity of the site soils, as per IECA (2008) (Table 6.1) when soils are exposed during the land clearing, grubbing, stripping and construction phases. Soil runoff coefficients are likely to change because of soil compaction during construction, higher sheet flow velocities are expected to exceed the maximum permissible velocities of the site’s soils.

The extent of earthworks, roads, infrastructure, natural topography and drainage patterns will limit the ability to maintain sheet flow conditions to reduce the erosion potential of runoff.

Table 6.1 Maximum 'permissible' velocities for different soil types (after IECA 2008)

Soil description	Allowable* velocity (m/s)	Impacted by the project
Extremely erodible soils	0.3 m/s	No
Sandy soils	0.45 m/s	No
Highly erodible soils	0.4–0.5 m/s	No
Sandy loam soils	0.5 m/s	Yes
Moderately erodible soils	0.6 m/s	Yes
Silty loam soils	0.6 m/s	Yes
Low erodible soils	0.7 m/s	Yes
Firm loam soils	0.7 m/s	Yes
Stiff clay very colloidal soils	1.1 m/s	Yes

* velocity below which erosion of the type of soil is unlikely to occur.

There are substantial clean run-on water catchments above most of the proposed construction areas and either diversion of these catchments around the active work areas or safe conveyance through the active work areas without coming into contact with exposed soils is desirable. The highest run-on water risk areas include the new Dungowan Dam wall and decommissioned existing Dungowan Dam wall. A concrete lined diversion tunnel approximately 8.5 m in diameter will be constructed within the left bank abutment to divert Dungowan Creek through the active new Dungowan Dam wall construction area. The diversion tunnel will remain during the operational phase as it will house the outlet conduit and will provide access for maintenance and operation of the dam's outlet works. Hydraulically applied soil stabilising polymers can provide erosion protection equivalent to 60% grass cover for up to three months. Therefore, soil stabilising polymers will be employed as an important temporary erosion control in sheet flow environments within the site, particularly in preparation for periods of predicted heavy rainfall, wind or during extended construction shut down periods.

Potential on site erosion and sedimentation impacts include but are not limited to:

- erosion of constructed landform such as embankments, roads, tracks, powerline construction pads and stockpiles, requiring rework to repair and increased maintenance costs during the construction and operational phases;
- erosion along the pipe trench resulting in rework and repair during the construction and operations phases;
- unsafe work conditions due to the presence of gullies, tunnels, mud, uncontrolled water and dust;
- construction downtime and delays due to access restrictions and the time taken to repair and desilt the site;
- decrease in dam capacity and water quality due to upstream deposition of eroded sediment; and
- reputational damage and litigation costs associated the non-compliance and pollution events.

As discussed in Section 3.4, Dungowan Creek is a high gradient gravel-based creek system with the bed material dominated by loose gravel and rocks. The creek has obvious pool and riffle sequences.

An increase in fine and coarse sediments due to inadequate erosion and sediment control can fill the voids between natural bed gravels causing the following adverse effects:

- loss of essential aquatic habitat areas (both within the pools and riffles);
- a reduction in the total submerged surface area (by infilling bed and riffle voids and other surface irregularities) thus reducing the potential food supply; and
- an increase in the stability of riffle rock, thus reducing the natural movement and sorting of the bed material.

A constant supply of introduced bed sediment can eventually turn a gravel-based stream into either a sand or clay-based system (IECA 2008). An increase in sediment load can result in the creek changing its channel form in order to transport the increased bed load (Rosgen 1996).

Effective sediment controls that trap sediment and treat turbid runoff are therefore required to protect Dungowan Creek from potential construction related sedimentation impacts of the project. Although Landcom (2004) recommends the use of conventional 'batch' basins on construction sites in NSW, high efficiency sediment (HES) basins designed and constructed in accordance with Appendix B of IECA (2008) has greater capability to treat more turbid runoff whilst allowing continuous through flow. HES basins occupy a similar footprint to a batch basin and provide the following additional advantages:

- ability to retain water for construction purposes (Type B HES basin);
- lower water treatment costs;
- improved safety of operation (no personnel access into the basins is required to treat turbid water during wet and slippery conditions);
- lower de-silting costs as most of the sediment is captured in the forebay instead of the main pond; and
- turbid water from dewatering of excavations can be pumped to the basin(s) and treated in a timely manner.

Potential off-site erosion and sedimentation impacts include:

- eutrophication of downstream waters due to erosion of soils with high phosphorous and nitrogen levels during the construction and operation phase;
- increases in downstream turbidity due to release of untreated turbid runoff during the construction phase;
- infilling of natural bed material and pools in Dungowan Creek due to eroded sediments during the construction phase;
- decreased creek channel flow capacity due to channel in-filling from eroded sediment during the construction phase;
- change in creek channel form and associated bed and bank erosion due to sediment deposition during the construction phase;
- change in creek channel form and associated bed and bank erosion due to changes in flow conditions during the construction and operational phase; and
- erosion of the creek bed and banks at the tunnel and spillway outlet points during flood events.

7 Management and mitigation recommendations

Recommended safeguards and mitigation measures for land, soil and erosion are listed in Table 7.1.

Table 7.1 Safeguards and mitigation measures – soils, land capability and erosion

Ref#	Aspect / Impact	Mitigation measure	Responsibility	Timing
	Land and Soil Capability			
LSE_01	Administrative controls	A Construction Soil and Water Management Plan (CSWMP) will be prepared and implemented as part of the Construction Environmental Management Plan (CEMP). The CSWMP will identify all reasonably foreseeable risks relating to soil erosion and water pollution and describe how these risks will be addressed during construction. The CSWMP will: • assess and detail the requirements to comply with relevant policies guidelines, legislation and other approvals; • be developed in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction, Volume 1 (Landcom 2004)* and other relevant volumes; • contain Erosion and Sediment Control Plans (ESCPs) for all work sites. ESCPs will be implemented in advance of site disturbance and will be updated as required as the work progresses and the sites change; • contain management procedures for activities, which may result in water pollution or to minimise the risk of erosion and sedimentation; • detail the review and inspection processes for onsite measures to mitigate erosion and sedimentation and water quality risks; • detail the responsibilities for the management and implementation of the CSWMP; and • be complementary to the Landscaping and Revegetation Plan.	Contractor	Pre-construction Construction Post Construction
LSE_02	Soil stripping and management plan	Prepare a Soil Stripping and Management Plan (SSMP) to ensure the preservation of soil resources, including quantity and quality to be managed, through the implementation of soil management measures incorporated within the CEMP.	Contractor	Pre-construction
LSE_03	Soil stripping and management	Strip and save topsoil resources from disturbance areas that will be inundated to use for rehabilitation (if suitable) of other project related disturbed areas.	Contractor	Construction
LSE_04		Measures for the management of topsoil should be included in the CEMP.	Contractor	Construction
LSE_05	Soil replacement and rehabilitation	Backfill pipeline trench with subsoil generally in the same sequence that existed prior to excavation.	Contractor	Construction
LSE_06		Final rehabilitation of lands would be as agreed with landowners.	Contractor	Construction

Table 7.1 Safeguards and mitigation measures – soils, land capability and erosion

Ref#	Aspect / Impact	Mitigation measure	Responsibility	Timing
	Erosion and sediment control			
LSE_07	Administrative controls (for all areas)	Preparing an Overarching ESCP and Progressive Erosion and Sediment Control Plans (PESCPs) for all project disturbances and phases in accordance with Landcom (2004), DECC (2008) and *Appendix P – Land-based pipeline construction* (IECA 2015) including: • access roads; • internal roads and haul roads; • powerline tracks and pads; • upstream and downstream coffer dams; • laydown areas; • accommodation camp and associated facilities; • borrow and quarry areas; • dam construction site; • tunnel construction areas; • spoil disposal areas; and • existing dam decommissioning areas. The ESCPs shall be prepared and certified by a suitably qualified and experienced certified professional in erosion and sediment control.	Contractor	Pre-construction
LSE_08	Erosion and sediment control	Demarcate clearing limits to minimise unauthorised clearing and disturbance	Contractor	Construction
LSE_09		Install clean water diversion drains and sediment basins prior to other land disturbing activities.	Contractor	Construction
LSE_10		Strip, save and stockpile topsoil including the borrow areas for stabilisation works in accordance with the SSMP.	Contractor	Construction
LSE_11		Ensure appropriate safeguards to reduce erosion in accordance with Landcom (2004) and other relevant volumes	Contractor	Construction
LSE_12		Undertake regular inspections of sediment and erosion controls.	Contractor	Construction
LSE_13		When open trenching water courses with active or anticipated water flows, ensure clean upstream flows are safely diverted or pumped around the active construction zone.	Contractor	Construction
LSE_14		Install sediment controls to protect sensitive waterways and lands.	Contractor	Construction
	Decommissioning of existing dam			
LSE_15	Erosion and sediment control	Install appropriate sediment and turbidity controls on the downstream side of the existing Dungowan Dam wall prior to decommissioning works to minimise pollution of dam waters from wall decommissioning.	Contractor	Construction
LSE_16		Construct an appropriate barrier around the perimeter of the proposed spoil emplacement area to isolate the emplacement area from the dam.	Contractor	Construction

8 Conclusion

This LSE assessment has considered available mapping and a limited soil sampling program, to characterise the existing environment and identify constraints within, and impacts arising from, the Dungowan Dam and pipeline project. The assessment has considered the potential impacts of the project on land and soil capability and erosion risks.

A field soil survey was completed from 8–9 September 2020 mapped the project inundation extent into two soil mapping units. These are very similar in nature, being Dermosols, with the only difference being the presence of large coarse fragments resulting in shallow refusal depths and subsequent classification of Rudosols in the DE/RU SMU unit. The physical and chemical characteristics of both SMUs are consistent outside of these factors. The soil chemistry of both SMUs is benign, with no limitations from soil pH, sodicity, salinity or cations.

The SMUs within the inundation extent are consistently LSC class 6–8, due to limitation to the LSC classes of shallow soils and rockiness and water erosion. Of the 20 soil investigation sites, 10 are constrained by water erosion hazard (Class 6 or 7) due to steep slopes and five of the remaining 10 sites are limited by prohibitively shallow and rocky soils (Class 7–8). Generally this means the land and soil capability of the inundation extent is low to extremely low capability land, generally; *very high* (Class 6) *to severe limitations* (Class 8) *for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation* (Class 6) or *incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation* (Class 8). The remaining five sites, all within the DE SMU, are LSC class 4 due to shallow soils and rockiness hazard.

Land capability of areas upstream of the new Dungowan Dam wall along Dungowan Creek will be impacted during construction and then ultimately inundated when the dam fills and will not be available for agricultural production. However, it is noted that no agricultural enterprises currently exist upstream of the new Dungowan dam embankment.

While decommissioning of the existing dam will reduce the existing area of inundation, the resulting exposed lands will be too steep and isolated for viable agricultural production.

The land and soil capability of agricultural lands along the pipeline and powerline easement are unlikely to change from their current capability, provided appropriate management and mitigation measures are implemented.

Due to the variability of slopes and soil types within the project footprint, the project has been assessed as having a wide-ranging erosion hazard, categorised as very low to very high.

The potential impacts to be mitigated would occur during both construction and operation. These impacts can be mitigated and managed through appropriate engineering design and the development and implementation of relevant management plans and sub plans.

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Annexure A
Soil chemical data and profiles

EMM
creating opportunities

A.1 Dermosol – DE

A.1.1 Site EMM01

Table A.1 Site EMM01 (DE) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	30.0	30.0	40.0	LC	6.61	0.12	L	1.03	NS	14	19.6	3.76	1.11	0.14	24.6	1%	NS	5.21
0.3–0.4	55.0	10.0	35.0	SC	6.85	0.03	VL	0.26	NS	5.13	6.9	1.51	0.64	0.14	9.18	2%	NS	4.57

4. PSA (sand/silt/clay) calculated from texture
5. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
6. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)

Photograph A.1 EMM01 soil profile

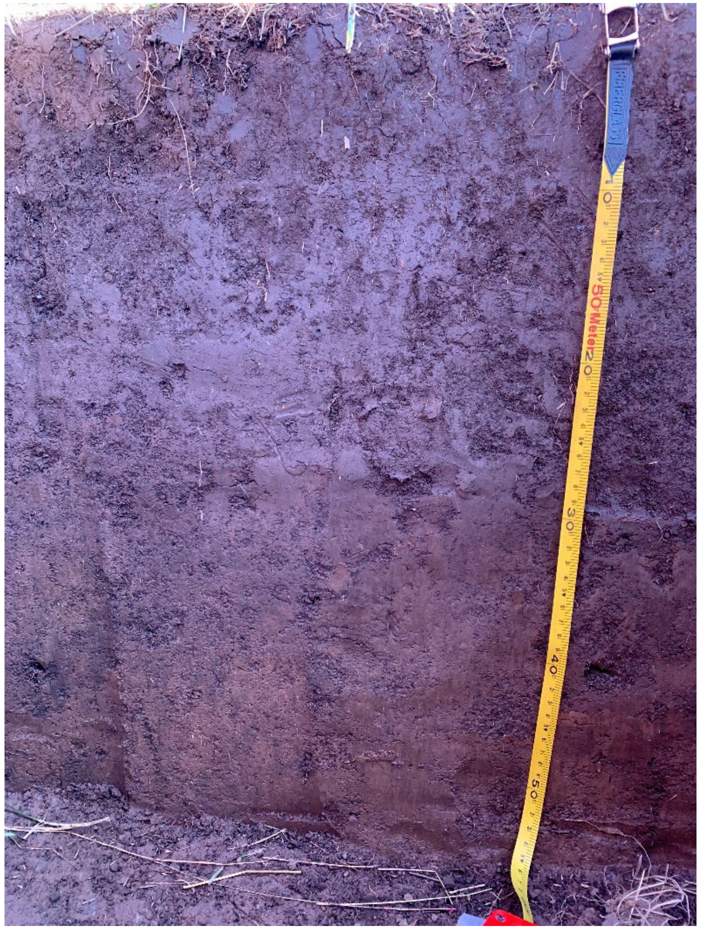
Photograph A.2 EMM01 soil landscape

A.1.2 Site TP18

Table A.2 Site EMM01 (DE) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	30.0	30.0	40.0	LC	6.45	0.05	VL	0.43	NS	11.5	11.6	2.76	0.81	0.12	15.3	1%	NS	4.2
0.2–0.3	30.0	30.0	40.0	LC	6.43	0.03	VL	0.26	NS	6.42	11.1	2.5	0.53	0.21	14.3	1%	NS	4.43
0.4–0.5	30.0	25.0	45.0	LMC	6.72	0.02	VL	0.17	NS	4.86	8.06	2.26	0.23	0.08	10.6	1%	NS	3.57

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)



Photograph A.3 **TP18 soil profile**

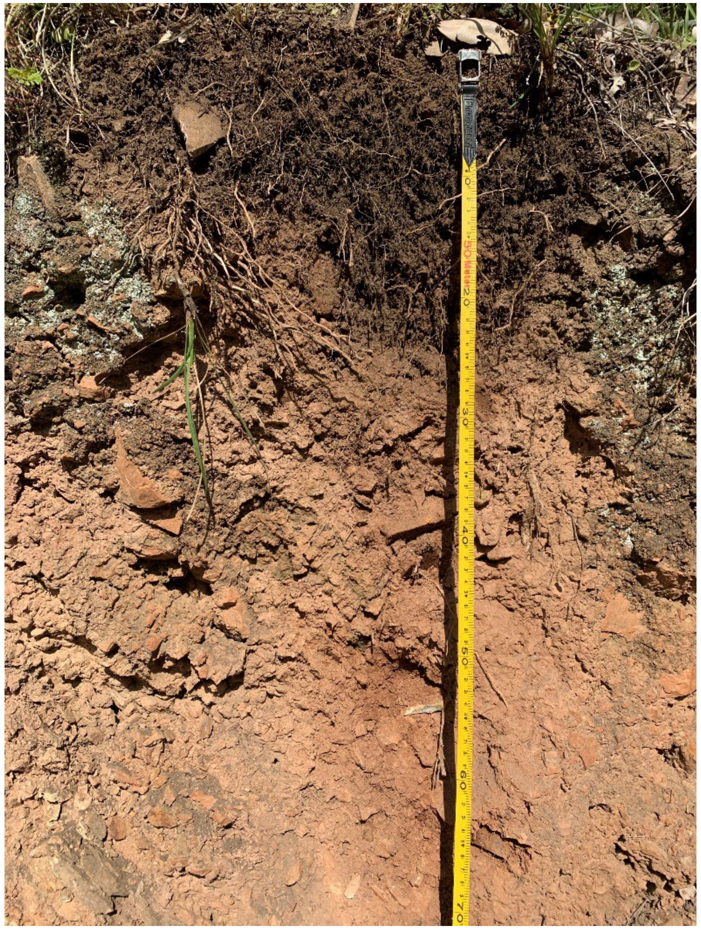
Photograph A.4 **TP18 soil landscape**

A.1.3 Site TP37

Table A.3 Site TP37 (DE) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	55.0	10.0	35.0	SC	6.18	0.04	VL	0.34	NS	8.69	8.8	2.93	0.81	0.12	12.7	1%	NS	3.01
0.2–0.3	55.0	10.0	35.0	SC	6.75	0.02	VL	0.17	NS	4.91	2.99	1.58	0.54	0.06	5.16	1%	NS	1.9
0.4–0.5	55.0	10.0	35.0	SC	6.68	0.02	VL	0.17	NS	9.45	2.84	1.69	0.35	0.14	5.03	3%	NS	1.68

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)



Photograph A.5 **TP37 soil profile**

Photograph A.6 **TP37 soil landscape**

A.1.4 Site TP52

Table A.4 Site TP52 (DE) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0.5–0.6	55.0	10.0	35.0	SC	6.62	0.02	VL	0.17	NS	4.08	7.49	1.81	0.19	0.17	9.65	2%	NS	4.14

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)

Photograph A.7 **TP52 soil profile**

Photograph A.8 **TP52 soil landscape**

A.1.5 Site TP91

Table A.5 Site TP91 (DE) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	30.0	25.0	45.0	LMC	6.25	0.04	VL	0.34	NS	4.66	6.14	1.97	1	0.09	9.2	1%	NS	3.12
0.5–0.6	30.0	30.0	40.0	LC	6.64	0.02	VL	0.17	NS	3.08	6.47	2.82	0.25	0.15	9.69	2%	NS	2.3

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)

Photograph A.9 **TP91 soil profile**

Photograph A.10 **TP91 soil landscape**

A.1.6 Site TP97

Table A.6 Site TP97 (DE) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	55.0	10.0	35.0	SC	6.06	0.12	L	1.03	NS	15.4	10.2	3.62	1.43	0.12	15.4	1%	NS	2.82
0.2–0.3	55.0	10.0	35.0	SC	6.39	0.05	VL	0.43	NS	5.47	5.79	1.66	0.68	0.07	8.19	1%	NS	3.49

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)

Photograph A.11 **TP97 soil profile**

Photograph A.12 **TP97 soil landscape**

A.1.7 Site TP100

Table A.7 Site TP100 (DE) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	55.0	10.0	35.0	SC	6.22	0.06	VL	0.52	NS	12	3.04	1.11	1.09	0.06	5.3	1%	NS	2.74
0.2–0.3	55.0	10.0	35.0	SC	5.95	0.07	VL	0.6	NS	11.2	3.07	1.22	1.08	0.11	5.48	2%	NS	2.52
0.5–0.6	30.0	25.0	45.0	LMC	6.03	0.02	VL	0.17	NS	6.56	2.89	1.51	0.48	0.12	5	2%	NS	1.92

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)

Photograph A.13 **TP100 soil profile**

Photograph A.14 **TP100 soil landscape**

A.2 Dermosol/Rudosol – DE/RU

A.2.1 Site TP31

Table A.8 Site TP31 (DE/RU) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	60.0	10.0	30.0	SCL	6.60	0.06	VL	0.57	NS	9.04	8.67	2.94	0.37	0.25	12.2	2%	NS	2.95

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)

A.2.2 Site TP90

Table A.9 Site TP90 (DE/RU) – soil profile chemistry data

Depth (m)	Particle size (%) [1]			Lab soil texture	pH (H_2O)	EC (dS/m)	EC rating (VL, L, M, H, VH, E)[2]	ECe (dS/m)	ECe rating[3]	Cl^- (mg/kg)	Exchangeable cations (meq/100 g)					ESP (%)	Sodicity (NS, S, SS)	Ca:Mg ratio
	Sand	Silt	Clay								Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC			
0–0.1	55.0	10.0	35.0	SC	6.45	0.05	VL	0.43	NS	5.94	3.18	1.85	0.26	0.12	5.4	2%	NS	1.72

1. PSA (sand/silt/clay) calculated from texture
2. Rayment & Lyons (2011) – very low salinity (VL), low salinity (L), moderately saline (M), highly saline (H), extremely saline (E)
3. Hazelton & Murphy (2016) – non-saline (NS), slightly saline (S), moderately saline (M), highly saline (H), extremely saline (E)

Photograph A.15 **TP90 soil profile**

Photograph A.16 **TP90 soil landscape**

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